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Recent language experience influences cross-language activation in bilinguals with different scripts

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Abstract

Purpose—This study aimed to examine whether the phonological information in the non-target language is activated and its influence on bilingual processing.

Approach—Using the Stroop paradigm, Mandarin-English bilinguals named the ink color of Chinese characters in English in Experiment 1 and named the Chinese characters in addition to the color naming in English in Experiment 2. Twenty-four participants were recruited in each experiment. In both experiments, the visual stimuli included color characters (e.g. 红, *hong2, red*), homophones of the color characters (e.g. 洪, *hong2, flood*), characters that only shared the same syllable segment with the color characters (S+T–, e.g. 轰, *hong1, boom*), characters that shared the same tone but differed in segments with the color characters (S–T+, e.g. 瓶, *ping2, bottle*), and neutral characters (e.g. 牵, *qian1, leading through*).

Data and analysis—Planned *t*-tests were conducted in which participants' naming accuracy rate and naming latency in each phonological condition were compared with the neutral condition.

Findings—Experiment 1 only showed the classic Stroop effect in the color character condition. In Experiment 2, in addition to the classic Stroop effect, the congruent homophone condition (e.g. 洪 in red) showed a significant Stroop interference effect. These results suggested that for bilingual speakers with different scripts, phonological information in the non-target language may not be automatically activated even though the written words in the non-target language were visually presented. However, if the phonological information of the non-target language is activated in advance, it could lead to competition between the two languages, likely at both the phonological and lemma levels.

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Originality and significance—This study is among the first to investigate whether the translation of a word is phonologically encoded in bilinguals using the Stroop paradigm. The findings improve our understanding of the underlying mechanism of bilingual processing.

Keywords

Phonology; bilingual; different script; cross-language activation; language experience

Introduction

When a bilingual speaker is speaking one of his/her languages, whether the non-target language is activated has been studied extensively (e.g. Colomé, 2001; Costa, Miozzo, & Caramazza, 1999; Hermans, Bongaerts, de Bot, & Schreuder, 1998; Hoshino & Kroll, 2008; Jared & Kroll, 2001; Moon & Jiang, 2012; Schwartz & Kroll, 2006). The activation of the non-target language may facilitate or inhibit the response in the target language, depending on the similarity between the two languages and other factors (e.g. recent language experience and task demands). Some researchers have argued that activation of the non-target language is automatic at the lemma level, whereas phonological activation may be easier to suppress (e.g. Hermans et al., 1998). The lemma level specifies the semantic and syntactic properties of words, while the lexeme level specifies the orthophonological properties (Kempen & Hoenkamp, 1987; Kempen & Huijbers, 1983; Roelofs, Meyer, & Levelt, 1998). The paradigms used to examine cross-language activation and its effects on bilingual processing include Picture-Word Interference (PWI, e.g. Hermans et al., 1998), phoneme monitoring (e.g. Colomé, 2001; Moon & Jiang, 2012), simple picture naming (e.g. Hoshino & Kroll, 2008; Jared & Kroll, 2001), and Stroop (e.g. Sumiya & Healy, 2004, 2008). Some studies have studied bilinguals whose two languages share a number of cognates, such as Spanish and Catalan in Colomé (2001) and Costa et al. (1999), while other studies have studied the languages that share the same alphabetic script, such as English and Spanish in Schwartz and Kroll (2006). The methodological limitation of using such language combinations is that the high degree of phonological and orthographic similarity may increase the likelihood of cross-language activation. The current study examined Mandarin-English bilingual speakers' color naming in English as second language (L2) using the Stroop paradigm. This bilingual population is ideal for teasing apart the influence of phonological and orthographic similarity on cross-language activation, as Mandarin and English have different types of scripts and share few cognates. The present study investigated, when naming in the L2 among this population, whether the first language (L1), the translation of L2 names in particular, is activated at the phonological level and how it affects the L2 naming.

The Stroop task (Stroop, 1935) requires participants to name the ink color of words while ignoring the name of the words. For example, compared with a non-color word (e.g. CAT printed in red), participants are generally slower to name the ink color of an incongruent color word (e.g. RED printed in blue) and faster to name the ink color of a congruent color word (e.g. RED printed in red). The Stroop paradigm is one of the most powerful experimental paradigms to address unintentional, automatic word processing. Although participants are explicitly instructed to name the ink color of the word, the name of the word

is activated nonetheless. In the bilingual version of the Stroop task, color words are printed in one language (e.g. RED) and bilinguals are asked to name the ink color in another language (e.g. *rojo* in Spanish, meaning *red*). Bilinguals are slower to name the ink color of the word *rojo* printed in blue, and the naming speed is faster when the ink color is red. These between-language Stroop effects suggested that bilinguals could not inhibit the activation of the non-target language (i.e. the language of the printed word) even when they were asked to name the colors in the target language only (e.g. Brauer, 1998; Chen & Ho, 1986; Tzelgov, Henik, & Leiser, 1990; Tzelgov, Henik, Sneg, & Baruch, 1996). The present study extended these findings by investigating whether there is an independent activation of phonological information in the non-target language using the bilingual Stroop task.

LI activation and its related factors in a L2 task

Previous studies using Stroop tasks or PWI tasks did not reach a consensus as to whether and how the L1 word is phonologically encoded in a L2 naming task. Tzelgov et al. (1996) observed the between-language Stroop facilitative effect among Hebrew-English bilinguals for cross-script homophones (e.g. ת in Hebrew) in the congruent condition (e.g. a red ת), which have the same pronunciations across the two languages (e.g. both ת and *red* are pronounced as /red/ in English and Hebrew), but with different meanings and written in different scripts (e.g. ת means *to go down-in* Hebrew). Correspondingly, a Stroop interference effect was also shown for cross-script homophones in the incongruent condition (e.g. a blue ת). The above Stroop effects suggested that the L1 phonology is automatically activated in a L2 naming task if the L1 pronunciation matches the L2 response needed for the task.

Sumiya and Healy (2004, 2008) also examined phonological activation in bilingual readers with different scripts. Proficient Japanese-English bilingual speakers named the ink color of Japanese words in English. The Japanese words were either written in the Katakana script (e.g. レッド, /reddo/), which is phonologically similar to the corresponding English color words (e.g. red), or in the Hiragana script (e.g. あか, /aka/), which is phonologically dissimilar to the corresponding English color words. Both Hiragana and Katakana use Kana letters, but the Katakana script produced a significantly larger between-language interference effect. Note that both Hiragana and Katakana scripts produced the Stroop effects and they only differed in the effect size. The above results indicated that phonological similarity between Katakana and English contribute to the between-language Stroop effects, suggesting that Japanese L1 translation is phonologically encoded. However, a limitation of Sumiya and Healy (2004) is that Katakana words and English words are cognates—words that share both meaning and pronunciation across the two languages. Blumenfeld and Marian (2007) suggested that cognate status may influence the phonological activation of the non-target language even when bilinguals are instructed to process the target language only. For example, in an auditory English word identification task, English-German bilinguals were presented with four pictures, and there were two critical conditions. In the first condition the pictures may or may not be English-German cognates (e.g. *Hen* has a German cognate *Henne*) and in the second condition the pictures were the German competitors that shared the similar sounds with the target name (e.g. *Hemd*, meaning “shirt”). Eye-movements to German competitors were used to serve as an index for the co-

activation of German. If German language was activated as well, participants should look at the German competitor longer. Only when the pictures were cognates did native English speakers show longer fixation time on the German competitors, suggesting that cognates boosted parallel language activation (e.g. English and German). Therefore, it seems that the result about L1 phonological activation in Katakana may not be generalizable to non-cognates.

Using non-cognates, Hermans et al. (1998) investigated the phonological activation of L1 translation of the L2 target word in a L2 PWI task, and showed that L1 translation is not phonologically encoded. Proficient Dutch-English bilingual speakers named pictures in L2 English when an auditory distractor in L1 Dutch was presented. Similar to a Stroop task, in the PWI task, participants need to inhibit unrelated language information (i.e. the distractor, which is the name of the word in both Stroop and PWI tasks), and only focus on the target language information (i.e. the printed color in the Stroop task and the picture in the PWI task). The Stimulus Onset Asynchrony (SOA) for the auditory distractor varied. The onset of the auditory distractor preceded the presentation of the picture by 300 ms (−300 ms), by 150 ms (−150 ms), coincided with the presentation of the picture (0 ms), or followed the presentation of the picture by 150 ms (+150 ms). For example, one of the target picture names is *mountain* and its Dutch translation is *berg*, which is phonologically different from the English name. There were four types of Dutch distractor words: phonologically similar to the English name of the picture (e.g. *mouw*, “sleeve”), phonologically similar to the Dutch name of the pictures (i.e. Phono-Dutch distractors, e.g. *berm*, “verge”), semantically related words (e.g. *dal*, “valley”), and unrelated words (e.g. *kaars*, “candle”). The rationale for this design was that, if the Phono-Dutch distractors produce a significant interference effect at the SOAs at which semantic interference does not occur (e.g. +150 ms), the interference from Phono-Dutch distractors is likely to occur at the lexeme level, which involves phonological processing. If Phono-Dutch distractors produce interference effects (hereafter Phono-Translation interference effects) at SOAs at which semantic interference occurs (e.g. −300, −150, and 0 ms), the interference is likely to have occurred at the lemma level, which involves semantic processing. Their results revealed an interference effect only in the latter case (i.e. −300, −150, and 0 ms), suggesting that only semantic information but not phonological information is activated in a L2 picture-naming task. Similar Phono-Translation interference effects were shown in highly proficient Spanish-Catalan bilinguals (Costa, Colomé, Gómez, & Sebastián Gallés, 2003). In two PWI tasks, the researchers observed a significant Phono-Translation interference effect at the SOAs (i.e. −300, −150, and 0 ms) when the semantic interference effect is likely to occur.

Costa, Albareda, and Santesteban (2008) also failed to find evidence for phonological activation of the non-target L1 translation in highly proficient Spanish-Catalan bilinguals. More importantly, they did not replicate the Phono-Translation interference effect observed by Hermans et al. (1998) using the Stroop tasks. Participants were asked to name the ink color of Spanish words in Catalan. One of the critical conditions was the Phono-Translation condition in which the visual Spanish word was phonologically related to the translation of the color name (e.g. the visual word AZUCAR (“sugar” in Spanish) printed in blue ink is related to AZUL (“blue” in Spanish)). The Phono-Translation condition did not lead to any significant facilitation in naming in Experiment 1 in which the response set (i.e. the number

of unique items) was six, and it only showed a trend of facilitation in Experiment 2 in which the response set was 10. On the other hand, using the PWI task, Knipsky and Amrhein (2007) showed significant facilitation in the Phono-Translation condition at 0 ms SOA (e.g. the distractor word *muñeca*, which is the Spanish translation for the word *doll*, facilitated Spanish-English bilinguals' naming of the picture *dog*).

These inconsistent results in previous studies implied that the Phono-Translation effect might be a mediated effect in which lexical information mediates the phonological effect, instead of the direct input-to-output activation (Hall, 2011). As a result, the Phono-Translation effect was not as robust as other effects (e.g. the direct phonological facilitation or semantic interference effect). In summary, findings about the Phono-Translation effect suggested that L1 translation was not phonologically encoded automatically in a L2 naming task, although Sumiya and Healy (2004, 2008) suggested otherwise. One possible reason for this discrepancy is that cognate status may influence the phonological activation of the L1 in a L2 task. If the L1 translation of a L2 word is not only semantically similar but also phonologically similar to the L2 word (such as Katakana and English words), the L1 may be phonologically encoded; however, semantic similarity only may not be able to trigger L1 phonological activation, and this may be the reason why Phono-Dutch distractors only produced an interference effect at the SOAs when semantic interference occurred in Hermans et al. (1998). The present study contributed to the further debate concerning the phonological activation of L1 translation in L2 naming by examining the Phono-Translation effect when target names in the two languages are not phonologically similar.

In addition to phonological similarity between L1 and L2, recent language experience may also affect cross-language phonological activation. In Jared and Kroll (2001), English-French and French-English bilinguals were asked to name English words with or without French enemies (i.e. an orthographically driven naming task). A French enemy of an English word is a French word (e.g. FAIT) that shares the same word-body with the English word (e.g. BAIT) but is pronounced differently (e.g. –AIT is pronounced with a short /e/ in French). Participants' naming latencies were influenced by whether they had read French words recently: the French-English bilinguals who were more dominant in French showed a significantly stronger interference effect in naming English words with French enemies after a French reading session compared to that before the reading session. Some other factors may also affect cross-language phonological activation, such as language mode (e.g. Canseco-Gonzalez et al., 2010) and whether the L1 or L2 is used in the task (e.g. Elston-Guttler & Gunter, 2008; Elston-Guttler, Gunter, & Kotz, 2005).

Although a number of factors may influence this process, we focused on the influence of recent L1 reading experience in the present study. Mandarin-English bilinguals provide an ideal testing case in studying cross-language phonological activation for two reasons. Firstly, Chinese and English have different writing systems so that the possibility that the between-language Stroop effect is due to script similarity can be excluded. More importantly, the lack of cognates between Mandarin and English allows us to investigate whether the L1 is phonologically encoded when L1 translation of a L2 word is only semantically similar to the L2 word. In other words, using noncognates allows us to identify whether cross-language activation occurs phonologically independently of semantic information.

Previous literature has investigated cross-language activation at the phonological level between languages with different scripts in various tasks. For example, Hoshino and Kroll (2008) showed that, when Japanese-English bilinguals named pictures in English, their response time (RT) was significantly shorter when the name of the picture was cognate in Japanese and English. Using the priming paradigm, Zhou, Chen, Yang, and Dunlap (2010) showed that phonological information in L1 Mandarin was activated in L2 English when Mandarin-English bilingual speakers performed a L2 lexical decision task and a naming task. Mandarin-English bilinguals' response to a target English word (e.g. bay /be I/) was faster when it was preceded by a Chinese character prime that has a similar pronunciation as the English word (e.g. 备, *bei4*, to prepare). The current study aimed to examine whether cross-language phonological activation would be shown in a color-naming task by manipulating the Phono-Translation distractors. Compared with Zhou et al. (2010), we focused on whether the L1 translation of the target L2 name was phonologically encoded. The L1 lexical item was not the translation of the L2 target name in Zhou et al. (2010).

Wu and Thierry (2010) showed that Mandarin-English bilinguals' L1 is phonologically encoded in an English task that required participants to judge whether the two visual English words were semantically related. The Chinese translation of the two English words may be phonologically similar (e.g. Experience-Surprise, the pronunciation of the Chinese translations is *jīng1yan4-jīn-glyā4*) or orthographically similar (e.g. Account-Conference, the spelling of the Chinese translations is 会计-会议). Only the phonologically related condition, but not the orthographically related condition, showed reduced N400 amplitude (i.e. a negative event-related potential (ERP) waveform that is related to semantic violation). Compared with Wu and Thierry (2010), which involved disyllabic words and a wide range of concepts as stimuli, the present study involved a limited number of simple concepts/words (i.e. color names) in a classic Stroop paradigm that taps into the automatic access and encoding of the non-target language. We aimed to investigate whether the L1 is activated automatically even with the simple concepts/words with a number of repetitions. It is likely that the repetitions of a set of simple concepts/words may help reduce or minimize the need of L1 phonological activation in a L2 naming task. Otherwise, it would offer strong evidence for automatic L1 activation in a L2 task.

In summary, few studies have investigated the phonological activation of L1 translation in a L2 naming task by examining the Phono-Translation effect among Mandarin-English bilinguals, and the present study aimed to fill this gap. A number of factors may influence the effect, including phonological similarity between the two languages, speakers' recent language experiences, and differences in task demands and materials. The present study focused on Mandarin-English bilinguals whose two languages have different scripts and are phonologically dissimilar when a limited number of simple concepts/words are involved and recent L1 reading experience is taken into consideration.

Reading in Chinese

Unlike the alphabetic writing systems, such as English, French or German, the Chinese writing system is morphosyllabic in that each character maps onto a morpheme and a syllable (see DeFrancis, 1989). For example, 马 is pronounced as *mā3* (the letters denote

Pinyin, a Roman alphabetic system that transcribes the pronunciation of Chinese characters, and the number denotes tone), and means *horse*. Since minimal phonological information is represented in the orthography, some researchers argued that phonological information may only play a subsidiary role in visual Chinese character recognition (e.g. Zhou & Marslen-Wilson, 2009; Zhou, Shu, Bi & Shi, 1999). Nevertheless, a number of studies have suggested that phonological information is activated automatically when reading Chinese (e.g. Leck, Weekes, & Chen, 1995; Perfetti & Tan, 1998, 1999; Ren, Liu, & Han, 2009; Xu, Pollatsek, & Potter, 1999). In particular, phonological activation has been consistently observed in monolingual Stroop tasks with native Mandarin speakers (Guo, Peng, & Liu, 2005; Li, Lin, Wang, & Jiang, 2013; Spinks, Liu, Perfetti, & Tan, 2000). In these studies, native Mandarin readers were required to name the ink color of Chinese characters in Mandarin. There were three types of characters: color characters (e.g. 红, hong2, *red*), the homophones of color characters (e.g. 洪, hong2, *flood*), and neutral characters that do not have any phonological similarity with the color characters (e.g. 费, guan4, *pass through*). In addition to the classic Stroop effects shown with color characters, a significant facilitation effect was also shown with the homophones of color characters. For example, participants named the ink color of 洪 (hong2, *flood*) printed in red ink faster than the control character, 费 (guan4, *pass through*) printed in red. These results suggested that phonological activation occurs automatically even when participants were explicitly instructed to inhibit the character names. In the current study, we extended previous findings to examine whether Chinese L1 phonological information is activated in an English L2 Stroop task. Chinese-English is a unique language pair in bilingual studies. Unlike alphabetic language pairs (e.g. French-English), Chinese and English have dissimilar scripts. Furthermore, cognates rarely exist between Chinese and English. Although Hiragana and English also have different scripts and few cognates, Hiragana does not have as many homophones as Chinese does. As a result, we are able to include homophone conditions in Chinese to investigate phonological activation. Taken together, these features motivated us to utilize the Chinese-English language pair to investigate the cross-language phonological activation in bilinguals.

The present study

In the present study, proficient Mandarin-English bilingual speakers took part in two between-language Stroop experiments. In both experiments, participants were asked to name the ink color of Chinese characters in English. The key difference between Experiments 1 and 2 was that in Experiment 2 the participants completed a Chinese character-naming task prior to the English color-naming task. The rationale for this manipulation was to investigate whether and how recent language experience (i.e. reading Chinese) could influence the activation of the L1 in a L2 task. The visual stimuli included six conditions: congruent color characters (e.g. 红, hong2, *red*, written in red), congruent homophones of the color characters (same segment same tone-S+T+, e.g. 洪, hong2, *flood*, in red), congruent characters that only shared the same syllable segment with the color characters (S+T-, e.g. 轰 hong1, *boom*, in red), congruent characters that shared the same tone but differed in segments with the color characters (S-T+, e.g. 瓶, ping2, *bottle*, in red), incongruent color characters (e.g. 红, hong2, *red*, in blue), and neutral characters (e.g. 牵, qian1, *leading through*, in red). If L1 phonology is activated in a L2 color-naming task, at least the homophone condition should show significantly different naming latency compared to the

neural condition. If the homophone characters activate the phonological information of the corresponding color character (e.g. 红, *red*), it may in turn facilitate the naming of the color in the L2 (e.g. red) due to the shared conceptual information. However, another possibility is that the phonological information in the L1 will compete with that in the L2 for the same lexical item (i.e. *red* completing with *hong2*); thus, speakers may take longer to name the homophones than the neutral characters. In other words, the Phono-Translation interference effect may occur at the lemma level, although it is initiated by the phonological information.

Phonological information consists of segmental and suprasegmental information. The majority of the aforementioned studies did not tease them apart in their investigations. Li et al. (2013) examined the independent activation of segmental and suprasegmental information in L1 lexical access. In their Stroop experiment, native Mandarin speakers named the ink color (e.g. 红, *hong2*, *red*) of a Chinese character that may only share the segmental information with the ink color (S+T-, e.g. 轰, *hong1*, *boom*, which was printed in red) or only share the tonal information with the ink color (S-T+, e.g. 瓶, *ping2*, *bottle*). Compared with the control condition in which a character shared nothing systematically in common with the ink color name (S-T-, e.g. 牵, *qian1*, *leading through*), the researchers found significant facilitation for both S+T- and S-T+ conditions, suggesting that both segmental and tonal information are activated automatically and independently of one another. In the current study, we examined whether segments and tones in the L1 could also be activated in the same way in a L2 color-naming task. With regards to the influence of recent L1 reading experience, if L1 phonology is only activated in bilinguals with recent L1 reading experience, the homophone (i.e. S+T+) or partial homophone condition (i.e. S+T- or S-T+) would only show a facilitative Stroop effect compared to the neutral condition after a L1 reading session.

Experiment 1

In Experiment 1, Mandarin-English bilinguals named the ink color of Chinese characters in English. The purpose of Experiment 1 is to investigate whether and how Chinese L1 is phonologically encoded when Mandarin-English bilinguals name colors in the L2 without recent L1 reading experience.

Participants

Participants consisted of 24 graduate students (16 females) from a Mid-Atlantic university. Ages ranged from 21 to 30 years ($M = 24.6$, $SD = 1.34$). Participants were all Mandarin-English bilingual speakers with Mandarin as their native language and had normal or corrected-to-normal vision. Their length of residence in the USA ranged from 1 to 6 years ($M = 2.7$ years, $SD = 1.05$), and the age of English acquisition ranged from 9 to 10 years ($M = 9.8$, $SD = .38$). Participants reported their TOEFL (Test of English as a Foreign Language) scores as a proxy of their English proficiency. We calculated percentages by dividing raw scores from the total possible scores for either the paper-based or internet-based version. The average percentages for all participants were 85.7% ($SD = 11.0\%$). Given their relatively high proficiency level in English, it is reasonable to assume that they know all the color names used in the current experiment.

Design and materials

The visual stimuli were written in four different ink colors: red, yellow, green, and blue. Among the 132 trials, 72 (six conditions $\times$ four colors $\times$ three repetitions) were critical trials while the other 60 were fillers. The six conditions included congruent color characters, congruent S+T+ characters, congruent S+T- characters, congruent S-T+ characters, neutral characters, and incongruent color characters. We used the same four colors as Li et al. (2013): 红 (hong2, red), 黄 (huang2, yellow), 蓝 (lan2, blue), and 绿 (lv4, green), and the same visual characters were also used in the present study. Three of the four colors carry the second tone in Chinese. Note that we did not include any incongruent S+T+, incongruent S+T-, or incongruent S-T+ characters. If we have an S-T+ character (e.g. 瓶, ping2, bottle in the *red* group) printed in yellow or blue to create an incongruent S-T+ trial, it becomes a congruent trial for the other two colors, 黄 (huang2, yellow) and 蓝 (lan2, blue), because they both carry the second tone. As a result, the only way to create incongruent S-T+ trials is to have all S-T+ characters from the red, yellow, and blue groups to be printed in green (lv4, green), which carries the fourth tone. However, this will result in unbalanced color distribution. Given the difficulty in creating the incongruent S-T+ characters, the incongruent S+T+ and S+T- characters were also excluded.

Each participant received all conditions. In each condition, every character was repeated three times. As the neutral characters could serve as fillers, we only added 60 instead of 72 fillers. Table 1 shows the types of stimuli and their characteristics. Polyphones and characters with phonetic radicals were not selected. All participants expressed that they knew all the characters.

Procedure

The experiment was implemented using DMDX software (Forster & Forster, 2003), with the following procedure: after the instructions were given, a 500 ms fixation (“+”) appeared at the center of the screen, followed by the target character that disappeared as soon as a color-naming response was made. The inter-trial interval was 1000 ms. If no response was made within 3000 ms, the current trial was automatically terminated. The stimuli in the experiment were pseudo-randomized so that the same color or character did not appear consecutively. Each stimulus was presented at the center of the screen in bold 48 song-ti font. Participants were required to name the color of the stimulus in English as quickly and accurately as possible. There were eight practice trials. During the experiment, the first author sat behind the participants and scored their naming accuracy. Participants received one point for each correct pronunciation and 0 points for incorrect pronunciation or no response. No half points were given.

Results and discussion

RT analyses were based on correct trials only (which resulted in deletion of 2% of the trials). Less than 1% of the RT data were removed because the naming responses failed to trigger the voice key. Data that were two standard deviations above or below the cell mean were also excluded from data analysis (3%). The mean RT, standard deviations, and error rates for each condition in Experiment 1 are presented in Table 2. All the analyses were based on log-transformed data to improve normality and linearity.

Planned paired t -tests replicated the classic Stroop effect in the color character condition. There was a significant 40 ms facilitation in the congruent color character condition ($t(23) = 3.349, p = .003$) and a significant 210 ms inhibitory effect in the incongruent color character condition ($t(23) = -4.780, p < .001$). No other congruent conditions showed significant differences compared to the neutral condition (all $ps > .30$). The error rates were low, ranging from 0% to 4.6%, and the analysis of error rates did not show any significant Stroop effect (all $ps > .10$). To rule out the possibility that the repetition of the items may influence the patterns of results, we included only the items that appeared for the first time in the analysis. It turned out that the same patterns of results still held (68 ms facilitation in the congruent color character condition and 201 ms inhibition in the incongruent color character condition, $ps < .01$, while no clear trend was shown in any other conditions, $ps > .50$), suggesting that the repetition did not change the participants' performance.

The correlation between participants' TOEFL scores and their between-language Stroop effect was not significant, $r = .115, p = .661$ for the Stroop facilitation effect, and $r = .089, p = .733$ for the Stroop interference effect. These results suggested that participants' English proficiency was not associated with the magnitude of the between-language Stroop effect.

Due to the difficulty in stimuli selection, word frequency across conditions could not be well controlled (see Table 1). We co-varied the frequency factor in the above analysis. However, this was not done for the subject analysis since each condition has its own frequency; hence, condition and frequency are within-subject variables. Frequency was treated as a covariate in the item analysis, although typically only subject analysis was reported in a Stroop task (e.g. Spinks et al., 2000; Sumiya & Healy, 2008) due to the limited number of items in each condition. An analysis of variance (ANOVA; item analysis) was conducted among all the congruent conditions, and there was no significant main effect of frequency ($F(1, 14) = .518, p = .484$), and frequency did not interact with any other variables (i.e. S+T+, S+T-, and S-T+ conditions and the color character conditions; all $Fs < 1$), suggesting that the unbalanced character frequencies across the conditions did not affect the pattern of the results. Since there was no significant difference between any of the two conditions in terms of the number of strokes, we decided not to include it as a covariate in the analysis ($ps > .10$).

The only significant effects in Experiment 1 were the classic Stroop facilitation with the congruent color characters and interference with the incongruent color characters. In other words, characters that share full or partial phonological information with the color names in Chinese did not show a significant difference in naming latency. The absence of the Stroop effect in the S+T+, S+T-, and S-T+ conditions was unlikely to be a result of the logographic characteristics of Chinese characters, since previous research using the same materials showed significant facilitation in the congruent S+T+, S+T-, and S-T+ conditions when the response language was Chinese (Li et al., 2013). The results of the current Experiment 1 suggested that phonological information in L1 Chinese may not be activated automatically during a color-naming task in L2 English. In Experiment 2, we tested whether L1 phonological activation could be induced by priming participants to pay attention to L1 phonology by adding a Chinese character-naming task prior to the L2 task.

Experiment 2

Experiment 2 examined whether and how the prior activation of L1 phonology would influence L2 naming. Jared and Kroll (2001) suggested that bilingual speakers' non-target language activation was influenced by their recent language experience (i.e. whether they have used the non-target language recently); it is likely that naming Chinese characters would influence L1 phonological activation in the subsequent L2 color-naming task. We hypothesized that, if recent language experience could influence the automatic activation of L1 phonology in a L2 task, at least the homophone characters in Experiment 2 should produce a significant Stroop facilitation. If recent language experience could not influence L1 phonological activation, then the results in Experiment 2 should replicate those in Experiment 1.

Participants

Twenty-four graduate students (14 females) who were from the same population as those in Experiment 1 participated in Experiment 2. None of them participated in Experiment 1. All participants were Mandarin-English bilingual speakers with normal or corrected-to-normal vision. Their ages ranged from 19 to 30 years ($M = 24.4$, $SD = 3.0$). Their length of residence in the USA ranged from two months to five years, and all of them began to learn English at 9 or 10 years old. The average TOEFL scores were 81.6% ($SD = 8.7\%$).

Materials and design

The character conditions and the stimuli were exactly the same as those in Experiment 1. A total of 48 critical trials (six conditions $\times$ four colors $\times$ two repetition) and 48 fillers were included in this experiment. We decreased the number of repetitions in order to shorten the length to avoid a fatigue effect, since two character-naming blocks were added. The 48 trials were pseudo-randomly divided into two blocks, with 24 critical trials and 24 fillers in each, and with a character-naming block prior to each color-naming block. In each color-naming block, there were at least two characters from each of the critical conditions and four repetitions for each of the four colors (e.g. at least four characters were printed in red). The stimuli in each block were pseudo-randomized so that the same color or character did not appear more than three times in a row. The character-naming block consisted of 48 trials. The characters were printed in black ink. They were the same as those in the subsequent color-naming block, but presented in a different order.

Procedure

All participants completed four blocks (character naming 1, color naming 1, character naming 2, and color naming 2). Participants were randomly assigned to either order 1: character naming 1 $\rightarrow$ color naming 1 $\rightarrow$ character naming 2 $\rightarrow$ color naming 2 or order 2: character naming 2 $\rightarrow$ color naming 2 $\rightarrow$ character naming 1 $\rightarrow$ color naming 1.

The procedure was the same as that in Experiment 1. Participants were instructed to read aloud the characters in Chinese as quickly and accurately as possible in the character-naming block, and name the color of the visual stimuli in English as quickly and accurately as possible in the color-naming block. There were eight practice character-naming trials

followed by eight practice Stroop trials before the experiment. Instructions were presented when the tasks switched. The first author scored participants' responses using the same criteria as those in Experiment 1.

Results and discussion

The accuracy rate for the character-reading block was 97.2%. The procedure of data cleaning was the same as that in Experiment 1. Overall, less than 2% of the original RT data was removed. The mean RT, standard deviation, and error rate for each condition are presented in Table 3. All analyses were based on log-transformed data.

Planned paired sample *t*-tests showed the classic Stroop facilitation and interference effects (for congruent color characters, $t(23) = 4.730$, $p < .001$; for incongruent color characters, $t(23) = -6.508$, $p < .001$). Participants were also significantly slower to name the colors in the congruent homophone character condition than those in the neutral character condition ($t(23) = -2.787$, $p = .010$). Neither S+T- nor S-T+ showed a significant difference compared with the neutral condition in RT or accuracy rates (all $ps > .20$). The correlation between participants' TOEFL scores and their between-language Stroop effect was not statistically significant (both $ps > .1$). The repetition of the items again did not change the patterns of results. Similar to Experiment 1, we treated frequency as a covariate in the item analysis to investigate whether unbalanced frequency across conditions might have influenced participants' performance. There was no significant main effect of frequency ($F(1, 14) = .338$, $p = .570$), and frequency did not interact with any other variables (i.e. different L1 phonological conditions and the color character condition; all $Fs < 1$), suggesting that the unbalanced character frequencies across conditions did not affect the pattern of the results.

The homophone condition did not show any significant effect in Experiment 1. However, this condition showed a significant interference effect in Experiment 2 when L1 phonological information had been activated prior to the L2 task. This result suggests that recent experience with the non-target language (i.e. naming characters in the L1) made a difference in naming colors in the L2. The interference effect might be a result of language competition, namely, participants making efforts to inhibit their L1. The result was consistent with the Phono-Translation interference effect (Costa et al., 2003; Hermans et al., 1998). In Experiment 2, since a character-naming block that aimed to activate L1 phonological information in advance was added before each color-naming block, the L1 phonological information (e.g. hong2) of the target color (e.g. red) was activated in the congruent S+T+ condition and competed with the L2 phonological information (e.g. /red/). In addition, language competition may also occur at the lemma level, so that the two lexical items (the concept of *flood* and the concept of *red*) compete with each other. However, the present study was not able to tease apart whether the competition occurs at the phonological or lemma level. We suggest that it is likely a result of joint competition at both the phonological and lemma levels. Although similar competition at the phonological level might have also occurred in the congruent color character condition, the L1 translation (e.g. 红) of the target color (red) led to a much larger facilitation at the lemma level; thus, the overall effect was facilitation.

Our results were also consistent with Misra, Guo, Bobb, and Kroll (2012). In this study, Chinese-English bilinguals were instructed to use one language to name pictures, and then switch to the other language to name the same pictures. Results showed that when participants named pictures in their L1 first, they showed significantly longer name latencies and larger error rates after they switched to their L2. In addition to the behavioral responses, participants also showed greater N2 component in their ERPs, suggesting that bilinguals need to inhibit their L1 persistently. An N2 component refers to negative ERP waveform peaks at about 250–350 ms after stimulus onset, and is typically generated when a response must be suppressed. In contrast, when participants used their L1 after L2 naming, both behavioral and ERP data showed significant facilitation, suggesting a repetition priming effect. Both the present Experiment 2 and Misra et al. (2012) suggested that bilingual speakers might need to suppress their L1 when naming in their L2, thus leading to an interference effect.

General discussion

The present study used the Stroop paradigm to examine the activation of phonological information in the non-target L1 in a L2 naming task. The findings of Experiments 1 and 2 jointly suggest that L1 phonology may not be activated automatically in bilinguals who use two different scripts. However, it appears that recent language experience influences L1 phonological activation. If bilinguals have named L1 words recently, their L1 is likely to be phonologically encoded in a L2 naming task. The theoretical significance of the current study is three fold. Firstly, it demonstrated that the activation of the non-target language in bilingual language processing might not be automatic if the L1 and L2 do not share a high degree of phonological and orthographic similarity. Secondly, it showed that recent use of the non-target language could heighten its degree of activation in a task supposedly involving only the target language, despite the lack of similarity between the two scripts. Finally, even though Li et al. (2013) showed that segmental and suprasegmental information is processed independently in a monolingual (Mandarin) task, the present study demonstrated that these two types of phonological information in Mandarin are likely to be activated as an integral unit in a bilingual task.

The influence of recent language experience

The most important finding of the present study is the presence of a significant interference effect in the homophone condition in Experiment 2 but not in Experiment 1. This result suggests that whether bilinguals have read aloud their L1 recently influences L1 phonological activation in a subsequent L2 color-naming task. The result is consistent with Jared and Kroll (2001, Experiment 4) who used a L2 word-naming task. Participants in that study named English words with French enemies before and after a French word-reading task. The French-English bilinguals who were more dominant in French showed a significantly stronger inhibition in naming English words with French enemies after the French reading session compared to that before the reading session, suggesting that recent experience with L1 phonology influences L1 activation in the subsequent L2 task.

In Experiment 1 of the current study, L1 was likely to be activated only at the lemma level (i.e. semantic level). Therefore, congruent color characters (e.g. 红, hong2, red) were able to produce a facilitative Stroop effect since they share the same semantic information with the target L2 color names (e.g. red). In contrast, the homophone of the a color character (e.g. 洪, hong2, flood) was less likely to influence color naming in the L2 since it only provides useful information at the lexeme level (i.e. phonological level) but not at the lemma level, and the L1 may not be activated at the lexeme level without prior activation of L1 phonology. Our results, as well as those from Jared and Kroll (2001), suggest that the influence of recent language experience in cross-language phonological activation may be generalizable to bilinguals who speak two languages with either similar or different scripts in a L2 naming task that is either conceptually driven (i.e. color naming) or orthographically based (i.e. word naming).

The influence of phonological similarity

Sumiya and Healy (2004) showed that Katakana words (e.g. レッド), which are phonologically similar to the target English words (e.g. red), produced significantly larger Stroop effects than Hiragana words (e.g. あか) did. Words in Hiragana are only semantically related to the L2 color names, while words in Katakana are both semantically and phonologically similar to the L2 color names. Therefore, the larger Stroop effect in Katakana suggests that L1 Japanese phonology plays a role in L2 English. Although Katakana and English have different scripts, all words in Katakana are loan words that are phonologically similar to their English translation. Therefore, it is possible that the Katakana script encourages Japanese-English bilinguals to activate not only the semantic information but also the phonological information of the visual words in an English L2 task, so that Katakana words led to a larger Stroop effect than Hiragana words did. In contrast, neither the Hiragana nor the Chinese stimuli in our study share similar phonological information with the target language, so that the translation of the English words in these writing systems may not be phonologically encoded, although they are semantically encoded. Using non-cognates and homophones in our study allowed us to tease apart the phonological and semantic relatedness between the target and non-target languages, thus to address the possibility that phonological activation of the non-target language in bilinguals may be influenced by the phonological similarity between the two languages (i.e. whether the same concepts were pronounced similarly in the two languages).

Phonological similarity may also help explain the discrepancy in the results between Zhou et al. (2010) and the current study. In addition to the methodological differences between the priming and Stroop paradigms, the stimuli were also different. The primes used by Zhou et al. shared similar phonological information with the target English L2 words (e.g. 备 (*bei4*, to prepare) and bay /bei/), leading to the cross-language phonological facilitation effect in their study. The Chinese characters in our Stroop experiment, on the other hand, are not phonologically similar to the target English L2 words. Instead, they are phonologically similar to the L1 translation of the target English L2 words (e.g. 洪 (*hong2*, flood) is phonologically similar to 红 (*hong2*, red), the translation of red). Our findings suggest that when naming English L2 words, their Chinese L1 translations may not be phonologically encoded automatically. Note that phonologically similar Chinese-English word pairs are

uncommon given the great differences in phonological structures between the two languages. For example, a large number of Chinese syllables are open syllables (about 62%, see Wang & Cheng, 2008) and only two nasal consonants are allowed at the coda position (/n/, /ŋ/). Furthermore, initial consonant clusters are not allowed in Chinese syllables. Therefore, Zhou et al.'s findings may not be generalizable to a wide range of Chinese-English word pairs.

In addition to recent language experience and phonological similarity between the two languages, some other factors may also influence L1 phonological activation in a L2 task, such as the difficulty of materials. For example, the results of our Experiment 1 were different from those of Wu and Thierry (2010), which showed that Chinese-English bilinguals' L1 is phonologically encoded in an English task when judging whether the two visual English words were semantically related. As mentioned earlier, Wu and Thierry (2010) found that, when the Chinese translation of the two English words was phonologically similar (e.g. Experience-Surprise, the pronunciation of the Chinese translations is *jīnglǎn4-jīnglǎ4*), a reduced N400 amplitude was shown. This difference might be related to the materials of the two studies as well as different methodologies. The materials to be named in the Stroop paradigm (i.e. the four colors) are very simple and repeatedly represented. In contrast, the materials in Wu and Thierry (2010) involved disyllabic words and a wide range of concepts not limited to colors. It appears that the activation of L1 phonology in a L2 task may be dependent upon the experimental tasks and materials involved. When only a limited number of simple target concepts are involved with repetitions, it is possible that the phonological information of L1 translation of the L2 target is no longer activated automatically, at least for highly proficient Chinese-English bilinguals. Methodologically, Wu and Thierry studied ERP signals of cross-script phonological activation. It is likely that ERP waves are more sensitive than the Stroop paradigm to the encoding and activation of the non-target language. Clearly, future research employing different experimental paradigms and different methodologies is needed to examine the existence and generalizability of the potential cross-script phonological activation.

Language competition

A significant interference effect was shown in the homophone condition in Experiment 2. We speculated that the effect might be a result of language competition between the L1 and L2, consistent with the Phono-Translation interference effect observed in previous studies using the PWI paradigm (Costa et al., 2003; Hermans et al., 1998). Although previous studies have suggested that the Phono-Translation competition occurred at the lemma level, the current study could not tease apart whether the competition occurs at either the lexeme or lemma level, and we suggest that it is likely a joint competition at both levels.

The suppression of Chinese L1 may also explain the difference in RTs in the incongruent color character condition between Experiments 1 and 2. Although both experiments showed significant interference effects in this condition, the RT difference was 211 ms in Experiment 1 and 94 ms in Experiment 2. It is possible that the character-naming block in Experiment 2 had activated participants' L1 in advance and participants realized that they needed to suppress their L1 in order to perform well in the incongruent color character

condition. Participants might have failed to realize the relationship between the English name of the color and the pronunciation of the Chinese character in the other conditions, but the relationship was very obvious in the incongruent color character condition.

Integral phonological activation

The present study also investigated whether partial L1 phonological information can be activated in a L2 color-naming task. Our results suggest that neither L1 segmental nor tonal information play an independent role in conceptually driven English L2 naming. Even after the prior activation of L1 phonology in the character-naming task in Experiment 2, neither S+T− nor S−T+ conditions produced significant effects. This finding highlights the difference underlying the activation of L1 phonology in a L1 versus L2 color-naming task. Li et al. (2013) showed that segments and tones independently facilitated L1 color naming whereas such facilitation was absent in the current study. It appears that L1 segments and tones are activated as an integral unit in a L2 naming task; either segmental or tonal information alone could not reach threshold in the mental lexicon for affecting the performance during a L2 task (with L1 distractors).

A limitation of the present study is that we used identical Chinese characters in the naming task in Experiment 2 as the distractors in the Stroop task. If a list of unrelated characters were used in the naming task, it is unclear whether the same level of interference in the homophone condition would be expected. It is possible that the interference may be reduced, since the phonological information that has been activated in advance would not be helpful in the color-naming block. Furthermore, future research should consider including different color characters from the ones used in our study in order to create incongruent phonological trials. However, the challenge in Chinese is that many other colors may have multiple names (e.g. orange color can be named as 橙, cheng2 or 橘, ju2 in Chinese). It is also difficult to find homophones for some color names, for example, 黑, hei1, black, does not have corresponding S+T+ characters.

Conclusion

For bilinguals with different scripts, phonological information in the L1 (the L1 translation of the target L2 word in particular) may not be activated automatically in a conceptually driven L2 task. Recent experience with naming L1 words encourages bilinguals to activate their L1 phonology in a L2 task, and this activation may yield a homophone interference effect for Chinese-English bilinguals, suggesting that there may be a joint competition at both the lexeme and lemma levels.

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Table 1

Stimuli in critical trials.

Condition	Color characters	S+T+	S+T-	S-T+	Neutral
Frequency	红 423	洪 91	轰 102	瓶 54	罕 55
Number of strokes	6	9	8	10	9
Pronunciation	hong2	hong2	hong1	ping2	qian1
Translation	red	Flood	boom	bottle	lead along
	黄	皇	晃	缠	趁
Frequency	373	247	47	34	32
Number of strokes	11	9	10	13	12
Pronunciation	huang2	huang2	huang4	chan2	chen4
Translation	yellow	Emperor	sway	wrap around	take advantage of
	蓝	婪	览	尝	宫
Frequency	116	8	43	60	166
Number of strokes	13	11	9	9	9
Pronunciation	lan2	lan2	lan3	chang2	gong1
Translation	blue	greedy	view	taste	palace
	绿	虑	旅	洞	涂
Frequency	137	192	178	157	51
Number of strokes	11	10	10	9	10
Pronunciation	lv4	lv4	lv3	dong4	tu2
Translation	green	ponder	travel	hole	paint

Note. Frequency information was obtained from the character frequency database on the Chinese Text Computing website (Da, 2004; <http://lingua.mtsu.edu/chinese-computing/>). All frequencies are character frequency per million characters. S and T refer to syllable Segment and Tone, respectively. + and - refer to whether the segment or tone is same or not. For example, S+T+ means that both the segment and tone are same between the target color and the character.

Table 2

Errors (SD) and reaction time (SD) in each condition in Experiment 1.

Condition	RT (ms)	Errors (%)	Stroop effect (ms)
Congruent color character	748 (87)	0.4 (2.0)	40 [*]
Congruent S+T+	797 (108)	0.9 (2.7)	-9
Congruent S+T-	778 (89)	1.8 (3.5)	10
Congruent S-T+	778 (81)	0.9 (2.7)	10
Incongruent color character	999 (267)	4.6 (6.5)	-211 ^{***}
S-T- (neutral condition)	788 (88)	1.8 (3.6)	

^{*}
 $p < .05$;

^{***}
 $p < .001$.

RT: reaction time.

Table 3

Errors (SD) and reaction time (SD) in each condition in Experiment 2.

Condition	RT (ms)	Errors (%)	Stroop effect (ms)
Congruent color character	678 (78)	0.5 (2.6)	60***
Congruent S+T+	798 (126)	0.5 (2.6)	-60**
Congruent S+T-	734 (69)	0.0 (0.0)	4
Congruent S-T+	714 (85)	0.0 (0.0)	24
Incongruent color character	832 (119)	0.2 (1.6)	-94***
S-T- (neutral condition)	738 (86)	0.5 (2.6)	

**
 $p < .01$;

 $p < .001$.

RT: reaction time.