Journal of Neurolinguistics 59 (2021) 100998

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Research paper

Processing past time reference in a tenseless language: An ERP study on the Mandarin aspectual morphemes *-le* and *-guo*

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A R T I C L E I N F O

Keywords:
Time reference
Aspect marker
Event sequence
Anterior negativity
P600
PADILIH

A B S T R A C T

Reference to the time of an event can be encoded through various devices in language. While the neural processing of time reference in tense languages has been explored through tense inflection, relatively little is known about such processing through aspect in a tenseless language. The current study investigated how Mandarin speakers process perfective aspect markers *-le* and *-guo*, which are usually related to past time. Through the manipulation of the (dis)agreement between time adverbs and perfective markers, the results revealed that when co-occurring with a future/incongruent time adverb, compared with a past/congruent one, *-le* induced an early anterior negativity, while *-guo* triggered a P600. These distinct ERP patterns suggest that there is no unitary mechanism underlying perfectives in Mandarin, and that aspect modulates the relation of an event to time reference in a tenseless language, just like what tense inflection does in a tense language.

1. Introduction

Time reference (or temporal reference), the perception of an event that occurred in the past, is happening right now, or is about to occur in the future, is generally considered a common function of human cognition. However, the expression of time reference in language exhibits a great number of crosslinguistic differences since it can be encoded using different devices, including categories of *tense* and *aspect*. Tense is "grammaticalized expression of location in time" and can be further distinguished between *absolute tense* (taking the time of speech as its exclusive reference time) and *relative tense* (when any time interval can be taken as its reference time as long as it is contextually available (Comrie, 1985). Aspect is "different ways of viewing the internal constituency of a situation" (Comrie, 1976) and can be categorized into *viewpoint aspect* and *situation aspect* (Smith, 1997). Specifically, viewpoint aspect is related to the subjective focus of a situation, such as *perfective* (taking the whole situation as its focus–beginning and ending times included) and *imperfective* (paying attention to the internal part of a situation–beginning and ending times excluded), while situation aspect is related to the objective aspectual features of a lexical verb, such as *stative/dynamic* (e.g., stative: 'to love someone'; dynamic: 'to run'), *telic/atelic* (e.g., telic: 'to run to the park' (with a spatial goal as an endpoint); atelic: 'to run in the park' (without an endpoint)), and *punctual/durative* (e.g., punctual: 'to win a race'; durative: 'to build a house'; Smith, 1997).[1] Not all languages give an equal importance to tense and aspect—"tense-prominent" languages tend to place events in time using tense (e.g., English, German), while

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[1] Mood/modality is another semantic category that can be used to express time reference. It is distinct from tense and aspect, in that mood/modality is better defined in terms of "possible worlds semantics" (i.e. semantic analysis making use of a possible world), while tense and aspect are time-relational (Klein, 1994).

https://doi.org/10.1016/j.jneuroling.2021.100998
Received 23 August 2020; Received in revised form 16 December 2020; Accepted 1 February 2021
Available online 18 February 2021

"aspect-prominent" ones refer to such time perception through aspect (e.g., Mandarin)–which makes the crosslinguistic differences even more diverse (Bhat, 1999).

Compared with the abundant literature in linguistics on the expression of time, only a few event-related brain potential (ERP) studies have been conducted regarding this topic. So far, most of the ERP studies on time expression were conducted in tense-prominent languages using a temporal mismatch paradigm. The first study of this kind was conducted in Dutch, in which a mismatch was created by placing a present tensed verb after a past time adverb (e.g., '*Last Sunday Vincent paints the window frames of his country house'; Baggio, 2008). This agreement violation elicited a left anterior negativity (or LAN, 200–400 ms) followed by a marginal P600 (400–700 ms) at the verb. Baggio (2008) interpreted the LAN as reflecting a failure of applying agreement rules between the time adverb and the tense morpheme, but the author did not discuss the marginal P600. In a follow-up study, Dragoy, Stowe, Bos, & Bastiaanse, 2012 also found that ERP response was sensitive to temporal mismatch between a time adverb and a verb; however, the pattern differed according to whether the verb was flexed for past or present tense: a P600 was observed when a past time adverb co-occurred with a present tensed verb, while no effect was found when a present time adverb was placed with a past tensed verb. Interestingly, Dragoy, Stowe, Bos, & Bastiaanse, 2012 found similarities between their discovery in temporal computations and prior findings of pronominal in the literature: a P600 was elicited when an agreement violation by a pronoun was judged as occurring within a sentence, while an early anterior negativity or no local effect occurred when the antecedent referred to by the pronoun was outside the sentence (e.g., *The aunt$_i$ heard that she$_i$/he$_{j/*i}$ had won the lottery*; Osterhout and Mobley, 1995). The authors thus explained the different patterns in their study with the "Past Discourse Linking Hypothesis (PADILIH)": processing past tense needs to retrieve/link its antecedent in the discourse (just as processing pronouns taking their referents outside the sentence), while processing present tense requires local binding at the sentence level (just as processing pronouns taking their referents inside the sentence). These results were later replicated and extended to Dutch periphrastic forms (i.e., an auxiliary plus a lexical verb; Bos, Dragoy, Stowe, & Bastiaanse, 2013). The 'auxiliary$_{\text{present tense}}$ + verb' structure in Dutch can refer to either past time reference (as 'have$_{\text{present tense}}$ + verb' in English) or future time reference (as 'will$_{\text{present tense}}$ + verb' in English). With a tense conflict, such forms elicited similar patterns as their counterparts involving a simple form, showing that the effects are due to a mismatch of time reference, not tense *per se*.

The findings discussed so far only show part of the picture of the neural processing of time in language, i.e., reference to the concept of time *via* tensed verbs. To have a more complete understanding of such processing, we also need to explore non-tense-prominent languages, and Mandarin Chinese is a good candidate.

Mandarin Chinese is generally seen as an aspect-prominent/tenseless language—there is a great variety of aspectual viewpoint markers, including perfective and imperfective, but no dedicated morpheme whose primary function is to locate a situation in time as in a tense language (Li & Thompson, 1981; Klein et al., 2000; Xiao & McEnery, 2004, among others).[2] Two main verbal perfective morphemes are often considered in Mandarin: (1) *-le*, indicating (among others) termination/completion of an event with consequences of this event still visible at the reference time, or indicating a sequence of events, and (2) *-guo*, marking an experiential aspect (or discontinuity with the present or other reference time; Smith, 1997). Specifically, the experiential meaning of *-guo* can be punctual, implying a completion of an event with no consequences visible at the reference time, or implying a sequence of events. Also, the experiential meaning of *-guo* can be extended to the lifetime, indicating that the event occurred at least once. Note that when a time adverb is found in the sentence, the termination/completion meaning of *-guo* is easily derived and that *-guo* can be interchangeable with *-le* in such cases (Xiao & McEnery, 2004). Although *-le* and *-guo* are often analyzed as marking perfective aspect, their meanings are slightly different. The example sentences in Table 1 (i.e., 'Lisi broke his left leg') can illustrate this point: when *-le* is attached to the verb, the interpretation of the sentence is that Lisi's left leg is still recovering. Contrastively, when *-guo* is used, the sentence is interpreted such that Lisi's leg has already healed. As for imperfectives, two types are often mentioned in the literature: (i) the postverbal durative *-zhe*, indicating that a state is perduring in time, and (ii) the preverbal progressive free morpheme *zai*, expressing an on-going dynamic event (See Table 1 for a summary of aspect makers in Mandarin).

Even though aspect markers in tenseless languages are generally not considered as tense markers, there are still temporal restrictions on their use (Li & Thompson, 1981; Tai, 1985). For example, a simple sentence with the occurrence of *-le* or *-guo* in Mandarin obtains a past time interpretation by default, and thus the use of a future time adverb is prohibited when only one event is mentioned (e.g., **Lisi xiageyue die-duan-le zuotui* '*Lisi broke his left leg next month', where *xiageyue* means 'next month'). Linguists provided two types of views to capture this default past interpretation phenomenon. The first type of view intended to offer a unified explanation for both *-le* and *-guo*. For example, Smith and Erbaugh (2005) proposed two pragmatic principles to explain the default past time interpretation: the "bounded event constraint" and the "simplicity principle interpretation". The bounded event constraint states that bounded events (i.e., an event that has a clearly defined temporal endpoint) are not located in the present and thus entails that *-le* and *-guo* do not place an event in the present time. The simplicity principle interpretation argues that speakers/comprehenders choose the interpretation that requires the least additional information. Therefore, since past events already happened and are cognitively available, while future events are only hypothesized, the principle entails that *-le* and *-guo* place the event in the past, not in the future. Another unified explanation for the default past interpretation was offered by Lin (2006), who argued that both *-le* and *-guo* introduce an "anteriority relation" (i.e., one event happens *before* another event) with a contextually given reference time, such that they are seen as relative past tense markers in addition to their aspectual meaning (e.g., the two examples in Table 1: *zuotian wo chi-le wanfan yihou qu zhao ni* 'I went to see you after I had supper yesterday'; *zuotian wo chi-guo wanfan yihou zhao-guo ni* 'I went to see you after I had supper yesterday'). In contrast to the first type of view, which treats both *-le* and *-guo* similarly, the second type of view explains the

[2] Note that more aspectual viewpoints are grammaticalized in Mandarin, such as the delimitative under the perfective category, and the inceptive and continuative under the imperfective category. They are not reviewed here as they are beyond the scope of the present paper.

Table 1
Main aspect markers in Mandarin.

Aspect	Marker	Function	Example
Perfective	*-le*	Indicating termination/completion of an event, with consequences of the event visible at the reference time (one event)	李四 跌-斷-了 左-腿。 Lisi die-duan-le zuo-tui Lisi fall-break-PFV(*le*) left-leg 'Lisi broke his left leg (still not healed).' (Lin, 2006, p. 13)
		Indicating a sequence of events (two events)	昨天 我 吃-了 晚飯 以後 去 找 你。 zuotian wo chi-le wanfan yihou qu zhao ni yesterday I eat-PFV(*le*) supper after go visit you 'I went to see you after I had supper yesterday.'
	-guo	Indicating an experiential aspect (extended to the lifetime, implying that the event occurred at least once)	李四 跌-斷-過 左-腿。 Lisi die-duan-guo zuo-tui Lisi fall-break-PFV(*guo*) left-leg 'Lisi broke his left leg (already healed).', or 'Lisi has already broken his left leg once.' (Lin, 2006, p. 9)
		Indicating experiential aspect (punctual, implying a completion of an event (with no consequences visible at the reference time), also for a sequence of events)	昨天 我 吃-過 晚飯 以後 找-過 你。 zuotian wo chi-guo wanfan yihou zhao-guo ni yesterday I eat-PFV(*guo*) supper after visit-PFV(*guo*) you 'I went to see you after I had supper yesterday.' (Xiao & McEnery, 2004, p. 142)
Imperfective	*-zhe*	Indicating the continuity of a state in time	他 穿-著 皮-鞋。 ta chuan-zhe pi-xie s/he put/on-DUR leather-shoe 'S/He is wearing his/her leather shoes.' (Li & Thompson, 1981, p. 221)
	zai	Indicating an on-going event	他 在 穿 皮-鞋。 ta zai chuan pi-xie s/he PROG put.on leather-shoe 'S/He is putting on his/her leather shoes.' (Li & Thompson, 1981, p. 221)

default past time interpretation by treating these two morphemes differentially regarding their aspectual meanings. Klein et al. (2000) proposed that *-le* implies two distinct times while *-guo* only implies one. The two distinct times implied by *-le* are (i) the assertion of the whole event included in a reference time (i.e., the perfective aspect), and (ii) the anaphoric assertion of the result state of the event (i.e., the interpretation of something depends upon another expression in context). Therefore, *-le* puts an event in the past since asserting the result state of an event at the speech time would automatically place that particular event before the speech time, while only one time point is introduced by *-guo*: the (not anaphoric, pragmatic) assertion of the time after the event (hence a perfective experiential aspect). These two types of assertions are schematically summarized in Table 2, abstracting the meaning of *-le* and *-guo* as exemplified in Table 1.

As illustrated in Table 2, due to the discontinuity between the posttime of the event and the actual event, *-guo* implies an "anteriority" meaning and the event is seen retrospectively. Specifically, when a sentence with *-guo* is uttered, the posttime of the event is by default placed at the time of speech, which in turn places the event before the time of speech. Note that the anteriority meaning implied by *-le* and *-guo* are different, and hence their indirect relation with the time of speech: (i) the event itself is considered with *-le* (including the result implied by the event), while *-guo* only asserts the posttime of the event, and (ii) *-le* asserts an anaphoric time in addition to another reference time (i.e., two time points), while *-guo* only asserts a (non-anaphoric) reference time (i.e., one time point). In sum, the second type of view states that *-le* links to past time reference by anaphoric assertion, searching for its antecedent in the available discourse, while *-guo* does so by pragmatic assertion.

From the above discussion, we can see that the linguistic debate over whether *-le* and *-guo* should be treated similarly when expressing past time reference is still far from being settled, and that is why the present study aimed to contribute to the literature by providing evidence from a cognitive science perspective.

Several ERP studies involving the aspectual viewpoint markers in Mandarin have been conducted. Although none of them directly addressed how *-le* and *-guo* should be considered, findings in two of these studies were relevant to the current discussion. Zhang and Zhang (2008) investigated agreement violations of Chinese grammatical aspect by placing both a perfective (*-le*) and a mismatched imperfective (*zhengzai*) marker in a sentence (see Table 3). While no difference was found at the verb, the perfective morpheme *-le* (presented in a different frame from the verb) in the violation condition induced a left-central and posterior negativity (at the 200–400 ms time window, different from a N400 and a LAN) followed by a P600 (450–800 ms time window). The authors interpreted the negativity as a failure to bind a perfective marker with a progressive marker, and the P600 as indexing syntactic repair or monitoring

Table 2
Schematic representation of the aspectual assertions of *-le* and *-guo* on the structure of an event following Klein et al.'s (2000) proposal.

Event structure	Pretime of the event	The event itself	Result of the event	Posttime of the event
-le	/	Time 1: assertion of the event	Time 2: anaphoric assertion	/
-guo	/	/	/	Assertion of posttime

Table 3
Example sentences and brain response from prior ERP studies on time and aspect in Mandarin.

Study	Example	Brain response
Zhang and Zhang (2008)	蘇君 已經/*正-在 預備 了 水果 和 甜點。 Su Jun yijing/*zheng-zai yubei le shuiguo he tiandian Su Jun already/*just-PROG prepare PFV(*le*) fruit and cookies 'Su Jun prepared fruit and cookies already.'	left-central and posterior negativity (200–400 ms) followed by a P600 (450–800 ms)
Qiu and Zhou (2012)	上個月/*下個月 聯合國 派出-過 特別 調查組。 shanggeyue/*xiageyue lianheguo paichu-guo tebie diaochazu last month/*next month UN dispatch-PFV(*guo*) special invest.team 'Last month/*Next month the United Nations dispatched a special investigation team.'	P600 (600–1000 ms)

and resolving the conflict caused by the aspectual disagreement.

Qiu and Zhou (2012) used disagreement between a time adverb (e.g., 'next month') and the perfective *-guo* as one condition to investigate temporal processing in Mandarin (see Table 3; note that the primary focus of this study was to inspect the neural processing of time adverbs, not the abovementioned mismatch pattern). The occurrence of *-guo* (presented with the verb in the same frame) after a mismatched future time adverb resulted in a P600 effect (at the 600–1000 ms time window), when compared with its occurrence after a past time adverb. The P600 here was taken as reflecting a failure of checking the temporal agreement between the time adverb and *-guo* at the morphosyntactic level.

While both studies provide important insights into the neural processing of *-le* and *-guo*, there are still some limitations. First, the above two studies cannot be directly compared because Zhang and Zhang (2008) relied on the mismatch between two aspect markers (imperfective preverbal marker *zhengzai* + perfective postverbal marker *-le*), while Qiu and Zhou (2012) relied on the incongruity between a future time adverb and *-guo* (similar to previous designs in tense languages discussed above). Moreover, the use of *zhengzai* in Zhang and Zhang (2008) might be controversial because *zhengzai* can be further decomposed into two parts: the temporal adverb *zheng* 'just, sharp' and the progressive morpheme *zai* (Lin & Liu, 2004, pp. 169–175). Thus, the design in Zhang and Zhang (2008) might be confounded by violations of both temporal (*zheng*) and aspectual (*zai*) constraints, which might explain the observation of the rarely seen early posterior negativity in language processing (instead of an N400 or a LAN). As for Qiu and Zhou (2012), as pointed out by the authors, due to the diversity of the kinds of time adverbs used in their study, the attention of the participants might have been guided to the grammatical properties of the sentences rather than the semantic features of the markers, enhancing a P600 and thus reducing an N400 effect at the same time.

To directly address the question regarding whether *-le* and *-guo* are different or similar perfective aspect markers when it comes to time reference, the present study aimed to use the ERP technique to investigate how these two makers were processed by looking into their relationships with time adverbs. Specifically, based on the theoretical considerations of the Mandarin aspectual system and previous ERP findings reviewed above, we planned to examine first whether there was indeed a default past time interpretation with the use of perfective morphemes and, if so, whether such interpretation was obtained through similar or different mechanisms for these two morphemes. To this end, we adopted the general experimental designs from tense-prominent languages (e.g., Baggio, 2008; Dragoy, Stowe, Bos, & Bastiaanse, 2012; Bos et al., 2013) and aspect-prominent languages (e.g., Qiu and Zhou (2012)), in which a temporal concord or mismatch between a time adverb (setting the time frame of a sentence) and a particular morpheme attached to the verb was manipulated. Our hypothesis was straightforward: If processing *-le* and *-guo* involves a general strategy (based on the default deictic pattern; Smith & Erbaugh, 2005), the temporal incongruency of both markers should elicit a qualitatively similar component, which could be an early anterior negativity or an absence of local effect (as the findings of Dutch past tense in Baggio (2008), Dragoy, Stowe, Bos, & Bastiaanse, 2012 and Bos, Dragoy, Stowe, & Bastiaanse, 2013) or a P600 (as the finding of Mandarin in Qiu and Zhou (2012)). On the other hand, if the perfective markers are related to past time reference on different bases (i.e., *-le* asserts an anaphoric time in addition to another reference time (i.e., two time points), while *-guo* only asserts a (non-anaphoric) reference time (i.e., one time point)), then different ERP components should be observed. Specifically, a P600 should be found for *-guo*, if the finding in Qiu and Zhou (2012) is replicated, and a different component should be observed for *-le*, which could possibly be an early anterior negativity or an absence of local effect, as reported in previous research on tense-prominent languages (as in Baggio, 2008; Dragoy, Stowe, Bos, & Bastiaanse, 2012; Bos, Dragoy, Stowe, & Bastiaanse, 2013).

2. Methods

2.1. Participants

Twenty-six naïve participants (19 females, age 20–35 years old, mean: 23.1) took part in the ERP experiment. They were all native speakers of Mandarin Chinese in Taiwan, with normal or corrected-to-normal vision. They were right-handed as assessed by a simplified version of the Edinburgh Handedness Inventory (Oldfield, 1971) and had no history of neurological surgery or disorder. A written consent form approved by the Research Ethics Office of National Taiwan University, in which the whole procedure of the experiment was described, was obtained before the experiment. The participants were paid after the experiment.

2.2. Materials

All the sentences consisted of five segments: Subject – Time adverb – Verb – Perfective aspectual morpheme (*-le* or *-guo*) – Object. The main manipulation of the materials was administered on the two perfective morphemes and the time adverbs (see Table 4). The time adverbs varied between past and future time adverbs, with the former compatible and the latter incompatible with the two morphemes. Also, we included time adverbs with different degrees of remoteness, from 'instant' (e.g., 剛剛 *ganggang*, 'one instant ago') to 'year' unit (e.g., 去年 *qunian*, 'last year'), for two reasons: (i) the lexical semantics of some verbs sounded more plausible with certain time units, and (ii) the diversity of the sentences could be increased. In total, five degrees of remoteness were chosen in regard with their time unit: instant, day, week, month and year. Since both aspectual morphemes were acceptable after a past time adverb but not after a future one, filler sentences acceptable in a future time context but not in a past time context were added to prevent a predictive effect from the subjects before seeing the presentation of the aspectual morphemes. Note that the syntactic constraints of the materials were also controlled: although both *guo*-sentences and *le*-sentences with a future time adverb are not acceptable, this unacceptability occurs only when the sentences contain one clause. Continuing the sentence with another clause (i.e., treating the two clauses as a complex sentence) could render the sentence acceptable (Li & Thompson, 1981; Tai, 1985; Xiao & McEnery, 2004). Therefore, we made sure that all the sentences in the study could equally be 'saved' by adding an extra clause.

The rest of the sentence segments were selected with the following criteria. First, the verbs were one-to two-character long. Since stative verbs have a different interpretation when co-occurring with *-le* and *-guo* (*-le* is often not accepted with stative verbs, unlike *-guo* which does not obey to such constraints; Xiao & McEnery, 2004; Lin, 2006), only dynamic verbs that can co-occur with the progressive *zai* were chosen. For two-character verbs, we also avoided morphologically complex verbs, such as compound verbs, coordinate verbs, and verbs for which the two characters can be decomposable into synonymous or near-synonymous elements, since they might add additional processing cost to the subjects (Liao & Lau, 2020).[3] As for the nouns, they were all of two-character length regardless of their position in the sentence. The nouns in the subject position were all human (i.e., animate agentive), such that their co-occurrence with dynamic verbs was more natural. Proper names and pronouns were avoided due to their referential functions. Nouns in the object position consisted of animate and inanimate nouns. Since a generic noun in this position could affect the naturalness of *le*-sentences (e.g., ?*wo he-le cha* 'I drink-LE tea', intended: 'I drank tea'; Li & Thompson, 1981, p. 200), we only chose object nouns according to their specificity.

Prior to the ERP experiment, 70 participants (none of them were later recruited for the ERP experiment) took part in an online sentence acceptability survey to rate the acceptability of the experimental sentences (37 sentences per condition, total number: 222 sentences) on a 7-point scale (1 = not acceptable, 7 = acceptable) via Ibex Farm (https://spellout.net/ibexfarm/). After removing deviant sentences, both *-le* and *-guo* were judged acceptable in a past time context (*-le*: 6.58; *-guo*: 6.45) and not acceptable in a future time context (*-le*: 2.04; *-guo*: 1.48) in the resulting sentences (33 sentences per condition, total number: 198 sentences; interaction Time x Marker: $F(2,138) = 1262$, $p < .0001$; Pairwise comparisons: *le*, Past vs. Future: $t(187) = 36.137$, $p < .0001$; *-guo*, Past vs. Future: $t(187) = 39.08$, $p < .0001$). Filler sentences were also judged as predicted. The finalized materials were distributed into six lists using a Latin square design (including the filler sentences, hence the number of lists despite the four conditions) to counterbalance the conditions across the sentences so that none of the similar sentences (e.g., the four sentences in Table 4) was repeated within the same list. No difference in rating was found between the lists, and the same pattern of result was obtained regardless of the degree of remoteness of the time adverb. The length of the verbs was also controlled for across the conditions within the same list, so that the number of one- and two-character verbs was the same for each condition. Each participant of the ERP experiment only saw one list.

2.3. Procedure

The experiment took place at the Neurolinguistics Lab at National Taiwan Normal University. The participants were comfortably seated in front of a computer screen, on which the instructions and the experimental sentences were displayed. They were also asked to put their hands on the keyboard in front of them. The experiment began with the instruction and practice sessions. The stimuli were then presented with the following sequence: a '+' sign was first shown for 600 ms in the center of the screen for the participants to focus their gaze, followed by a 600-ms blank screen. Afterwards, the sentences were randomly presented, with five segments appearing one at a time: the subject NP, the time adverb, the verb, the aspectual morpheme, and the object NP. The object NP was presented along with a full stop, signaling the end of the sentence (note that this presentation was adapted from Zhang and Zhang (2008), and differed from Qiu and Zhou (2012), in which the verb and the aspectual morpheme were displayed together). Each segment appeared for 600 ms, followed by a 200 ms inter-stimulus interval (i.e., SOA was 800 ms). After the full sentence was presented, a question mark appeared, prompting the participant to judge the acceptability of the sentence by pressing a key on the keyboard using their left or right hand. This choice was binary (acceptable vs. non-acceptable), and the keys corresponding to each option were counterbalanced across the participants. An example trial is graphically summarized in Fig. 1.

The experimental session was divided into four blocks of 49–50 sentences each, with a short break between them to let the

[3] An example of Mandarin compound verbs is resultatives, which are verbs consisting of two elements, the first one denoting the process of the event, the second one indicating the result of the process; e.g., *die-duan*, 'fall-break', meaning that something was 'broken' because of a previous 'falling' event). Coordinate verbs composed of two elements that occurred sequentially without a cause-consequence connotation; e.g., *da-ma* 'hit-scold', meaning that someone were scolded after being hit. Examples of verbs of composed of (near) synonymous characters are *you-yong* 'to swim' (literally, 'swim' + 'action of swimming'), or *bang-zhu* 'to help' (literally, 'help' + 'help').

Table 4
Experimental design and example materials.

Conditions	Sentence examples
Past-Le (congruent)	漁夫 昨天 釣-了 鮭魚。 yufu zuotian diao-le guiyu fisherman yesterday fish-PFV(*le*) salmon 'Yesterday, the fisherman fished salmons.'
Future-Le (incongruent)	*漁夫 明天 釣-了 鮭魚。 *yufu mingtian diao-le guiyu *fisherman tomorrow fish-PFV(*le*) salmon Intended: '*Tomorrow, the fisherman fished salmons.'
Past-Guo (congruent)	漁夫 昨天 釣-過 鮭魚。 yufu zuotian diao-guo guiyu fisherman yesterday fish-PFV(*guo*) salmon 'Yesterday, the fisherman fished salmons.'
Future-Guo (incongruent)	*漁夫 明天 釣-過 鮭魚。 *yufu mingtian diao-guo guiyu *fisherman tomorrow fish-PFV(*guo*) salmon Intended: '*Tomorrow, the fisherman fished salmons.'

participants rest. The experiment itself lasted about 20 min.

2.4. Data acquisition and analyses

E-prime 2.0 (Psychology Software Tools Incorporated) was used to present the experimental data, record the participants' behavioral responses (judgment and reaction time), and send the event codes for ERP processing. EEG data were recorded from 32 electrodes (FP1, FP2, F7, F3, FZ, F4, F8, FT7, FC3, FCZ, FC4, FT8, T3, C3, CZ, C4, T4, TP7, CP3, CPZ, CP4, TP8, T5, P3, PZ, P4, T6, O1, OZ, O2, A1, A2), disposed according to the 10/20 system. Four additional electrodes (VEOU, VEOL, HEOR, HEOL) were placed around the eyes (two on the outer canthus of each eye and two on the upper and lower ridge of the left eye) to record blinks and eye movements. The channels were referenced online by averaging the left and right mastoid electrodes. The impedance of all the electrodes was kept below 5kΩ. The sampling rate was 1000 Hz and the amplifier rate (Gain) 19. The EEG signals were filtered between DC to 100 Hz.

ERP analyses were time-locked to the onset of the aspectual morpheme (*-le* and *-guo*). The EEG data were processed using EEGLAB (Delorme & Makeig, 2004) and ERPLAB Toolbox (Lopez-Calderon & Luck, 2014) in Matlab (MathWorks, 2005). The four eye electrodes were first transformed into two bipolar channels (VEOG for vertical movements, and HEOG for horizontal movements). The continuous EEG data were then filtered with a high-pass filter (IIR Butterworth, 0.1 Hz), and contaminated continuous waves were rejected with visual inspection before performing an Independent Component Analysis (Jung et al., 2000). After removing the ICA components responsible for eye movements and muscle activities, an event list was created to epoch the continuous data (from 200 ms prior to the presentation of the segment to 800 ms after its presentation). The epoched data were baseline corrected from −200 ms to 0 ms. Epochs with excessive artifacts were first automatically detected using two ERPLAB functions: moving window peak-to-peak for all the electrodes (200-ms moving time window from −200 ms to 800 ms relative to the stimulus onset in 100-ms increments, threshold voltage: 100 μV) and step-like artifacts for horizontal eye movements (HEOG channel, 400-ms moving time window from −200 ms to 800 ms relative to the stimulus onset in 100-ms increments, threshold voltage: 15 μV). Epochs contaminated with alpha waves were then manually rejected. The overall rejection rate across participants was 16.81% (SD: 5.88%). The average ERPs for each segment were then computed for each participant. The individual ERPs were low-pass filtered (IIR Butterworth, 30Hz) before averaging them altogether.

Both behavioral and ERP data were statistically analyzed using R (R Core Team, 2018). The behavioral analyses consisted of two within-subject factors, with two levels each: Time (*past* vs. *future*) and Marker (*le* vs. *guo*). Since the task required a binary response from the participants, the accuracy rate was analyzed using generalized linear mixed-effects models (*glmer* function from the lme4 package (Bates et al., 2015). Repeated-measures ANOVA (*ezANOVA* function from the ez package; Lawrence, 2016) were used for the reaction time, with post hoc comparisons being Bonferroni corrected. The ERP analyses were conducted on the mean amplitudes during two time windows: 300 ms–500 ms (related to anterior negativity), and 500 ms–700 ms (related to P600). These time windows were chosen for their representativeness of linguistic ERP components (LAN/N400 and P600) from models of sentence processing (Friederici, 2002, 2011; Hagoort, 2003). The ERP data from midline and lateral electrodes were selected for analysis (see Zhang et al.

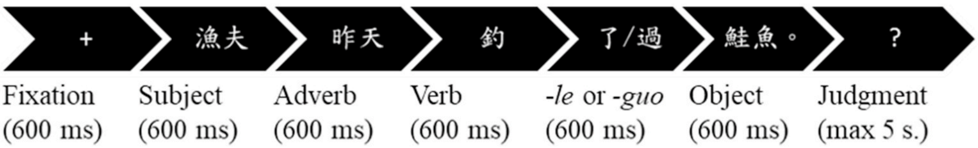

Fig. 1. Presentation of stimuli.

(2012) and Chan (2019) for similar analysis). For the midline analyses, three electrodes were selected (FZ, CZ and PZ), corresponding to a frontal, central and posterior distribution. A three-way repeated-measures ANOVA was conducted on the mean amplitude for each time window with the following factors: Time (*past* vs. *future*), Marker (*le* vs. *guo*) and Electrode (*FZ* vs. *CZ* vs. *PZ*). For the lateral analyses, six representative electrodes were selected to better capture the spatial distribution of the components (F3 and F4 for frontal left/right, C3 and C4 for central left/right, P3 and P4 for posterior left/right). A four-way repeated-measures ANOVA with the factors of Time (*past* vs. *future*), Marker (*le* vs. *guo*), Anteriority (*frontal* vs. *central* vs. *posterior*) and Hemisphere (*left* vs. *right*) was conducted on the mean amplitude for each time window. When the Mauchly's test of Sphericity was violated for the Electrode or Anteriority factor, the *p*-value was corrected by applying the Greenhouse-Geisser correction, with the original degrees of freedom being reported. For both midline and lateral analyses, when a main effect or interaction was significant involving the Time and/or Marker factor, follow-up paired t-tests were conducted and the *p*-values were Bonferroni corrected.

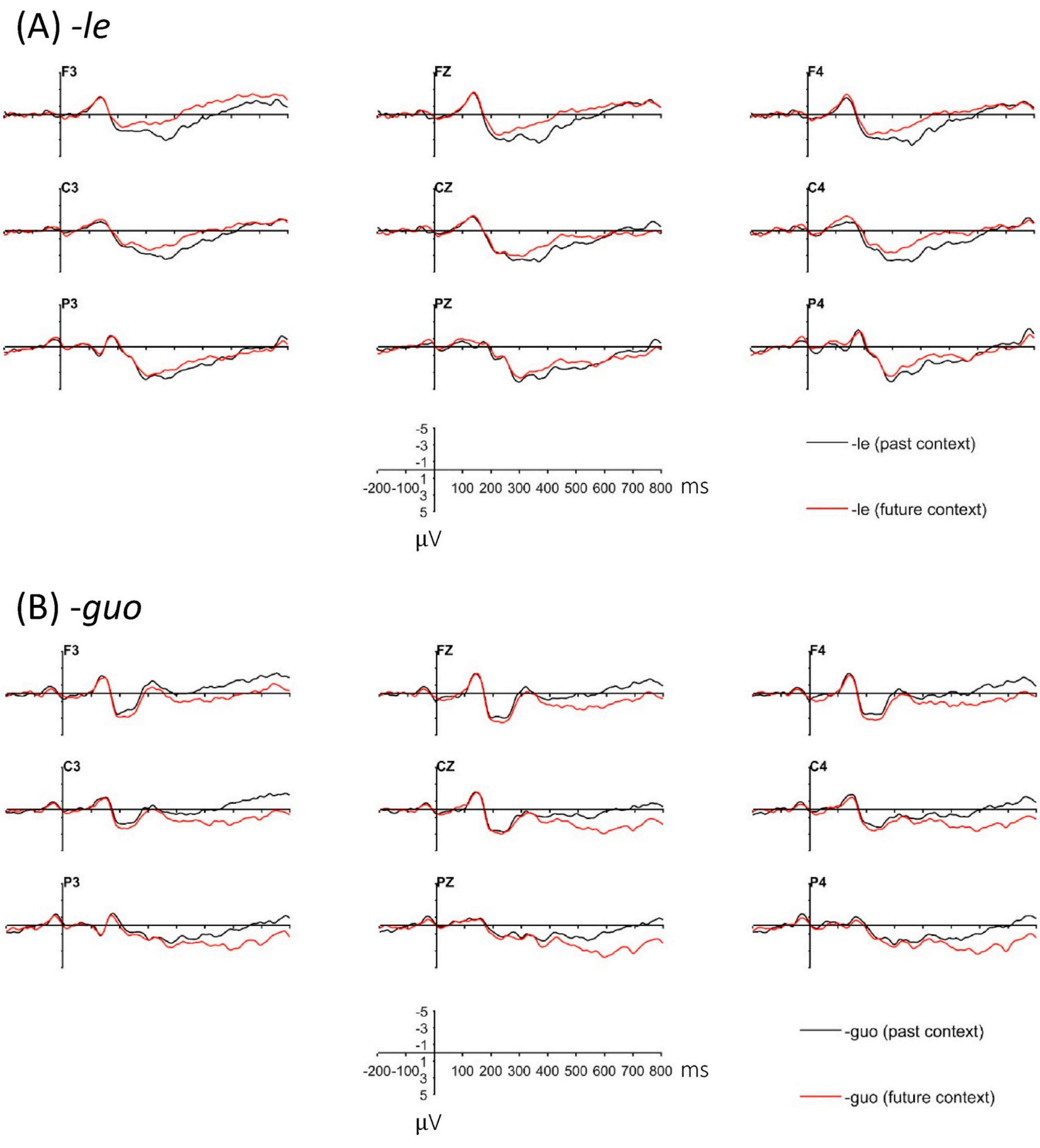

Fig. 2. Brainwaves at -le (upper panel (A) and -guo (lower panel (B), with the congruent condition (past sentences) plotted in black and the incongruent condition (future sentences) in red. -

3. Results

3.1. Behavioral results

The behavioral data from one participant were lost during data collection. Overall, the behavioral results were similar to the online sentence acceptability survey before the ERP experiment, in which sentences with a past time reference were accepted, whereas future time reference sentences were judged unacceptable. Therefore, the accuracy rate rather than the acceptability judgment is reported for the task performed during the ERP experiment. The accuracy rates for the two markers with a past or future time reference were: *le* with past: 95.8%; *-le* with future: 93.6%; *-guo* with past: 97.1%; *-guo* with future: 96.8%. Statistical analyses revealed no main effects for Time and Marker (Time: $\beta = -0.15$, $z = -1.57$, $p = 0.12$; Marker: $\beta = 0.1$, $z = 0.09$, $p = 0.3$), but the interaction between the two factors was significant ($\beta = 0.3$, $z = 3.24$, $p < 0.01$). Follow-up pairwise comparisons showed a significant effect of Time when judging *-le* ($z(24) = -3.46$, $p(\text{corr}) < 0.01$), while the effect of Time was not significant for *-guo* ($z(24) = 1.13$, $p(\text{corr}) = 1$). In addition, in a future time context, the effect of Marker was significant ($z(24) = 3.17$, $p(\text{corr}) < 0.01$).

As for the reaction times (RTs), the RTs for sentences with the past and future time references were 994 ms and 1096 ms, respectively. As for the individual conditions, the RTs were: *le* with past: 998 ms; *-le* with future: 1171 ms; *-guo* with past: 989 ms; *-guo* with future: 1020 ms. Although the RTs seemed to be longer for the future than the past conditions, the statistical analyses did not reveal any significant differences (Time: $F(1,24) = 3.68$, $p = 0.07$; Marker: $F(1,24) = 2.49$, $p = 0.13$; Time x Marker: $F(1,24) = 3.28$, $p = 0.08$). The insignificance of the effects was likely due to the fact that subjects' behavioral response was delayed after the appearance of the sentence-final question mark to avoid data contamination.

3.2. ERP results

The brainwaves of the grand average across the participants for *-le* and *-guo* are shown in Fig. 2. The topographic maps of the difference brainwave (future - past condition) for both *-le* and *-guo* in both time windows of interest are presented in Fig. 3.

Visual inspection of the brainwaves reveals different patterns for the two aspect markers. Concerning *-le*, the future condition seems to induce a larger negativity at the fronto-central sites (LAN) as early as 200 ms after the onset of the morpheme, compared with its past counterpart. This negativity appears to be more intense at the 300–500 ms time window, before deflecting after 500 ms. On the other hand, the difficulty of processing time reference for the *-guo* sentences does not seem to affect the brainwave response during the early time window; instead, a larger positivity component at the posterior sites is found, beginning at 400 ms after the onset of *-guo* and peaking at 600 ms (P600). The topographic maps also reveal apparent differences in terms of the polarity and distribution of the ERP components. Statistical tests were assessed to verify these observations.

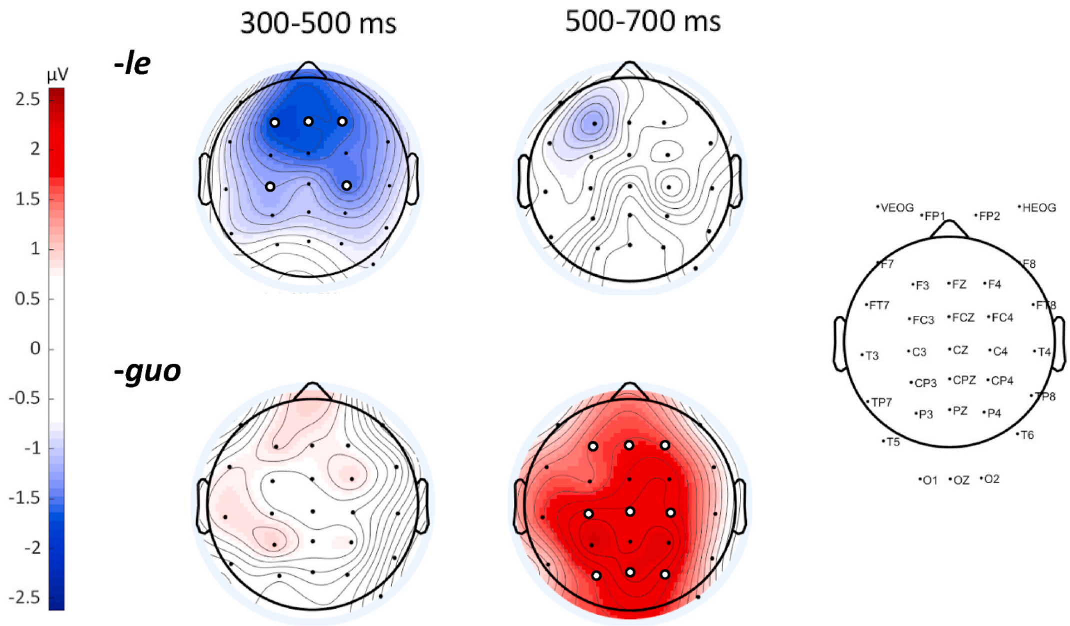

Fig. 3. Topographic maps of the difference wave (future minus past) at -le (upper panel) and -guo (lower panel), for the 300–500 ms (left panel) and 500–700 ms (right panel) times window (positivity in red, negativity in blue). Electrodes for which the future-past contrast is significant are marked with white circles.

3.2.1. 300–500 ms time window

The midline and lateral sites were statistically analyzed using two separate ANOVAs. For the midline sites, a three-way repeated measures ANOVA with the factors of Time, Marker and Electrode revealed a main effect of Marker ($F(1,25) = 6.2$, $p < .05$), a significant interaction between Time and Marker ($F(1,25) = 9.19$, $p < .01$), and a marginal three-way interaction of Time x Marker x Electrode ($F(2,50) = 3.46$, p(corr) = 0.054). Follow-up t-tests on the three-way interaction showed that the future condition induced a stronger negativity at Fz for the *-le* condition (mean voltage for past and future: 2.19 μV and 0.53 μV; Fz: $t(25) = -4.291$, p(corr) < 0.01; Cz: $t(25) = -2.849$, p(corr) = 0.40; Pz: $t(25) = -1.794$, p(corr) = 1), but no such pattern was found in the *-guo* condition (Fz: $t(25) = 1.96$, p(corr) = 1; Cz: $t(25) = 1.563$, p(corr) = 1; Pz: $t(25) = 1.526$, p(corr) = 1).

For the lateral sites, a four-way repeated measures ANOVA revealed a significant Marker effect ($F(1,25) = 7.65$, $p < .05$), a Time x Marker interaction ($F(1,25) = 13.41$, $p < .01$), as well as a three-way interaction of Time x Marker x Anteriority ($F(2,50) = 5.86$, p(corr) < 0.05). Follow-up t-tests on this three-way interaction showed that, for *-le*, the past vs. future difference was significant at the anterior and central sites (Anterior: mean voltage for past and future: 2.17 μV and 0.48 μV, $t(25) = -5.001$, p(corr) < 0.0001; Central: mean voltage for past and future: 2.64 μV and 1.27 μV, $t(25) = -4.055$, p(corr) <0.01; Posterior: mean voltage for past and future: 2.79 μV and 2.08 μV, $t(25) = -2.101$, p(corr) = 1). In contrast, none of the follow-up comparisons between past and future were significant at any anteriority sites for *-guo* (all corrected p's = 1). See Tables 5 and 6 for a summary of the ANOVAs for the midline and lateral sites, respectively (note that only tests involving the Time and Marker factors are reported.).

Overall, the statistical results confirmed that a fronto-central negativity was found for *-le* but not for *-guo* when placed in a future time context (compared with its past counterpart), suggesting that the temporal reference of a sentence only affected the processing of *-le* but not *-guo* during 300–500 ms.

3.2.2. 500–700 ms time window

Similar to the previous time window, the statistical results of midline and lateral electrodes are reported separately. For the midline electrodes, both the main effect of Time ($F(1,25) = 23.16$, $p < .001$) and the Time x Marker interaction were significant ($F(1,25) = 12.43$, $p < .01$), while the three-way interaction of Time x Marker x Electrode was not ($F(2,50) = 0.03$, p(corr) = 0.92). Follow-up *t*-test comparisons on the two-way interaction showed that while no significant difference was found for *-le* between past and future conditions ($t(25) = -0.625$, p(corr) = 1), the difference for *-guo* between past and future was highly significant (mean voltage for past and future: 0.3 and 2.29, $t(25) = 5.469$, p(corr) < 0.0001).

As for the lateral analyses, both the main effects of Time ($F(1,25) = 21.69$, $p < .001$) and Marker ($F(1,25) = 4.39$, $p < .05$), as well as the interaction of Time x Marker, were significant ($F(1,25) = 23.62$, $p < .001$). No three-way or four-way interactions involving Time or Marker were found. Follow-up t-tests on the Time x Marker interaction revealed no difference between past vs. future conditions for *-le* (mean voltage for past and future: 0.32 μV and −0.2 μV, $t(25) = -1.863$, p(corr) = 0.42), whereas the comparison of the same conditions for *-guo* was significant (mean voltage for past and future: −0.14 μV and 1.69 μV, $t(25) = 6.542$, p(corr) < 0.0001). See Tables 5 and 6 for a summary of the ANOVAs.

In sum, at the 500–700 ms time window, the statistical analyses revealed that the fronto-central negativity found at *-le* in the previous time window was not present anymore. On the other hand, *-guo* placed in a future context induced a larger positivity spread over the scalp, when compared with its past counterpart. Due to the timing and distribution of this positivity, it can be seen as an instance of P600.

4. Discussion

The aim of this paper was to determine whether there was a default past time interpretation with the use of perfective morphemes, *-le* and *-guo*, in Mandarin, and if so, whether their access to past time reference was similar or different. To address this, a temporal violation of the two morphemes with a future time adverb was checked against a congruent counterpart with a past time adverb using

Table 5
Midline analysis: Summary of the degrees of freedom and F values of repeated-measures ANOVAs for different time windows.

	df	300–500 ms	500–700 ms
Main effect			
Time	1	1.7	23.16[d]
Marker	1	6.2[b]	2.96[a]
2-way interaction			
Time x Marker	1	9.19[c]	12.43[c]
Time x Electrode	2	3.11[a]	2.74[a]
Marker x Electrode	2	2.56	5.57[b]
3-way interaction			
Time x Marker x Electrode	2	3.46[a]	0.03

[a] = $0.1 > p > 0.05$.
[b] = $p < 0.05$.
[c] = $p < 0.01$.
[d] = $p < 0.001$.

Table 6
Lateral analysis: Summary of the degrees of freedom and F values of repeated-measures ANOVAs for different time windows.

	df	300–500 ms	500–700 ms
Main effect			
Time	1	3.66	21.69[d]
Marker	1	7.65[b]	4.39[b]
2-way interaction			
Time x Marker	1	13.41[c]	23.62[d]
Time x Anteriority	2	2.2	4.35[b]
Time x Hemisphere	2	0.81	0.97
Marker x Anteriority	2	3.06	0.08
Marker x Hemisphere	1	6.48[b]	2.2
3-way interaction			
Time x Marker x Anteriority	2	5.86[b]	1.7
Time x Marker x Hemisphere	1	0.03	0.28
Time x Anteriority x Hemisphere	2	0.44	1.52
Marker x Anteriority x Hemisphere	2	3.19[a]	2.63[a]
4-way interaction			
Time x Marker x Anteriority x Hemisphere	2	0.66	1.17

[a] $= 0.1 > p > 0.05$.
[b] $= p < 0.05$.
[c] $= p < 0.01$.
[d] $= p < 0.001$.

the ERP technique. The results clearly showed that *-le* and *-guo* were incompatible with a future time adverb and that these two morphemes triggered different processes in response to such incompatibility: the perfective *-le* elicited an early anterior negativity during 300–500 ms (LAN), while *-guo* induced a broad positivity at the 500–700 ms time window (P600). Overall, the results confirmed that there was indeed a default past time interpretation with the use of perfective morphemes since the occurrence of future time adverbs within the same sentence induced stronger ERP responses than those induced by past time ones. As for whether both perfective makers are similar or different, our results did not support the hypothesis that both morphemes are related to past time reference by the same mechanism. Instead, our results buttressed the alternative hypothesis that they are different.

As discussed in the Introduction and also illustrated in Table 2, two distinct times are implied by *-le*: (i) the assertion of the whole event included in a reference time (i.e., the perfective aspect), and (ii) the anaphoric assertion of the result state of the event (i.e., the interpretation of something depends upon another expression in context; Klein et al., 2000). Therefore, when the future time adverb was encountered, it introduced a reference time, in which the event itself is fully included due to the perfective meaning of *-le*. Now the result state of the event needed to find its antecedent, and two potential problems might occur: (i) if the result state took the time of the adverb in the sentence as its referent, the event and its result state would occur at the same time and thus the processing would crash since the result should follow the event it results from; (ii) if the result state took the time of speech as its reference (i.e., another time available in the discourse), the temporal order would become problematic because now the result state happened at the time of speech, but the time of the event was actually in the future. Such illogical sequences of the event and the result state possibly induced the strong anterior negativity observed at *-le*.

In fact, the finding of the sequence-related anterior negativity is consistent with previous literature. Münte, Schiltz, & Kutas, 1998 compared the processing of sentences involving two types of beginning: a subordinate clause beginning with either 'before' or 'after' followed by a matrix clause. The idea is that a sentence beginning with an *after*-clause reflects the real temporal order of the events as they happened, as in 'after the psychologist submitted the article, the journal changed the policy' (conceptual temporal order: the psychologist submitted the article, the journal changed the policy; same linguistic order). The situation is reversed for *before*-sentences, as in 'before the psychologist submitted the article, the journal changed the policy' (conceptual temporal order: the journal changed the policy, the psychologist submitted the article; reversed linguistic order). An anterior negativity as soon as 300 ms after the onset of 'before' was found, when compared with "after." More recently, Cohn, Paczynski, Jackendoff, Holcomb, & Kuperberg, 2012 investigated the processing of sequential images forming a narrative structure. Four conditions were constructed: (a) normal sequencing (the sequence of images created a coherent event structure, and the images were all semantically related), (b) semantic only (the sequence of images did not form a coherent narrative structure, but they were all semantically related), (c) structure only (the narrative sequencing was coherent, but the images were not semantically related), and (d) scrambled (no coherent narrative structure and no semantic relations existed among the images). While the semantically non-related sequences elicited an N400 compared to the semantically related sequences (i.e., structure only vs. normal), an incoherent sequence of images (i.e., semantic only vs. normal, and scrambled vs. structure only) elicited a frontal negativity similar to morphosyntactic LANs. This LAN was interpreted as an increased processing load to reorder the sequence of events aiming to recreate a coherent narrative structure. Based on Münte, Schiltz, & Kutas, 1998 and Cohn & Paczynski, 2019 findings, our explanation of the oddness of *-le* after a future time adverb as a problem of temporal sequencing is plausible.

Alternatively, one may think that the anterior negativity elicited by *-le* can be associated with an increasing demand of working memory because the odd *le*-sentences (i.e., *-le* placed after a future time adverb) could be saved by adding a following clause involving a subsequent event (note that *-le* was presented separately from the frame of the object with a full stop, indicating the end of the sentence). Therefore, it is plausible that when the subjects saw *-le* in the future condition, they might hold the sentence information in their working memory for further disambiguation by a subsequent clause, which resulted in the emergence of the anterior negativity. Yet, there are several pieces of evidence that do not support the working memory interpretation. First, as remarked by Bott (2010), a working memory LAN is often sustained over a longer period of time (starting at 300 ms after the onset of the critical word and lasting until the end of the epoch), but the latency of the anterior negativity found at *-le* does not fit the description. Second, the past sentences containing *-le* could also be continued with a subsequent clause, such that *-le* indicated a sequence of events in the past. Therefore, maintaining the first event in the working memory before the mention of the second event is an explanation that can hold for both *-le* in the past and in the future, but the anterior negativity was found only for *-le* in a future context compared with a past context. Finally, sentences with *-guo* in a future context could also be saved by a subsequent event, but such sentences did not evoke an anterior negativity. In sum, it is unlikely that the anterior negativity reflects a maintenance operation in the working memory.

Also, one may alternatively argue that the anterior negativity is an instance of N400, reflecting semantic/world knowledge incongruity. Even though the timing of the anterior negativity (300–500 ms after the onset of *-le*) is similar to that of a typical N400, the topographic distribution greatly differed: classic N400s are distributed at the centro-parietal sites of the scalp, while the distribution of the negativity in the present experiment was stronger at the anterior sites, as shown by the visual inspection of the brainwaves and the statistical analyses. Therefore, the anterior negativity found at *-le* in the incongruent condition was unlikely to be an N400.

If the anterior negativity induced by *-le* in a future context is sequencing-related (i.e., two time points either became one or were reversed), did the P600 induced by *-guo* in a future context index a process related to one time point, as stated in our hypothesis? Cohn and Paczynski (2019) noticed that the violation of an event structure is indicated by a P600 effect, be it at the syntactic or cognitive level, or be it involving linguistic or pictorial stimuli. This generalization of the P600 in the case of event structure provides a clue to interpreting the P600 induced by *-guo* with a future time adverb in the present study. The future time adverb always appeared first in the experiment, entailing that the occurrence of an event is placed in a time after the time of speech. The verb presented after the adverb fills the slot of the event inferred by the use of the adverb, such that the structure of the event is projected in the future. The morpheme *-guo* then appeared, indicating a retrospective view of the event. Now a clash emerged between the event structure in the future (created by the future time adverb and the following verb) and the event structure induced by *-guo*. The notion of "retrospective" conceptually calls for a reference point according to which the event is "looked back" at. This means that when the sentence involves only one event, this event is examined from the time of reference, with the event put before this time of reference. In the case of a sentence with a future time adverb, there is no available reference point to anchor so that one can "look back" at this event. Such a structural violation induced P600. Note that, as mentioned earlier, just like *-le*, *-guo* can occur in a future context when two events are stated (in such cases, *-guo* is retrospectively seen from the point of view of the second event). The absence of a LAN in *-guo* further supports our previous argument that the anterior negativity induced by *-le* was not a working memory component because, if so, we should have observed a LAN effect for the *-guo* condition since subjects might be expecting another clause to appear.

We would like to point out that the P600 effect in the present study replicated Qiu and Zhou's (2012) finding. Such a replication revealed that even though the stimulus presentation was different (presenting *-guo* along with the verb in the same frame or separated from the verb in two different frames; placing the time adverb at the initial position of the sentence (i.e., topic-like position) or between the subject and the verb (i.e., unmarked position)), the same type of violation still induced similar processes. Interestingly, Qiu and Zhou (2012) argued that due to the diversity of time adverbs and the occurrence of the aspectual morpheme *-guo* in their study, the attention of the participants might have been guided to the grammatical properties of the sentences, enhancing a P600 and thus reducing an N400 effect at the same time. Our explanation of the conflict between the event structure provided by the time adverb and that provided by *-guo* offers a different perspective for the interpretation of the P600.

Taken together, the underlying mechanisms for processing *-le* and *-guo* are different. Processing *-le* involves two different time points (the time of the event itself, and the time of the result state of this event), which should be chronologically ordered (i.e., the result time of the event has to be *after* the time of the event). The problem with the use of *-le* in a future context (in a simple sentence) comes from this anaphoric process, which can only find its antecedent placed *before* the time of the event, breaking the coherence of the chronological structure. Such a sequencing breakdown induced the anterior negativity (LAN). On the other hand, *-guo* only involves one time point due to its retrospective meaning: the assertion of the posttime of an event. Asserting such a retrospective view requires a conceptual reference for this viewpoint, which is not available in a future simple sentence. This clash in the representation of the event structure is indexed by the P600.

The results of the present experiment can be compared with those found in tense-prominent languages, where time reference is marked on the verb. A dissociation between past vs. non-past has been found for Dutch: the incongruity of a past-tensed verb with a non-past time adverb produced a LAN or no local effect, while the incongruity of a present-tensed verb with a past adverb elicited a P600 (Dragoy, Stowe, Bos, & Bastiaanse, 2012). As described in the Introduction, neurolinguists tried to capture this phenomenon with the Past Discourse Linking Hypothesis (PADILIH). This hypothesis states that processing non-past time reference (i.e., non-past tensed verbs) requires a local binding relation at the sentence level, thus inducing a marker of local binding disruption—P600 (note that such P600 was caused by time reference, not tense violations of the verb; Bos, Dragoy, Stowe, & Bastiaanse, 2013), while processing a past time reference (i.e., past-tensed verbs) induces an anaphoric relation between the time of the event and the speech time ("discourse-linking"), which does not induce a P600 local effect.

Mentioning time reference instead of tense *per se* allows the PADILIH to be crosslinguistically tested. The two aspectual morphemes *-le* and *-guo* are interpreted as having a past time reading by default; therefore, the PADILIH should predict that their temporal violation would have elicited an anterior negativity or no effect at their occurrence due to the difficulty in discourse-linking. However, this prediction is borne out only by *-le*, for which an anterior negativity without a P600 was found, but not by *-guo*, whose violation induced a P600. Hence, our results suggest a finer revision of the original PADILIH, which takes all the expressions of past time reference as equivalent. This revision would include a subdivision between (i) anaphorically-anchored references to past time (as is the case of *-le*), and (ii) non-anaphorically-anchored references to past time (as is the case of *-guo*). This difference between anaphoric and non-anaphoric past time seems to be crucial in terms of its impact on sentence processing. Indeed, a closer look at the designs of Dragoy, Stowe, Bos, & Bastiaanse, 2012 and Bos, Dragoy, Stowe, & Bastiaanse, 2013 revealed that the incongruent verbs were placed in subordinate (relative) clauses. The occurrence of tense in such types of clauses may imply an anaphoric use rather than a deictic (contextually dependent) use of tense (Comrie, 1985; Klein, 1994). Therefore, the tense violation in Dragoy, Stowe, Bos, & Bastiaanse, 2012 and Bos, Dragoy, Stowe, & Bastiaanse, 2013 is, strictly speaking, a violation of the anaphoric use of tense, and not its deictic use. In addition, there exists neurolinguistic counterevidence against the original version of the PADILIH provided by tense-prominent languages. In the investigation of the neurolinguistic processing of events in German, Bott (2010) adopted the violation of a past-tensed verb by a preceding future time adverb (compared with a past-tensed verb placed after a past time adverb), with verbs being placed in simple sentences (i.e., deictically used). This time reference violation elicited a broad P600, against the predictions made by the PADILIH. Taken together, previous ERP experiments regarding the processing of time reference (and past time reference in particular) and our current research argue for a difference between anaphoric vs. non-anaphoric reference to a past event, regardless of the linguistic device used to express such a reference (i.e., tense or aspect) and the typology of the language (tense- or aspect-prominent).

A final note is needed before we end the discussion. As mentioned in the Materials section, the present experiment employed five degrees of remoteness for the temporal adverbs (instant, day, week, month and year) to make the sentences sound more natural and to increase the diversity of the sentences. Although we did not intend to study the effect of "remoteness" and did not observe any difference in the online acceptability rating regarding the degree of remoteness, it is important to point out that temporal distance of events can modulate the brain response during sentence comprehension. Ditman et al. (2008) revealed that the longer the temporal distance between two events, the larger the amplitude of the N400. Becker et al. (2013) also found that long intervening events (e.g., 'studied the map' vs. 'grabbed the map') could wipe out the effects of grammatical and lexical aspect, indicating how temporal information associated with verbs can interact with long vs. short temporal shifts. Future research is needed to find out whether temporal distance of temporal adverbs, as employed in the current study, has an influence on the processing of *-le* and *-guo*.

5. Conclusion

The findings from this experiment expand the knowledge of the neural processing of time reference in tense languages and provide new insights from the perspective of a tenseless language—Mandarin Chinese. The present study reveals that not all the references to past time through aspect in an aspect-prominent language are processed in the same way. Importantly, the results further show that the distinction between anaphoric and non-anaphoric references to time, as respectively demonstrated in *-le* and *-guo* in Mandarin, seems to be a better crosslinguistic explanation for the different processing patterns found in the ERP literature.

Funding

This research was supported by grants from the Ministry of Science and Technology (formerly National Science Council) of Taiwan (MOST 106-2410-H-003-137-MY2 and MOST 108-2410-H-003-020-MY3).

CRediT authorship contribution statement

Aymeric Collart: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Shiao-hui Chan:** Conceptualization, Methodology, Formal analysis, Resources, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

None.

Acknowledgments

The authors are thankful for the valuable comments of two anonymous reviewers on an earlier draft of this manuscript, as well as for the constructive comments and discussion on previous interpretations of the results from the 32nd and 33rd Annual CUNY Human Sentence Processing Conferences (2019: University of Colorado, Boulder, Colorado, USA; 2020: UMass Amherst, Amherst, Massachusetts, USA (online sessions). The authors also thank the research assistants of the Neurolinguistics Lab at National Taiwan Normal University for their help during the data collection process.

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