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Abstract

The perfective aspect marker in Chinese is partly functionally similar to inflectional suffixes in Indo-European languages, but is non-inflectional and lexical in nature, lying thus at the semantics-syntax interface. This provides us with the opportunity to compare directly the syntactic and semantic constraints during L2 sentence processing. The present study explored how L2 Chinese learners with Indo-European languages as their L1s process the Chinese perfective marker. The Competition Model prioritizes syntactic processes entailed by cross-linguistic transfer from the participants' L1s, but this prediction might be challenged by the concurrent functioning of semantic processes. In an ERP experiment, 22 European language-speaking L2 Chinese learners with low to intermediate proficiency level and 20 native Chinese speakers (i.e., the control group) participated. An aspectual agreement paradigm was used for materials. Results showed that in the aspect marker mismatch condition, L2 Chinese learners with a shorter learning experience were more likely to show a P600-like component, indicating a morpho-syntactic routine, supporting thus the predictions of cross-linguistic transfer based on the Competition Model. Those with a longer L2 learning experience were more likely to show a N400-like component similar to native Chinese speakers. This shift from P600 to N400 for more advanced learners suggest that L1-L2 syntactic similarity may exert much stronger influence than semantic constraints for learners with shorter L2 experience.

Key words: L2 Chinese learners; grammatical aspect marker; cross-linguistic transfer; the Competition Model; semantic-syntactic interface

1. Introduction

Second language (L2) morpho-syntactic processing has attracted a lot of attention in psycholinguistic studies (Caffarra, Molinaro, Davidson, & Carreiras, 2015; Dowens, Vergara, Barber, & Carreiras, 2009; Kotz, 2009). Psycholinguistic models have tried to address how L2 speakers process morphemes or syntactic constructions not present in their L1. For L2 Chinese learners with Indo-European languages as L1s, on one hand, the Chinese perfective aspect marker may be analyzed morphologically similar to the inflectional suffixes indicating past tense in their L1 (e.g., verb-*ed* in English) (Huang et al., 2009; Lin, 2003; Qiu & Zhou, 2012). On the other hand, the Chinese perfective marker differs from inflectional suffixes in that it is a lexical device, not an inflected suffix attached to verbs (Cao & Xu, 2017, 2019; Liu, 2015). One influential theoretical framework for the L2 syntactic processing mechanism is the Competition Model (MacWhinney, 2005, 2008, 2012). However, it is not sure whether the predictions of this model would be challenged by the perfective grammatical aspect marker in Mandarin Chinese (e.g., "过(guo)"), which is at the semantic-syntactic interface involving both semantic and syntactic processes through semantic and syntactic cues. According to the Competition Model (MacWhinney, 2005, 2008, 2012), the assumed morphological resemblance between aspectual markers in the learners' L1 and the L2 may elicit positive cross-linguistic transfer for the L2, prioritizing a morpho-syntactic processing routine underlying inflectional suffixes in the L1. However, there is also a possibility that semantic processing but not morpho-syntactic processing is prioritized, especially now that the Chinese perfective marker is lexical in nature, and form a word combination with the verb. The present study aimed to test the above contradictory predictions by exploring how L2 Chinese learners who are speakers of Indo-European languages with inflectional suffixes for aspect marking process Chinese perfective aspect marker. Investigations on this issue would reveal the different weights of syntactic and semantic constraints during L2 sentence processing.

1.1. The grammatical aspect system in Chinese

Chinese is reckoned as a "tenseless" language (Cao & Xu, 2017, 2019; Liu, 2015), i.e., the verb form does not change to indicate the time of the event, as it would be the case with past tense forms in English. The time of the event is expressed through adverbs or context (Cao & Xu, 2019; Liu, 2015). Despite being "tenseless", Chinese does have clear aspect distinctions (Xiao & McEnery, 2004). There are four major grammatical aspect markers in Chinese, including two perfective markers "了(le)" (indicating bounded events) and "过(guo)" (indicating a discontinued prior experience) and two progressive markers (also called imperfective markers) "在(zai)" (preceding the verb, indicating the progression of an event) and "着(zhe)" (following the verb, indicating the durativity of an event). All of these are lexical morphology marking devices attached to verbs either as a verb-final marker or a pre-verbal marker to mark verb aspect (Klein, Li, & Hendriks, 2000). However, it should be noted that verbal aspect in Chinese is lexical, whereas verbal aspect in most Indo-European languages (e.g., English, Italian, and Dutch) is denoted via morphological inflection by verb-endings like "verb-*ed*" for perfective aspect (also syncretic for past tense) and "verb-

ing” for progressive aspect in English.

Briefly speaking, Chinese perfective aspect markers are verb-final in a way morphologically similar to inflectional suffixes attached to verbs in most Indo-European languages (Huang et al., 2009; Lin, 2003; Qiu & Zhou, 2012). For example, perfective markers “了(le)” and “过(guo)” immediately follow the verb and are typically used with past events, just like the English past tense marker “*–ed*”. Meanwhile, Chinese perfective aspect markers are also different from inflectional suffixes since they are lexical devices, non-inflectional, and have not been grammaticalized (Cao & Xu, 2017, 2019; Liu, 2015). Hence, Chinese perfective aspect markers are at a semantic-syntactic interface, where both syntactic and semantic cues are functional in online processing.

This would undoubtedly cause a strong and complex cross-linguistic competition between semantic and syntactic processes, and make it hard for L2 learners of Chinese to develop a native-like syntactic processing mechanism.

1.2. Previous studies on aspectual processing in Chinese

Existing studies on grammatical aspect in L2 Chinese have mainly tried to tap into its status in the L2 grammar using behavioral methods, such as structured oral production task (Yang & Wu, 2014; Wen, 1995). Yang & Wu (2014) explored the acquisition of the perfective aspect marker “了(le)” by English-speaking Chinese learners in different learning contexts: a formal instruction program, a domestic immersion program, a study abroad program. Participants in Yang & Wu’s study were asked to conduct various oral production tasks (e.g., describing pictures, favorite reading, and talking about topics like whether to eat at home or in a restaurant, job-hunting, or family). The number of "了(le)" produced at the beginning and the end of the program, and the biographic information about their use of the L2, and contact hours with Chinese speakers were measured. The results showed that in both the pre-test and post-test phase, L2 learners from all three study programs produced significantly fewer "了(le)" compared with a group of native Chinese speakers (i.e., the control group). Moreover, a comparison between the pre-test and post-test revealed no significant increase in the use of "了(le)" in the three groups, indicating that the aspect marker is undersupplied in production by low-proficiency English-speaking learners of Chinese. The authors conclude that the lack of a transparent aspect system (i.e., lack of clear-cut rules for the use of aspect marker) in Chinese makes the acquisition of aspect markers quite difficult, and it is hard for L2 Chinese learners to use aspect markers well in natural speech production.

Up until now, there have not been many studies yet on the real-time aspectual processing by L2 Chinese learners. To reveal the underlying aspectual processing mechanism, more sensitive paradigms (e.g., self-paced reading) and techniques (e.g., eye-tracking and event-related potentials) are required. Relevant previous studies have focused only on native Chinese speakers (Qiu & Zhou, 2012; Zhang & Zhang, 2008). In the present study, we take this evidence from native Chinese speakers as a starting point for parallel research on L2 Chinese (Mai, 2016).

Zhang & Zhang (2008) conducted an event-related potential study to investigate the on-line processing of Chinese grammatical aspect by native Chinese speakers through aspect agreement violations between the aspectual marker “了(le)” and the temporal adverb. Two other control conditions were included: semantic violations and no violation. Participants were asked to judge whether the sentence is acceptable or not after reading it (i.e., acceptability judgment task). Results showed that aspectual disagreement elicited a biphasic pattern of negativity (i.e., negativity within 200-400 ms with a posterior and left central distribution) + positivity (i.e., P600 within 450-800 ms). The authors argued that the negativity indicates an earlier detection of aspectual errors, and the positivity reflects syntactic repair or the resolution of aspectual violations. Altogether, these findings suggest that the processing of grammatical aspect in Chinese may involve syntactic processes (as indicated by the P600).

Qiu & Zhou (2012) explored the neural correlates of the temporal agreement between the perfective marker “过(guo)” and temporal noun phrases (e.g., last month). A group of native Chinese speakers were recruited and asked to perform a sentence acceptability judgment task. Results showed that the incogruency between the perfective marker and temporal noun phrases elicited a centro-parietal P600 effect and no negativity effect was observed. The authors argued that the P600 effect for the incongruent “过(guo)” might be associated with morpho-syntactic violations.

Both “了(le)” in Zhang & Zhang’s study and “过(guo)” in Qiu & Zhou’s study are verb-final perfective aspect markers, so they are expected to implicate a similar processing mechanism (Qiu & Zhou, 2012). However, a biphasic negativity (within 200-400 ms) + positivity (i.e., P600) pattern was observed for perfective marker “了(le)” in the study of Zhang & Zhang (2008), but a monophasic P600 pattern was found for perfective marker “过(guo)” in the study of Qiu & Zhou (2012). The possible reasons for the different findings between these two studies might be that the aspectual particle “了(le)” was presented separately following the verb in Zhang & Zhang’s study, but “过(guo)” was presented together with the verb as a suffix in Qiu & Zhou’s study. Nonetheless, both studies obtained the P600 component for aspectual processing in Chinese, probably because of a similar task assigned to participants, namely the sentence acceptability task, which might direct participants’ attention to sentence correctness explicitly.

So far, studies on aspectual processing by native Chinese speakers are still rare, not to mention L2 Chinese learners. No agreement has been reached yet about the cognitive mechanism of aspectual processing in Chinese, that is, whether it is semantic in nature, or syntactic in nature, or an interplay of both semantic and syntactic processes. Therefore, the present study recruited both L2 Chinese learners and native Chinese speakers, with an aim to reveal more information about these two groups of speakers.

1.3. Theoretical predictions for aspectual processing by L2 Chinese learners

How do L2 Chinese learners with an Indo-European language background (L1) process the perfective aspect marker in Chinese, which lies at the semantic-syntactic interface, i.e., being morphologically similar but lexically different between their L1 and L2?

According to the Competition Model (MacWhinney, 2005, 2008, 2012), L2 syntactic analysis is parasitic on the L1, and L2 learning is heavily influenced by transfer from the L1 to the L2. If the L1 and L2 syntactic systems are similar, positive

L1-L2 cross-linguistic transfer will occur, that is, processing routines could be transferred from the L1 to the L2 (Hernandez, Li, & MacWhinney, 2005; Tokowicz & MacWhinney, 2005). However, when the L1 and the L2 are different or when a syntactic feature is unique to the L2, negative cross-linguistic transfer will occur, that is, L1 properties or processing routines may give rise to probably ungrammatical solutions in the L2. Since the L1-L2 functional resemblance is prominent between aspectual markers in Chinese and Indo-European languages, it could be predicted that positive cross-linguistic transfer would occur for Chinese perfective aspect marker, prioritizing a morpho-syntactic processing routine underlying inflectional suffixes in the L1. If this prediction is true, L2 Chinese learners may exhibit neural correlates of aspectual processing in Chinese similar to the morpho-syntactic processing of inflectional suffixes reported for Indo-European languages. Previous relevant studies on Indo-European languages used an incongruent tense paradigm (i.e., incorrect inflectional suffix), and found a left anterior negativity (LAN)-P600 pattern (i.e., a biphasic LAN-P600 pattern) for tense violations (Baggio, 2008; Newman et al., 2007; Steinhauer & Ullman, 2002). The LAN (300-500 ms or earlier) reflects an early automatic stage of phrase-structure building, and the P600 (500-800 ms) reflects a later more strategic stage of syntactic reanalysis and repair (Friederici et al., 1996; 2002).

However, it is also possible that L2 Chinese learners may rely more on semantic processes instead of morpho-syntactic processes in aspectual processing, since the Chinese perfective marker is lexical in nature and has greater semantic complexity than normal affixes. Because it also forms a word combination together with the verb, L2 learners may memorize the “verb-aspect marker” combination as a chunk without rule-driven combinatorial processes. Therefore, it could also be predicted that L2 Chinese learners may exhibit an aspectual processing mechanism relying more on semantic analyses. The relevant ERP indicator for this is the N400 component which is sensitive to semantic violation and integration (Kutas & Federmeier, 2000, 2011).

1.4. The present study

The present study aimed to test the above two contradictory predictions by exploring how L2 Chinese learners with Indo-European language background (L1) process Chinese perfective aspect marker. To this end, the electrophysiological technique was used because its fine temporal resolution could reveal real-time language processing (Luck, 2005).

A congruency violation paradigm was used in this study, which involves aspectual agreement in Chinese (but could be temporal in Indo-European languages). This paradigm has been proved to be valid for studying aspectual processing in Chinese (Qiu & Zhou, 2012; Zhang & Zhang, 2008). Two aspect marking conditions were designed: Correct marker and Wrong marker. Unlike previous studies which used an explicit sentence acceptability judgment task (Qiu & Zhou, 2012; Zhang & Zhang, 2008), the current study adopted an implicit task, namely a sentence-picture matching task, trying to reveal an implicit sentence processing routine and keeps the interference of participants’ explicit reasoning and strategy to a minimum. In this task, a picture showed up after the sentence was presented segment-by-segment, and participants were asked to judge whether the picture matches with the scene mentioned in the sentence or not.

Most participants of the present study were native speakers of English and some of them were speakers of other European languages which are typologically different from Chinese (see section 2.1 for details). They were University-level students majoring in L2 Chinese and have attained a low to intermediate proficiency level in Chinese. Proficiency tests showed that their vocabulary was large enough to understand the materials used in this study. Moreover, these participants were asked to fill out an offline questionnaire (i.e., by judging sentences offline) to check whether they have acquired L2 (Chinese) aspect marking rules. Meanwhile, native Chinese speakers were also recruited as a control group. They were assigned with the same tasks used for L2 Chinese learners.

Based on the two predictions explicated in section 1.3, one possibility is that L2 Chinese learners would show a morpho-syntactic routine reflected by LAN-P600 components in aspectual processing. The other possibility is that L2 Chinese learners would show a processing mechanism implicating more semantic processes, i.e., a semantic processing routine reflected by the N400 component.

2. Method

2.1. Participants

Participants included 22 L2 Chinese learners (11 males; mean age = 22.5, SD = 2.5 ranging from 19 to 28) enrolled at a large UK university. They were undergraduate or postgraduate students majoring in Mandarin Chinese and would get an honors degree in Chinese upon graduation. Their native languages included: English (15 people), Dutch (1), Italian (3), Polish (2), Swedish (1). Here it should be noted that it is hard to the recruit participants with the same L1 (e.g., English only) to control their L1 language experience. This problem seems to be common in studies on L2 Chinese learners (Grüter, Lau, & Ling, 2020). However, all L1s of the L2 speakers in our sample mark aspect inflectionally. Participants were first exposed to Chinese at a mean age of 17.9 (SD = 4.5 ranging from 4 to 25), and have been learning Chinese through university courses for an average of 3.6 years (SD = 1.3 ranging from 2 to 6). As required by the curriculum, all of them had been to China at the third semester to study in a Chinese University for half a year and got fully immersed in a Chinese environment. Their L2 proficiency level was measured by an abridged version of the Test of Chinese as a Foreign Language (TOCFL; Reading, Band A) developed by the Steering Committee for the Test of Proficiency-Huayu. The abridged test includes 30 multiple choice question items covering word use and grammar, and the total score is 30. Moreover, a six-point scale self-assessment grid for language skills developed by the Council of Europe (2001) ("1"for quite poor, "6" for highly proficient) was administered to measure their L2 listening, reading, spoken interaction, spoken production, and writing. Participants were asked to read the detailed descriptions for each scale carefully before reporting their L2 profile. All the scores about L2 proficiency measurement are presented in Table 1. Generally speaking, the L2 group could be considered as low to intermediate Chinese learners with sufficient reading ability to understand the stimuli used in the present study.

Twenty-three native Chinese speakers (11 males; mean age = 23.7, SD = 2.6 ranging from 18 to 29) were recruited from the same University to form the control group. They were undergraduate or postgraduate students majoring in various subjects, and had been staying in the UK for an average of 1.5 years (SD = 0.8) at the time of data collection. Data from three native Chinese speakers were excluded due to excessive artifact in the raw EEG, leaving 20 participants in the final data sheet (8 males; mean age = 23.9, SD = 2.7 ranging from 18 to 29). Participants in the control group also finished the Chinese proficiency test and self-assessment questionnaire mentioned above (see Table 1).

Table 1. Mean score, SD, and score range in the Chinese proficiency test and self-assessment for L2 Chinese learners and native Chinese speakers. Standard deviation is reported in parentheses.

	TOCFL	Listening	Reading	Spoken Interaction	Spoken Production	Writing
L2 Chinese	27.4 (2.3)	3.3 (1.1)	3.8 (1)	3.2 (1)	3.4 (0.8)	3.6 (0.9)
learners	20-30	1-6	2-6	1-5	2-5	2-6
Native Chinese	29.4 (0.7)	5.8 (0.5)	5.7 (0.5)	5.4 (0.6)	5.6 (0.6)	5.6 (0.6)
speakers	27-30	4-6	5-6	4-6	4-6	4-6

All participants were right-handed, had normal or corrected-to-normal vision, and reported no neurological or psychiatric impairment. They signed a consent form and received monetary compensation for doing this.

2.2. Materials

The current study was designed to investigate how the perfective marker “过(guo)” is processed. The aspectual particle “过(guo)” is a verb-final experiential marker, indicating someone has “the experience” of having done something (i.e., a past experience). To be specific, it follows the verb to express the event as terminated and discontinued according to a reference time, i.e., a past, discontinued experience in the current time (Liu, 2015). It does not indicate the specific time when the event occurred.

Examples of the materials used in the Experiment are presented in Table 2. The critical sentences were designed according to two aspect marking conditions: Correct marker and Wrong marker. In the Correct marker condition, the aspect marker “过(guo)” matches with the temporal adverb “昨天(yesterday)” at the beginning of the sentence. In the Wrong marker condition, the aspect marker “过(guo)” mismatches with the temporal adverb “明天(tomorrow)”. There were 45 sentences for each condition and 90 critical sentences in total. The two aspect marking versions (i.e., correct and wrong) of the 90 sentences were assigned to two stimulus lists according to Latin Square design, with each version appearing only in one list. All the sentences were simple in structure, containing frequently used and highly familiar verbs and nouns, so that participants would not have any difficulty in reading comprehension.

Altogether, 180 filler sentences were designed, and randomized among the critical sentences in each list, to ensure that all the materials were balanced across the frequency of “昨天(yesterday)” and “明天(tomorrow)”, the appearance and omission of “过(guo)”, and sentence grammaticality. To be specific, the filler sentences consisted of 45 grammatical sentences with “明天(tomorrow)” at the beginning without any aspect marker (i.e., omitted) and 45 with “昨天(yesterday)” at the beginning without any aspect marker. It should be noted here that these sentences without aspect marker “过

(guo)” are still grammatical in Chinese. The rest of the 90 filler sentences were ungrammatical, either having wrong word order or containing non-words. To sum up, all the materials were balanced in a way that there were: two sentence patterns beginning with “昨天(yesterday)”, two beginning with “明天(tomorrow)”, two with aspect marker “过(guo)”, two without any aspect marker, half grammatical sentences and half ungrammatical sentences.

A sentence-picture matching task was used instead of sentence reading comprehension or acceptability judgment task in order to keep participants fully blind to the purpose of the study, and this way their implicit responses could be measured. Accordingly, 270 colored pictures were selected. Half of them matched with the scene mentioned in the sentence (i.e., picture-sentence consistent condition), while the other half did not (i.e., picture-sentence inconsistent condition).

Table 2. Examples of the materials used in the experiment.

Stimuli	Temporal adverb	Aspect marker	Consisten-cy	Gramma-ticality	Example
Critical	昨天 (yesterday)	过 (guo)	Match	Correct	**昨天,** / 他 / **烤过** / 面包, / 今天不了。 zuó tīan / tā / kǎo guò/ miàn bāo / jīn tīan bù le **Yesterday** / he / **baked** / bread. / He won’t do it today.
	明天 (tomorrow)	过 (guo)	Mismatch	Incorrect	**明天,** / 他 / **烤过** / 面包, /今天不了。 míng tīan / tā / kǎo guò/ miàn bāo / jīn tīan bù le **Tomorrow** / he / **baked** / bread. / He won’t do it today.
Filler	昨天 (yesterday)	Omitted	N/A	Correct	**昨天,** /他 / **烤** / 面包,/ 今天不了。 zuó tīan / tā / kǎo/ miàn bāo / jīn tīan bù le **Yesterday** / he / **bake** / bread. / He won’t do it today.

明天 (tomorrow)	Omitted	N/A	Correct	**明天,** / 他 / **烤** / 面包。 míng tīan / tā / kǎo/ miàn bāo / **Tomorrow** / he / **bake** / bread.
这几天 (these days)	N/A	N/A	Incorrect	这几天, / 他 / **欢喜**/ 足球比赛。 zhè jǐ tīan / tā / huān xǐ / zú qiú bǐ sài These days / he / **like** / football match.
这几天 (these days)	N/A	N/A	Incorrect	这几天, / 他 / 足球比赛/ **喜欢**。 zhè jǐ tīan / tā / zú qiú bǐ sài / xǐ huān These days / he / football match / **likes**.

Notes: 1. Aspect markers are allowed to be omitted in Chinese, and the sentence is still grammatically correct. 2. In the filler condition, some sentences contain non-words, e.g., “liek”.

2.3. Procedure

Upon arrival to the lab, each participant was asked to fill out a general demographic information questionnaire and a language background questionnaire, and then complete the Chinese proficiency test and self-assessment questionnaire.

Afterwards, each participant was seated comfortably in the EEG recording booth, and was randomly assigned to one of the two stimulus lists. All the trials were presented randomly. The trial procedure is illustrated in Figure 1. Each trial began with a fixation cross for 1000 ms, and then a stimulus sentence was presented word segment by word segment with each lasting for 600 ms. A 500 ms blank screen was presented between word segments. Sentence ending was indicated by the appearance of a full stop, upon which a picture appeared immediately. The picture was presented for 3000 ms, and participants were asked to judge as quickly and accurately as possible whether the picture is consistent with the scene described in the sentence. If no response was detected within 3000 ms, the next trial would start. The left or right hand for the “match” and “mismatch” response was counterbalanced across participants. Furthermore, participants were required to keep blinks and movement to a minimum while reading the sentence, and were allowed to have a rest during the break in the formal EEG experiment.

Following EEG data collection, participants were asked to finish a word translation test (Chinese to English) to further check whether they were familiar with the words used for the critical sentences or not. The test contained 42 words (i.e, 20 verbs and 22 nouns) which were randomly selected from the critical sentences used in the experiment, and the total score was 42. Besides, in order to see whether participants had acquired the rule of aspect marking in Chinese, they were also asked to do an offline sentence grammaticality judgment test and point out the error if they thought the sentence is ungrammatical. This grammaticality test had 40 sentences, including 10 with correct aspect marker, 10 with wrong marker, 10 without marker, and 10 anomalous sentences in other structures. The whole experiment lasted for about 2.6 hours.

<Insert Figure 1 near here>

2.4. Data acquisition and analysis

Biosemi Active Two system was used to acquire the EEG activity at 1000 Hz sampling rate with 64 Ag/AgCl sintered active electrodes mounted on an elastic cap that was positioned according to the 10-20 international system (American Clinical

Neurophysiology Society, 2006). Eye movements were measured using four external electrodes placed vertically aligned with right pupil (i.e., below or above the right eye) and horizontally aligned with left and right pupils (i.e., lateral to the outer canthi of the two eyes). Two extra electrodes were placed on left and right mastoid bones, with the left mastoid for online reference and the mean activity at the left and right mastoids for offline re-reference. Impedances were kept below 5 KΩ. The EEG signals were filtered on-line with a bandpass of 0.16-100 Hz, and later low-pass filtered off-line (30 Hz, zero-phase shift digital filter).

EEG data analysis was performed using EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014) toolboxes for Matlab (Matlab 2015, The Mathworks). Slow drifts were removed from the EEG data first. Epochs time-locked to the onset of the critical word segment, i.e., verb with perfective marker "过(guo)", were extracted from −200 to 900 ms. Epoched data were normalized through baseline correction based on a pre-stimulus period of −200 to 0 ms. Because the temporal adverb differed between the Wrong marker condition and the Correct marker condition (i.e., "tomorrow" for the Wrong marker condition and "yesterday" for the Correct marker condition), we checked whether the ERP waveforms prior to the presentation of the critical words differed. We compared the mean amplitudes of the pre-stimulus baseline interval (-200 to 0 ms) between the Wrong marker and the Correct marker conditions to check whether there were baseline artifacts. Gladly, no baseline differences were found (all ps > .1). Furthermore, EEG epochs exceeding either ±75 μV at any channel (i.e., including horizontal and vertical eye channels) were excluded off-line. The remaining clean epochs with accurate responses (i.e., an average of 79.4 % of trials, SD =13.9 for the Correct marker condition and an average of 77.4 % of trials, SD = 14.1 for the Wrong marker condition) were averaged for the two aspect marking conditions for each participant separately.

ERP components of interest, LAN, N400 and P600, were quantified using mean amplitude measures. Based on previous reports, the LAN and the N400 occur within a similar time range: 300-500 ms (Molinaro, Barber, & Carreiras, 2011; Molinaro et al., 2015). Therefore, data analysis in the current study focused on only two time windows: 300-500 ms for the LAN or the N400, and 500-800 ms for the P600. Since the scalp distributions of the LAN, N400, and P600 cover the left anterior, central-parietal, and parietal regions, nine ROIs were computed to investigate the exact topographic distribution of the relevant effects. The nine ROIs were derived by hemisphere (left, midline, right) × anteriority (anterior, medial, posterior): left anterior (F1, F3, F5, FC1, FC3, FC5), left medial (C1, C3, C5, CP1, CP3, CP5), left posterior (P1, P3, P5, PO3, PO7), midline anterior (FZ, FCZ), midline medial (CZ, CPZ), midline posterior (PZ, POZ), right anterior (F2, F4, F6, FC2, FC4, FC6), right medial (C2, C4, C6, CP2, CP4, CP6), right posterior (P2, P4, P6, PO4, PO8). Within each time window, repeated-measures ANOVAs were computed with aspect marking condition (Correct marker, Wrong marker), hemisphere (left, midline, right), and anteriority (anterior, medial, posterior) as within-subjects factors. Moreover, visual inspection found an unexpected individual variation in the polarity of the ERP responses among L2 Chinese learners, so two subgroups were formed. Consequently, the unequal number of participants makes it impossible to make a direct comparison between native Chinese speakers and the two subgroups of L2 Chinese learners, so separate analyses were conducted on them. Since the main concern of the current study was the presence of aspect marking effect, only when reliable interactions involving aspect marking were found, further analysis was performed. The Greenhouse-Geisser correction was applied to adjust the significance levels of the F ratios where appropriate and the corrected p values are reported. False discovery rate (FDR) correction was applied to the significance level of simple effect analysis when two-way or three-way interactions were found.

3. Results

3.1. Behavioral results

Starting with the *word translation test* (from Chinese to English, full score = 42), the mean score for L2 Chinese learners was 38.5 (SD = 3.7 ranging from 28 to 42), indicating that their Chinese vocabulary was large enough and they reported no difficulty in understanding the materials in the ERP Experiment. All native Chinese speakers obtained a ceiling score in this test. As for the *offline sentence grammaticality judgment test* (full score = 40), the mean score for L2 Chinese learners was 38.2 (SD = 2.6 ranging from 30 to 40) and all native Chinese speakers obtained a ceiling score, suggesting that both L2 Chinese learners and native Chinese speakers could differentiate clearly the ungrammatical sentences with wrong marker or anomalous structures. In other words, they had acquired the rule of aspect marking in Chinese and formed a clear mental representation of Chinese aspect marking. The mean accuracy rate in the *sentence-picture matching task* for L2 Chinese learners was 86.3% (SD = 7.7% ranging from 65% to 98%), and for native Chinese speakers was 96.7% (SD = 1.7% ranging from 95% to 100%). This was high enough to ensure that participants were paying attention to the task and could understand the sentences.

3.2 ERP results

No obvious effect of grammatical aspect marking was observed for L2 Chinese learners as a whole group in both 300-500 ms and 500-800 ms time windows (see Figure 2). This was further checked via statistical analyses which showed neither the main effect of aspect marking nor the interactions involving aspect marking were significant (all *p*s > .05). However, visual inspection of individual waveforms of L2 Chinese learners showed that they were not homogeneous in their brain response profiles. As showed by the scatterplot of the mean amplitudes within 300-500 ms and 500-800 ms in the difference waves of the Wrong minus Correct marker condition (Figure 3), there was a continuum from positivity-dominant to negativity-dominant brain responses for both time windows. Therefore, the aspect marking effect seems to be canceled out in the grand mean across all 22 L2 Chinese learners by an average of the positivity- and negativity-dominant ERPs. Similar individual variances in ERP responses have also been reported in many previous studies (Kim, Oines, & Miyake, 2018; Osterhout, 1997; Tanner, McLaughlin, Herschensohn, & Osterhout, 2013; Tanner & Van Hell, 2014; Tanner, Inoue, & Osterhout, 2014).

<Insert Figure 2 near here>

<Insert Figure 3 near here>

Therefore, in order to take individuality into consideration and investigate the real existence of aspect marking effect for L2 Chinese learners, two sub-groups were created: positivity-dominant group and negativity- dominant group (Tanner & Van Hell, 2014; Tanner, Inoue, & Osterhout, 2014). Therefore, L2 Chinese learners were divided into two based on the positive and negative values in the Wrong minus Correct marker condition. Specifically, those whose amplitudes were positive within both 300-500 ms and 500-800 ms time windows formed the positivity-dominant L2 group (n = 12); those whose amplitudes were negative within both time windows formed the negativity-dominant L2 group (n=10).

Repeated measures ANOVA testing aspect marking effect was conducted for positivity- and negativity-dominant groups separately. Waveforms and topographic maps averaging across L2 learners who showed a positivity-dominance are presented in Figure 4, and those for L2 learners who showed a negativity-dominance are presented in Figure 5.

<Insert Figure 4 near here>

<Insert Figure 5 near here>

For the **positivity-dominant L2 group**, the main effect of aspect marking was found significant in the 300-500 ms time window, $F(1, 11) = 13.9$, $p < .01$, $\eta^2_P = .55$, but all the interactions involving aspect marking, i.e., aspect marking × hemisphere, aspect marking × anteriority, aspect marking × hemisphere × anteriority, were non-significant (all *p*s > .1), suggesting that the Wrong marker condition elicited significantly larger positive ERP responses than the Correct marker condition across the whole brain region. In the 500-800 ms time window, significance was observed in the main effect of aspect marking, $F(1, 11) = 11.75$, $p < .01$, $\eta^2_P = .51$. Still, all the interactions involving aspect marking were not significant (all *p*s > .1), with the wrong marker condition eliciting significantly larger positive ERP responses than the Correct marker condition across the whole brain region.

For the **negativity-dominant L2 group**, a significant main effect of aspect marking, $F(1, 9) = 14.02$, $p < .01$, $\eta^2_P = .61$, was observed in the 300-500 ms time window. All the interactions involving aspect marking were not significant (all *p*s > .05). So, the Wrong marker condition elicited significantly larger negative ERP responses than the Correct marker condition across all brain regions. In the 500-800 ms time window, significance was observed in the main effect of aspect marking, $F(1, 9) = 10.87$, $p < .01$, $\eta^2_P = .54$. None of the interactions involving aspect marking were significant (all *p*s > .1). Again, the Wrong marker condition elicited significantly larger negative ERP responses than the Correct marker condition across the whole brain region.

To explore what factors might contribute to the polarity continuum from positivity to negativity in the ERP responses among L2 Chinese learners, we correlated the mean amplitudes within 300-500 ms and 500-800 ms in the Wrong minus Correct condition with a list of behavioral factors (See Table 3 for details). The results of correlation analysis revealed that *Age* had marginally negative correlation with the mean amplitudes in both 300-500 ms and 500-800 ms time windows. *Years of L2 learning as a major* showed significantly negative correlation with the mean amplitudes within 300-500 ms ($p < .05$).

Table 3. The results (i.e., Pearson *r*) of the correlation analysis on L2 Chinese learners, including a list of behavioral factors and the mean amplitudes within 300-500 ms and 500-800 ms in Wrong minus Correct difference waves.

	300-500 ms	500-800 ms
Age	**−.401** $^{p = .064}$	**−.396** $^{p = .068}$
AoA	-	-
Years of L2 learning as major	**−.435** $^{p = .043}$	-
L2 TOCFL score	-	-
L2 listening score	-	-
L2 reading score	-	-
L2 spoken-interaction score	-	-

L2 spoken-production score	-	-
L2 Writing score	-	-
Vocabulary test score	-	-
Accuracy in the ERP task	-	-

Notes: * Correlation is significant at the 0.05 level (2-tailed); - Non-significant data is not provided; the scores for L2 listening, reading, spoken-interaction, spoken-production, and writing are self-rated (see Table 1).

For **native Chinese speakers** (see Figure 6), significance was observed in the main effect of aspect marking, $F(1, 19) = 6.03$, $p < .05$, $\eta^2_P = .24$, and the interaction of aspect marking × hemisphere, $F(2, 38) = 3.65$, $p < .05$, $\eta^2_P = .16$, in the 300-500 ms time window. Simple effect analysis by hemisphere found the Wrong marker condition elicited significantly larger negative ERP responses than the Correct marker condition in the left and middle brain areas (ps < .05), but not in the right hemisphere ($p > .05$). In the 500-800 ms time window, a marginally significant main effect of aspect marking was found, $F(1, 19) = 3.65$, $p = .07$, $\eta^2_P = .16$. All the interactions involving aspect marking were non-significant (all ps > .1).

<Insert Figure 6 near here>

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4. Discussion

The main goal of the present study was to explore how Indo-European language-speaking L2 Chinese learners process perfective aspect marker in Chinese. The Chinese perfective marker is partly functionally similar to the inflectional suffixes in the learners' L1s (Huang et al., 2009; Lin, 2003; Qiu & Zhou, 2012), but is non-inflectional and lexical in nature (Cao & Xu, 2017, 2019; Liu, 2015), thus lying at the semantic-syntactic interface. This interface provides us with the opportunity to compare directly the syntactic and semantic cues during L2 sentence processing. According to the Competition Model (MacWhinney, 2005, 2008, 2012), the L1-L2 partly functional and morphological resemblance would bring about positive cross-linguistic transfer, prioritizing a morpho-syntactic processing routine as indicated by the LAN and P600 components. However, it is also possible that L2 Chinese learners would be more sensitive to semantic cues and prioritize semantic processes as indicated by the N400 component. In the experiment, sentential aspectual agreement between aspect marker and temporal adverb was manipulated, and two aspect marking conditions were created: Correct marker and Wrong marker. A sentence-picture matching task was used instead of sentence acceptability task in order to elicit participants' implicit brain responses to aspect marking. A comparison between Wrong vs. Correct marker could reveal participants' aspectual processing routine.

L2 Chinese learners' scores on the *word translation test* (mean = 38.6, SD = 3.7, full score = 42) showed that their vocabulary size was large enough to understand the materials used in the ERP experiment. As for the *offline sentence grammaticality judgment test*, L2 Chinese learners could successfully identify the ungrammatical sentences with wrong aspect marker, indicating that they had acquired aspect marking rules in Chinese. Moreover, the accuracy score in the ERP experiment is high enough (mean = 86.3%, SD = 7.5%) to ensure that L2 Chinese learners were attentive and understood most of the sentences in the experiment. To sum up, these behavioral results as a whole suggest that the L2 Chinese learners recruited for this study had knowledge of the aspectual marker in Chinese and sufficient vocabulary to process the experimental sentences.

Visual inspection of the ERP data found that there were no classic LAN, N400, or P600 profiles in the ERP waveforms. Statistical analyses showed that native Chinese speakers elicited larger negative ERP responses in the Wrong marker condition than the Correct marker condition in both 300-500 ms and 500-800 ms time windows. In contrast, L2 Chinese learners showed no main effect of aspect marking in the above two time windows as a whole group, the absence of which was probably due to a polarity continuum from positivity to negativity in their ERP responses. Similar individual variances in ERP responses have also been reported in many previous studies (Kim, Oines, & Miyake, 2018; Osterhout, 1997; Tanner, McLaughlin, Herschensohn, & Osterhout, 2013; Tanner & Van Hell, 2014; Tanner, Inoue, & Osterhout, 2014). For the L2 positivity-dominant subgroup (n = 12), the Wrong marker condition elicited significantly larger positive ERP responses than the Correct marker condition across the whole brain region in the 300-800 ms time range. For the L2 negativity-dominant subgroup (n = 10), the Wrong marker condition elicited significantly larger negative ERP responses than the Correct marker condition across the whole brain region in the 300-800 ms time range. The above individual variance of ERP responses from positivity dominance to negativity dominance among L2 Chinese learners could probably be accounted for by *Age* and *years of L2 learning as a major*, as further correlation analysis revealed. These two factors showed negative correlation with the ERP responses in the Wrong marker condition.

The positivity-dominance and negativity-dominance of the ERP patterns in L2 Chinese learners extended from 300 ms to 800 ms in the wrong marker condition. There might be just a single component at play here for the two time windows 300-500 ms and 500-800 ms, instead of being two separate processes, for either positivity- or negativity- dominant group. Firstly, inspection of the raw waves in Figure 4 and 5 showed that there was only one continuous deflection in the wave; Secondly, inspection of the topographic maps in Figure 4 and 5 showed that the scalp topography was similar across the two time windows, suggesting that this was one single component that was being modulated, not two separate ones. We are going to specify the ERP components in the next paragraph.

The Wrong marker condition resembles the incongruent past tense marker "-*ed*" in English in morphology, e.g., "*Tomorrow, I watched** *a movie*" (Huang et al., 2009; Lin, 2003; Qiu & Zhou, 2012). This condition was designed to explore whether L2 Chinese learners rely more on morpho-syntactic processes or semantic processes. The results revealed two ERP patterns in L2 Chinese learners, i.e., positivity-dominant and negativity-dominant ERP responses in comparison with Correct marker condition. The positivity-dominant ERP responses might be a variant of the P600, i.e., P600-like, which starts earlier (from 300 ms) and last longer (more than 800 ms based on visual inspection) than a typical P600 component. Likewise, the negativity-dominant ERP responses might be a variant of the N400, i.e., N400-like, which extends longer (from 300 ms-800 ms) than a typical N400 component. No Left Anterior Negativity (LAN) component was observed in the whole ERP time range. The above ERP polarity of positivity and negativity was negatively correlated with participants' *Age* and *Years of L2 learning as a major*, suggesting that L2 Chinese learners who were younger and had a shorter L2 learning experience were more likely to show a P600-like component which indicates a morpho-syntactic processing routine under the influence of L1-L2 "morphological resemblance" cue. L2 Chinese learners who were older and had a longer L2 learning experience were more likely to show a N400-like component which suggests a semantic processing routine. These learners with a longer L2 learning experience showed a processing mechanism closer to native Chinese speakers (see Figure 6), i.e., negativity-dominant N400-like responses along the time range of 300-800 ms in the Wrong marker condition. In a word, it seems that less advanced learners were treating the perfective marker "过(guo)" as if it were the English past tense for which violations trigger a P600. Later on, learners seemed to be processing the Chinese perfective marker more in its own right and shift to the N400.

Theoretically speaking, the above findings are consistent with the prediction based on the Competition Model (MacWhinney, 2005, 2008, 2012), in the sense that L1-L2 partly functional and morphological resemblance produces positive cross-linguistic transfer for L2 beginners, prioritizing a morpho-syntactic processing routine underlying inflectional suffix in participants' L1s. So, L1-L2 syntactic similarity may exert a much stronger influence than semantic constraints on L2 beginners. With more L2 learning experience, L2 learners could inhibit L1 strategies and develop an L2-specific (native-like) processing routine. This developmental change could probably be explained in terms of the shift of cue-weight setting. That is, L1-L2 syntactic similarity has a stronger cue weight than semantic cues at the beginning stage and gradually this weight setting would be revised with more L2 learning experiences. Here it should be noted that syntactically being similar between L1 and L2 does not always bring about benefit or positive transfer, sometimes it brings about processing cost. In other words, not all kinds of syntactic similarity produce positive transfer. For example, Foucart & Frenck-Mestre (2012) found that when the surface order was similar in L1 and L2 but the syntactic rules of the two languages differed, online processing of L2 syntactic agreement became more difficult (i.e., was hindered).

Previous relevant studies on L2 Chinese learners used a structured oral production task, and found that low-proficiency English-speaking learners of Chinese tended to undersupply aspect marker in oral production compared with native Chinese speakers (Yang & Wu, 2014; Wen, 1995). Even though behavioral results could not be compared with online processing evidence directly, both previous behavioral and the current ERP findings seem to support that it takes time for L2 beginners to develop an L2-specific (i.e., native-like) processing routine in dealing with L2 information which is different from their L1 to some extent.

The current finding that native Chinese speakers elicited negativity-dominant ERP responses (i.e., N400-like) from 300 ms to 800 ms for the Wrong marker condition is only partly consistent with the results from Zhang & Zhang (2008), and totally different from Qiu & Zhou (2012). Zhang & Zhang (2008) explored how native Chinese speakers process aspect marker "了(le)", which is similar to "过(guo)", using a sentence acceptability judgment task. The results showed that aspectual violations elicited negative ERP responses within 200-400 ms in the posterior and left central area, which was followed by a positive component recognized as the P600. Qiu & Zhou (2012) also used sentence acceptability judgment task to investigate how native Chinese speakers process aspect marker "过(guo)", and found the disagreeing aspect marker elicited a centro-parietal P600 effect. The different findings between the present study and the above two previous studies might be accounted for by the different tasks assigned to participants. The current study used an implicit picture-sentence consistency judgment task, trying to capture an implicit syntactic processing routine and keeps the interference of participants' explicit reasoning and strategy to a minimum, while Zhang & Zhang (2008) and Qiu & Zhou (2012) used an explicit sentence acceptability judgment task which obviously directs participants' attention to sentence form.

One limitation of the present study is that it is hard to explain why N400-like and P600-like components were obtained instead of classic N400 and P600 components. The N400-like and P600-like components exceeded the typical time windows previously found for the N400 and P600. One tentative explanation is that the prolonged negativity or positivity may reflect a second-repair for semantic or syntactic integration, i.e., a second-pass repairing process that corrects errors and creates coherent interpretations for the sentence. The other limitation of the present study is that the number of participants was very small for the two subgroups of L2 Chinese learners (12 for the positivity-dominant L2 group and 10 for the negativity-dominant L2 group), due to unexpected large individual variances among L2 learners. We suggest that more L2 participants may need to be recruited in relevant experiments in future studies so that large individual differences, if observed, could be analyzed in a more appropriate way.

5. Conclusion

In summary, the present study explored how L2 Chinese learners with Indo-European language background (L1) process Chinese perfective aspect marker which is morphologically similar to the inflectional suffix in their L1, but is non-inflectional and lexical in nature. The results showed that L2 Chinese learners who have a shorter L2 learning experience are more likely to show a P600-like component which indicates a morpho-syntactic processing routine, supporting the predictions of cross-linguistic transfer based on the Competition Model. Those who have a longer L2 learning experience are more likely to show a N400-like component closer to native Chinese speakers. So, L1-L2 syntactic similarity may exert much stronger influence than semantic constraints for learners with shorter L2 experience. Gradually, L2 learners could inhibit L1 “accent” and shift to an L2-specific (native-like) processing routine with more L2 learning experience.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research,

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References

Baggio G (2008) Processing temporal constraints: An ERP study. *Language Learning* 58 (s1): 35-55.

Caffarra S, Molinaro N, Davidson D and Carreiras M (2015) Second language syntactic processing revealed through event-related potentials: An empirical review. *Neuroscience and Behavioral Reviews* 51: 31-47.

Cao D and Xu L (2017) The study of genuine tenseless languages (in Chinese with English abstract). *Contemporary Linguistics* 19 (1): 93-121.

Cao D and Xu L (2019) Is Mandarin Chinese a (Semi-) tensed language? (in Chinese with English abstract) *Contemporary Linguistics* 21 (3): 451-465.

Delorme A and Makeig S (2004) EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods* 134 (1): 9-21.

Dowens MG, Vergara M, Barber H and Carreiras M (2009) Morphosyntactic processing in late second-language learners. *Journal of Cognitive Neuroscience* 22 (8): 1870-1887.

Foucart A and Frenck-Mestre C (2012) Can late L2 learners acquire new grammatical features? Evidence from ERPs and eye-tracking? *Journal of Memory and Language* 66: 226-248.

Friederici AD and Mecklinger A (1996) Syntactic parsing as revealed by brain responses: First-pass and second-pass parsing processes. *Journal of Psycholinguistic Research* 25 (1): 157-176.

Friederici AD, Steinhauer K and Pfeifer E (2002) Brain signatures of artificial language processing: Evidence challenging the critical period hypothesis. *Proceedings of the National Academy of Sciences* 99 (1): 529-534.

Grüter T, Lau E and Ling W (2020) How classifiers facilitate predictive processing in L1 and L2 Chinese: the role of semantic and grammatical cues. *Language, Cognition and Neuroscience* 35 (2): 221-234.

Hernandez A, Li P and MacWhinney B (2005) The emergence of competing modules in bilingualism. *Trends in Cognitive Sciences* 9 (5): 220-225.

Huang CT, Li YHA and Li Y (2009) *The syntax of Chinese*. Cambridge: Cambridge University Press.

Kim AE, Oines L and Miyake A (2018) Individual differences in verbal working memory underlie a tradeoff between semantic and structural processing difficulty during language comprehension: An ERP investigation. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 44 (3): 406-420.

Klein W, Li P and Hendriks H (2000) Aspect and assertion in Mandarin Chinese. *Natural language & Linguistic Theory* 18: 723-770.

Kotz SA (2009) A critical review of ERP and fMRI evidence on L2 syntactic processing. *Brain & Language* 109: 68-74.

Kutas M and Federmeier KD (2000) Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences* 4 (12): 463-470.

Kutas M and Federmeier KD (2011) Thirty Years and Counting: Finding Meaning in the N400 Component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology* 62: 621-647.

Lin JW (2003) Temporal reference in Mandarin Chinese. *Journal of East Asian Linguistics* 12 (3): 259-311.

Liu M (2015) *Tense and aspect in Mandarin Chinese*. Oxford: Oxford Handbooks Online.

Lopez-Calderon J and Luck SJ (2014) ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience* 8: 213.

Luck S (2005) *An introduction to the event-related potential technique*. Massachusetts Institute of Technology: MIT Press.

MacWhinney B (2005) A unified model of language acquisition. In: Kroll JF and de Groot AMB (eds) *Handbook of Bilingualism: Psycholinguistic Approaches.* New

York: Oxford University Press, pp. 49-67.

MacWhinney B (2008) A unified model. In: Ellis N and Robinson P (eds) *Handbook of Cognitive Linguistics and Second Language Acquisition*. New Jersey: Lawrence Erlbaum Press, pp. 341-371.

MacWhinney B (2012) The logic of the unified model. In: Gass S and Mackey A (eds) *Handbook of Second Language Acquisition*. New York: Routledge, pp. 211-227.

Mai Z (2016) L2 Chinese: Grammatical development and processing. *Second Language Research* 32 (1): 123-141.

Molinaro N, Barber HA and Carreiras M (2011) Grammatical agreement processing in reading: ERP findings and future directions. *Cortex* 47: 908-930.

Molinaro N, Barber HA, Caffarra S and Carreiras M (2015) On the left anterior negativity (LAN): The case of morphosyntactic agreement. *Cortex* 66: 156-159.

Newman AJ, Ullman MT, Pancheva R, Waligura DL and Neville HJ (2007) An ERP study of regular and irregular English past tense inflection. *NeuroImage* 34 (1): 435-445.

Osterhout L (1997) On the brain response to syntactic anomalies: manipulations of word position and word class reveal individual differences. *Brain and Language* 59: 494-522.

Qiu Y and Zhou X (2012) Processing temporal agreement in a tenseless language: An ERP study of Mandarin Chinese. *Brain Research* 1446: 91-108.

Steinhauer K and Ullman MT (2002) Consecutive ERP effects of morpho-phonology and morpho-syntax. *Brain and Language* 83: 62-65.

Tanner D, McLaughlin J, Herschensohn J and Osterhout L (2013) Individual differences reveal stages of L2 grammatical acquisition: ERP evidence. *Bilingualism: Language and Cognition* 16 (2): 367-382.

Tanner D, Inoue K and Osterhout L (2014) Brain-based individual differences in online L2 grammatical comprehension. *Bilingualism: Language and Cognition* 17 (2): 277-293.

Tanner D and Van Hell JG (2014) ERPs reveal individual differences in morphosyntactic processing. *Neuropsychologia* 56: 289-301.

Tokowicz N and MacWhinney B (2005) Implicit and explicit measures of sensitivity to violations in second language grammar: An event-related potential investigation. *Studies in Second Language Acquisition* 27: 173-204.

Wen X (1995) Second language acquisition of the Chinese particle *le*. *International Journal of Applied Linguistics* 5 (1): 45-62.

Xiao R and McEnery T (2004) *Aspect in Mandarin Chinese*. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Yang B and Wu Q (2014) Acquiring the perfective aspect marker *LE* in different learning contexts. In: Jiang N (eds) *Advances in Chinese as a second language: Acquisition and processing.* Newcastle: Cambridge Scholars Publishing, pp. 10-32.

Zhang Y and Zhang J (2008) Brain responses to agreement violations of Chinese grammatical aspect. *NeuroReport* 19 (10): 1039-1043.

Figure Captions

Figure 1. The procedure of stimulus presentation in the experiment.

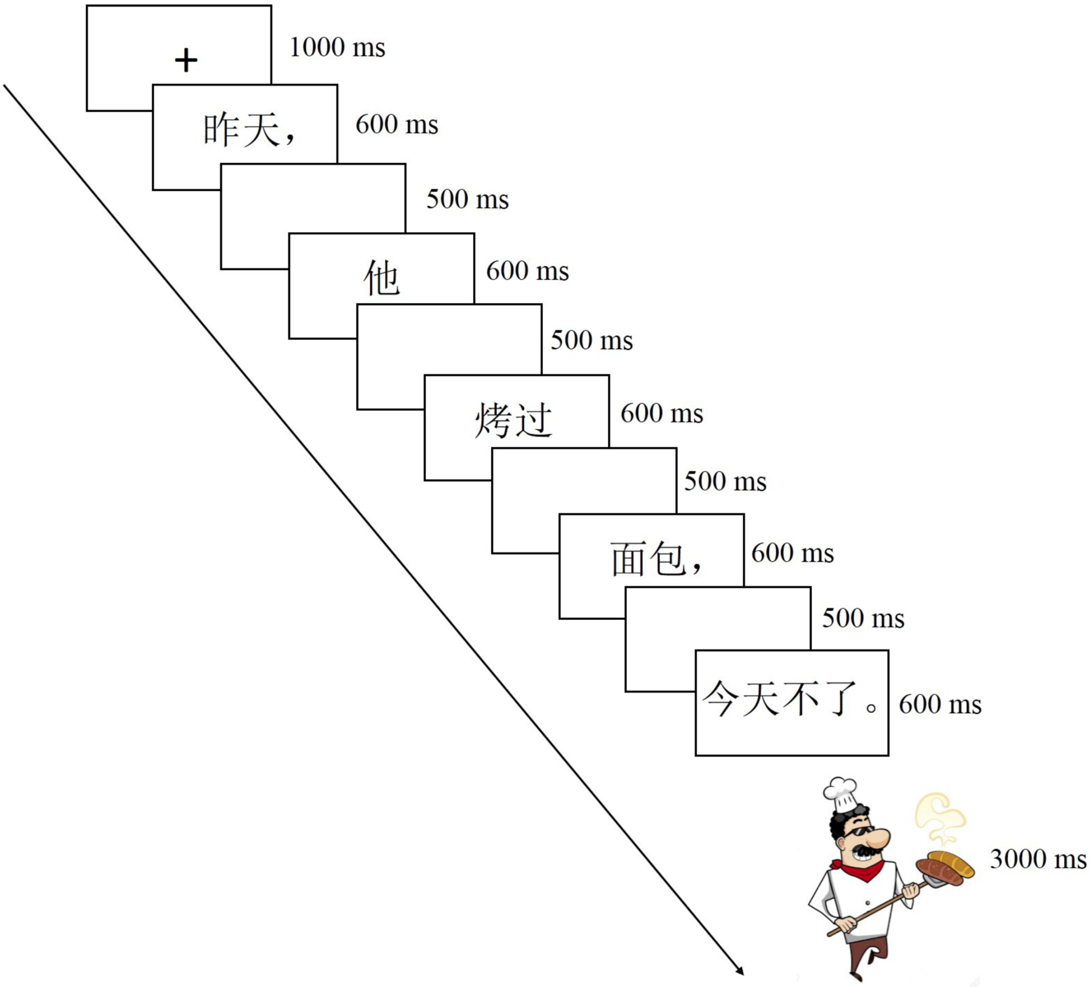

Figure 2. The grand average ERPs time-locked to the onset of the critical word segment, i.e., verb with aspect marker “过(guo)”, as well as the topographic maps of the Wrong marker minus Correct marker condition during 300-500 ms and 500-800 ms for L2 Chinese learners as a whole group.

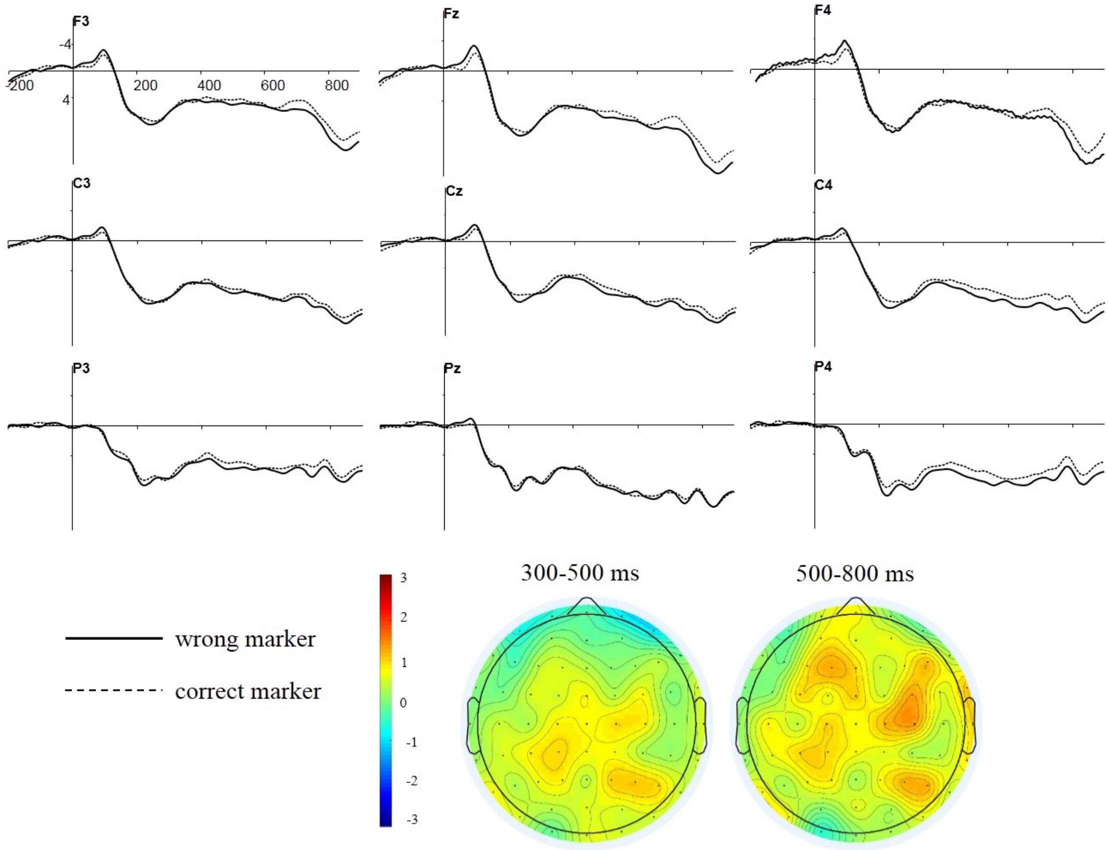

Figure 3. The scatterplot of the mean amplitudes of the difference waves at the midline medial region for Wrong minus Correct marker in L2 Chinese learners.

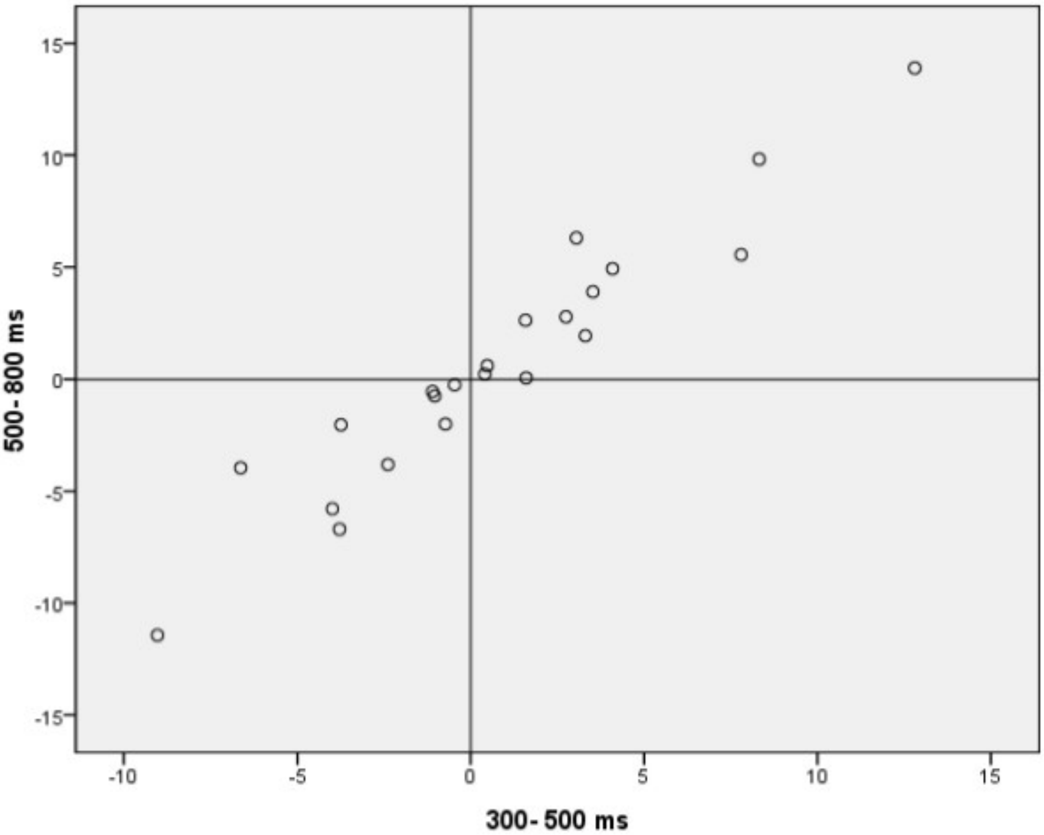

Figure 4. The grand average ERPs time-locked to the onset of the critical word segment, i.e., verb with aspect marker "过(guo)", as well as the topographic maps of the Wrong marker minus Correct marker condition during 300-500 ms and 500-800 ms for positivity-dominant L2 Chinese learners.

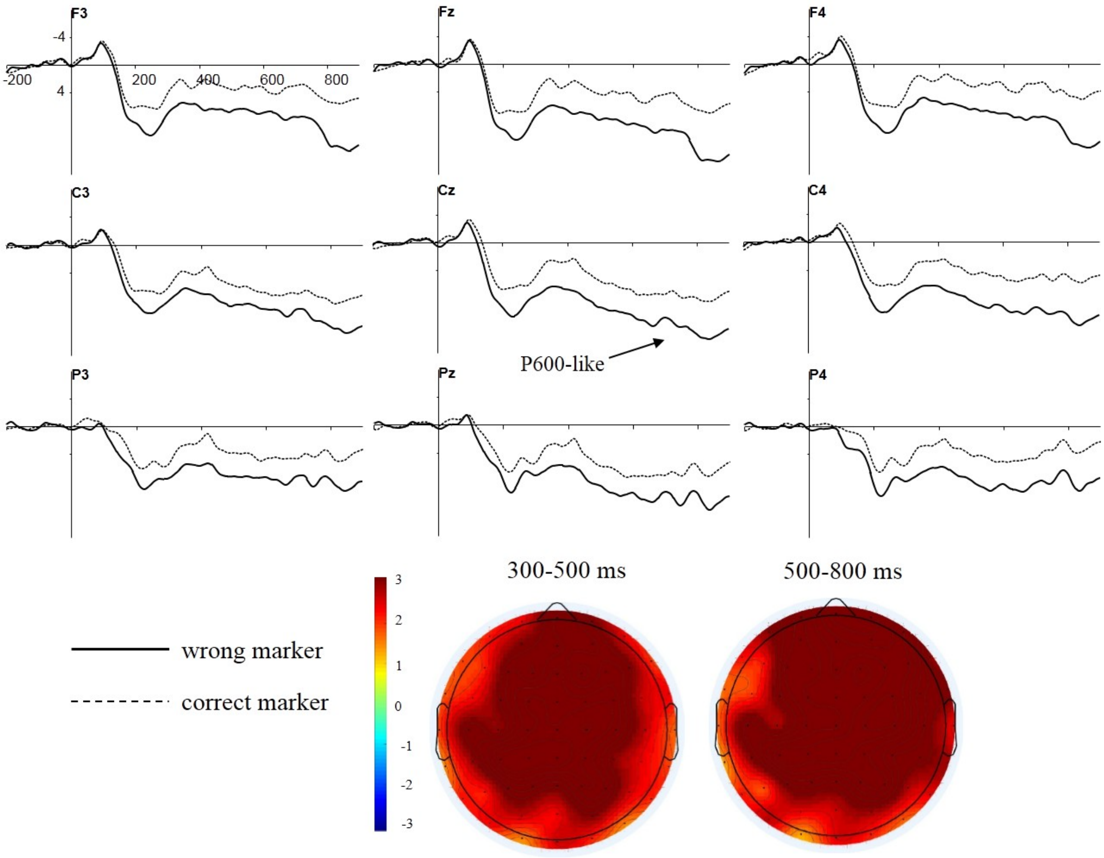

Figure 5. The grand average ERPs time-locked to the onset of the critical word segment, i.e., verb with aspect marker "过(guo)", as well as the topographic maps of the Wrong marker minus Correct marker condition during 300-500 ms and 500-800 ms for negativity-dominant L2 Chinese learners.

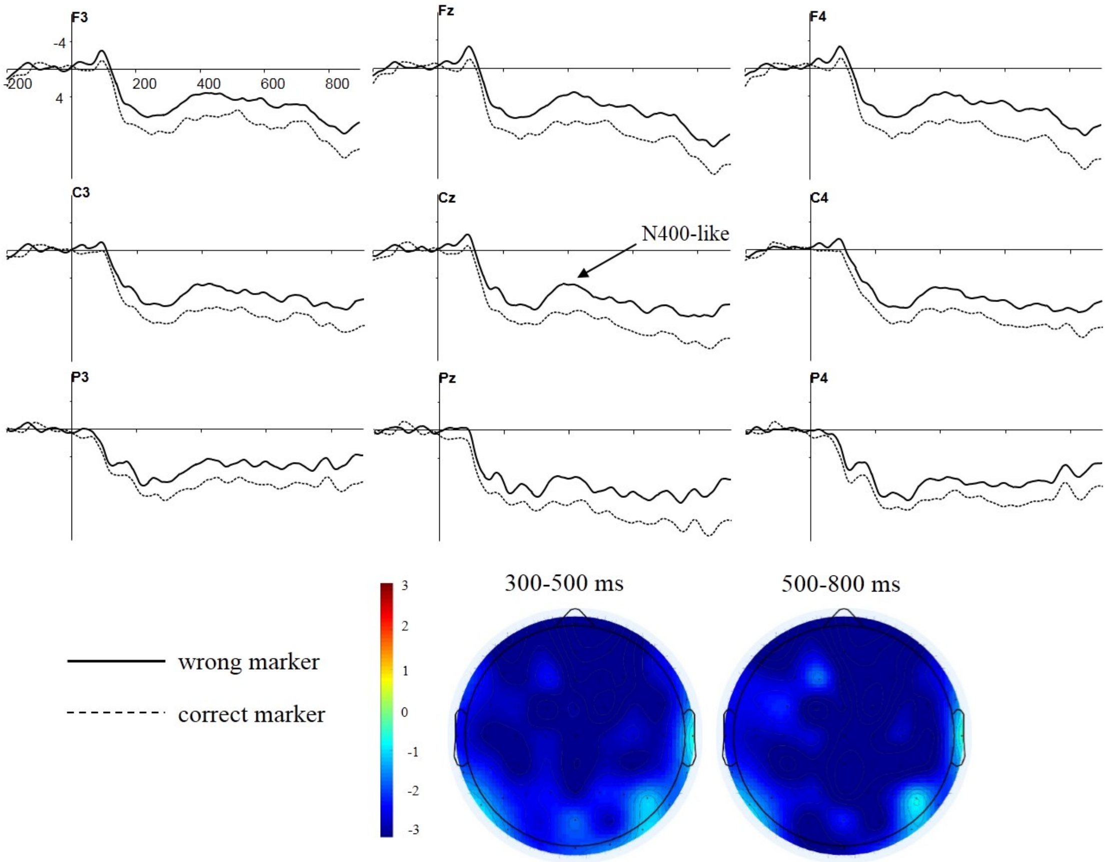

Figure 6. The grand average ERPs time-locked to the onset of the critical word segment, i.e., verb with aspect marker "过(guo)", as well as the topographic maps of the Wrong marker minus Correct marker condition during 300-500 ms and 500-800 ms for native Chinese speakers.