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Reading Chinese but with Korean in mind: ERP evidence for nonselective lexical access in sentence reading

Jinyi Xue[1], Yu-Fu Chien[2] and Kunyu Xu[3]

[1]College of Foreign Languages and Literature, Fudan University, Shanghai, China; [2]Department of Chinese Language and Literature, Fudan University, Shanghai, China and [3]Institute of Modern Languages and Linguistics, Fudan University, Shanghai, China

Research Article

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Corresponding author:
Kunyu Xu;
Email: kunyuxu@fudan.edu.cn

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Abstract

Previous studies have investigated whether lexical access in sentence reading is language-selective using interlingual homographs, but have yielded inconsistent results. In this study, event-related potentials were measured when Korean-Chinese bilinguals read the Chinese version of false-cognates (e.g., "放学", after school) in Chinese sentence contexts that biased the meaning towards the Korean version (e.g., "방학", school vacation). With the match words as the baseline, Chinese monolinguals elicited similar N400 and P600/LPC effects when reading the false-cognates and mismatch words, whereas Korean-Chinese bilinguals produced a smaller N400 effect for false-cognates than for mismatch words, indicating activation of the Korean version. The P600/LPC effect was observed for false-cognates in bilinguals, reflecting increased integration difficulties or enhanced cognitive control. The study supported the nonselective view and proposed a theoretical extension of the BIA+ model, claiming that bilingual interactive activation might be mediated by shared morphemic representations between languages.

Highlights

- The monolinguals elicited similar N400 for false-cognates and mismatch words
- The false-cognates produced a smaller N400 than the mismatch words in bilinguals
- The P600/LPC effect was found for the false-cognates in bilinguals
- Language context did not make word recognition language-selective
- Bilingual interactive activation mediated by shared morphemic representations

1. Introduction

Bilinguals can read in either language, and of course they know which language they are reading in. But does this mean that their brains are dedicated to processing the target language, or is the other language still activated? One of the central questions in bilingual word recognition is whether lexical access is restricted to one language (language-selective) or not (language-nonselective). Many empirical studies have demonstrated that lexical candidates from different languages are activated during isolated word recognition, suggesting that bilingual lexical access is basically language-nonselective (for a review, see Dijkstra, 2005).

However, words are usually not recognized in isolation, but in sentence context. Thus, recent studies have turned attention to investigating whether sentence context, which contains information about language membership, semantic and syntactic constraints, can modulate the word recognition system and make it more language selective. This focus has been fueled by ongoing debates regarding the degree to which language processing is modular or interactive across different levels of processing (Schwartz & Van Hell, 2012). In related studies, cognates (words that share a high degree of meaning and form overlap in two languages) showed an advantage in recognition over noncognates when they are placed in sentence contexts, but the facilitative effects may be eliminated in high-constraint sentences (e.g., Dijkstra, Van Hell, & Brenders, 2015; Duyck et al., 2007; Libben & Titone, 2009; Schwartz & Kroll, 2006; Titone et al., 2011; Van Assche et al., 2011; Van Hell & De Groot, 2008). Interlingual homographs (words that share the same orthography but have different meanings in two languages) are a more powerful diagnostic tool than cognates, because the meanings of them in the two languages are drastically different. If nonselective lexical access is correct, the non-target meaning would also be activated. However, related studies have produced mixed results. Elston-Guttler, Gunter and Kotz (2005) used a joint method that included reaction times (RTs) and event-related potentials (ERPs) measures and found that semantic context, local language context, and global language context allow German-English bilinguals to "zoom in" to a more language-selective mode of processing. Libben and Titone (2009) used eye movement measures and found that nonselective bilingual lexical access

at early stages of comprehension is rapidly resolved in semantically biased contexts at later stages of comprehension in French-English bilinguals. Using ERP technique, Jouravlev and Jared (2014) found that Russian-English bilinguals automatically activated representations in both languages when reading interlingual homographs in English sentences, indicating that the combination of a language-specific script and the preceding language context still failed to make word recognition language-selective. Using eye movement measures, Hoversten and Traxler (2016) found that when the sentence context biased the task-irrelevant meanings of interlingual homographs, English monolinguals and Spanish-English bilinguals showed equivalent implausibility effects at early stage, suggesting that proficient bilinguals may dynamically adapt to contextual cues and selectively access information associated with the contextually cued language under certain conditions. Although there are no conclusive findings on this issue, existing empirical data support that language membership does not provide a powerful cue to allow for selective access within a language, but rich semantic information may constrain the time-course of language non-selectivity (Schwartz & Van Hell, 2012). That is, the comprehension system is interactive and feedback from the sentence context may have a top-down influence on the language selectivity of lexical access. However, the mechanism of this influence remains to be further explored.

In the literature on bilingual visual word recognition, alphabetic languages with the same or similar scripts make up the majority, and cross-language orthographic overlap is relatively easy to find in these languages. However, there are also many bilinguals whose two languages use very different scripts. Bilinguals of these languages are excellent participants for investigating language selectivity in visual word recognition because they can help demonstrate whether higher-order lexical processing (e.g., phonological and semantical processing) is still language-nonselective when orthographic information has already indicated language membership. Several studies have observed a facilitative masked priming effect when primes and targets are in different-script languages but phonologically and/or semantically similar, supporting automatic activation of the task-irrelevant language, i.e., the language-nonselective view (e.g., Gollan, Forster, & Frost, 1997; Kim & Davis, 2003; Nakayama, Ida, & Lupker, 2016; Nakayama et al., 2012; Voga & Grainger, 2007). In languages with different scripts, interlingual homographs (i.e., orthographic overlaps) do not seem to exist. However, for some language pairs, although they have different scripts, some of their morphemes share a systematic mapping relationship, such that some compound words may be composed of corresponding morphemes. Since the same morpheme combination may preserve different interpretations between the two languages, these compound words may also have different lexical meanings in the two languages. An example of this is Chinese and Korean. There is a large proportion of Sino-Korean words in the Korean vocabulary. Sino-Korean words are not Mandarin loanwords. They are derived from Classical Chinese and have been assimilated into the Korean language. They all have corresponding Chinese characters/morphemes, but are now written in Hangul (Korean alphabetic script) and have no direct phonetic or phonological correspondences with modern Mandarin (Koo et al., 2015; Wang, 2012). For example, in Korean, "학" /hak/ has a corresponding Chinese character/morpheme of "学", which generally means "study, school", but "学" is pronounced as /ɕyɛ^{35}/ in modern Mandarin used in mainland China. When this particular morpheme is combined with another morpheme, the Chinese and Korean versions of the compound word may have the same meaning and can be treated as cognates. For example, when "학/学" is combined with "교", whose corresponding Chinese character/morpheme is "校", both "학교" and "学校" mean "school". However, some morpheme combinations are interpreted differently in the two languages. For example, when "학/学" is combined with "방/放", which generally means "dismiss", the Korean version "방학" means "school vacation", but the Chinese version "放学" means "after school". These interlingual words are similar to interlingual homographs, but different in nature because interlingual homographs share the same letters, which can be directly seen, while the connection between "방학" and "放学" is not something that can be directly seen or heard. Moreover, for the common letters shared by interlingual homographs, each letter has no meaning by itself. Thus, words that happen to use the exact same letters can have very different meanings. But for "방학" and "放学", their lexical meanings (school vacation vs. after school) differ only because the same morpheme combinations (dismiss + school) are interpreted differently in the two languages. Therefore, their lexical meanings are different but not completely unrelated. Given that these morphemes have the same origin, we use the term "false-cognates" to refer to those words that share corresponding morphemes but have different lexical meanings in two languages, although they differ to some extent from the conventionally defined "false-cognates".

Whether the Korean and Chinese versions of the false-cognates activate each other during visual word recognition is a question that has yet to be addressed and may broaden the theoretical framework of bilingual word recognition. The Bilingual Interactive Activation Plus model (Dijkstra & van Heuven, 2002) proposed that the lexical representations of different languages are stored together in an integrated lexicon and are accessed in a language non-selective way. It is the cross-linguistic orthographic, phonological, and semantic similarities that determine cross-linguistic activation. Within this framework, previous bilingual word recognition studies involving Chinese have mainly considered cross-linguistic phonological similarities, as Chinese does not share orthography with most other languages (e.g., Chen et al., 2022; Zhou et al., 2010). Zhang et al. (2019) argued that the opaque mapping from orthography to phonology in Chinese may even hinder the phonological effect in bilingual visual word recognition. However, the Sino-Korean words composed of Chinese-origin morphemes remind us that there may be a connection between Chinese and Korean lexical representations that goes beyond visual or auditory similarities, but is based on correspondence of morphemes. This assumption is compatible with some previous studies on alphabetic languages that have also considered language-independent morphemic representations in the bilingual lexicon (Cristoffanini, Kirsner, & Milech, 1986; Davis et al., 2010; Sánchez-Casas & García-Albea, 2005; Voga & Grainger, 2007). Therefore, the case of Korean-Chinese false-cognates may extend the BIA+ model by emphasizing the role of morphemes, thus improving our understanding of the architecture of the bilingual mental lexicon.

2. The present study

The present study aims to investigate whether the Korean version of the false-cognates is activated when Korean-Chinese bilinguals (L1 Korean, L2 Chinese) read the Chinese version in a Chinese sentence. The design of the experimental materials is analogous to that of Jouravlev and Jared (2014). The Chinese sentence contexts were constructed in such a way that the Korean meanings of the false-cognates were expected, so that the Chinese version of the

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false-cognates would then make the sentence semantically implausible. For example, "放学", which means "after school" in Chinese while its Korean counterpart "방학" means "school vacation", was embedded at the end of the sentence "学期结束了，明天开始进入____。" ("The semester is over. ____ starts tomorrow."). The semantic (in this case, also syntactic) constraint clearly signaled that "放学" ("after school") is incongruent. In this sentence context, the Chinese match word is "假期" ("vacation"). "放学" ("after school") should be as semantically implausible as its (near-)synonym "下课" ("after class"), which is not a Korean-Chinese false-cognate. However, if "放学" is recognized by bilinguals in a nonselective manner, the Korean version "방학" ("school vacation"), whose meaning is congruent with this sentence context, should also be activated. In this study, we instructed Chinese monolinguals and Korean-Chinese bilinguals to read Chinese sentences end with the match word ("假期", vacation), the false-cognate ("放学", after school), or the mismatch word ("下课", after class), and judge whether the sentences were semantically plausible while their cortical electroencephalogram (EEG) were continuously recorded. We predict that if the recognition of false-cognates is nonselective in Korean-Chinese bilinguals, an inhibitory effect will be found, with lower accuracy and longer reaction times of semantic plausibility judgment in the false-cognate condition than in the mismatch condition. In terms of ERPs time-locked to the critical word onset, we focus on the N400 component, which is particularly sensitive to factors related to semantic fit (Kutas & Federmeier, 2011) and has been widely used in studies of bilingual language processing (for reviews, see Jankowiak & Rataj, 2017; Moreno, Rodríguez-Fornells, & Laine, 2008). We expect the Chinese monolinguals to produce robust and similar N400 effects in both the false-cognate and mismatch conditions relative to the match condition. In contrast, for Korean-Chinese bilinguals, if the Korean version of the false-cognate is also activated when reading the Chinese version, a smaller N400 is expected in the false-cognate condition than in the mismatch condition because the Korean meaning is semantically congruent with the sentence context. On the other hand, the P600 or Late Positive Complex (LPC), which has been hypothesized to be associated with syntactic reanalysis processes or syntactic integration processes (Kaan et al., 2000), can also emerge because the false-cognate and mismatch words may also lead to syntactic violations. However, bilinguals do not necessarily show the P600/LPC effect when processing syntactically incorrect sentences in their second language (Clahsen & Felser, 2006; Hahne & Friederici, 2001; Sabourin & Stowe, 2008). Whether the P600/LPC effect can help to detect activation of both languages is still unknown. In addition, because the duration and scalp distribution of N400 effects in L1 and L2 processing may differ (Jankowiak & Rataj, 2017; Moreno, Rodríguez-Fornells, & Laine, 2008), the present study also attempts to evaluate whether the effects of interest have different spatiotemporal distributions in Chinese monolinguals and Korean-Chinese bilinguals.

3. Methods

3.1 Participants

A monolingual and a bilingual group of right-handed participants with normal or corrected-to-normal vision were recruited for this experiment. The monolingual group consisted of 15 native Mandarin Chinese speakers, including 8 males and 7 females, aged between 20 and 28 (M = 24.5). They all reported to have no knowledge of Korean, Japanese, or Vietnamese, which contain words of Chinese origin. The bilingual group consisted of 15 native Korean speakers who learned Chinese as a second language, including 6 males and 9 females, aged between 19 and 35 (M = 24.1). They all reported that they had lived in China for more than 3 years (M = 9.3), studied Chinese for more than 4 years (M = 8.6), and obtained the HSK Level 6 certificate, demonstrating their advanced Chinese proficiency. Their self-rating of Chinese proficiency on a ten-point scale showed higher proficiency in comprehension than in production (listening: 8.0; reading: 7.9; speaking: 6.9; writing: 6.4). They reported an average of 50.9% use of Korean, 33.6% use of Chinese and 15.5% use of other languages (mainly English) in their daily lives.

3.2 Materials

Eighteen pairs of disyllabic Korean-Chinese false-cognates were selected for this study. These words are selected from Korean textbooks and are common basic words. Their false-cognate status was determined through the *Naver Korean-Chinese Dictionary*, which provides both Chinese translations and corresponding Chinese characters/morphemes of the Sino-Korean words. Where there is a difference between the Chinese translations and the corresponding Chinese characters/morphemes, the words were determined as false-cognates. For each pair of false-cognates, a match word, which was the Chinese translation of the Korean version, and a mismatch word, which was the (near-) synonym of the Chinese version, were selected. The critical words and their meanings in English are shown in Table 1. For words with more than one meaning, only the meaning used in the sentence context is shown in the table. The Korean versions of the false-cognates are also presented for reference. All match and mismatch words were not Korean-Chinese false-cognates. Most pairs of the false-cognates and match words belonged to different word classes in Chinese, which was inevitable, but we ensured that the mismatch words and their corresponding false-cognate words were from the same word class. We have also compared the word frequencies of the critical words obtained from SUBLEX-CH (Cai & Brysbaert, 2010) across different conditions. The frequency of "导演" (director) was left blank because it was not in the corpus. Results of ANOVA showed that there was no significant difference in word frequency among the three conditions ($F(2,50) = 1.035$, $p = .363$) or between any two conditions (all ps > .1).

By providing semantic backgrounds and constraining the collocation of the sentence-final critical word with the preceding word, sentence contexts were constructed in such a way that match words were congruent, while false-cognates and mismatch words were incongruent. For each of the eighteen critical word triplets, three sentence contexts were similarly constructed to increase the number of trials, resulting in a total of 54 sentence contexts (see Supplementary Material for all sentence contexts). The sentence contexts have an average of 7 words, and the word length ranges from 1 to 3 Chinese characters. Three experimental lists were created using a counterbalanced design. Each list contained all 54 critical words in all 54 sentence contexts, but each word was embedded in different sentence contexts in different lists. All three conditions of a word triplet were tested in all three sentence contexts. This balanced out any potential differences among the three contexts. A norming study was carried out with 45 native Chinese speakers who had no learning experience of Korean, Japanese or Vietnamese at the time of the test. They were divided into 3 groups of 15, and were asked to rate the semantic plausibility of the experimental sentences using a five-point scale, ranging from 1 = highly implausible to 5 = highly plausible. As expected, sentences with match words were rated as plausible (M = 4.73, SD = .61), while sentences with false-cognates

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Table 1. Critical words and their meanings in English. The Korean words in brackets are the Korean versions of the false-cognates. The Korean version has a different meaning from the Chinese version, but has the same meaning as the match word on the left.

Match		False-cognate			Mismatch	
饺子	dumpling	(만두)	馒头	steamed bread	面包	bread
活动	*event*	(행사)	行事	*conduct*	办事	*handle (affairs)*
火车	*train*	(기차)	汽车	*car*	轿车	*car*
成果	*result*	(결실)	结实	*sturdy*	强壮	*strong*
疏忽	*negligence*	(방심)	放心	*reassuring*	安心	*at ease*
句子	*sentence*	(문장)	文章	*article*	著作	*publication*
报纸	*newspaper*	(신문)	新闻	*news*	消息	*news*
传说	*legend*	(설화)	说话	*speak*	讲话	*speak*
回避	*avoid*	(외면)	外面	*outside*	外边	*outside*
导演	*director*	(연출)	演出	*performance*	表演	*performance*
楼梯	*stairs*	(계단)	阶段	*stage, phase*	进程	*process*
假期	*vacation*	(방학)	放学	*after school*	下课	*after class*
严重	*serious*	(심각)	深刻	*in-depth*	深入	*in-depth*
学习	*study*	(공부)	工夫	*effort*	精力	*effort*
约定	*appointment*	(약속)	约束	*constraint*	限制	*limitation*
谨慎	*discreet*	(조심)	操心	*worry*	顾虑	*concern*
建造	*build*	(조성)	造成	*cause*	导致	*lead to*
小时	*hour*	(시간)	时间	*time*	时期	*period of time*

($M = 1.74$, $SD = 1.00$) and mismatch words ($M = 1.55$, $SD = .86$) were rated as implausible. Results of ANOVAs by both participants and items revealed a main effect of condition (F_1 (2, 42) = 671.5, $p_1 < .0001$; F_2 (2, 51) = 641.4, $p_2 < .0001$). Post-hoc pairwise comparisons showed that both false-cognates and mismatch words got lower scores than the match words (all *p*s < .0001), while there were no significant differences between the false-cognates and mismatch words ($t_1 = 1.948$, $p_1 = .138$; $t_2 = 1.904$, $p_2 = .148$).

3.3 Procedure

Participants were seated 70 cm away from a 19" LCD screen with a refresh rate of 60 Hz in a dark, soundproof, electromagnetically shielded room. They were instructed to silently read the Chinese sentences presented on the screen and to decide as quickly and correctly as possible whether they were semantically plausible or not. In each trial, participants first saw a fixation point in the center of the screen for 1000 ms. Then, a sentence was presented word-by-word in the center of the screen. Each word remained on the screen for 500 ms, with an interstimulus interval (ISI) of 500 ms. After the last word and a 500 ms interval, an instruction appeared in the center of the screen, and the participants had to judge whether the sentence just displayed was semantically plausible by pressing the key on the keyboard as quickly and accurately as possible. "J" represented semantically plausible, while "F" represented semantically implausible. After the key response, participants received feedback on the screen indicating whether their judgment was correct or not. All stimuli were presented as white text on a black background in 128 pixels SimSun font. Stimulus presentation and behavioral data collection were programmed via PsychoPy (Peirce et al., 2019). Participants' key responses and reaction times were recorded.

In addition to behavioral responses, the EEG data were recorded continuously using the BrainAmp EEG system (Brain Products GmbH, Munich, Germany) at a sampling rate of 1000 Hz. Sixty-four electrodes were placed over the scalp according to the international 10-05 system and referenced online to the FCz electrode. A hardware band-pass filter (0.1-250 Hz) was applied to the data. The impedance of the electrodes was maintained below 5 kΩ.

The experimental materials were presented in three blocks, each block containing a sentence list (54 sentences) and 18 semantically correct filler sentences. Thus, half of the sentences in each block were semantically plausible (match, filler) and half were not (false-cognate, mismatch). The order of the three blocks was counterbalanced across participants. Participants were allowed to rest between blocks. Prior to the formal experiment, a practice session of 6 trials was conducted to ensure that participants were familiar with the procedure. The whole experiment took about 40 minutes. After the experiment, the participants completed a questionnaire assessing their language background. All the instructions throughout the experiment were given in Chinese for both participant groups to promote a global monolingual Chinese context.

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

3.4 Data analysis

Trials with reaction times beyond two standard deviations from the mean were excluded from further analysis (4.09% of the data). For each participant group, logistic mixed-effects modeling and linear mixed-effects modeling were performed in R (R Core Team, 2023) using the lme4 package (Bates et al., 2015) to analyze error rates

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(ERs) and reaction times (RTs) of correct responses, respectively. Condition was used as the explanatory variable, while participant and item were entered as random variables with random intercepts. The significance of the fixed effects was determined using the Anova function provided by the car package (Fox & Weisberg, 2019). Post-hoc pairwise comparisons were performed using the emmeans package (Lenth, 2023). Tukey method was used for adjusting *p*-values for multiple comparisons.

For ERP analysis, the EEGLAB Toolbox (version 2023.0) was used to pre-process the data. After cropping out the breaks, the raw data were passed offline through a 1 Hz high-pass filter and a 50 Hz low-pass filter and were resampled to 250 Hz. Eleven bad channels from 7 participants were removed, and none of them were the channels used in the later ERP analysis. All data were then re-referenced to the mastoid average (TP9 and TP10). Finally, the EEG dataset was subjected to Independent Component Analysis (ICA) to remove artifacts such as blinks, horizontal eye movements, muscle movements, and channel noises (6.4 components on average). The pre-processed data were then imported into MNE-Python (Gramfort et al., 2013; Larson et al., 2023) for ERP analysis. Only experimental trials with correct responses were analyzed. Continuous data were segmented into epochs from -100 ms to 900 ms relative to critical word onsets, with a baseline correction based on the 100 ms pre-onset. Bad epochs were rejected with a threshold of 150 μV (3.3% of the data). Three time windows were selected to examine components of interest. 300-500 ms was selected to detect the N400 component. 500-700 ms and 700-900 ms were chosen to capture the P600/LPC component because visual inspection revealed that the bilingual group appeared to have two different waveform patterns in the two time windows. Data on 9 channels (F3/z/4, C3/z/4, P3/z/4) were included in the statistical analysis and coded along the anteriority (frontal, central, parietal) and laterality (left, medial, right) dimensions. Single-trial mean amplitudes in each time window were calculated and transferred to R for statistical analysis using the same packages as above. Linear mixed-effects modeling was performed for each participant group and time window, with condition, anteriority, and laterality as three interactive explanatory variables to examine whether the N400 and P600/LPC differ across different conditions and to characterize the scalp distribution of the effects. Random-intercept-only models with participant and item entered as random variables were constructed because after adding the by-participant random slopes of condition, some random-slope models failed to converge.

4. Results

4.1 Behavioral results

The mean error rates (ERs, %) and correct reaction times (RTs, ms) of semantic plausibility judgments are shown in Table 2.

Table 2. The mean error rates (ERs, %) and correct reaction times (RTs, ms) of semantic plausibility judgments

Condition	Chinese monolingual		Korean-Chinese bilingual	
	ERs (%)	RTs (ms)	ERs (%)	RTs (ms)
Match	1.3	714	16.6	760
False-cognate	2.1	669	23.7	857
Mismatch	1.8	627	11.6	836

Regarding ERs, no significant main effect of condition was found in the Chinese monolingual group ($\chi^2(2) = 1.951$, $p = .3771$). While in the Korean-Chinese bilingual group, there was a main effect of condition ($\chi^2(2) = 42.123$, $p < .0001$). The false-cognate condition elicited higher ERs than the match condition (*estimate* = -.476, *SE* = .137, *z* = -3.479, *p* = .0015) and mismatch condition (*estimate* = -.951, *SE* = .148, *z* = -6.429, *p* < .0001). ERs in the match condition was also higher than that in the mismatch condition (*estimate* = -.475, *SE* = .154, *z* = -3.085, *p* = .0058).

In terms of RTs, condition showed a significant main effect ($\chi^2(2) = 18.44$, $p < .0001$) in the Chinese monolingual group. Pairwise comparisons revealed that only the match condition elicited longer RTs than the mismatch condition (*estimate* = 86.8, *SE* = 20.2, *t* = 4.294, *p* = .0001). In the Korean-Chinese bilingual group, the main effect of condition also reached significance ($\chi^2(2) = 7.633$, $p = .022$). Longer RTs were detected in the false-cognate condition than in the match condition (*estimate* = 88.1, *SE* = 34.0, *t* = 2.590, *p* = .0261).

4.2 Event-related potential (ERP) results

As shown in Figure 1, the false-cognate and mismatch conditions elicited similar patterns of ERP waveforms in the Chinese monolingual group. However, in the Korean-Chinese bilingual group, the waveforms of these two conditions present different patterns as depicted in Figure 2, implying that there may be different neural processes underlying the comprehension of the false-cognates and the mismatch words by Korean-Chinese bilinguals.

300-500 ms time window

In the Chinese monolingual group, the model revealed a significant main effect of condition ($\chi^2(2) = 48.44$, $p < .0001$) and a significant condition by anteriority interaction ($\chi^2(4) = 28.23$, $p < .0001$). Post-hoc comparisons showed that in the frontal region, no significant differences were found between the three conditions (all *p*s > .1). However, in both central and parietal regions, the mean amplitudes were more negative in the mismatch condition (central: *estimate* = -1.115, *SE* = .236, z = -4.734, *p* < .0001; parietal: *estimate* = -1.465, *SE* = .236, z = -3.221, *p* < .0001) and false-cognate condition (central: *estimate* = -.780, *SE* = .237, z = -3.295, *p* = .0028; parietal: *estimate* = -1.467, *SE* = .237, z = -6.195, *p* < .0001) when compared to the match condition. The mean amplitudes in the false-cognate and mismatch conditions did not show significant differences (all *p*s > .1).

In the Korean-Chinese bilingual group, the model detected a significant main effect of condition ($\chi^2(2) = 57.13$, $p < .0001$), but no significant condition by anteriority or laterality interactions. Pairwise comparisons showed that the mean amplitudes were more negative in the mismatch (*estimate* = -.989, *SE* = .132, z = -7.497, *p* < .0001) and false-cognate (*estimate* = -.626, *SE* = .138, z = -4.542, *p* < .0001) conditions than in the match condition. Moreover, the mismatch condition showed more negativity than the false cognate condition (*estimate* = -.363, *SE* = .136, z = -2.675, *p* = .0205).

500-700 ms time window

In the Chinese monolingual group, a significant main effect of condition ($\chi^2(2) = 21.32$, $p < .0001$) was found. Pairwise comparisons showed that the mean amplitudes were more positive in the mismatch condition (*estimate* = .517, *SE* = .138, z = 3.756, *p* = .0005) and false-cognate condition (*estimate* = .581, *SE* = .138, z = 4.202,

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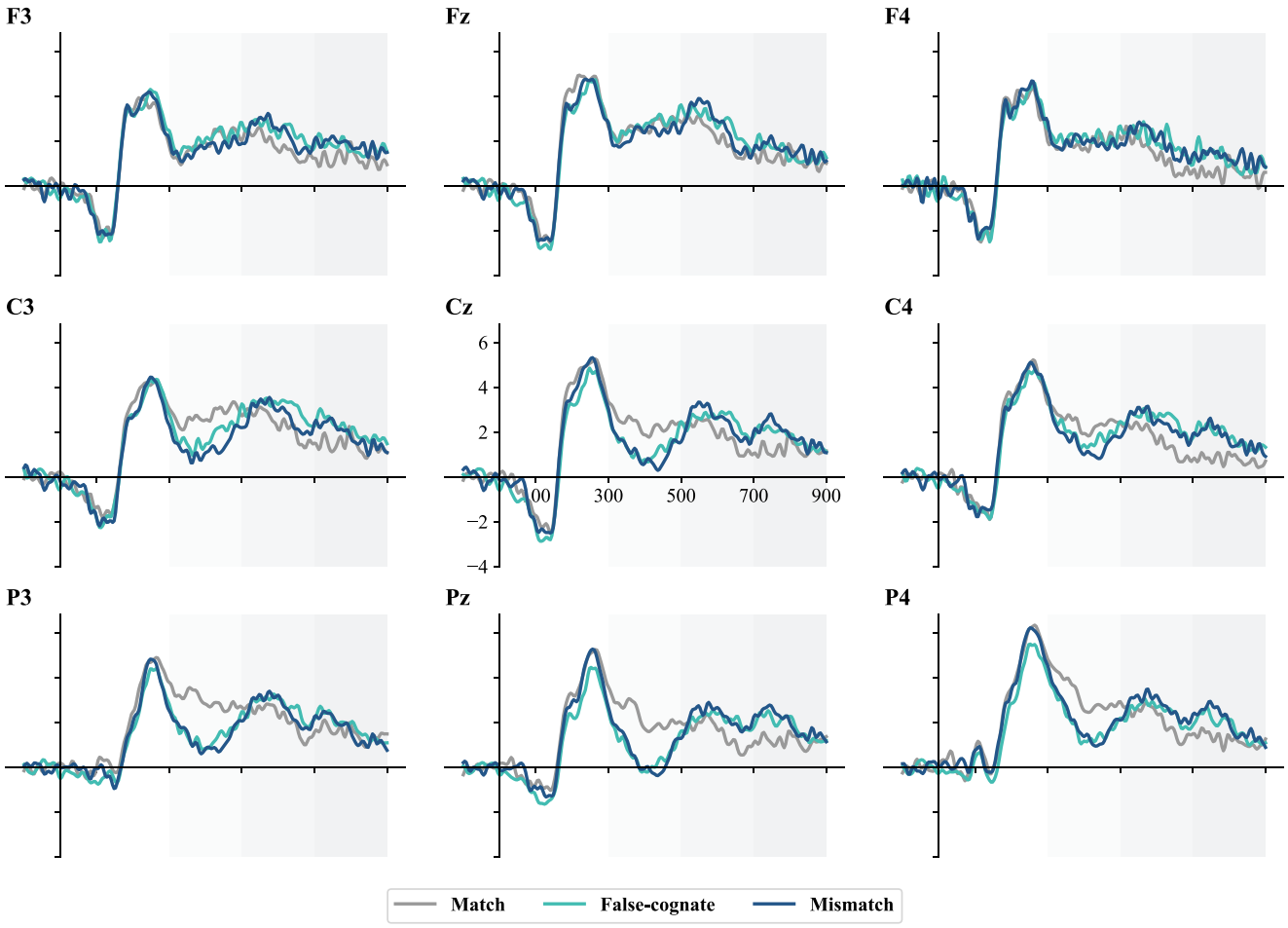

Figure 1. Grand average waveforms of match, false-cognates, and mismatch conditions in Chinese monolingual group. The false-cognate and mismatch conditions elicit similar ERP waveforms.

p = .0001) than in the match condition. No significant difference was found between the mismatch and false-cognate conditions (p > .1).

In the Korean-Chinese bilingual group, the model revealed a significant main effect of condition ($\chi^2(2)$ = 82.25, p < .0001). Different from the Chinese monolingual group, mean amplitudes in the mismatch (*estimate* = -1.168, *SE* = .129, z = 9.054, p < .0001) and false-cognate (*estimate* = -.543, *SE* = .135, z = -4.031, p = .0002) conditions were still more negative than that in the match condition, with mismatch condition showing more negativity than the false cognate condition (*estimate* = -.625, *SE* = .133, z = 4.707, p < .0001). This was consistent with the patten observed in the 300-500 ms time window.

700-900 ms time window

In the Chinese monolingual group, the model detected a significant main effect of condition ($\chi^2(2)$ = 26.72, p < .0001). Consistent with the 500-700 ms time window, pairwise comparisons showed that the mean amplitudes were more positive in the mismatch condition (*estimate* = .585, *SE* = .129, z = 4.533, p < .0001) and false-cognate condition (*estimate* = .573, *SE* = .130, z = 4.416, p < .0001) than in the match condition. The mismatch and false-cognate conditions still showed no significant difference (p > .1).

In the Korean-Chinese bilingual group, the model revealed a significant main effect of condition ($\chi^2(2)$ = 21.90, p < .0001). Interestingly, the false-cognate condition elicited more positivity when compared to both match condition (*estimate* = .356, *SE* = .128, z = 2.782, p = .0149) and mismatch condition (*estimate* = .587, *SE* = .126, z = 4.668, p < .0001). The difference between mismatch and match conditions did not reach significance (p > .1).

Summary of ERP results

Although the participant number in the present study is not too large, the statistical results of the ERPs reached a reliable level of significance. As illustrated in Figure 3, for the Chinese monolingual group, the mismatch and false-cognate conditions presented similar centro-parietally distributed negative effects in the 300-500 ms time window and similar positive effects in both the 500-700 ms and 700-900 ms time windows compared to the match condition. In contrast, for the Korean-Chinese bilingual group, the mismatch and false-cognate conditions showed negative effects compared to the match condition in both the 300-500 ms and 500-700 ms time windows, with the false-cognate effect being smaller than the mismatch effect. In the 700-900 ms time window, the false-cognate condition showed a positive effect compared to the match and mismatch conditions.

5. Discussion

The behavioral and ERP results of the present study consistently support that the Korean version of the false-cognates was activated

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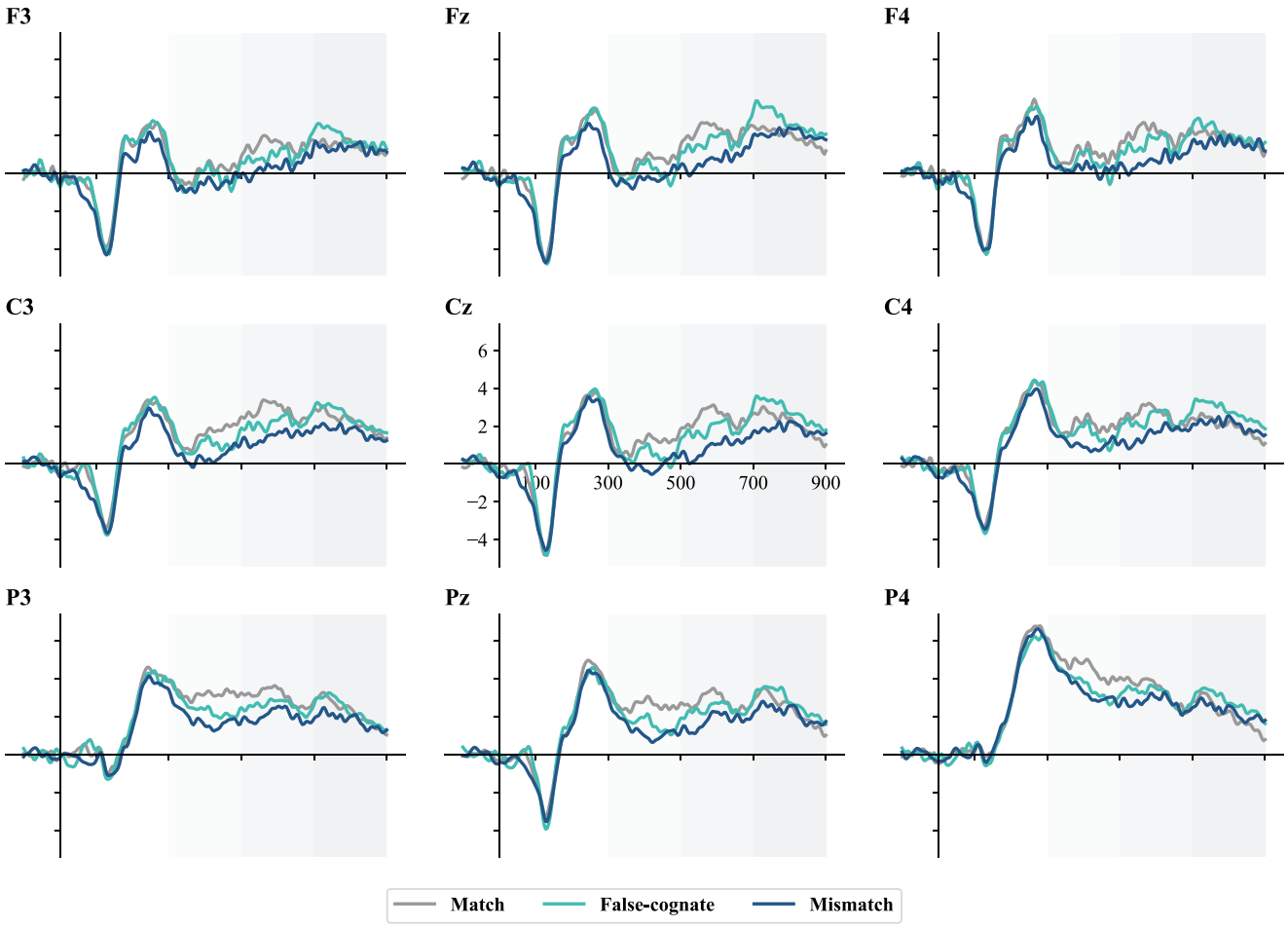

Figure 2. Grand average waveforms of match, false-cognates, and mismatch conditions in Korean-Chinese bilingual group. Generally, the false-cognates produce different ERP waveforms as compared to the match words and the mismatch words.

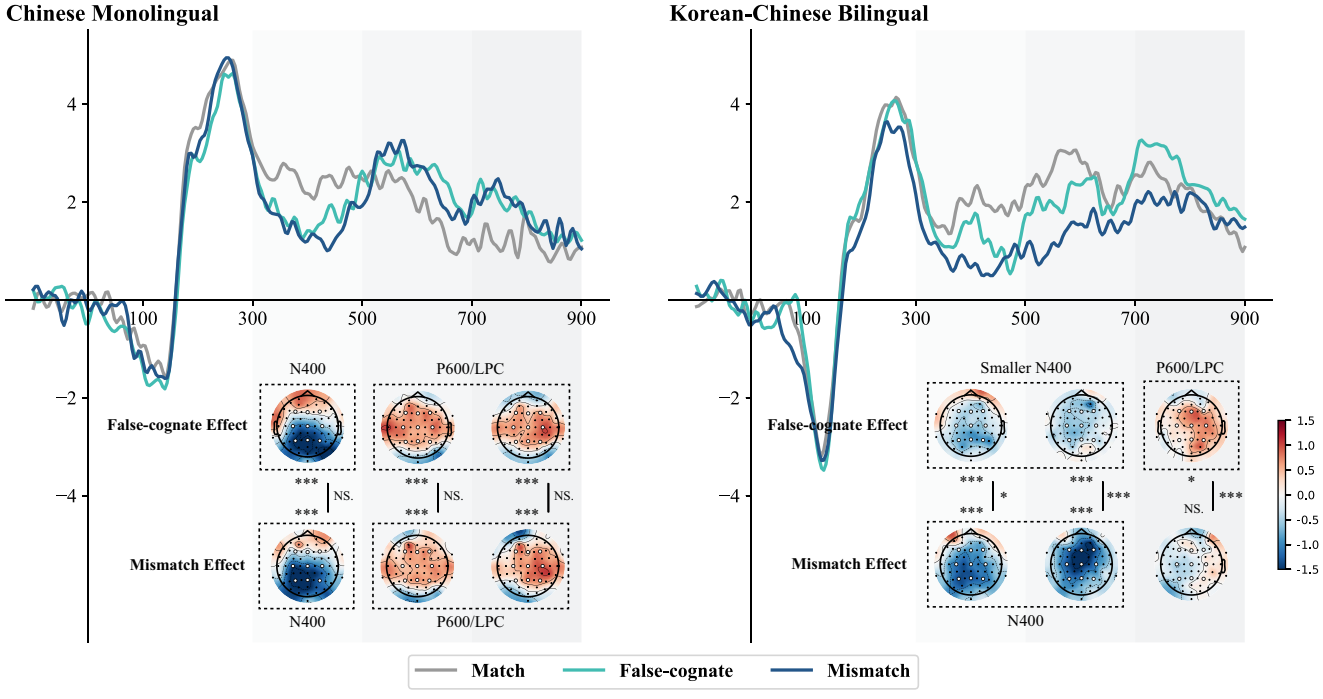

Figure 3. Average ERP waveforms of the 9 analyzed channels and scalp topographies of the false-cognate effect (false-cognate vs. match) and the mismatch effect (mismatch vs. match). Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05.

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when Korean-Chinese bilinguals read the Chinese version. Although the behavioral data from the offline semantic plausibility judgments do not directly reflect the lexical access of the critical word, the highest error rate and longest reaction time in the false-cognate condition suggest that Korean-Chinese bilinguals had difficulty processing sentences with false-cognates, probably due to the co-activation of contextually incongruent Chinese meaning and contextually congruent Korean meaning. In addition, we found that Chinese monolinguals were slower in the match condition than in the mismatch condition. It is possibly because they needed to recall the entire sentence when judging it as semantically plausible, but they only needed to detect an error produced by the sentence-final word to make a semantically implausible judgment. Regarding the ERPs, significant N400 effects were found in both groups in the false-cognate and mismatch conditions compared to the match condition. As expected, the false-cognate condition produced a smaller N400 effect in amplitude compared to the mismatch condition in the Korean-Chinese bilingual group, whereas such differences did not exist in the Chinese monolingual group. This may indicate that the Korean version of the false-cognates, whose meaning was congruent with the sentence context, was also activated during bilingual word recognition, resulting in attenuated neural responses to semantic incongruity. The results of the N400 effects are consistent with those of Jouravlev and Jared (2014), who used a similar design and tested Russian-English bilinguals with interlingual homographs. However, the Russian-English interlingual homographs are visually similar even though they have different scripts, whereas the Korean-Chinese false-cognates do not have such similarities. Therefore, the reason for the bilingual interactive activation should be different. In addition, we also observed differences in the spatiotemporal distribution of N400 effects as well as different P600/LPC patterns between the two groups of participants. The ERP results and the mechanism underlying nonselective lexical access to Korean-Chinese false-cognates deserve further discussion.

In the Chinese monolingual group, typical N400 effects were detected in the 300-500 ms time window with a centro-parietal distribution. However, in the Korean-Chinese bilingual group, the N400 effects were longer lasting and had a broader scalp distribution. Previous research has reported similar findings that the N400 effects tend to be delayed and/or longer lasting in bilinguals' second language than in monolinguals, and has attributed this to the fact that bilinguals may take more time than monolinguals to recognize the word at a semantic level and integrate it into the prior context (Hahne, 2001; Hahne & Friederici, 2001; Lehtonen et al., 2012; Moreno & Kutas, 2005). Furthermore, it can be observed that the match condition elicited a more positive-going late component in the bilingual group than in the monolingual group. This is consistent with the findings of Hahne and Friederici (2001), who explained it as a greater difficulty in the syntactic integration processes of the correct sentence in bilinguals as compared to monolinguals. Therefore, the late positivity elicited by the baseline match condition could also be a reason for the longer-lasting N400 effects in bilinguals. As for the scalp distribution, we found that the N400 effects were broader in bilinguals than in monolinguals. Although it does not provide direct information about its neural generators, it could potentially reveal that the mechanisms behind the N400 effects in monolinguals and bilinguals are partially different and require further study.

In the late time range, we found the P600/LPC effects in each group. In the Chinese monolingual group, significant and similar P600/LPC effects in the false-cognate and mismatch conditions compared to the match condition may reflect the processes of syntactic reanalysis or syntactic integration (Kaan et al., 2000), given that most of false-cognate and mismatch words also violated the grammatical structure of the sentence context. However, in the Korean-Chinese bilingual group, only the false-cognate condition produced a P600/LPC effect compared to the match condition, and it appeared later than the monolingual group. Based on the integration view of P600/LPC effect (Kaan et al., 2000), the absence of the P600/LPC effect in the bilingual group when comparing match with mismatch conditions may reflect that syntactic integration in correct sentences perhaps induce a similar processing load as the repair processes in syntactically incorrect sentences for bilinguals (Hahne & Friederici, 2001). On the other hand, the significant P600/LPC effect yielded by the false-cognates might be largely due to the co-activation of both the Korean and Chinese versions of the false-cognates which induced supreme integration difficulties. Alternatively, the P600/LPC effect is also comparable to that found in intra-sentential code-switching studies (e.g., Jackson et al., 2001; Litcofsky & Van Hell, 2017; Moreno, Federmeier, & Kutas, 2002). The sentences in the false-cognate condition might be processed by bilinguals as a 'hidden' code-switched sentence, as bilinguals might switch to Korean when they tried to integrate the false-cognate into the prior context, but have to switch back to Chinese to make the semantic plausibility judgment. Therefore, the P600/LPC effect in the false-cognate condition may also reflect higher demands for cognitive control (Rodriguez-Fornells, De Diego Balaguer, & Münte, 2006). In general, the P600/LPC effect can further support the nonselective lexical access in sentence reading.

Previous studies investigating bilingual processing of interlingual homographs have only provided evidence for the nonselective access from visual input to orthographic representations in two languages (see the left panel of Figure 4). Even in languages with different scripts, such as Russian and English in Jouravlev and Jared (2014), interlingual activations were still based on similar-looking letters, i.e., visual similarity. In the present study, we instead adopted Korean-Chinese false-cognates as experimental materials, which are different from interlingual homographs in that they do not look alike at all, but still found evidence for language-nonselective lexical access. In the absence of orthographic similarity, and with very limited phonological similarity, the Bilingual Interactive Activation Plus model (Dijkstra & van Heuven, 2002) does not seem to provide an adequate explanation for why visual recognition of the Chinese versions of false-cognates can activate the semantic representation of their Korean counterparts. Given that Sino-Korean words are composed of morphemes of Chinese origin, it is reasonable to argue that the correspondence of morphemes between the two languages is represented in the bilingual mental lexicon. As illustrated in the right panel of Figure 4, the morphemic representations are shared between Chinese and Korean. For example, the morpheme "학/学"(study, school) has interactive activation with both its Korean form "학" and Chinese form "学". Therefore, the Chinese version of the false-cognate can activate the representations of the morphemes that compose it, which then activate the Korean version.

The results of the present study also shed some light on how sentence context might influence the language selectivity of lexical access. According to Schwartz and Van Hell (2012), sentence context includes language membership of words, semantic information from top-down comprehension processes, and syntactic features of the sentence structure. In addition, there may also be effects of global language contexts, such as watching a film narrated in a particular language before the experiment, and the target

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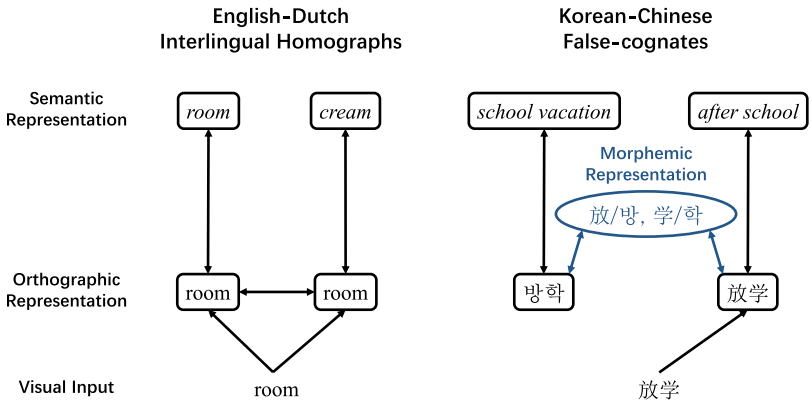

Figure 4. Bilingual nonselective lexical access of English-Dutch interlingual homographs and Korean-Chinese false-cognates. While the interlingual activations of interlingual homographs rely on cross-linguistic orthographic overlap, the Korean-Chinese false-cognates may depend on shared morphemic representations.

language of the task (Elston-Guttler, Gunter, & Kotz, 2005). In the present study, similar to Jouravlev and Jared (2014), the task was all in the target language, but the sentence context contained only language membership cues to the target language, whereas the semantic (and syntactic) constraints biased the lexical meaning toward the task-irrelevant language, potentially having a top-down influence on the lexical access. Therefore, we did not observe the zooming-in effect as in Elston-Guttler, Gunter and Kotz (2005), where global contexts were manipulated but all the sentence context cues lead to the target language. Whether lexical access to Korean-Chinese false-cognates is still language nonselective in low-constraint sentences or in sentences that biased the lexical meaning toward the target language should be further investigated. Furthermore, the findings from the ERP evidence in both the present study and Jouravlev and Jared (2014) differed from those of Hoversten and Traxler (2016), who used the eye-tracking technique and measured the time course of interlingual homograph processing in natural reading. They found that bilinguals did not differ from monolinguals in early measures (gaze duration, regression path time), and only differed in the later measure (total time). They interpreted the results as indicating that bilinguals may selectively access the meaning in the contextually cued language in early processing stages and later access the contextually congruent meaning in the non-target language when integrating it into the sentence. It remains to be seen whether a similar pattern occurs in natural reading for Korean-Chinese false-cognates.

6. Conclusions

In conclusion, both the Korean and Chinese versions of false-cognates are activated when Korean-Chinese bilinguals read the Chinese version embedded in Chinese sentences that biased the meaning towards the Korean version. The N400 and P600/LPC effects elicited by the bilinguals provide clear evidence for the language nonselective lexical access. Further, the present study proposes a possible theoretical extension of the BIA+ model, claiming that bilingual interactive activation may be mediated by shared morphemic representations between the two languages.

Supplementary material. To view supplementary material for this article, please visit http://doi.org/10.1017/S1366728924000798.

Data availability statement. The data presented in this study are openly available in FigShare at [https://doi.org/10.6084/m9.figshare.23956830].

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Author contribution. Jinyi Xue: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing—original draft preparation, Writing—review and editing, Visualization. Yu-Fu Chien: Validation, Writing—review and editing. Kunyu Xu: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Writing—original draft preparation, Writing—review and editing, Supervision, Project administration, Funding acquisition.

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Competing interest. The authors declare no conflict of interest.

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