Brain responses to agreement violations of Chinese grammatical aspect

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Introduction

The event-related potential (ERP) studies of language have suggested that the brain honors not only the distinction between semantic and syntactic processes, but also the distinction of some syntactic operations. For example, the N400, a negativity maximal over the centroparietal areas, reflects semantic processing \cite{1}. The early left anterior negativity (ELAN, 100–300 ms) has been taken to reflect the computation of local phrase structure, whereas the left anterior negativity (LAN, 300–500 ms) has been taken to reflect morphosyntactic processing \cite{2,3} (but see Refs \cite{4–7} for alternative views). Within the morphosyntactic domain, LAN-type effects or patterns have been observed for agreement violations of person, number, gender, or tense \cite{8–14}, although only a P600 is obtained for these violations sometimes \cite{15–17}. The brain therefore seems to be also equipped for commonalities among a variety of morphosyntactic processing.

Recently, a study of tense agreements has found that violations of regular past tense inflection (e.g. Yesterday I frown at Billy) evoke a LAN, but violations of irregular past tense inflection do not \cite{18}. This finding suggests that LAN reflects rule-governed compositional processes at the syntactic level (see Ref. \cite{19}, for evidence from the LAN evoked by overregularizations of irregular verbs, e.g. bringed), rather than the syntactic tense violation itself. LAN has also been explained as reflecting domain-general, rule-governed processing of symbols, including nonlinguistic sequencing \cite{6}.

This study aims at investigating ERP effects of agreement violations of Chinese grammatical aspect. Aspects are defined as ‘different ways of viewing the internal temporal constituency of a situation’ \cite{20}, p. 3). The grammatical aspect captures ways in which a language uses grammatical markers to describe the temporal structure of an event. An event-related potential experiment was conducted to investigate event-related potential correlates of agreement violations of Chinese grammatical aspect. Participants read sentences containing either aspect agreement violations, semantic violations, or no violations. Semantic violations elicited an N400, whereas aspectual violations elicited a 200–400 ms posterior and left central negativity, followed by a P600, instead of left anterior negativity or N400, suggesting that left anterior negativities may not reflect a general, rule-governed, syntactically compositional process, and that grammatical aspect processing is at least not completely semantically driven. The negativity mostly reflects a failure to bind aspect markers or the detection of aspectual errors. NeuroReport 19:1039–1043 © 2008 Wolters Kluwer Health | Lippincott Williams & Wilkins.

\textbf{Keywords}: agreement violations, early posterior negativity, event-related potentials, grammatical aspect, language, left anterior negativity, P600, syntax.

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This study aims at investigating ERP effects of agreement violations of Chinese grammatical aspect. Aspects are defined as ‘different ways of viewing the internal temporal constituency of a situation’ \cite{20}, p. 3). The grammatical aspect captures ways in which a language uses grammatical markers to describe the temporal structure of an event (completed, ongoing, etc.). Chinese has several aspect markers, for example, perfective markers le and yijiong (‘already’) and progressive (imperfective) markers zhe and zhengzai (‘ongoing’). Both yijiong and zhengzai are adverbs. In contrast, the grammatical status of le and zhe is of great debate linguistically (inflectional suffixes or auxiliary words).

In a Chinese sentence, the perfective markers yijiong and le and the progressive markers zhengzai and zhe can co-occur, with yijiong or zhengzai before and le or zhe after a verb, as in (1a) in Table 1. However, as a rule, le cannot co-occur with zhengzai; their co-occurrence induces an aspect disagreement, as in (1b). In addition, each of these four markers can occur by itself. Thus, a sentence containing zhengzai but no zhe is grammatical. If the LAN reflects general, rule-governed, syntactically compositional processes, a LAN should be elicited by agreement violations of grammatical aspect.

To our knowledge, no studies have investigated ERP responses to the processing of grammatical aspect itself, although using both behavioral and ERP data, an earlier study has demonstrated the effect of verb aspect on the activation of event knowledge, by showing that the progressive form of a verb (e.g. was skating) leads to expectancies about the location of the event denoted by the verb \cite{21}.

If the co-occurrence of le and zhengzai (‘ongoing’), as in (1b), constitutes only a semantic violation of progressiveness, an N400 should be observed at le. We therefore also used sentences with semantic violations, for example, (1c), to observe the spatiotemporal patterns of the N400 effects.
were significantly more acceptable (mean ¼ 4.45, P = 0.01). Moreover, compared with the sentences containing aspectual violations, correct counterparts (containing the progressive marker zhengzai but not the perfective marker le) were significantly more acceptable (mean ¼ 4.45, P < 0.01). Three experimental lists were created by rotating the conditions of the critical items. For each list, 120 critical items were pseudorandomly mixed with 260 filler items, to counteract the verb-medial structure of the critical items, balance the numbers of correct and incorrect items, and prevent the participants from predicting the perfective marker le at the position immediately following the verb.

The fillers consisted of 190 verb-final sentences (110 syntactically or semantically incorrect) and 70 correct subject-verb-object sentences (40 contained zhengzai, and 30 yijing and sentence-final le). Each participant received only one experimental list.

**Procedure**
Participants sat about 1 m away from a computer screen. They read the sentences sequentially, as each word (or sometimes a short phrase) appeared in the center of the screen. Verbs, the perfective marker le, and critical NPs were always presented individually. Each trial started with a central fixation cross presented for 800 ms, followed by a 500-ms blank. Each word or short phrase appeared for 400 ms, with an additional 100 ms interstimulus interval. After the last segment of each sentence there was an 800-ms blank, followed by a row of question marks (?????) which reminded participants to make the acceptability judgment by pressing a button. This cue remained on the screen until the participant had responded or for maximum 3 s.

**Event-related potential recording and data analysis**
The EEG was recorded from 62 Ag/AgCl electrodes mounted in an elastic cap (Quick-Cap, NeuroScan Inc., Herndon, Virginia, USA). Recordings were referenced to the left mastoid, but rereferenced to linked mastoids offline. The horizontal and vertical electrooculogram was also monitored. Electrode impedances were kept below 5 kΩ. The EEG and electrooculogram were amplified with a band-pass from DC to 70 Hz and the sample rate was 500 Hz. ERPs were low-pass filtered off-line with 10 Hz for the plots only. The epoch interval was 1200 ms, ranging from 200 ms before the onset of the critical word to 1000 ms after it. We used a 200-ms prestimulus baseline for le and the critical NP and a 100-ms poststimulus baseline for the verb (because the word immediately preceding the verb differed between the correct and the aspectual violation conditions, see Table 1).

ERPs were analyzed separately for midline and lateral electrodes. Omnibus ANOVAs for midline electrodes included two within-subject factors: electrode (Fz, Cz, Pz) and condition. For lateral electrodes, three within-subject factors were included: hemisphere (left, right), region (anterior, central, posterior), and condition. Crossing the variables region and hemisphere yielded six regions of interest, with six electrodes each: left anterior (F3, F5, F7, FC3, FC5, and FT7); left central (C3, C5, T7, CP3, CP5, and TP7); left posterior (P3, P5, P7, PO3, PO7, and O1); right anterior (F4, F6, F8, FC4, FC6, and FT8); right central (C4, C6, T8, CP4, CP6, and TP8); and right posterior (P4, P6, P8, PO4, PO8, and O2). The Greenhouse–Geisser correction was applied when evaluating effects with more than one degree of freedom in the numerator.

**Results**
Average accuracy was 96.67% across conditions, indicating that participants distinguished the acceptable from the unacceptable sentences. Figures 1 and 2a show the grand average ERPs elicited by the perfective marker le and the verb, respectively, for the correct and the aspectual violation conditions. Figure 2b shows the ERPs elicited by the first object NP for the correct and the semantic violation conditions.
As shown in Fig. 1a, aspectual violations elicited a 200–400 ms negativity with a posterior and left central distribution, followed by a 450–800 ms positivity. For this positivity, mean amplitudes were computed relative to a baseline of 200–400 ms following the onset of le to compensate for the preceding ERP amplitude differences. As visible from Fig. 1b, the late positivity after the renormalization in the 200–400 ms window had a centroparietal focus typical of the P600.

In the 100–500 ms range, the verb did not elicit any differences between the correct and the aspectual violation conditions. Thus, the 200–400 ms negativity observed at le should be due to the presentation of le itself. In addition, semantic violations elicited a 300–500 ms negativity, which had a broad distribution and was larger over right compared with left hemisphere (see Fig. 2b). This was an N400.

All these observations were verified statistically. At le, the global ANOVAs revealed an interaction of condition (correct vs. aspectual violation) and electrode at the midline sites [F(2, 34)=24.46, P<0.001] and an interaction of condition, region, and hemisphere at the lateral sites [F(2, 34)=3.61, P<0.05] in the 200–400 ms window. These interactions remained significant when the mean amplitude measures were normalized with the vector scaling procedure recommended by McCarthy and Wood [22] [midline: F(2, 34)=30.46, P<0.0005; lateral: F(2, 34)=3.37, P=0.054]. Separate analyses revealed a main effect of condition at both Pz [F(1, 17)=13.8, P<0.01] and the bilateral posterior and the left central regions [F(1, 17)=7.27–20.26, P<0.05].

**Fig. 1** Grand average event-related potentials time locked to the onset of the perfective marker le, for the correct and aspectual violation conditions. (a) Shows the negativity effects; (b) Shows the P600 effects after the renormalization in the 200–400 ms window.

**Fig. 2** Grand average event-related potentials time locked to the onset of the verb for the correct and aspectual violation conditions (a) and to the onset of the first object noun phrase for the correct and semantic violation conditions (b). A 100-ms poststimulus baseline was used for the verb (a) (see text for reason) and a 200-ms prestimulus baseline for the noun phrase (b).

For the 450–800 ms window, the global ANOVAs revealed an interaction of condition and electrode at the midline sites [F(2, 34)=12.68, P=0.001; normalized: F(2, 34)=15.71, P<0.0005] and an interaction of condition and region at the lateral sites [F(2, 34)=12.63, P=0.001; normalized: F(2, 34)=16.58, P<0.0005]. Separate analyses revealed a main effect of condition at each midline electrode and lateral region [F(1, 17)=10.11–48.08, P<0.01]. The ANOVA with post-hoc Newman–Keuls comparisons performed on the mean difference amplitudes between the aspectual violation and the correct conditions showed that the P600 effect was larger at the centroposterior region (including Cz and Pz) compared with the anterior region (including Fz, P<0.01).

At the verb, the ANOVA revealed neither a main effect of condition nor any interaction of condition and the other variables in both the 100–300 ms and the 300–500 ms windows (F<1 or P>0.10). At the object NP, the ANOVA revealed an interaction of condition and electrode at the midline sites in the 300–500 ms window [F(2, 34)=7.18, P<0.01]. This interaction was, however, no longer significant when the normalization procedure was used [F(2, 34)=1.57, P=0.228]. For the lateral sites, there was an interaction of condition and hemisphere [F(1, 17)=4.03, P=0.061; normalized: F(1, 17)=4.73, P<0.05], with a larger negativity effect over right hemisphere [left: F(1, 17)=7.81, P<0.05; right: F(1, 17)=54.25, P<0.0005].
Discussion

This study revealed a 200–400 ms negativity with a posterior and left central distribution, followed by a 450–800 ms P600, for agreement violations of Chinese grammatical aspect. The P600, which has been commonly observed for agreement violations of person, number, gender, or tense [8–18], may reflect syntactic repair or the monitoring and resolution of conflict caused by the aspect disagreement (see Ref. [23] for a review of the functional significance of the P600).

One might question whether the negativity at least partly reflects the difference on the temporal structure of an event, because the event denoted by the verb was completed in the correct condition, for example, already prepared in (1a), but was ongoing in the aspectual violation condition, for example, was preparing in (1b). This possibility is, however, excluded by the finding of no differences at the verb in the 100–500 ms window between the two conditions. The negativity therefore was elicited by the presentation of the perfective marker le itself.

Is the negativity a LAN or does it include a LAN? We do not think it likely, because anterior distribution is strongly characteristic of LAN effects. Although the negativity was stronger over the left compared with the right sites, it had a posterior and left central rather than anterior distribution. Thus, no LAN effects were found for agreement violations of Chinese grammatical aspect, although some earlier studies have revealed LAN effects or patterns for agreement violations of person, number, gender, or tense in Indo–European languages [8–14]. Given that it is a clear rule that the perfective marker le cannot co-occur with the progressive marker zhengzai, the lack of a LAN in this study suggests that LANs typically elicited by morphosyntactic violations in Indo–European languages may not reflect a general, rule-governed, syntactically compositional process, although what processes the LAN exactly reflects goes beyond the purpose of this study (see Refs [2–7] for views on this issue).

Does the negativity reflect just a semantic violation of progressiveness, given that the progressive marker zhengzai (‘ongoing’) had occurred before the perfective marker le was presented? No, because this negativity had very different spatiotemporal characteristics from the N400 to the semantic violations. In addition, this negativity, but not the N400, was followed by a P600. However, one possibility, which cannot be completely excluded, is that an N400 effect may be included in the negativity. Thus, the processing of grammatical aspect is at least not completely semantically driven. This conclusion has important implications for understanding Chinese sentence comprehension, given a widely held conjecture that sentence comprehension in Chinese relies more on semantic analyses compared with Indo–European languages. Some caution is required, given that the aspectual and semantic violations were observed with fixed closed-class and variable open-class words, respectively.

What does the negativity mostly reflect? It may reflect a failure to bind a perfective marker and a progressive marker together. Alternatively, it may reflect the detection of aspectual errors. In the sentences containing aspectual violations, le was an ‘intruder’ according to the syntactic context where it occurred (the sentences are grammatical without le). At least two earlier studies have found similar (but not completely the same) negativity [24,25]. In one study, phrase structure violations, as in ‘Max’s of proof …’, elicited an ELAN (called N125) and a left temporoparietal negativity between 300 and 500 ms [24]. In the other study, anomalous object shifts, as in the word-by-word Swedish version of ‘You bought paint not but …’, elicited a 200–400 ms bilateral posterior negativity [25]. As the perfective marker le, the critical words in both the studies (e.g. of or not) are also closed-class words. More importantly, they were also intruders according to the syntactic context in which they occurred (the sentences are grammatical without them). These posterior negativities therefore might reflect a more general detection of the intrusion of a closed-class word (a perfective marker in this study). Further study is necessary to determine what processes the 200–400 ms negativity exactly reflects.

Conclusion

The agreement violations of Chinese grammatical aspect are associated with a biphasic 200–400 ms posterior and left central negativity and P600 pattern, instead of LAN or N400. The negativity may reflect either a failure to bind aspect markers or the detection of aspectual errors, whereas the P600 may reflect syntactic repair or the monitoring and resolution of conflict caused by the aspect disagreement. In addition, the processing of Chinese grammatical aspect is at least not completely semantically driven and the LAN effects typically indexing morphosyntactic processing may not reflect a general, rule-governed, syntactically compositional process.

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References