Phonological similarity effects in cross-script word processing

Evidence from Sino-Korean word processing by Cantonese learners

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The present study explored the conditions under which phonological similarity effects arise without orthographic confounds by testing languages with true cognates but divergent scripts. We investigated the similarities and differences between within- and cross-script processing patterns by providing data from an understudied language pair, Korean and Cantonese, which have many cognates but bear no orthographic resemblance. In two word-naming and translation tasks, beginning and intermediate Cantonese-speaking learners of Korean ($N=112$) were tested for the processing speed of Sino-Korean words. The results of the word-naming experiments showed that phonologically similar words were processed faster than dissimilar ones, regardless of L2 fluency, especially when the logographic L1 characters were used as primes. However, facilitation by shared phonology was not observed in the translation experiments in either direction. L1-to-L2 forward translation was much faster than L2-to-L1 backward translation, indicating conceptual memory being used as a primary processing pathway. The characteristics of cross-script processing patterns were discussed in terms of the structure of bilingual memory.

Keywords: Sino-Korean, Cantonese, cognates, phonological similarity, Chinese characters

Introduction

Cognate advantage in word processing is well documented in the literature. Previous studies have shown that cognates are processed faster in lexical decision tasks (e.g., de Groot, Borgwaldt, Bos, & van den Eijnden, 2002; de Groot &

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Nas, 1991; Dijkstra, Grainger, & Van Heuven, 1999; Kroll, Michael, Tokowicz, & Dufour, 2002; Sánchez-Casas, García-Albea, & Davis, 1992), are translated faster than non-cognates (e.g., de Groot, 1992; Kroll et al., 2002; Kroll & Stewart, 1994), and are produced more quickly in word-naming (e.g., de Groot et al., 2002; Kroll et al., 2002) and picture-naming (e.g., Costa, Caramazza, & Sebastián-Gallés, 2000). The significant facilitatory effect of cognates is thought to stem from their relative transparency in lexical form, often manifested in both orthographic and phonological overlap.

Some studies investigating the complex nature of form similarity and its role in cognate recognition, however, have found that it may, in fact, manifest in a more variable way. That is, cognates may overlap in both orthography and phonology, while others overlap in only phonology or orthography. In a study with English-Spanish bilinguals, Schwartz, Kroll, and Diaz (2007) found a significant effect of phonological similarity for cognates with matching orthography-phonology (e.g., *piano-piano* for Spanish-English), but not for cognates with mismatching orthography (e.g., *tren-train*). In a similar vein, Dijkstra et al.'s (1999) study of Dutch-English bilinguals showed that orthographically similar cognates (e.g., *type-type*; /tiːpə/-/taɪp/) were recognized faster than phonologically similar cognates (e.g., *klok-clock*; /klɔk/-/klɑk/). Taken together, these findings call into question the role of phonology, independent of orthography, in cognate facilitation.

However, many languages, especially those extensively studied in bilingual studies, share most of their writing systems based on the Roman alphabet, making it hard to disentangle the underpinnings of form similarity effects. Thus, languages with cognates that do not share the same scripts provide a unique opportunity to isolate the effect of phonology from orthography in word processing. The present study aims to provide further empirical evidence for phonological similarity effects in word processing using cognates with differing scripts. By comparing Cantonese and Korean, which employ entirely different scripts but share many historical cognates, we manipulated experimental variables and paradigms to explore how and when shared phonology influences cross-script processing.

Cross-script word-processing: Findings and limitations

Gollan, Forster, and Frost (1997) were among the first to address the independent role of shared phonology in cognate processing. Using a cross-language masked priming paradigm, they found general facilitation in cross-script word identification for Hebrew-English bilinguals. More interestingly, cognate pairs (e.g., פילטר /fiːlter/ for English target FILTER) showed consistently greater priming than noncognate pairs (e.g., ארמון /armon/ for English target CASTLE). Given the absence of orthographic overlap between Hebrew and English, cognate facilitation may have arisen solely from phonological overlap. Nevertheless, given that Hebrew and English are still both alphabetic systems, language pairs with completely different scripts are needed in order to explore this issue further.

A growing number of recent studies have corroborated earlier findings on cross-script facilitation using a variety of experimental paradigms. A large facilitatory effect of cognates has been found between French and Greek in lexical decision tasks with masked primes (Voga & Grainger, 2007). For Japanese-English bilinguals, robust cognate facilitation was identified in lexical decision tasks (Ando, Jared, Nakayama, & Hino, 2014; Miwa, Dijkstra, Bolger, & Baayen, 2014; Nakayama, Sears, Hino, & Lupker, 2012), picture-naming (Hoshino & Kroll, 2008), or both tasks (Allen & Conklin, 2013). Reliable cognate facilitation was obtained for Korean-English bilinguals in masked priming experiments for lexical decision, naming, and semantic categorization (Kim & Davis, 2003). However, some studies have reported no facilitation between Arabic and French cognates in overt long-term priming experiments (Bowers, Mimouni, & Arguin, 2000). In the case of Chinese-English bilinguals, masked primes of English cognates facilitated lexical decision of Chinese targets, but such priming effects were absent for the other direction, namely Chinese cognate primes did not aid the processing of English target words (Zhang, Wu, Zhou, & Meng, 2019). All bilingual participants examined in these studies were unbalanced bilinguals whose L1 is unambiguously dominant, but they were advanced learners of their respective L2, having learned the L2 for an extensive period of time (7~10 years) and/or having lived in an L2 immersion environment. This begs the question of whether less proficient L2 learners (like those in the present study) can also benefit from cognate facilitation.

Test stimuli in cross-script processing studies are generally limited to loanwords because languages with entirely different scripts are usually historically unrelated and it is impossible to find etymological cognates as defined in within-script studies. Importantly, when loanwords are adopted from unrelated languages, they tend to undergo substantial phonological modifications due to the differences in sound systems. Allen and Conklin (2014) had Japanese participants rate Japanese-English word pairs in terms of phonological similarity on a 5–point scale along with other norming experiments. While the mean similarity rating was significantly higher for loanword cognate pairs ($M = 3.5$) than for noncognate pairs ($M = 1.1$), the ratings within the cognate pairs were on a continuum ranging widely from pairs of remotely similar words (e.g., テレビ /tʰerebi/ for 'television' /tʰɛləvɪʒən/, similarity rating = 2.4) to those with a high similarity (e.g., スプーン /supu:n/ for 'spoon' /spun/, similarity rating = 4.3). Likewise, many phonologically distinct pairs are found among English loanwords in Chinese (e.g., 巧克力

/tɕʰaʊ²¹⁴.kʰɤ⁵¹.li⁵¹/ for 'chocolate' /tʃɔ́klət/; 三明治 /san⁵⁵.miŋ³⁵.tʂʅ⁵¹/ for 'sandwich' /sændwɪtʃ/; 雪茄 /ɕye²¹⁴.tɕʰa⁵⁵/ for 'cigar' /sigɑ́ɹ/) (Zhang et al., 2019).

Compared to nearly identical phonological forms (e.g., Spanish-English *piano-piano* in Schwartz et al., 2007) or minimally different ones (e.g., Dutch-English *klok-clock*; /klɔk/-/klɑk/ in Dijkstra et al., 1999) carried by cognates in within-script processing, the phonological distance tends to be much greater in cross-script studies. As such, attempts have been made in recent studies to treat phonological similarity as a continuous variable rather than as a categorical one (Allen & Conklin, 2014; Miwa et al., 2014). Weak or null effects of cognate facilitation in some cross-script experiments may be, therefore, attributable to the qualitative differences in what constitutes phonological similarity in cognates.

Presumably due to insufficient numbers of clear and well-known cognates, some of the stimuli used in previous studies are questionable as to whether they are true cognates. Some stimulus items in Kim and Davis (2003), for example, are at best either English words simply transcribed in Korean orthography or bound morphemes (i.e., part of compound loanwords), but not English loanwords that have gained a legitimate lexical status in contemporary Korean. For example, '검' (/kʌm/) was used as the cognate of the English word 'gum', but in written Korean, '검' can only mean 'sword'. Likewise, '카' (/kʰa/) was used as the cognate of the English word 'car', but it cannot appear in isolation, but only as part of compound loanwords such as /kʰa-sentʰʌ/ *car-center* 'car repair shop'. It follows that without careful consideration of the potential differences in the degree of phonological similarity in cognates, it could be difficult to draw comparisons between cross-script and within-script processing studies.

Strictly cross-script processing: Cantonese and Sino-Korean words

In the current study, we investigated the structure of the bilingual mental lexicon by testing cross-script languages. The two languages, Korean and Cantonese, bear no orthographic resemblance. While the Korean script is based on a unique but transparent phonetic alphabet, *Hangul* (Sohn, 1999), the Chinese script, used in written Cantonese, is logographic in nature. Moreover, unlike Mandarin speakers who are taught the official romanization system *Pinyin* early in their education, Cantonese speakers in Hong Kong are not formally taught any romanization system for Cantonese, although they are still exposed to *Pinyin* in their Mandarin classes (only about two lessons per week). They learn Chinese characters primarily by penmanship and rote learning. Previous studies have shown that Hong Kong students have weaker phonological awareness than their mainland Chinese counterparts (McBride-Chang, Bialystok, Chong, & Li, 2004; McDowell

& Lorch, 2008). The qualitative differences in orthographic systems and the weaker phonological awareness of Hong Kong Cantonese speakers provide a good opportunity to test the role of phonological similarity without a confounding effect of orthographic overlap.

Although Chinese and Korean belong to different language families, frequent contact for geographic and historical reasons has resulted in a considerable number of Chinese loanwords in the Korean lexicon. Sino-Korean (SK) words, the target materials in the current study, are borrowings from Middle Chinese (AD 25-907) (Chen, 1999), many of which are cognates of corresponding Modern Chinese words. The majority of Chinese compounds consists of multiple monosyllabic morphemes, and this morpho-phonological structure is adopted faithfully into SK-words. Therefore, SK words and corresponding Mandarin or Cantonese cognates have the same number of syllables, and the differences in the pronunciation primarily lie in the individual segments constrained by the phonological systems of the languages. In particular, the degree of phonological correspondence was shown to be higher when the entire rimes VC are compared between SK and Mandarin words than when only the vowels are considered (Luo, Yang, Sun, & Chen, 2019). Korean and Chinese also share some similarities in terms of the complex structure of the scripts. Unlike many writing systems that employ a left-to-right simple linear order, the Korean writing system groups alphabetic letters into syllabic blocks in two dimensions. Similarly, Chinese characters combine radicals and strokes into square-shaped blocks, although each component does not correspond to an individual phoneme as is mostly the case for Korean.

Cognate facilitation for Korean-Mandarin pairs has been observed in the literature. In an eye-tracking study using a boundary paradigm, experienced Korean-speaking learners of Mandarin were shown to benefit from cognates during cross-script sentence reading (Wang, Yeon, Zhou, Shu, & Yan, 2015). For the processing of a target Chinese word (e.g., 基本 [tɕi.pən] 'basic') embedded in a sentence, three types of SK primes were used: cognates (e.g., 기본 [ki.bon] 'basic'), semantically-related non-cognates (e.g., 초급 [tɕʰo.gɨp˺] 'beginning'), and unrelated primes (e.g., 무료 [mu.ɾjo] 'free'). The results demonstrated that target Chinese characters were skipped more frequently and processed faster when primed by SK cognates than by other SK primes. The cognate facilitation found in this study points to the role of phonological overlap in word processing to the exclusion of orthographic overlap.

Interestingly, compared to Mandarin, Cantonese and SK retain many phonological features of Middle Chinese (Li, 1994; Martin, 1992; Qian, 2018; Sohn, 1999) while Modern Mandarin has gone through substantial sound changes. Both Cantonese and Korean have /p t k/ obstruent finals and final nasals /m n ŋ/

(Baur & Benedict, 1997; Li, 1994), for example. As a result, many Cantonese-SK cognates show an even greater phonological similarity than Mandarin-SK cognates, enabling us to effectively address cognate facilitation arising from similar phonology.

Unlike most previous studies where cognates are considered a uniform category (i.e., phonologically similar word pairs), the present study utilizes cognates from two ends of the phonological similarity spectrum. For example, some SK words are very similar in pronunciation to the corresponding Cantonese words (e.g., 참가 [tɕʰam.ga] vs. 參加 [tsʰam^{55}.ka^{55}] 'participation'), while others are comparatively dissimilar (e.g., 연습 [jʌn.sʰɨp˺] vs. 練習 [lin^{22}.tsap^{2}˺] 'practice'). In order to obtain a relatively objective scale of phonological similarity for a large number of cognates, a combination of a corpus study and similarity judgment task was employed in this study. In doing so, we examined whether phonologically similar cognates have greater facilitatory effects than dissimilar cognates in processing.

Instead of using non-cognates as a baseline, as has commonly been done, we tested only cognates, but used non-similar cognates as the baseline. In addition, the stimuli included unknown cognates as well as known ones. The motivation for the addition of the unknown cognates is twofold. First, given the nature of the experimental tasks, it is important to ensure that the processing of words involves word recognition. A few studies have raised the possibility that word-naming is subject to bypassing word recognition, particularly for languages that allow for transparent grapheme-to-phoneme correspondence (de Groot, 2011; de Groot et al., 2002; Paap, McDonald, Schvaneveldt, & Noel, 1987). For example, de Groot et al. (2002) found that word frequency effects manifested themselves to a much smaller degree in naming tasks compared with lexical decision tasks, particularly with orthographically shallow scripts (e.g., Dutch) than deeper scripts (e.g., English). Korean, the target language of the current study, is indeed one of the languages in which simple script-to-sound conversion is, in principle, possible during reading.[1] Indeed, for the unknown cognates, learners will simply be reading the orthography, a more time-consuming task than actual lexical

1. Korean has many phonological rules applied to hetero-syllabic consonant clusters, e.g., post-obstruent tensing in which lenis consonants turn tense when following another obstruent (e.g., /tɕʰok-tɕin/ → [tɕʰok-tɕ'in] 'facilitation') (Sohn, 1999). In the stimuli set, a few words in the CVC-CV(C) forms met this condition, however, small laryngeal differences were ignored when coding the results. More importantly, the orthographic divergence from the actual pronunciation is minor for those featural changes. The stimuli set did not include other cases involving complex phonological rules, and the orthography was mostly faithful to the actual pronunciation.

processing. Faster processing of known cognates would, therefore, verify the engagement of lexical processing during word-naming tasks.

Second, the addition of unknown cognates enables the testing of phonological similarity effects; facilitation by similar phonology, if any, is predicted to be stronger for the known cognates. None or weaker similarity-driven facilitation is expected for unknown cognates because lexical representations of those words are lacking in the learners' mental lexicon, and also because they need to implicitly learn the relationship between the unknown cognates in our experiments (see more below). The interaction between phonological similarity and word familiarity (known vs. unknown cognates) will, therefore, provide empirical evidence for the learners' lexical mediation during L2 word processing.

Phonological facilitation by logographic L1 orthography

The classic word-naming method involves participants reading aloud L2 words displayed on a screen. In this study, we added another experimental condition where L1 characters were provided along with the SK stimuli. This condition was included to facilitate the participants' awareness of the phonological similarity between the cognates without explicit instructions. If phonological codes are activated during Chinese character recognition, it is possible for the activated L1 phonological code to interact with alphabet-based L2 targets, or vice versa, similarly to alphabet-based primes and targets.

The findings of the studies on Chinese character recognition are mixed, however. Some studies have shown that the retrieval of phonological codes from printed Chinese characters takes place very early in processing (Perfetti & Zhang, 1991; Tan, Hoosain, & Peng, 1995). For instance, Perfetti and Zhang (1991) have shown that phonetic masks (e.g., 事 /ʂɻ̩^{51}/ 'matter') facilitate the identification of target characters (e.g., 视 /ʂɻ̩^{51}/ 'see') to a similar degree as semantic masks (e.g., 看 /k^{h}an/ 'see'). In Zhou et al. (2010), a phonologically similar Chinese prime (e.g., 把 /pa^{214}/) was shown to facilitate the naming of an English target (e.g., bar). However, others have demonstrated a limited role of phonology in accessing lexical representations during Chinese character recognition conducted in varying behavioral tasks (Chen & Shu, 2001; Wong, Wu, & Chen, 2014; Zhou & Marslen-Wilson, 1999). In addition, event related potential (ERP) studies have shown that phonological activation takes place later than semantic processing of single character words (Wang, Mecklinger, Hofmann, & Weng, 2010) or a negligible role of phonology was obtained in processing of two-character words (Wong et al., 2014). Considering these controversies, Chinese characters were presented as masked primes with a slightly long 75 ms prime duration in Experiment 2 and overtly in Experiment 1.

While L1 characters are likely to have a general facilitatory effect for L2 word processing, their effect is predicted to be asymmetrical with respect to the level of shared phonology. Lexical items with similar phonology are likely to be processed faster than those with dissimilar phonology. Further, we also predicted that the L1 characters would facilitate the processing of unknown cognates as well as known ones, as learners are likely to associate unknown L2 words with corresponding L1 words. To this end, we employed two word-naming studies differing in the way in which L1 characters were presented. In Experiment 1, L1 characters were presented overtly alongside SK stimuli, whereas they were presented covertly as backward masked primes in Experiment 2. In Experiment 1, participants were not told that the L1 characters are cognates of the L2 words, but they would implicitly learn about this based on the known cognates.

Facilitation by shared phonology across experimental paradigms

The literature on cross-script processing is still meager, and we tested cross-script bilinguals in varying experimental paradigms: a translation experiment in addition to two word-naming experiments. Whereas word-naming tasks may allow for prelexical as well as lexical processing, translation tasks force participants to think about words' meanings.

Translation studies have often shown asymmetrical patterns depending on translation direction. L1 semantic primes tend to have large facilitatory effects on the translation of L2 targets (L1-to-L2 forward translation) whereas a negligible effect is found for the other direction (L2-to-L1 backward translation) (e.g. Davis et al., 2010; Gollan et al., 1997; Jiang & Forster, 2001). This directional asymmetry appears to suggest that the former takes place, by and large, through conceptual mediation, while the latter takes place through lexical mediation. Furthermore, L2-to-L1 backward translation is found to be faster than L1-to-L2 forward translation, especially for less fluent bilinguals (e.g. Kroll et al., 2002; Kroll & Stewart, 1994). Taken together, the directional asymmetry has been taken to indicate that learners may undergo developmental changes from lexical to conceptual mediation with more experience in the L2.

However, the association between translation direction and processing modes has been challenged by later works. Many studies, in fact, have reported evidence for both form similarity (de Groot, Dannenburg, & van Hell, 1994; Kroll & Stewart, 1994) and conceptual mediation (de Groot et al., 1994; de Groot & Poot, 1997; Duyck & Brysbaert, 2004; Francis & Gallard, 2005; La Heij, Hooglander, Kerling, & Van Der Velden, 1996; van Hell & de Groot, 1998) in translation for both directions. Further, some studies have shown that the translation direction does not necessarily interact with L2 fluency (de Groot & Poot, 1997; Duyck & Brysbaert, 2004; La Heij et al., 1996). In de Groot and Poot (1997), for example, L1 Dutch speakers at three different levels of L2 English (2.5 years of classroom learning for the low fluency group, 4.5 years for the medium, and 6 years for the high fluency group) were tested for both directions of word translation. The results showed that L2-to-L1 backward translation was, in fact, slower than for L1-to-L2 forward translation for the two lower-proficiency groups, and no directional differences were obtained for the highest L2 fluency group. This finding runs counter to the strong connection between the particular processing mode (lexical vs. conceptual meditation) and translation direction (backward vs. forward translation). The authors speculated that faster L2-to-L1 translation in some of the previous studies may be a brief and transient phenomenon found in the absolute beginning of the L2 learning, and conceptual memory is principally engaged in all translation tasks regardless of L2 fluency.

Building upon the findings of the past studies, the current study explores the patterns of translation by bilingual speakers of cross-script languages. The participants were recruited from two levels of L2 proficiency, beginner versus intermediate learners, to examine psycholinguistic models of the structure of bilingual memory. The comparison of the two directions of word translation is expected to provide additional empirical evidence for the role of concept mediation in translation and its interaction with form similarity. Along with the findings of the word-naming experiments, the results of the translation experiment are expected to help draw a fuller picture of the characteristics of strictly cross-script processing.

Experiment 1. Explicit word-naming

The first experiment tested the effect of phonological similarity in cognate processing using a word-naming paradigm. To examine the effect of L1 characters in L2 word processing, Chinese characters were presented overtly alongside the target SK stimuli.

Method

Participants

Thirty-two participants (aged 20–24) were recruited for the experiment from the Chinese University of Hong Kong. No participant reported a history of language impairment, and all were paid for their participation. All participants were native speakers of Cantonese, born and raised in Hong Kong. They started learning English from around three years old as English is a compulsory second language in Hong Kong, however, their English proficiency is not expected to influence their performance in the experiment. They were enrolled in elective Korean language courses at the time of the study. The first group (beginners) included 16 students in the Korean III class who had completed 120 hours of classroom learning. The second group of 16 intermediate learners were in Korean VI who had finished 240 hours of classroom learning, the highest level of Korean courses at the University. Although the length of acquisition is relatively short, the Korean pop culture is vibrant in Hong Kong as well as in other Asian countries, and those students enrolled in Korean classes are likely to have considerable exposure to Korean songs and dramas outside the classroom. The combined effect of the familiarity with the phonetic properties of the Korean sounds and the explicit learning of the letters is likely to ensure a good mastery of Hangul reading by the learners.

Their Korean textbooks were written in English, and the medium of instruction was English and Korean with an increasing use of Korean at higher levels. All instructors were native Korean speakers. The Korean classes cover vocabulary, grammar and conversational practices with various activities. With the acknowledgement that the differences in oral fluency levels between the two groups may be slight and that groupings based on the university's language courses may not be homogeneous in terms of fluency, we are cautious in our interpretation of the results of the two groups in this study.

Materials

In order to compile a list of stimuli with varying degrees of phonological similarity, we carried out a small-scale corpus study followed by a perceptual judgment task. Around 1,200 disyllabic SK regular nouns with a frequency of more than 40 times pmw (per million words) were compiled from the written Korean National Corpus using a Python script (Kang & Kim, 2004; Kim, 2006, 2014). The selected words were divided into two categories, known versus unknown, based on leaners' familiarity. The "known" words were chosen from their textbooks. Two experienced native Korean instructors at the Chinese University of Hong Kong confirmed that those words were taught to students at the beginner and intermediate levels. Phonological similarity was then assessed by the first and second authors and a research assistant who knew both Cantonese and Korean. The words were ranked on a scale of 1 to 5, 1 being very dissimilar and 5 being very similar. Finally, a total of 180 words were chosen, including 60 words judged to be similar, 60 words to be intermediate, and another 60 words to be dissimilar.

All the SK stimuli were recorded by the first author, a female native Korean speaker, in a falling pitch contour. A corresponding Cantonese word list was recorded by a female native Cantonese speaker with a comparable voice quality. Stimulus pairs consisting of a Cantonese word followed by a corresponding SK word were combined in Praat (Boersma & Weenink, 2017) with an inter-stimulus interval (ISI) of 500 ms. The average intensity of each token was scaled to 65 dB.

A perceptual judgment task was run through Experigen, an online experiment platform (Becker & Levine, 2010). Twenty-nine native speakers of Cantonese (aged 18–22) with minimum training in phonetics were recruited from the linguistics department and received course credit for their participation. With the exception of three participants with minimal background in Korean, none had prior experience in Korean. Using a computer in a quiet place of their choice, participants listened to the 180 pairs of Cantonese and Korean words and were asked to judge the relative similarity on a five-point scale. Previous studies have confirmed the validity of conducting rating/perception experiments online (Becker & Gouskova, 2016; McAllister Byun, Halpin, & Szeredi, 2015; McAllister Byun & Tiede, 2017). The participants were instructed to ignore the tones of the Cantonese stimuli and focus on the segmental similarities between the words in the stimulus pairs.[2] The stimuli were presented in a random order for each participant, and breaks were given every 60 trials. The results of the judgment task are summarized in Figure 1 which shows that perceptual similarity is gradient even within cognate items.

Based on the results of this similarity test, 40 words were selected from each of the two endpoints of the similarity scale. Note that in the current study, phonological similarity was taken as a binary variable, not a gradient one (Allen & Conklin, 2013; Miwa et al., 2014), for simpler analyses. Of the 80 words, 44 were known and 36 were unknown cognates, each divided by an equal number of similar versus dissimilar items. The slight imbalance in familiarity resulted from balancing various types of orthographic complexity in the L2 Korean syllable structure across conditions. Orthographic complexity refers to the syllable structure in Korean. The Korean writing system groups letters, roughly similar to phonemes, into syllabic blocks. We controlled for the visual complexity of these syllables (CV or CVC; onset-less syllables (V) begin with a place-holder letter ‘ㅇ’

2. An anonymous reviewer raised a question about the difficulty with ignoring lexical tones in perceptual similarity judgments given the limited phonetic training of the participants. We performed a *Pearson* correlation test to compare the similarity judgments made by these participants with those given by the three experimenters (first and second authors, and an RA) who have extensive phonetic training. The results showed that the judgments given by the two groups were highly correlated ($r = 0.882$) and statistically significant ($t(78) = 16.51$, $p < .0001$).

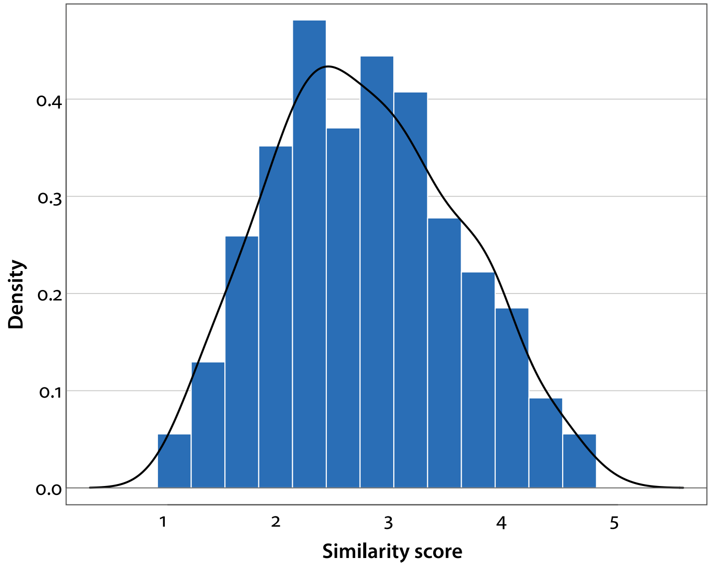

Figure 1. Histogram and estimated density for similarity judgment ratings. Similarity score is 1 for 'very dissimilar' judgment and 5 for 'very similar' judgment

so these are similar to CV in terms of visual complexity) across the conditions of the experiment. The more complex syllables could cause delay in processing, and thus were controlled in the stimuli selection. Table 1 summarizes the distribution of stimuli with relevant examples along with mean log frequency and similarity ratings of the selected words.

Table 1. Examples of the stimuli (Korean vs. Cantonese*) in IPA (top). Mean (and standard deviation) of log frequency and similarity ratings (bottom)

Syllable complexity	**Phonologically *similar***		**Phonologically *dissimilar***	
	Known	**Unknown**	**Known**	**Unknown**
CV-CV	te-hwa vs. tøy-wa 대화 vs. 對話 'conversation'	ki-ho vs. kei-hou 기호 vs. 記號 'symbol'	i-he vs. lei-kai 이해 vs. 理解 'understand'	no-je vs. lou-tɐi 노예 vs. 奴隸 'slave'
CV-CVC	po-tʰoŋ vs. pʰou-tʰʊŋ 보통 vs. 普通 'normal'	po-dʑɨŋ vs. pou-tsɪŋ 보증 vs. 保證 'guarantee'	ne-njʌn vs. lɔi-lin 내년 vs. 來年 'next year'	tɕʰe-k'wʌn vs. tsai-kyn 채권 vs. 債券 'bonds'
CVC-CV	kwal-li vs. kun-lei	tɕaŋ-sʰu vs. tsʰœŋ-sɐu	hjʌn-dʑe vs. jin-tsɔi	sʰʌm-nju vs. tsʰim-wɐi

Table 1. *(continued)*

Syllable complexity	Phonologically *similar*		Phonologically *dissimilar*	
	Known	Unknown	Known	Unknown
CVC-CVC	관리 vs. 管理 ‘management’ kin-dʑaŋ vs. kɐn-tsœŋ 긴장 vs. 緊張 ‘tension’	장수 vs. 長壽 ‘longevity’ tɕ^{h}iŋ-tɕ^{h}an vs. ts^{h}ɪŋ-tsan 칭찬 vs. 稱讚 ‘compliment’	현재 vs. 現在 ‘current’ s^{h}eŋ-hwal vs. sɐŋ-wut 생활 vs. 生活 ‘living’	섬유 vs. 纖維 ‘fabric’ ʌp-tɕ’ʌk˺ vs. jip- tsɪk 업적 vs. 業績 ‘achievement’
Log frequency	7.54 (0.94)	6.28 (0.13)	7.57 (0.92)	6.29 (0.17)
Similarity ratings	3.70 (0.54)	3.75 (0.30)	1.95 (0.28)	1.66 (0.37)

* Cantonese tones are not shown.

Procedure

The 80 stimuli were divided randomly into four blocks, each of which was counterbalanced for phonological similarity (similar vs. dissimilar) and word familiarity (known vs. unknown). Additionally, the presentation mode varied and alternated between two blocks of Sino-Korean words only (SK-only, hereafter, 40 stimuli with two repetitions) and two blocks of both Korean and Chinese characters (with-CHN, hereafter, also 40 stimuli with two repetitions). Participants were randomly assigned to either SK-only first or with-CHN first block. Each participant saw a target word only once, either in SK-only or in with-CHN condition. No specific instructions were given regarding the Chinese characters, but it was implicitly learned during the experiment that the Chinese characters corresponded to the SK stimuli. No post-test survey was done to confirm this knowledge, but the results below do show that this was the case.

The word-naming task was conducted using the E-Prime 2.0 software (Psychology Software Tools, 2015). This task was not done online because a more controlled environment is needed for precise measurement of reaction time data based on speech (see more below). Each experimental trial began with a fixation cross appearing at the center of the monitor for 1000 ms, followed by an SK word with or without Chinese characters (Figure 2). Stimulus items within a block were presented in random order. Participants were asked to produce SK-words as quickly and accurately as possible. Written instructions were given in English (as is standard for all instructions and signs used in the university), and a Cantonese-speaking experimenter gave clear verbal instructions in Cantonese before starting the experiment. The participants were given 3 seconds to name the stimulus item after it appeared on the screen before the next trial began automatically.

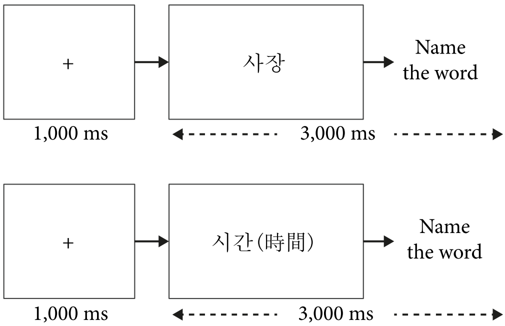

Figure 2. Examples of display sequence in Experiment 1. SK-only condition (top) and Chinese-character condition (bottom)

The production of the stimuli was recorded for all participants along with the reaction time (RT) of their utterances. It should be noted that serious caveats have been raised in the psycholinguistics literature related to intensity-based voice keys (as available in E-Prime) not reliably detecting the onset of the initial sounds of an utterance (Pechmann, Reetz, & Zerbst, 1989; Rastle & Davis, 2002; Roon, 2013; Sakuma, Fushimi, & Tatsumi, 1997). As the validity of the experiments carried out in this study relies heavily on precise and accurate RT measurements, we employed a novel technique following the methodology implemented in Roon (2013). As shown in Figure 3, the E-Prime script was designed to send two simultaneous signals of visual stimuli presented on the computer screen and a brief beeping sound as a marker tone. As soon as participants produced the words prompted by the visual stimulus on the screen, their utterances were directly recorded by a Zoom H4n recorder, which can receive two simultaneous stereo signals, one through a built-in microphone and another through a line-in connection. To provide the timing information of the onset of the visual stimuli presented to the participants, the marker tone was recorded (inaudibly to participants) through the line-in connection. The experiment was carried out in a sound-attenuated booth, and each session lasted approximately 20 minutes.

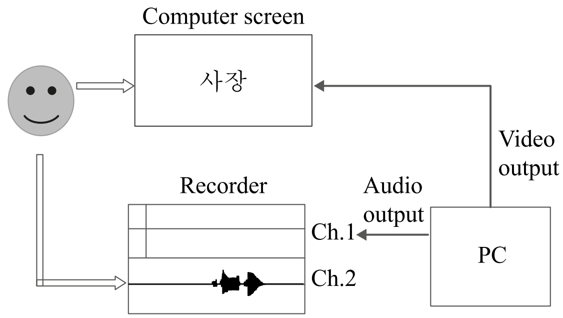

Figure 3. Experiment hardware setup. The PC sends two simultaneous signals, one for visual presentation of the stimuli and the other for a marker tone. The external recorder captures two signals through two separate channels, one for the marker tone from the PC and the other for the participants' production

Data analyses

With very few missing responses, the overall response rate was higher than 99% for both groups of participants. Minor pronunciation errors were frequent but ignored as they were common errors for L2 learners. Specifically, most of the segmental errors fell into one of the following four categories: (i) lenis-aspirated stop confusion (e.g., [**k**o.to] produced as [**k$^{(h)}$**o.to] 'height'); (ii) deletion of finals (e.g., [toŋ.mu**l**] as [toŋ.mu] 'animal'); (iii) nasal place replacement (e.g., [bo**n**.nɨŋ] as [bo**ŋ**.nɨŋ] 'instinct'); and iv) vowel confusion (e.g., between /ʌ/ and /o/, and between /u/ and /o/). While such errors certainly contribute to foreign-accented speech, it was clear that the participants had the correct target SK words in mind. Tokens with minor pronunciation errors were, therefore, included in the following analyses.

Naming latencies were measured as follows. The two signals, one from participants' utterance and the other from the marker tone, were saved into a single stereo signal (Figure 3). Next, word boundaries were marked automatically using a Praat script designed to detect boundaries whenever the signal had greater or lower values in intensity determined by the experimenter (e.g., 40 dB). The automatic boundary detection was efficient but imperfect; errors were corrected manually by the authors. Using another Praat script, the temporal information of word boundaries was collected, and naming latency was computed by subtracting the time point of each marker tone from the onset of the following utterance.

Mixed-effects regression analyses were carried out with log-transformed naming latency values as the dependent variable. All categorical fixed effect variables in the model were contrast coded manually so that the weights of all levels summed to 0 (Davis, 2010). The model included fixed effects for (cognate) Familiarity (known = −1 vs. unknown = 1), (phonological) Similarity (similar = −1 vs. dissimilar = 1), and (presentation) Mode (with-CHN = −1 vs. SK-only = 1), as well as L2level (Beginner = −1 vs. Intermediate = 1) and Order (SK-only first = −1 vs. with-CHN first = 1). In addition to the main effects, two-way interactions were included between each of the first three main effects and L2level and between Mode and Order. In particular, the Mode-Order interaction was motivated to address a potential effect of the order of the presentation mode on the degree of facilitation by L1 characters. Learners may benefit more from the L1 characters when they appeared in the first block (with-CHN first and SK-only next) compared to the condition with an opposite order (SK-only first and with-CHN next). The model also included random intercepts for participants and items. A larger model with by-speaker random slopes for the fixed factors did not converge. The statistical models were implemented in R using the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015), and *p*-values were computed using the *LmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2016).

Results

The results of Experiment 1 are summarized in Figure 4. From the graphs, it is evident that known cognates elicited faster processing than unknown ones did, regardless of Mode and L2level. In addition, broad facilitation by similar phonology and L1 characters appears to be generally present in many comparisons.

Table 2 presents the overall effects of the three fixed factors.[3] The predictor Familiarity was included to ensure that word recognition took place during word naming. The model indeed revealed a significant main effect of Familiarity such that known cognates were named faster ($M = 887$ ms) than unknown ones ($M = 1019$ ms). This indicates that word recognition was part of the word processing for known cognates, while the production of unknown words was delayed due to script-to-sound conversion, presumably a more time-consuming process. This confirms that although the Korean script is orthographically shallow, cognates are processed through some level of mental representations of stored words.

The key factor Similarity addresses whether similar phonology between L1 and L2 lexical items facilitates L2 word processing. A significant main effect of Similarity was found, wherein SK-words with similar phonology to L1 forms were processed faster ($M = 919$ ms) than those with dissimilar phonology ($M = 973$ ms), suggesting learners rely on an L1–L2 lexical link when processing L2 words, consistent with the literature. Further, without interference from orthographic

3. All data and R code are available at https://osf.io/p6hqx/.

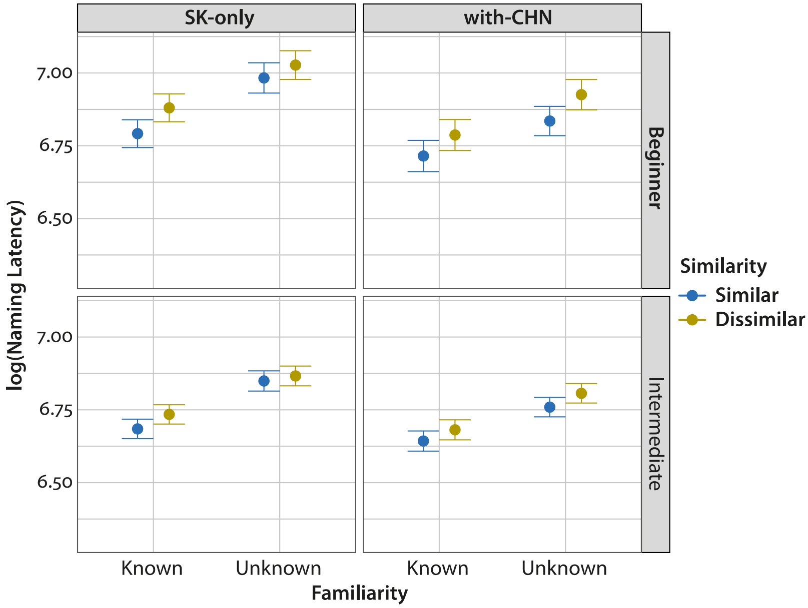

Figure 4. Mean naming latency as a function of phonological similarity and familiarity by SK-only (left) and Chinese-character (right) conditions. The top panels summarize the performance of beginners and the bottom panels summarize that of intermediate learners. Error bars indicate standard error computed over participant means

overlap, this finding confirms the independent role of phonological similarity in cognate processing.

The Mode predictor was used to evaluate whether Chinese characters facilitate SK-word processing based on the premise that a strong L1 representation may help process L2 words that are weakly represented in the mental lexicon. The results showed that Chinese characters indeed facilitated faster processing as indicated by the significant effect of Mode (*M* (with-CHN) = 905 ms, *M* (SK-only) = 988 ms).

While L2level alone did not drive a global difference in processing speed, its interaction with other predictors was shown to be significant. First, the Similarity-L2level interaction reached statistical significance despite its small effect size. Beginner learners benefitted more from the similar phonology between cognates (overall magnitude of facilitation: 77 ms, *M* (Similar) = 971 ms, *M* (Dissimilar) = 1048 ms) than intermediate learners did (31 ms, *M* (Similar) = 867 ms, *M* (Dissimilar) = 899 ms). L2level interacted further with the predictor Mode, indicating that learners benefitted from the L1 characters to a different degree. SK word naming was facilitated by the presence of Chinese characters by 101 ms for the beginner learners (*M* (SK-only) = 1060 ms, *M* (with-CHN) = 959 ms), but the magnitude of facilitation was attenuated for the intermediate learners (65 ms, *M* (SK-only) = 915 ms, *M* (with-CHN) = 851 ms).

An interaction between Mode and Order was indeed found to be significant. While a global facilitation effect driven by the Chinese characters is confirmed, the level of facilitation is further conditioned by whether participants were exposed to L1 characters in the first or second block. The results showed that learners exposed to L1 characters in the first block showed greater L1 facilitation (125 ms, *M* (with-CHN) = 849 ms, *M* (SK-only) = 974 ms) than those exposed to L1 characters later into the experiment (46 ms, *M* (with-CHN) = 954 ms, *M* (SK-only) = 1000 ms). The sensitivity to the presentation of L1 characters reflects task effects inevitably introduced by the experiment. Specifically, participants may have gained more practice in reading SK words without the aid of L1 characters in the first SK-only block. Having developed the strategy of reading L2 letters in such a condition, the presence of L1 characters in the later block may not have very strong facilitation for L2 word processing. On the other hand, participants who were exposed to the with-CHN condition first appear to benefit from the L1 characters throughout the experiment. Not only that explicit L1 characters facilitated the L2 word processing in the first block, but the awareness of the correspondence between L1 and L2 word pairs seems to have helped learners to process L2 words faster in the later SK-only block, especially for those with similar phonology. The slightly shorter mean response time for the SK-only condition seems to provide evidence in favor of this possibility.

Table 2. Summary of the mixed-effects regression model in Experiment 1. Formula: Log(NameLate) ~ Familiarity*L2level + Similarity*L2level + Mode*L2level + Mode*Order + (1|Subject) + (1|Word). Standard deviations of Subject, Word, and residuals are 0.1718, 0.0966, and 0.2154, respectively. Significant results are highlighted in bold

Predictor	Coefficient	*SE*	*t*-value	*p*
(Intercept)	**6.8100**	**0.0326**	**209.226**	**<.0001**
Familiarity (Unknown vs. Known)	**0.0727**	**0.0114**	**6.387**	**<.0001**
Similarity (Dissimilar vs. Similar)	**0.0308**	**0.0114**	**2.691**	**0.0086**
Mode (with-CHN vs. SK-only)	**−0.0426**	**0.0046**	**−9.317**	**<.0001**
L2level (Beginner vs. Intermediate)	−0.0551	0.0307	−1.792	0.0836
Order (SK-only first vs. with-CHN first)	−0.0332	0.0308	−1.079	0.2895
Familiarity:L2level	−0.0037	0.0043	−0.858	0.3912
Similarity:L2level	**−0.0092**	**0.0043**	**−2.144**	**0.0321**
Mode:L2level	**0.0120**	**0.0043**	**2.807**	**0.0050**
Mode:Order	**−0.0176**	**0.0046**	**−3.858**	**0.0001**

Discussion

The results of the first experiment largely conformed to our predictions; phonologically similar cognates were processed faster than dissimilar ones, known cognates were processed faster than unknown cognates, and the presence of Chinese characters facilitated SK-word processing.

The results, however, revealed some qualitative differences in how SK words were processed by the Cantonese learners at different stages. Both phonological similarity and L1 characters showed greater facilitatory effects for the beginners than for the intermediate learners. This result appears to be consistent with previous findings that less fluent L2 learners tend to rely more on lexical mediation during L2 word processing. Many studies have found a significant reduction of cognate facilitation in more fluent bilinguals (e.g., Chen & Leung, 1989; Kroll et al., 2002; Kroll & Stewart, 1994). These results are taken to indicate that L2 learners at early stages primarily rely on the L1–L2 lexical link by which learners access conceptual representations through L1 translation equivalents. This dependency may gradually decrease with increasing L2 proficiency, and more proficient L2 learners may access meaning directly from the L2 lexical form. However, the particular groups tested in the present study are not remarkably different in terms of L2 fluency as in previous studies, whose differences, if any, may have been further attenuated by the special linguistic situation in Hong Kong where multilingualism is common. To further test the validity of the empirical findings obtained in this experiment, a second word-naming experiment was conducted with some modifications to the experimental design.

Experiment 2. Word-naming with masked primes

A second word-naming study was carried out with some modifications to the way in which Chinese characters were presented. As opposed to the overt presentation of L1 characters in Experiment 1, Chinese characters were presented covertly as backward masked primes in this experiment to further test the robustness of the effects observed in Experiment 1. Otherwise, the experimental design remained the same.

Method

Participants

A total of 40 Cantonese-speaking learners of Korean (aged 18–22) were recruited for the second word-naming experiment, including 20 beginner and 20 intermediate learners with similar backgrounds as those in Experiment 1. As in the first experiment, the beginners (Korean III) included learners who had completed 120 hours of classroom learning, and the intermediate group (Korean VI) included learners who had finished 240 hours of classroom learning. None of the subjects in the second experiment participated in the first experiment. Participants were paid for their participation, and none reported any history of speech or hearing disorders.

Materials

The same set of materials as in Experiment 1 was used for the backward masked prime experiment. For the Chinese-character condition, characters were presented prior to the presentation of corresponding SK words as masked primes. For the SK-only condition, pseudo-characters were used instead of CHN-primes. The pseudo-characters were randomly chosen from a website that automatically generates a passage of pseudo-characters (available at *http://technology.chtsai.org/pseudotext/*). The pseudo-characters are very rare and obsolete Chinese characters composed of common radicals and strokes (e.g., 毌防 and 唻菥). Because of their rarity, they were *de facto* pseudo characters for the participants.

Procedure

In this backward masked prime experiment, pseudo- or CHN-primes were presented for 75 ms, followed by a mask of five hash marks (#####) of 75 ms. A simple pre-test survey was done to confirm that the participants could not see the primes clearly. The stimulus onset asynchrony (SOA) was, therefore, 150 ms (75 ms for the prime plus 75 ms for the mask), which falls well within the range (57 ~ 243 ms) that was shown to give rise to phonological priming effects in previous studies (Chen & Peng, 2001; Chen, Wang, & Peng, 2003; Perfetti & Tan, 1998; Zhou, Chen, Yang, & Dunlap, 2010). Finally, the target SK stimuli were presented for 3 seconds as shown in Figure 5 below. As in the first experiment, participants were instructed to read the SK stimuli on the screen aloud as quickly and accurately as possible.

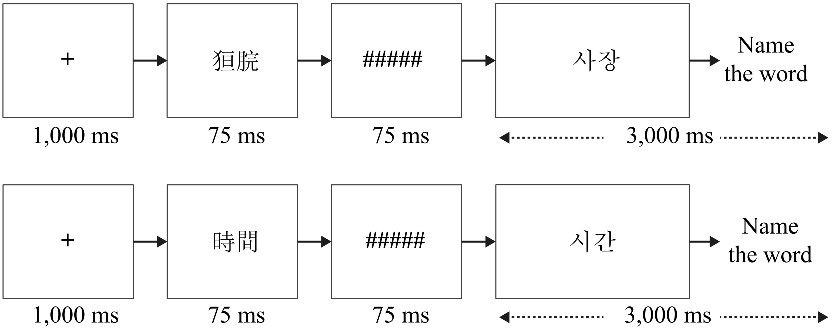

Figure 5. Examples of display sequence in Experiment 2. The SK-only condition with masked pseudo-characters (top) and the Chinese-character condition with masked characters (bottom)

Data analyses

As in Experiment 1, missing responses were rare, and the majority of mispronunciations of the target SK words mostly involved minor sub-phonemic errors and were included for data analyses. The semi-automatic naming latency measurement methodology using Praat scripts remained the same, and the results were analyzed using linear mixed effects models fit in R.

Results

Figure 6 plots the mean log-transformed naming latency as a function of Similarity and Familiarity divided by Mode and L2level in separate panels. As in Experiment 1, the effect of Familiarity was evident; known cognates were processed faster than unknown ones across all conditions. The two groups appeared to perform alike with respect to Similarity and Mode.

Statistical results summarized in Table 3 revealed significant main effects of all three fixed factors, pointing to facilitatory effects of cognates, similar phonology and CHN-primes. On average, learners were faster at processing known ($M = 844$ ms) than unknown cognates ($M = 987$ ms), similar L2 words ($M = 878$ ms) than dissimilar ones ($M = 938$ ms), and CHN-primes ($M = 810$ ms) than pseudo-primes ($M = 1{,}006$ ms).

The particularly large facilitatory effect of Chinese characters in this experiment (mean magnitude of facilitation = 196 ms, compared to 83 ms in Experiment (1) is worth noting. The enhanced role of L1 characters is reflected in the relative magnitude of coefficients as well (Experiment 1: $\beta = -0.0426$ vs. Experiment 2: $\beta = -0.1167$). This can be attributed to the intermediate learners' increased sensitivity to this variable, which was small in Experiment 1. Surprisingly, intermediate

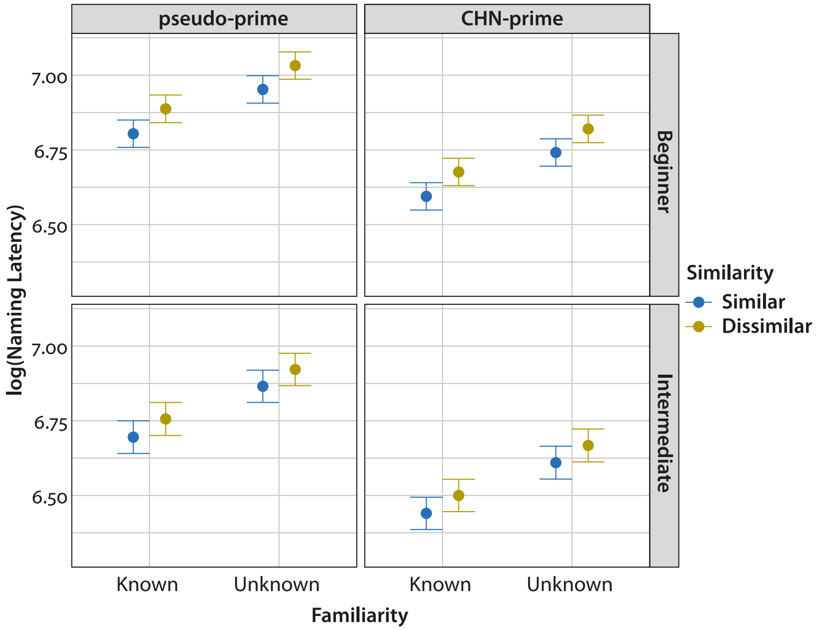

Figure 6. Mean naming latency as a function of phonological similarity and familiarity by SK-only (left) and Chinese-character (right) conditions in the backward masked priming task. The top panels present the performance of beginners and the bottom panels present the performance of intermediate learners. Error bars indicate one standard error computed over participant means

learners, in fact, benefitted from the Chinese primes even more (overall magnitude of facilitation: 213 ms) than beginner learners (178 ms). This reversal is reflected in the switch from a positive to a negative coefficient value of the significant Mode-L2level interaction term between the two experiments (Experiment 1: $\beta = 0.0120$ vs. Experiment 2: $\beta = -0.0111$).

Unlike Experiment 1, the Similarity-L2level interaction did not reach statistical significance, indicating that the two groups of learners benefited similarly from the phonological similarity between L1–L2 cognates.

Table 3. Summary of the mixed-effects regression model. Formula: Log(NameLate) ~ Familiarity*L2level + Similarity*L2level + Mode*L2level + (1|Subject)+(1|Word). Standard deviations of Subject, Word, and residuals are 0.2258, 0.0968, and 0.2330, respectively. Significant results are represented in bold

Predictor	Coefficient	*SE*	*t*-value	*p*
(Intercept)	**6.7470**	**0.0376**	**179.676**	**<.0001**
Familiarity (Unknown vs. Known)	**0.0762**	**0.0114**	**6.660**	**<.0001**
Similarity (Dissimilar vs. Similar)	**0.0337**	**0.0115**	**2.926**	**0.0045**
Mode (CHN-prime vs. pseudo-prime)	**−0.1167**	**0.0041**	**−28.274**	**<.0001**
L2level (Beginner vs. Intermediate)	−0.0658	0.0360	−1.830	0.0751
Familiarity:L2level	0.0056	0.0041	1.340	0.1805
Similarity:L2level	−0.0055	0.0041	−1.329	0.1839
Mode:L2level	**−0.0111**	**0.0041**	**−2.686**	**0.0073**

Discussion

As in Experiment 1, learners benefitted from word familiarity, phonological similarity, and L1 primes in this priming experiment. Unlike Experiment 1, however, the facilitation by similar phonology and L1 characters was greatly amplified for the intermediate learners in Experiment 2. Since the primary difference between the two experiments lies in how Chinese characters were presented, the differences in the learners' performance can thus be attributed to the specifics of the task that subjects had to complete.

It may seem counterintuitive that primed L1 in Experiment 2 which involved more subtle and subliminal processing elicited even greater facilitatory effects for intermediate learners than the overt L1 characters in Experiment 1. This may indicate that the explicit presentation of the L1 characters in Experiment 1 may have been distracting for the learners. The particular task involves reading two words while producing only one of them, which requires suppressing activated L1 phonological codes. The two phonological forms in the L1 and L2 are not entirely consistent, however. It might be that at the early stages of lexical development, the global lexical similarity is sufficient for cognate facilitation, but a small mismatch in phonology might inhibit L2 word processing as learners become more accustomed to the fine-grained phonetic differences between corresponding cognates. It follows that when L1 characters were processed subliminally and set to act positively for L2 processing in Experiment 2, intermediate learners did show sensitivity to similar phonology to a similar degree with beginner learners.

Experiment 3. Translation

In Experiment 3, both forward and backward translation tasks were employed to further investigate the facilitative effects of phonological similarity observed in Experiments 1 and 2, but now with a different task that is known for involving conceptual representation. This experiment aimed to reveal similarities and differences, if any, between different experimental paradigms during strictly cross-script processing.

Method

Participants

A total of 40 Cantonese-speaking learners of Korean (aged 18–22) participated in the translation experiment. Among those, 26 participants were beginners (Korean III, 7 excluded for analysis, see below), and the other 14 were intermediate learners (Korean VI). The participants' L2 learning experience remained similar to those described in the first two experiments. None of them participated in the previous word-naming tasks. No participant reported a history of language impairment, and all were paid for their participation.

Materials

Unknown SK words used in the naming studies were discarded, and only the forty-four known cognates balanced for phonological similarity were used for the translation study. Those words were randomly divided into two sets to be used in forward (L1-to-L2) or backward (L2-to-L1) translation.

Procedure

Using E-Prime, half of the stimuli was designed to begin with L2-to-L1 translation and the other half with the opposite direction, separate by different blocks. The order of translation direction was random for each participant; some participant began with backward translation first, and others began with forward translation first. Each L1–L2 pair was translated once only in one direction. They had 5 seconds to respond before the experiment moved on to the next trial automatically. Participants were instructed to produce a translation equivalent of the target word on the screen as quickly and accurately as possible. They were told to say [m̩^{21}.tʃi^{55}] in Cantonese ('I don't know') when they could not think of translation equivalents. Participants were given seven practice items prior to the experiment.

Data analyses

Unlike the word-naming tasks where production responses were given for most stimuli, some of the beginners had considerable difficulty with the translation task. On average, beginners gave 4 'don't know' responses out of the 22 stimuli items for each direction (M(L1-to-L2) = 3.93 vs. M(L2-to-L1) = 4.15). The small differences based on translation direction were not significant (t = 0.34, p = 0.74). In a few cases, participants provided alternative translations with equivalent meaning (e.g., 女人 'woman' for '여자' instead of 女子 'woman; more formal'); such responses were included in the analyses. Seven beginning learners were excluded for missing more than 10 stimulus items for either translation direction, and the data from the remaining nineteen participants were submitted to subsequent analyses. Missing responses were rare for intermediate learners (M(L1-to-L2) = 1.64 vs. M(L2-to-L1) = 2.21, t = 0.75, p = 0.46), and none of them missed more than 10 responses.

Translation latency, the dependent variable of the study, was measured in a semi-automatic way using Praat scripts and was subsequently log-transformed for statistical analyses. Mixed-effects regression models were fit with L2 level (beginner = −1 vs. intermediate = 1), Similarity (similar = 1 vs. dissimilar = −1), and (translation) Direction (L2-to-L1 = 1 vs. L1-to-L2 = −1), as well as their interactions as fixed effects. Random effects included random intercepts for participants and item, as a larger model with by-speaker random slopes for the fixed variables did not converge. All else remained the same with the statistical analyses implemented for the previous experiments.

Results

Figure 7 plots log-transformed translation latency against Similarity and (translation) Direction for each group of learners. Clearly, translation direction substantially impacted the learners' performance. Both groups of learners were much faster at translating from L1 words to L2 ones than in the opposite direction. This runs counter to previous findings, which will be discussed in detail below. While the directional asymmetry is more evident for the beginners than for the intermediate learners, neither group showed effects of Similarity.

Table 4 summarizes the coefficients of a mixed model fitted to the data, using log-transformed translation latency as a dependent variable. Consistent with the simple distribution of the latency data in Figure 7, the regression analysis revealed a strong main effect of translation direction, confirming that learners were faster at L1-to-L2 forward (1120 ms) than L2-to-L1 backward translation (1740 ms). The directional asymmetry in translation latency was reduced considerably for the intermediate learners, as shown by the significant interaction between Direction and L2level. Unlike the word-naming experiments, the main effect of phonological similarity did not emerge as a significant predictor of translation latency. There appeared to be a small facilitatory effect of Similarity for L2-to-L1 translation for beginners (*M*(similar) = 1,658 ms vs. *M*(dissimilar) = 1,807 ms), but the difference was not sufficiently large or consistent across all participants to reach statistical significance.

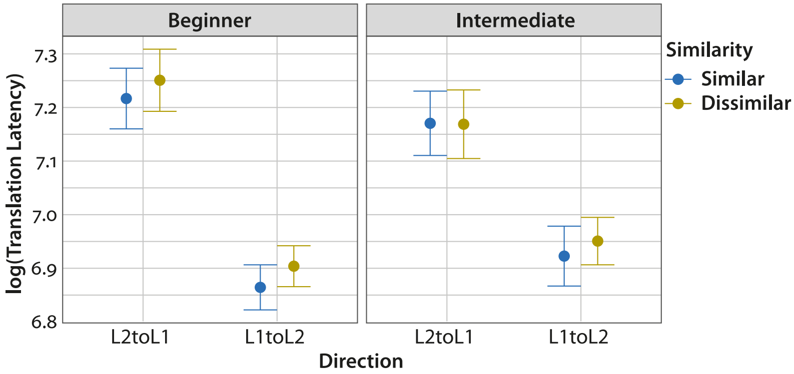

Figure 7. Mean translation latency as a function of phonological similarity and the direction of translation by beginners (left) and intermediate learners (right). Error bars indicate one standard error computed over participant means

Table 4. Summary of the mixed-effects regression model in Experiment 3. Formula: Log(NameLate) ~ Direction*L2level + Similarity*L2level + (1|Subject)+(1|Word). Standard deviations of Subject, Word, and residuals are 0.2210, 0.1497, and 0.3191, respectively. Significant results are represented in bold

Predictor	Coefficient	*SE*	*t*-value	*p*
(Intercept)	**7.0800**	**0.0456**	**155.161**	**<.0001**
Direction (L1-to-L2 vs. L2-to-L1)	**−0.1480**	**0.0068**	**−21.870**	**<.0001**
Similarity (Similar vs. Dissimilar)	0.0159	0.0238	0.669	0.5070
L2level (Beginner vs. Intermediate)	−0.0015	0.0395	−0.038	0.9700
Direction:L2level	**0.0314**	**0.0067**	**4.669**	**<.0001**
Similarity:L2level	−0.0064	0.0067	−0.959	0.3380

Discussion

The results of the translation study revealed that L2-to-L1 backward translation elicited longer response latencies than L1-to-L2 forward translation. This directional asymmetry in the translation speed was unambiguously present for both groups of learners (Beginner: M(forward) = 1120 ms vs. M(backward) = 1740 ms; Intermediate: M(forward) = 1185 ms vs. M(backward) = 1562 ms). It is noteworthy that the magnitude of directional effects (621 ms for the beginners and 377 ms for the intermediate learners) is larger than has been reported in previous work. De Groot and Poot (1997), for example, also found faster forward than backward translation for Dutch-English bilinguals, but the differences in the processing speed arising from translation direction were less than 200 ms even for the relatively low proficiency group (2.5 years of English learning).

This finding speaks against the classic model of the bilingual mental lexicon, e.g., the Revised Hierarchical Model (RHM) (Kroll & Stewart, 1994; Sholl, Sankaranarayanan, & Kroll, 1995), in which backward translation via a more direct lexical link is predicted to be faster than forward translation via an indirect conceptual memory. This directional asymmetry is predicted to be more prominent for the beginner learners as they are likely to access conceptual representations through L1 translation equivalents. On the contrary, the results of this study have demonstrated that backward translation is considerably more difficult for Cantonese-speaking learners whose L2 proficiency is lower than those in most previous studies. This result indicates that a translation task engages conceptual mediation principally for both directions as in the cases of within-script bilinguals (de Groot et al., 1994; de Groot & Poot, 1997; Duyck & Brysbaert, 2004; Francis & Gallard, 2005; La Heij et al., 1996; van Hell & de Groot, 1998). Under this hypothesis, the slow backward translation can be easily accounted for: the link between L2 forms and conceptual representations is much weaker than that for the L1, which could impose substantial cognitive loads for the access from L2 forms to concepts.

Furthermore, lexical competitions arising from a particular linguistic situation in Hong Kong may have contributed, to some extent, to the excessively long backward translation for the learners in this study. Most Hong Kong people grew up to become Cantonese-English bilingual speakers, and young Hong Kong people also learn Mandarin in school from an early age. That said, Korean comes in as the fourth language at best for most learners. Moreover, the medium of instruction of the Korean courses was English and Korean for our participants. For a single conceptual representation, if any, Hong Kong people often store multiple lexical forms from different languages which could have introduced lexical competition and hindered access to the conceptual memory.

A rather unexpected finding of the translation experiment was that neither beginners nor intermediate learners showed a reliable effect of phonological similarity. This contradicts common findings in translation tasks involving within-script bilinguals (e.g. de Groot, 1992; Kroll et al., 2002; Kroll & Stewart, 1994). In particular, cognate facilitation was observed virtually across different levels of L2 proficiency even for the studies where forward translation was shown to be faster than backward translation (de Groot & Poot, 1997). The lack of cognate facilitation in either translation direction in this study, therefore, suggests that the reliance on the conceptual memory during translation might be even greater in the cross-script translation tasks. We continue our discussion in the next section where the similarities and differences between cross- and within-script processing are reviewed based on the results of the present study.

General discussion

The present study attempted to isolate the effect of phonological similarity while controlling for orthographic overlap. The examination of how L1 and L2 processing affects each other can be quite complex when the pertinent languages have writing conventions that are very similar. Confounds of phonological similarity with orthographic similarity as in within-script processing make it difficult to obtain precise insight into how sound form and word meaning of the L1 and L2 interact. These confounds can be avoided by investigating languages that make use of very different writing systems. In this study, we investigated two such languages, Korean and Cantonese with completely different orthographic scripts. We aimed to show when and how phonological similarity effects arise without any confounding effects of orthographic overlap. Further, departing from the simple assumption that cognates constitute word pairs with uniformly similar phonology, we employed cognates with varying degrees of phonological similarity to explore the patterns of facilitation arising from phonological similarity alone.

Despite small but non-trivial differences, the two word-naming experiments showed that phonological form similarity facilitates word processing and this propensity was pronounced even more clearly when the L1 characters were used as primes. This could be because the overt presentation of the Chinese characters in Experiment 1 may be distracting to the participants. Rather unexpected results were obtained from the translation study such that similar phonology did not contribute to processing, contrary to general findings in past research. Below, we discuss implications of the findings in relation to the similarities and differences between within- and cross-script processing.

The phonological similarity effect in cross-script word processing: When and how it arises

To explore specific conditions in which similarity effects arise, word-naming studies were employed in conjunction with translation tasks. One of the major findings of the present study was that learners' sensitivity to similar phonology was conditioned by the experimental paradigm. Overall, learners were sensitive to similar phonology in word-naming tasks (stronger effects with L1 primes than with overt L1 characters), while the same factor did not affect responses in the translation task in either direction. We discuss how varying phonological similarity effects as a function of experimental tasks can be interpreted in relation to the theories of the structure of bilingual memory below.

The facilitatory effects of similar phonology in cross-script word-naming tasks can be accounted for using the Bilingual Interactive Activation (BIA+) model (Dijkstra & van Heuven, 2002), according to which a bilingual's mental lexicon is integrated across different languages and can be accessed in a language non-selective manner. Such an attempt has been made explicitly for cross-script processing by Ando et al. (2014), for example. The authors conjectured that phonological priming effects in cross-script word-naming arise from the activation of the common sounds in sublexical phonological representations. While the two languages do not share the same scripts and common sublexical orthographic units are entirely absent, similar sounds across the two languages are represented as a single sound in the sublexical phonological store. When an L1 prime, overt or implicit, activate the sounds in the lexical phonological store, their corresponding sublexical sounds are activated subsequently. The shared sublexical phonological sounds between Cantonese and Korean can then send excitatory signals to corresponding SK words at the lexical phonological level. A greater phonological overlap between L1 primes and L2 SK targets would amplify the magnitude of excitation of the target sounds, and hence faster word-naming.

Unlike the word-naming tasks, the results of the translation experiments did not show evidence of facilitatory effects of similar phonology for SK-Cantonese cognates. Recall that the translation data from many beginner learners, 7 out of 26 participants, were excluded because they were unable to do the task well, while missing responses were rare for the beginner learners in the two naming tasks. The clear difference between the results obtained with the two paradigms indicates that the meaning of newly acquired L2 words was not well consolidated for the beginner learners, in particular. Conversely, this finding confirms that the learners were relying primarily on the L2 forms in word-naming tasks, which, in turn, led to significant facilitation by form similarity. In contrast, the reliance on the conceptual memory in the translation task is likely to have attenuated such form similarity effects greatly.

Although the two experimental paradigms are generally known to engage different processing routes, cognate facilitation in such categorical all-or-none fashion across experimental paradigms is rarely observed. Kroll et al. (2002), for example, documented cognate facilitation in both word-naming and translation tasks for English-French bilinguals with different levels of fluency. In such within-script translations, a large overlap in the lexical orthographic representations between the two lexical forms could provide excitatory feedback to sublexical phonological representations, which could, in turn, facilitate translation of words with similar phonology. In the case of cross-script language pairs, however, the lack of overlapping units at the sublexical orthography seems to have discouraged the interactions between the two sublexical representations. However, we acknowledge that empirical data are limited and it remains to be seen whether the current finding is robustly replicated in other cross-script languages which could make it possible to fully assess the theoretical models of bilingual memory.

Phonological facilitation by L1 characters in cross-script processing

In the present study, we further tested the role of phonological similarity by introducing L1 characters as an experimental variable in the two word-naming studies. In Experiment 1, Chinese characters were presented alongside SK-words, whereas in Experiment 2, they were briefly presented as backward masked primes. Although the results of the previous studies of Chinese character recognition are split between those supporting instant activation of the phonological code (Perfetti & Zhang, 1991; Tan et al., 1995; Zhou et al., 2010) and those reporting more skeptical findings (Chen & Shu, 2001; Wong et al., 2014; Zhou & Marslen-Wilson, 1999), we did find general facilitatory effects of L1 as both groups of learners benefitted from this variable for the L1 priming study with a 75 ms prime duration. Intermediate learners as well as beginners responded positively to similarity with primed Chinese characters. When L1 characters were presented as masked primes, the phonological code of L1 would be instantly activated, eliciting a regular similarity effect for both groups of learners.

However, while the beginner learners responded positively to overt L1 characters in Experiment 1, the effect was attenuated greatly for the intermediate learners. One possible explanation for the interaction between L2 fluency and the L1 presentation mode is that the overt presentation of L1 characters along with target L2 in Experiment 1 could have been distracting for the intermediate learners more than for the beginner learners. Because of their lower proficiency, the presence of the Chinese characters clearly helped the beginner learners process L2 Korean. However, for the intermediate learners who could process Korean reasonably well, the presence of extra and different information may be visually distracting as it is difficult to stop processing one's L1, even in writing. Furthermore, global phonological similarity may be sufficient for cognate facilitation for the beginner learners, whereas similar but incomplete matches in phonological form may have been confusing for more advanced learners. Specifically, more proficient L2 learners would have developed full sensitivity to fine-grained phonetic details of the lexical items in the two languages and small mismatch in phonological forms may, in fact, introduce lexical competition between the two versions of cognates in two languages, leading to delayed processing.

Conclusion

We investigated the effect of phonological similarity on word processing by eliminating a potentially confounding influence of orthographic overlap. This was made possible by testing languages with widely different scripts, i.e., Korean based on a unique alphabetic script and Cantonese based on logographic characters. Overall, the results of the two word-naming experiments showed that Cantonese-speaking learners of Korean benefitted from form similarity, namely phonologically similar cognates were processed faster than dissimilar ones, especially under conditions where strong L1 effects emerged. This result corroborates the emerging findings of cross-script facilitation in recent studies. The translation study yielded somewhat surprising results: no significant form similarity effect was identified and forward translation was faster than backward translation. The excessively long backward translation seems to reflect the difficulty in associating a single conceptual representation with many different L2 forms especially for the truly multilingual speakers as in the present study. Nonetheless, the lack of form similarity effects during translation revealed unique characteristics of cross-script translation such that processing took place primarily via conceptual mediation due to the non-overlapping orthography between the two languages. Taken together, the results suggest that every language pair comes with its own specific challenges and opportunities, and it is imperative to extend the empirical coverage of the studies to understudied languages to obtain fuller picture of the structure of bilingual memory.

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Data were collected following standard ethical guidelines at the Chinese University of Hong Kong.

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