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ABSTRACT

This study explores the mechanism underlying shared syntactic representations for highly similar languages by investigating whether cross-linguistic syntactic priming is affected by language proficiency. In two experiments, native (L1) Mandarin-Chaoshanese speakers with moderate proficiency in Cantonese (L2) heard Chaoshanese and Cantonese dative sentences with a prepositional object (PO) or a double object (DO) structure, and then completed a description of a depicted ditransitive event using Mandarin. Priming from L2 to L1 was equal to that from L1 to L1, irrespective of whether the prime and the target involved cognate verbs. Similarly, priming from L2 to L1 was not affected by speakers' L2 proficiency, suggesting that shared representations across highly similar languages are insensitive to language proficiency. We interpret the results in terms of the development of shared representations for highly similar languages.

KEYWORDS: multilingualism; syntactic representation; cross-linguistic priming; highly similar languages

Introduction

When learning a second language (L2), people need to acquire the syntactic rules that determine how words can be combined into complete sentences. Not surprisingly, they find it is easier to learn an L2 which is similar to their native language (L1) than one that is less similar – something that is apparent in practical assessments of language-learning difficulty. One partial explanation is that multilingual speakers may develop more highly shared syntactic representations for languages that are more similar to each other than for those that are less similar. However, the mechanism underlying shared syntactic representations for highly similar languages remains unclear. In this paper, we report two experiments that investigate the extent to which such representations are shared across Mandarin, Cantonese, and Chaoshanese and whether such sharing is affected by proficiency. (We refer to these as languages throughout, though we note that terminology is controversial; for example, the Chinese Academy of Social Sciences refers to them as dialects of the same language, Chinese; Xing, 1991)

Although some early researchers claimed that bilingual speakers have completely separate representations for their L1 and L2 (De Bot, 1992; Pienemann, 1998), substantial evidence suggests that at least some representations are integrated (Hartsuiker, Pickering, & Veltkamp, 2004; Schoonbaert, Hartsuiker, & Pickering, 2007; Huang, Pickering, Chen, Cai, Wang, & Branigan, 2019; see Van Gompel & Arai, 2018). Much evidence for integrated bilingual representations comes from syntactic (or structural) priming effects, by which exposure to a particular structure facilitates

subsequent reuse of the same structure. In the classic study, participants described a dative event with a prepositional object (PO) sentence (e.g., *The rock star sold some cocaine to the undercover cop*) or a double object (DO) sentence (e.g., *The rock star sold the undercover cop some cocaine*) and then tended to use the same syntactic structure to describe a different picture representing a dative event (Bock, 1986). As a widespread and robust phenomenon (Pickering & Ferreira, 2008), priming appears informative about the nature of linguistic representations themselves (Branigan & Pickering, 2017). Results from such studies have played a major role in advancing theoretical and computational models of language production (e.g., Bock, 1986; Pickering & Branigan, 1998; Reitter et al., 2011).

Lexical/translation-equivalent boost in monolingualism and multilingualism

Pickering and Branigan (1998) found that within-language syntactic priming was enhanced by open-class lexical repetition between the prime and the target – a finding that they termed the lexical boost effect. They had participants complete prime fragments and target fragments with PO or DO structures, with the verb either repeated or not. Syntactic priming did occur without lexical repetition, but priming was stronger when the verb was repeated. They proposed a model to account for syntactic representation in monolinguals based on Levelt, Roelofs, and Meyer (1999), who assumed that syntactic information (e.g., number, gender) is encoded at the lemma stratum, and that lemmas are associated with syntactic information. Pickering and Branigan proposed that lemma nodes (e.g., for dative verbs: *give, return*) are

linked to shared combinatorial nodes (e.g., dative structure: PO, DO) that are associated with the structural information in which the words can occur. For example, the lemmas for *give* and *return* are linked to the same PO and DO combinatorial nodes. When the speaker produces a particular utterance, the associated lemmas and combinatorial nodes are activated. These nodes retain residual activation (see Roelofs, 1992), which increases the likelihood that the speaker will subsequently produce another utterance that uses those nodes. More specifically, when the prime and target do not share the verb, residual activation of the combinatorial node leads to (abstract) syntactic priming. When the prime and target share the verb, the residual activation of the lemma node, combinatorial node, and the strengthened link between these nodes leads to a larger priming effect – the lexical boost.

Priming occurs across languages in bilinguals, so long as the utterances are sufficiently similar that they involve the same structural representation (i.e., activate the same combinatorial node; Pickering & Ferreira, 2008; Van Gompel & Arai, 2018). Hartsuiker et al. (2004) had a participant and a confederate describe cards to each other and select the matching card from an array. Participants were more likely to use an English passive if the confederate had just used a Spanish passive than a Spanish active (see also Loebell & Bock, 2003). Schoonbaert et al. (2007) had a confederate and a participant take turns to describe pictures involving a dative event using Dutch (L1) and English (L2) respectively. They found priming from Dutch to English PO and DO structures. More importantly, priming was enhanced when prime and target had verbs that were translation equivalents (e.g., *geven* and *give*) versus when they

had unrelated verbs – the translation-equivalent boost. Schoonbaert et al. (2007) extended Pickering and Branigan's (1998) model for monolinguals and argued that, for multilingual speakers, the lemma nodes of different languages (e.g., *geven/give "give"*) are linked to shared combinatorial nodes (e.g., PO, DO). Finally, Bernolet et al. (2012) found that priming of possessive constructions (e.g., *the fork of the girl* vs. *the girl's fork*) between Dutch (L1) and English (L2) was enhanced when the prime and target contained cognates (e.g., *vork-fork*) with significant phonological overlap than when they had non-cognate translation equivalents (e.g., *eend-duck*) with little phonological overlap.

When the prime and target involve semantically unrelated head words, cross-language syntactic priming for proficient speakers appears to be as strong as within-language syntactic priming, so long as the order of phrases (such as V followed by NP, followed by PP) and the hierarchical structure (i.e., the relationships between phrases, for instance that a VP can comprise a V, an NP, and a PP) of the prime and target are identical across languages. Kantola and van Gompel (2011) found that cross-language priming in Swedish (L1)-English bilinguals was equivalent to within-language priming. Furthermore, Hartsuiker et al. (2016) found similar results in four syntactic priming experiments investigating the attachment of relative clauses in trilingual Dutch (L1)-English-French speakers. Supporting the model of Hartsuiker et al. (2004), these studies suggest that multilingual speakers may have fully shared or integrated syntactic representations across languages.

Influence of linguistic proficiency

The extent to which syntactic representations are shared may be affected by language proficiency. Bernolet et al. (2013) conducted two syntactic priming experiments using possessive structures (*the shirt of the boy* vs. *the boy's shirt*) on Dutch (L1)-English bilinguals with varying levels of proficiency in L2 (English). They found that larger cross-linguistic priming for high- than low-proficiency L2 speakers, both when the head noun of the target was a translation equivalent (e.g., *hemd/shirt-shirt*) of the prime and when it was not (e.g., *duim/thumb-shirt*). Furthermore, they found that cross-linguistic priming in fact disappeared in the low-proficiency L2 speakers. Hartsuiker and Bernolet (2017) reanalysed the data of Schoonbaert et al. (2007) and identified a proficiency pattern for cross-linguistic priming datives that was similar to that of Bernolet et al. (2013). In a study using English (L1)-Irish bilinguals, Favier et al. (2019) found a small cross-linguistic priming effect that appeared to be driven by higher-proficiency participants.

Hartsuiker and Bernolet (2017) proposed a developmental model to account for these findings, in which L2 syntactic representations change from item-specific to abstract during learning. Initially, L2 learners develop lexical representations without any structural information. As linguistic exposure increases, they form item-specific syntactic representations. For example, at this stage each L2 dative verb lemma (e.g., *give* or *return*) can develop its own independent syntactic representation (e.g., PO or DO). At the next stage, learners can develop syntactic representations that are shared within L2, but are still separated from L1 representations. For example, the L2 verb

lemmas *give* and *return* share PO and DO nodes, but they are not connected with the counterpart PO and DO nodes in L1. When L2 learners have sufficient linguistic exposure, they can finally form shared syntactic representations between languages. Thus speakers with high L2 proficiency can develop shared representations across languages and hence show cross-linguistic priming, but speakers with low L2 proficiency should not, and these predictions are consistent with the findings of Bernolet et al. (2013) and Hartsuiker and Bernolet (2017).

Influence of similarity across languages

Apart from language proficiency, shared syntactic representations may be affected by similarity across languages. When languages share have greater similarity in constituent structure and hierarchical structure, it is easier to observe cross-linguistic priming in multilingual speakers (Bernolet et al., 2013; Favier et al., 2019; Hartsuiker et al., 2016; Kantola & van Gompel, 2011; Schoonbaert et al., 2007). For example, as Swedish and English have similar structures for PO and DO sentences, Kantola and Van Gompel (2011) found between-language priming (e.g., between L2-English and L1-Swedish) that was equivalent to within-language priming (e.g., within English or within Swedish). Note, however, that Cai, Pickering, Yan and Branigan (2011) found smaller PO/DO ditransitive priming between Cantonese and Mandarin than within Mandarin.

However, when the structural configurations are different across languages, cross-linguistic priming is not consistently observed. For example, Loebell and Bock

(2003) found cross-linguistic priming of the dative structure, where English and German have the same word order; but they found no priming of the passive structure, where the two languages have different word order. In addition, Bernolet et al. (2007) did not find priming of relative clause structures between English and Dutch, which differ in word order. But another study did finding between passive structures in the two languages when those structures differ in word order (Bernolet et al., 2009). Therefore it is possible that the representations across languages may be partly rather than fully shared when surface constituent structure and hierarchical structure are not identical across languages (Van Gompel & Arai, 2018).

But what about syntactic representations across languages that are highly similar, such as Mandarin, Chaoshanese, and Cantonese? Chaoshanese (Teochew) is a form of Southern Min, spoken in eastern Guangdong province. These three languages are not mutually intelligible, but they are all tonal and monosyllabic. Moreover, they have many cognates, have the same orthographic system (e.g., *song/sang/sung "give"* have the same Chinese character "*送*"), and share considerable phonological and syntactic structures (e.g., PO and DO structures).

As we have noted, Cai et al. (2011) found cross-linguistic priming between Mandarin and Cantonese datives in native Cantonese-Mandarin speakers (i.e., bilingual speakers who acquired Cantonese and Mandarin simultaneously in early childhood as their native languages), suggesting that highly similar languages could develop shared syntactic representations just like less similar languages. Furthermore, Huang et al. (2019) investigated cross-linguistic dative priming from Cantonese to

Mandarin and from English to Mandarin, using trilingual Mandarin-Cantonese-English participants (with L1 Mandarin). When the prime and target had semantically unrelated verbs, priming from Cantonese to Mandarin was as strong as that from English to Mandarin, suggesting shared syntactic representations across the three languages. However, when the prime and target involved translation-equivalent verbs, the priming from Cantonese to Mandarin was larger than that from English to Mandarin.

Huang et al. (2019) extended the shared syntactic model of Hartsuiker et al. (2004) and Schoonbaert et al. (2007) and argued that native Mandarin speakers, after sufficient exposure to Cantonese, could develop a direct link between the lemmas for cognates (e.g., dative verbs) across Mandarin and Cantonese through Hebbian learning (see Figure 1). According to this model, after such speakers encountered a sentence containing a dative verb in Cantonese (e.g., *sung*), they would activate the verb's lemma node and the corresponding Mandarin lemma node (e.g., *song*). Such a link would not develop between distant languages such as Mandarin and English. Therefore, when the prime and target involved cognate verbs, the cross-linguistic priming (as a result of the translation-equivalent boost) from Cantonese to Mandarin was larger than that from English to Mandarin where such co-activation did not occur. Because Chaoshanese and Mandarin are closely related, we would expect that Chaoshanese-Mandarin speakers would similarly develop a direct link between the lemmas for cognates across Chaoshanese and Mandarin.

<Insert Figure 1 about here>

The present study

This study investigates the extent to which multilinguals share syntactic representations for highly similar languages, when both languages are native and when one language is native and one is not, and moreover whether in the latter case sharing is affected by language proficiency in the non-native language (i.e., L2). On the one hand, the development of the shared syntactic representations for highly similar languages (e.g., Mandarin vs. Cantonese) might be the same as that for dissimilar languages (e.g., English vs. Dutch), which has been found to be affected by language proficiency (Bernolet et al., 2013). Under Hartsuiker and Bernolet's (2017) model, they would first develop shared representations within an L2 itself, and then shared representations across different languages. So only highly proficient L2 speakers could develop shared representations across languages. Based on this assumption, we predict that cross-linguistic syntactic priming across a highly similar L1 and L2 would be affected by L2 language proficiency, echoing the findings of previous studies on less similar languages (Bernolet et al., 2013; Favier et al., 2019; Hartsuiker & Bernolet, 2017).

On the other hand, the development of shared syntactic representations for highly similar languages might not be affected by L2 language proficiency. If L1 and L2 are highly similar, L2 learners may not necessarily go through all of the developmental stages in Hartsuiker and Bernolet's (2017) model to ultimately develop shared

syntactic representations. Because the links between the lemmas for cognates could be developed very quickly, speakers might need less exposure to an L2 to develop shared syntactic representations of cognates and then (or simultaneously) generalize the shared representations across all lexical items. In support of this argument, cognate translations typically produce stronger priming than noncognate translations in a variety of paradigms (De Groot, 1992; Sáchez-Casas et al., 1992; Wen & Van Heuven, 2017). More importantly, the cognate priming effect seems not to be affected by L2 proficiency (Davis et al., 2010; Nakayama et al., 2012), suggesting that connections between the lemmas of cognates could be formed rapidly. Thanks to these links, multilingual speakers may quickly transfer syntax from L1 to L2 and develop syntactic representations shared between cognates, and then (or simultaneously) generalize the shared representations across all lexical items in L1 and L2. Based on this supposition, we might predict that when the L2 is highly similar to the L1, even low-proficiency L2 speakers may develop shared syntactic representations, which would in turn yield cross-linguistic priming comparable with that in high-proficiency L2 speakers (and this might pattern might occur even for non-cognates).

To test this prediction, we recruited trilinguals who are native Mandarin-Chaoshanese speakers and have a moderate level of Cantonese (L2) proficiency. We first aimed to investigate whether cross-linguistic priming with cognate repetition from L2 to L1 (Cantonese to Mandarin) is the same as from L1 to L1 (Chaoshanese to Mandarin). Importantly, our design compared between-language L2-to-L1 priming (Cantonese to Mandarin) with between-language L1-to-L1 priming

(Chaoshanese to Mandarin), rather than within-language L1-to-L1 priming (Mandarin to Mandarin). This allowed us to control for any irrelevant effects related to the identity/non-identity of the prime and target languages, given that Cai et al. (2011) found less between-language priming in Chinese languages (from Cantonese-L1 to Mandarin-L1) than within-language priming (from Mandarin-L1 to Mandarin-L1). Second, and critically, we tested whether priming from L2 to L1 is affected by L2 proficiency.

In our experiments, participants heard Chaoshanese and Cantonese dative sentences (PO and DO) and then finished a picture description containing a ditransitive event using Mandarin. The prime and the target involved cognate verbs (e.g., *sang/sung-song "give"*) in Experiment 1 and unrelated verbs (e.g., *huang/waan-song "return"-"give"*) in Experiment 2, allowing us to test whether any shared syntactic representations were restricted to cognates or generalised across the lexicon.

Experiment 1

Method

Participants

We recruited 44 right-handed participants (mean age =20.28 years, SD=1.50, range = 18-24) who were native Mandarin-Chaoshanese speakers. They grew up in a predominantly Chaoshanese-speaking region and acquired Mandarin during their kindergarten years (mean age of acquisition for Mandarin=2.89, SD=1.83), and they

used both languages daily. Hence we regarded both Mandarin and Chaoshanese as L1s. They were first exposed to Cantonese (L2) at 3 to 19 years old (mean=9.84, SD=3.99). To further investigate their proficiency in these three languages, we asked them to rate their general proficiency on a 5-point scale (1 = very poor, 5 = very proficient) and four sub-categories of proficiency on a 10-point scale (1 = very poor, 10 = very proficient) for each language (see Table 1). They reported their Cantonese as significantly less proficient than their Mandarin and Chaoshanese (*t*-test, all *ps*<.05), but their Mandarin and Chaoshanese did not differ significantly (all *ps*>.05).

This study was approved by the ethics committee of The School of Psychology, South China Normal University. Participants were required to read and sign the consent form before the experiment, and were paid 20 RMB each after the experiment.

<Insert Table 1 about here>

Materials

The materials were the same as those used in Experiment 2 of Huang et al. (2019) which focused on the priming from Cantonese and English to Mandarin and the prime and where the target involved cognate verbs (e.g., *sung-song, "give"*) or non-cognate translation-equivalent verbs (e.g., *give-song, "give"*). A speaker from the same participant pool as our participants was recorded reading aloud the prime sentences in Cantonese and Chaoshanese, resulting in 32 experimental and 96 filler

items. Each set of experimental items consisted of four spoken primes (Cantonese DO prime, Cantonese PO prime, Chaoshanese DO prime, and Chaoshanese PO prime; see Table 2), a corresponding prime picture, and a target picture.

The prime picture depicted a dative event (with three entities: agent, recipient, theme), with the Chinese character of the corresponding verb printed below (see Figure 2). The theme appeared in the center of each prime picture. In half of the prime pictures, the agent was on the left-hand side and the recipient was on the right-hand side. In the other half, their locations were reversed. Half of the prime pictures matched the spoken primes, and the other half differed with respect to one of the three entities.

The target picture also illustrated a dative event, with the positions of the agent and the recipient counterbalanced in the same way as in the prime pictures. The Chinese characters for the agent and the verb were printed below the picture (see Figure 2). The entities were different between the prime and target pictures, but the verb was repeated.

<Insert Table 2 about here>

<Insert Figure 2 about here>

Each filler item set also included a spoken prime, a corresponding prime picture, and a target picture. The 96 spoken primes included 24 DO primes (12 Cantonese and 12 Chaoshanese – we followed Cai, Pickering, & Branigan, 2012, in adding these DO

"primes" to the filler materials to counteract participants' tendency to produce predominantly PO responses when producing datives), 32 intransitive primes, and 40 transitive primes. The Chinese character of the verb was printed below the prime picture. Half of the prime pictures matched their spoken primes, and the other half did not. In total, 39 of the target pictures depicted an intransitive event, and 57 of them depicted a transitive event. The Chinese characters for the agent and the verb were printed below each picture.

We therefore had a 2*2 design, with prime language (Cantonese vs. Chaoshanese) and prime structure (DO vs. PO) as independent variables. We constructed four lists of materials, each containing 32 experimental items (8 items for each prime condition) and 96 filler items in a Latin Square design. The Cantonese primes and the Chaoshanese primes were presented to participants in two different blocks. The order of the blocks was counterbalanced across participants.

Procedure

Eleven participants were randomly assigned to each list. At the beginning of the experiment, participants were familiarised with the entities that would be used in the experiment by seeing a picture of each entity, together with its name. Once they reported that they were familiar with the pictures and the names, the experiment began.

Each trial started with a 500 ms fixation cross and a 200 ms blank screen, and then a spoken sentence was presented, followed by a 200 ms blank screen and a prime

picture. For the prime picture, participants had to decide whether the picture matched the spoken prime or not (by pressing the *F* or *J* button on the keyboard), which triggered a 200 ms blank and then the next trial. Each participant completed two blocks of experiments. Each block began with three practice trials, followed by 16 experimental trials and 48 filler trials in a randomised order. There were at least two filler trials between every two experimental trials. The experiment lasted around 40 minutes.

Scoring

We scored a response as: (1) a DO if it consisted of the given sentence preamble followed by a noun phrase expressing the recipient and then a noun phrase expressing the theme; (2) a PO if it contained the sentence preamble followed by a noun phrase expressing the theme and then the preposition *gei* ("给") preceding a noun phrase expressing the recipient; (3) other, which was excluded in the following data analysis.

Phonological similarity rating

In Experiment 1, the prime and the target involved cognate verbs sharing related phonological information. To investigate whether cross-linguistic priming was affected by phonological overlap, we recruited 32 further participants who did not take part in our experiments to carry out a phonological similarity rating study for the Chaoshanese-Mandarin verb pairs using a 7-point scale (1 = the two words sound very similar; 7 = the two words sound very dissimilar). For the Cantonese-Mandarin

verb pairs, we used the rating results from Huang et al. (2019), who also recruited 32 participants to carry out an equivalent rating study for the Cantonese-Mandarin verb pairs.

Results

Table 3 reports the frequencies of DO, PO, and other responses, and the proportion of DO responses (out of all responses) across the four prime conditions. For data analysis, we used Generalised logistic mixed models (glmer) with crossed random effects for participants and items, using the glmer program of the lme4 package (Bates & Mächler, 2010) in R; *p* values in glmer are based on asymptotic Wald tests. We followed Cai et al. (2011) in re-coding the responses as primed (DO response after DO prime and PO response after PO prime) or unprimed responses. Thus the priming effect was measured by the relative frequencies of primed and unprimed responses rather than by the interaction between prime and target, and was manifested as the intercept of the LMM model (i.e., whether there were more primed than unprimed responses).

<Insert Table 3 about here>

<Insert Table 4 about here>

To estimate whether Experiment 1 had appropriate statistical power to detect cross-linguistic priming, we determined the effect size of cross-linguistic priming

using Experiment 2 of Huang et al. (2019), which had the same design and similar materials as the present study, and then used the R package SIMR (Green & MacLeod, 2016) to run a Monte Carlo simulation on our data to estimate the power on the basis of 100 simulations. The results showed that we had 100% power for 44 participants to detect cross-linguistic priming.

To determine whether there was cross-linguistic priming and whether the priming was affected by prime language, we tested a model treating prime language as a fixed effect using the maximal random effects structure (model equation: Priming ~ PrimeLanguage + (PrimeLanguage + 1 | Subject) + (PrimeLanguage + 1 | Item)) (Barr et al., 2013). The results showed a significant difference between primed and unprimed responses (see Table 4), suggesting that cross-linguistic priming did occur. Further analyses (see supplementary materials for the random effects) revealed cross-linguistic priming from Cantonese to Mandarin (*Estimate*=0.65, *SE*=0.12, *Z*=5.42, *p*<.001) and from Chaoshanese to Mandarin (*Estimate*=0.75, *SE*=0.12, *Z*=6.01, *p*<.001). More importantly, the effect of prime language was not significant (see Table 4), suggesting that priming from Cantonese to Mandarin (L2 to L1) was as strong as that from Chaoshanese to Mandarin (L1 to L1). To further estimate how likely it was that the data reflected a null difference, we used a Bayes factor analysis (BF_{01}, from Wagenmakers, 2007). Specifically, we calculated the Bayesian information criterion (BIC) from a null-hypothesis (H0) LMM model (without the fixed effect of prime language) (model equation: Priming ~ 1 + (PrimeLanguage + 1 | Subject) + (PrimeLanguage + 1 | Item)) and an alternative-hypothesis (H1) LMM

model (with the fixed effect), and then computed the Bayes factor between them using the formulation: $BF_{01} = EXP\left(\frac{BIC_{H1} - BIC_{H0}}{2}\right)$. The Bayes Factor (BF)value was 31.5, suggesting that the null hypothesis was more than 30 times as likely as the alternative hypothesis. According to Raftery (1995), this provides strong evidence supporting the null hypothesis.

To investigate whether the cross-linguistic priming from Cantonese to Mandarin was affected by Cantonese proficiency, we took the mean of participants' self-ratings of general proficiency and four sub-categories of proficiency of Cantonese as the index of Cantonese proficiency (following Bernolet et al., 2013), and then built a model treating Cantonese proficiency as the fixed effect using the maximal random effects structure (model equation: Priming ~ Cantoneseproficiency + (Cantoneseproficiency + 1 | Subject) + (Cantoneseproficiency + 1 | Item)). We compared this model to a model without the fixed effect of Cantonese proficiency (model equation: Priming ~ 1 + (Cantoneseproficiency + 1 | Subject) + (Cantoneseproficiency + 1 | Item)). According to the model comparison, the effect of Cantonese proficiency was not significant (χ^2=1.01, p=.32). Furthermore, BIC analysis showed the Bayes Factor value was 32.33, suggesting that the null hypothesis was more than 30 times as likely as the alternative hypothesis. According to Raftery (1995), this provides strong evidence suggesting that Cantonese proficiency did not affect priming from Cantonese to Mandarin.

To test whether cross-linguistic priming was affected by phonological similarity between cognate verbs, we built two maximal models treating the phonological

similarity between Cantonese and Mandarin verb pairs, and that between Chaoshanese and Mandarin verb pairs, as the fixed effect (i.e., model equation: Priming ~ PhonologicalSimilarity + (PhonologicalSimilarity + 1 | Subject) + (PhonologicalSimilarity + 1 | Item)) . We compared these two models with models without the respective fixed effect (i.e., model equation: Priming ~ 1+ (PhonologicalSimilarity + 1 | Subject) + (PhonologicalSimilarity + 1 | Item)). The model comparison results demonstrated that neither phonological similarity effect was significant (*ps*>.1). BIC analysis further confirmed that the null hypothesis for the Cantonese and Mandarin verb pairs and for the Chaoshanese and Mandarin verb pairs were about 24 (BF = 24.5) and 26 times (BF = 25.79) more likely than the alternative hypothesis respectively, which strongly suggested that phonological similarity between cognate verbs did not affect either type of cross-linguistic priming.

Discussion

Experiment 1 revealed that the cross-linguistic priming from Cantonese to Mandarin was equivalent to that from Chaoshanese to Mandarin. Considering the Chanshanese and Mandarin both are participants' L1s, they should share syntactic representations. And the Cantonese primes behaved like Chaoshanese primes, suggesting that our multilingual speakers had developed fully shared syntactic representations of cognates across Mandarin (L1), Chaoshanese (L1), and Cantonese (L2). Furthermore, priming from Cantonese to Mandarin was not affected by Cantonese proficiency, suggesting

that the development of fully shared representations across an L1 and a closely related L2 does not depend upon proficiency.

Since the prime and the target in Experiment 1 involved cognate verbs, it was not clear whether the shared syntactic representations occurred for all verbs across these three languages. In Experiment 2, we examined this issue by using unrelated (non-cognate) verbs across prime and target.

Experiment 2

Method

Participants

We recruited 64 participants from the same pool as Experiment 1. To estimate whether Experiment 2 had acceptable statistical power to detect cross-linguistic priming, we fixed the effect size of the cross-linguistic priming in Experiment 1 of Huang et al. (2019), which used PO/DO structures to examine cross-linguistic priming (i.e., from Cantonese to Mandarin and from English to Mandarin) without verb repetition, and which also used 32 sets of experimental materials (8 items for each prime condition), and hence was very similar to the current study. Then we ran a Monte Carlo simulation of our data on the basis of 100 simulations. This showed 100% power for 64 participants to detect cross-linguistic priming.

Participants were similar to those in Experiment 1: right-handed and 18-24 years old (mean=20.47, SD=1.46). As native Chaoshanese speakers, they acquired Mandarin during the kindergarten years (mean age of acquisition for Mandarin=2.45,

SD=2.20). Their ages of exposure to Cantonese (L2) ranged from 2 to 17 years (mean=7.20, SD=4. 44). Their Cantonese proficiency was significantly lower than that for Mandarin and Chaoshanese (all *ps*<.05); their Mandarin and Chaoshanese proficiency did not differ significantly (all *ps*>.05). The participants were paid 20 RMB each after the experiment.

Materials

We used the same materials as in Experiment 1 and re-paired the prime and the target in the experimental items to create 32 sets of materials in which the Cantonese or Chaoshanese prime and the Mandarin target involved non-cognate verbs. After the re-pairing, there were six items that had one entity repeated between prime and target; for these items, we replaced the repeated entity with a different one.

Procedure and scoring

The procedure and the scoring were identical to those in Experiment 1.

Results

Table 5 reports the frequencies of DO, PO, and other responses, and the proportion of DO responses (out of all responses) across the four prime conditions. We built a model treating prime language as a fixed effect using the maximal random effects structure (model equation: Priming ~ PrimeLanguage + (PrimeLanguage + 1 | Subject) + (PrimeLanguage + 1 | Item)). The results showed a significant difference

between primed and unprimed responses (see Table 6), indicating cross-linguistic priming. Further analyses (see supplementary materials for the random effect) revealed cross-linguistic priming from Cantonese to Mandarin (*Estimate*=0.15, *SE*=0.07, *Z*=2.07, *p*=.04) and from Chaoshanese to Mandarin (*Estimate*=0.15, *SE*=0.07, *Z*=2.17, *p*=.03). More importantly, the effect of prime language was not significant (see Table 6), suggesting that the cross-linguistic priming from Cantonese to Mandarin was as strong as that from Chaoshanese to Mandarin. Furthermore, Bayes factor analysis (BF = 44.7) provided strong evidence supporting the null hypothesis, which was around 45 times more likely than the alternative hypothesis.

<Insert Table 5 about here>

<Insert Table 6 about here>

Additionally, to investigate whether the cross-linguistic priming from Cantonese to Mandarin was affected by Cantonese proficiency, we use the same method as in Experiment 1 and built a model treating Cantonese proficiency as the fixed effect using the maximal random effects structure, and then compared this model to a model without the fixed effect of Cantonese proficiency. The model comparison results demonstrated that the effect of Cantonese proficiency was not significant (χ^2=0.99, *p*=.32). BIC analysis (BF = 25.11) further revealed that the null hypothesis was around 25 times more likely than the alternative hypothesis, providing strong evidence that Cantonese proficiency did not affect the priming from Cantonese to Mandarin.

Combined analysis of Experiments 1 and 2

To test whether there was a translation-equivalent boost effect, we combined the data of Experiments 1 and 2 and built a model treating experiment (cognate verbs vs. unrelated verbs between the prime and target) as the fixed effect and including the random slope for item in the random structure model (model equation: Priming ~ Experiment + (1 | Subject) + (Experiment + 1 | Item)) for the priming from Cantonese to Mandarin and the priming from Chaoshanese to Mandarin respectively. The results (see supplementary materials for the random effect) indicated priming with cognate verbs (Experiment 1) was larger than that with unrelated verbs (Experiment 2) not only after the Cantonese primes (*Estimate*=0.45, *SE*=0.11, *Z*=4.12, $p<.001$), but also after the Chaoshanese primes (*Estimate*=0.55, *SE*=0.15, *Z*=3.66, $p<.001$), suggesting a translation-equivalent boost effect.

General Discussion

The present study revealed syntactic priming from Chaoshanese to Mandarin, and from Cantonese to Mandarin. Such priming occurred both when the prime and the target involved cognate verbs and when they did not, but was larger when the prime and the target involved cognate verbs (demonstrating a translation-equivalent boost effect).

Most importantly, priming from Cantonese (L2) to Mandarin (L1) was equal to that from Chaoshanese (L1) to Mandarin (L1), irrespective of whether or not the

prime and the target involved cognate verbs. In addition, individual speakers' priming from Cantonese to Mandarin was not affected by their Cantonese proficiency (which was lower than their proficiency in Chaoshanese and Mandarin). Because Chaoshanese and Mandarin are similar in syntax and participants were very highly proficient (i.e., native speakers) in both languages, we would expect them to have fully shared representations (based on previous findings; e.g., Cai et al., 2011; Hartsuiker et al., 2004). But crucially the equivalence of Cantonese-Mandarin priming to the Chaoshanese-Mandarin priming, and the lack of any effect of Cantonese proficiency on such priming, suggests that they had fully shared representations in Cantonese and Mandarin, irrespective of their level of proficiency in Cantonese. We do not have direct evidence for fully shared representations between Chaoshanese and Cantonese, but if representations in Mandarin are shared with representations in both Chaoshanese and Cantonese, then representations in Chaoshanese and Cantonese are presumably shared with each other.

Previous studies found that multilingual speakers with a high level of L2 proficiency showed stronger cross-linguistic priming than those with a low level of L2 proficiency, suggesting multilinguals could not develop fully shared syntactic representations until they reached a very high level of L2 proficiency (Bernolet et al., 2013; Favier et al., 2019; Hartsuiker & Bernolet, 2017). However, the present study found that, in a situation where L2 (Cantonese) was highly similar to L1 (Mandarin), cross-linguistic priming was not affected by L2 proficiency, suggesting the

multilingual speakers with a low level of L2 proficiency had already developed syntactic representations that were shared between their L2 and L1.

Why should our findings differ from these previous studies? We can conclude that our null effect of L2 proficiency is not based on a ceiling effect or a lack of power with respect to proficiency. First, participants' self-reported L2 proficiency was much lower than their self-reported proficiency for each L1. Second, the range of participants' L2 proficiency in the present study (the standard deviations of proficiency range from 0.84 to 2.18) was numerically wider than those of Bernolet et al. (2013) (the standard deviations of proficiency range from 0.56 to 1.30), who found that priming across less similar languages (Dutch and English) was affected by L2 proficiency. Third, the sample size and number of experimental observations (1408 and 2048 observations for Experiment 1 and 2) in our research were also larger than those of Bernolet et al. (2013) (1152 observations). Thus, our study should have enough power to test the proficiency effect if it were of a similar magnitude to theirs, and our Bayes Factors analyses give us further confidence in this conclusion. In other words, our null effect is not likely to be the result of a ceiling effect or lack of statistical power.

We used self-evaluation methods to measure proficiency. Recent research with bilinguals has use a variety of objective measurements that may offer advantages (e.g., Khare, Verma, Kar, Srinivasan, & Brysbaert, 2013; Lemhöfer & Broersma, 2012; Wen & van Heuven, 2017). But such measurements are not available for all of our languages. More importantly, our self-evaluation methods were modelled on those

used in previous studies (Bernolet et al., 2013; Favier et al., 2019; Schoonbaert et al., 2007; Huang et al., 2019) that have detected influences of proficiency on priming (e.g., Bernolet et al., 2013).

Another possibility is that proficiency effects occur only from L1 to L2, as found in Bernolet et al. (2013) and in Bernolet and Hartsuiker's (2017) re-analysis of Schoonbaert et al. (2007). However, we see no theoretical reason why this should be the case, and it is worth noting that much research has found that the magnitude of priming is unaffected by such directionality: Kantola and Van Gompel (2011) found that dative priming from L2 to L1 was equal to priming from L1 to L2, and Hartsuiker, Beerts, Loncke, Desmet, and Bernolet (2016) similarly found equal priming of relative clause attachment from L1 to L2 as from L2 to L3 in trilingual speakers of Dutch (L1), English (L2), and French (L3). We therefore conclude that the null effect of proficiency is a result of language similarity.

Hartsuiker and Bernolet (2017) proposed a model in which syntactic representations are first developed within an L2 and then become shared between L1 and L2. Bilinguals with low levels of proficiency have separate syntactic representations, but bilinguals with high levels of proficiency have shared syntactic representations. Hartsuiker and Bernolet therefore predict that less proficient participants will show no cross-linguistic priming, and that more proficient participants will show both abstract cross-linguistic priming and a translation-equivalent boost.

However, their model is based on data from languages that are less similar to each other than Cantonese, Chaoshanese, and Mandarin. We propose that bilinguals with low levels of proficiency in highly similar languages do share syntactic representations. Our account explains why we found both abstract cross-linguistic priming (Experiment 2) and a translation-equivalent boost (combined analysis of Experiments 1 and 2). In fact, both of these effects occurred both between L2 and L1 (Cantonese and Mandarin), and between two L1s (Chaoshanese and Mandarin). It also explains why we found no effect of L2 proficiency on cross-linguistic priming for translation-equivalent verbs (Experiment 1) – all our participants had sufficient Cantonese proficiency to share representations, even though their proficiency range was considerable (and greater than that of Bernolet et al., 2013).

Let us therefore sketch an explanation of the development of shared representations between Mandarin (L1) and Cantonese (L2). At the beginning of Cantonese lexical learning (e.g., when learning *sung*, meaning "give"), the corresponding cognates (here, *song*) in Mandarin are co-activated as they share the same meaning and orthography and are similar in phonology, and so links between their lemmas rapidly develop through Hebbian learning. This pattern is consistent with the finding from Huang et al. (2019) of a particularly strong translation-equivalent boost between Cantonese and Mandarin, and with the finding from both Huang et al. and the current study that priming with translation-equivalent verbs is unaffected by proficiency (within the range of our participants). These quickly developing links support the development of shared syntactic representations

between cognates, and subsequent (or simultaneous) generalization of shared representations across all lexical items in L1 and L2.

Of course, all our participants had at least three years of exposure to Cantonese. It is possible that a certain level of linguistic proficiency (or exposure) is necessary for shared representations to be developed. Further research is necessary to determine this level, but we claim that the threshold level for highly similar languages is lower than that for less similar languages. In conclusion, we have shown syntactic priming across highly related languages and have used our results to support the existence of syntactic representations that are shared from an early stage of acquisition.

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Table 1. Language background self-ratings in Experiments 1 and 2 (Standard Deviation in brackets).

	Experiment 1			Experiment 2		
Language background	Mandarin	Chaoshanese	Cantonese	Mandarin	Chaoshanese	Cantonese
Listening Comprehension	8.88(1.10)	9.25(1.02)	6.06(1.52)	8.72(1.25)	9.16(0.81)	5.97(1.26)
Reading Comprehension	7.78(1.58)	9.41(0.80)	5.06(1.61)	7.69(2.12)	9.38(0.66)	5.69(2.18)
Speaking Fluency	8.78(1.29)	9.16(0.99)	4.75(2.11)	9.00(1.32)	9.09(0.86)	4.31(2.04)
Speaking Pronunciation	8.56(1.37)	8.63(1.24)	4.50(1.67)	8.72(1.57)	8.47(1.22)	4.13(1.88)
General Proficiency	4.44(0.62)	4.78(0.55)	2.50(0.84)	4.34(0.94)	4.47(0.84)	2.29(0.94)

Table 2. Sample stimuli in Experiment 1.

Prime Condition	Example
a. Cantonese-DO	*Cyusi sung-bei muksi jatgo kau*.
	Chef gives-to priest a ball.
	(“The chef gives the priest a ball.”)
b. Cantonese-PO	*Cyusi sung-zo kau bei muksi.*
	Chef give-LE ball to priest.
	(“The chef gives a ball to the priest.”)
c. Chaoshanese-DO	*Douse sang-gib mogse zeggai giu.*
	Chef gives-to priest a ball.
	(“The chef gives the priest a ball.”)
d. Chaoshanese-PO	*Douse sang-liao giu gib mogse.*
	Chef give-LE ball to priest.
	(“The chef gives a ball to the priest.”)

Table 3. Experiment 1: Frequencies of PO, DO and other target responses by condition.

Prime	Cantonese DO	Cantonese PO	Chaoshanese DO	Chaoshanese PO
DO	176	68	192	72
PO	174	275	158	276
other	2	9	2	4
DO Proportion	0.50	0.19	0.55	0.20

Table 4. The lmer analysis of Experiment 1.

Random effects:

Groups	Name	Variance	SD
Subject	(Intercept)	0.33	0.58
	Language	0.002	0.01
Item	(Intercept)	0.001	0.04
	Language	0.37	0.61

Number of observations: 1391, Subject, 44; Item, 32

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.71	0.11	6.64	<.001
Language	0.10	0.16	0.59	0.56

Table 5. Experiment 2: Frequencies of PO, DO and other target responses by condition.

Prime	Cantonese DO	Cantonese PO	Chaoshanese DO	Chaoshanese PO
DO	184	147	160	126
PO	316	356	338	378
other	12	9	14	8
DO Proportion	0.36	0.29	0.31	0.25

Table 6. The lmer analysis of Experiment 2.

Random effects:

Groups	Name	Variance	SD
Subject	(Intercept)	0.0312	0.18
	Language	0.046	0.07
Item	(Intercept)	0.006	0.02
	Language	0.19	0.44

Number of obs: 2005, Subject, 64; Item, 32

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.15	0.05	3.37	<.001
Language	-0.004	0.12	-0.03	0.98

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Figure 1. Model of lexico-syntactic representations in Mandarin-Cantonese-English multilinguals. Adapted from Huang et al. (2019).

Figure 2. Procedure of Experiment 1.

Note. The character below the prime picture means "*give*", and the characters below the target picture mean "*The cowboy pass*_____."