The Functional Independence of Discourse-Referential from Syntactic Processing in Reading Chinese: Evidence from ERPs

Jing Yu and Yaxu Zhang

Peking University

Julie E. Boland

University of Michigan

Address correspondence to:

Yaxu Zhang, Ph.D.
Department of Psychology
Peking University
Beijing 100871, China

Tel: +86 10 62759770
Fax: +86 10 62761081
E-mail: yxzhang@pku.edu.cn

Abstract

An event-related brain potential experiment was conducted to investigate whether the computation of local phrase structure using syntactic category information necessarily precedes discourse referential processing during Chinese sentence reading. We manipulated both the correctness of syntactic category and the discourse-referential ambiguity of the critical nouns. Syntactic anomalies elicited a 300–500-ms left anterior negativity (LAN) and a 500–1000-ms bilateral anterior negativity, as well as a P600. Referential ambiguities elicited a sustained negativity (Nref) that started to appear in the 250–300-ms time window. Crucially, the Nref effects were not affected by whether the local phrase structure was correct or not during the early time window. These results suggest that local phrase structure building based on syntactic category information is not a necessary prerequisite for discourse-referential interpretations during Chinese sentence reading. We therefore argue against processing models that assume a functional primacy of syntactic category over discourse-referential processing.

Keywords: syntax, syntactic category, referential ambiguity, discourse context, language comprehension, ERPs

Language comprehension involves the construction of multiple levels of linguistic representation, including not only syntactic and semantic representations, but also discourse level representations, such as referential representations that indicate who or what is being talked about. How exactly these processes interplay is a central question, and theories of sentence processing differ in how and when semantic and discourse-referential information is used, relative to syntactic processing.

Modular, syntax-first theories of parsing assume that the parser is autonomous and that, syntactic structure building must occur prior to semantic and discourse processes. As a result, these non-syntactic processes can only occur on the basis of well-formed syntactic structures (e.g., Frazier, 1987; Friederici, 2002; Friederici & Weissenborn, 2007; Mitchell, Corley, & Garnham, 1992). Syntax-first accounts have been supported by event-related brain potential (ERP) studies that have demonstrated a functional primacy of syntactic over semantic processing (e.g., Friederici, Steinhauer, & Frisch, 1999; Hahne & Friederici, 2002, Experiment 1). These studies reported an absence of N400 (semantic anomaly) effects for combined syntactic and semantic anomalies, as in the German version of *The door lock was in-the* *eaten*, suggesting that failed syntactic processing blocks lexical semantic integration.

In contrast, in interactive theories, non-syntactic information is allowed to affect the initial parsing (e.g., Altmann & Steedman, 1988; Hagoort, 2005; MacDonald, Pearlmutter, & Seidenberg, 1994; Van Berkum, Brown, & Hagoort, 1999). In fact, some models have explicitly assumed the independence of semantic from syntactic processes (e.g., Boland, 1997a; Kim & Osterhout, 2005; Kuperberg, 2007). Interactive accounts have been supported by ERP evidence against the functional primacy of syntax relative to lexical-semantic integration (Kim & Osterhout, 2005; Yu & Zhang, 2008; Zhang, Yu, & Boland, 2010). For example, Zhang et al. (2010) observed a larger N400 for a word that was both semantically anomalous and of the wrong syntactic category compared to a word that was semantic sensible, but of the wrong syntactic category. This finding suggests that lexical-semantic integration occurred for this word despite the fact that it couldn't be syntactically integrated into a well-formed syntactic structure.

The present study builds upon Zhang et al. (2010), but is concerned with the interplay between syntactic category processing and discourse referential processing, rather than lexical-semantic integration. Using Chinese, we investigated whether the structure-building operations triggered by syntactic category processing necessarily precede discourse referential processing, an issue that has not been resolved empirically. Previous studies have investigated the mode of interplay between some aspects of discourse-level processing and syntactic ambiguity resolution (e.g., Altmann & Steedman, 1988; Boland, 1997b; Boland & Blodgett, 2001; Mitchell et al., 1992; Trueswell & Tanenhaus, 1991; Van Berkum et al., 1999). Some of these studies have explicitly focused upon referential discourse context, but (in contrast to the current study) they examined referential context in terms of the resolution of syntactic ambiguity. For example, using a self-paced reading task, Altmann and Steedman (1988) observed an immediate influence of referential context on the interpretation of disambiguating prepositional phrases. And using ERPs, Van Berkum et al. (1999)

found that in contrast to a one-referent discourse context, a two-referent context can immediately resolve the complement clause versus relative clause ambiguity, by favoring the relative-clause interpretations.

Although earlier studies have examined whether there is a temporal primacy of syntactic over discourse processing (e.g., Altmann & Steedman, 1988; Mitchell et al., 1992; Van Berkum et al., 1999), our study more directly addresses the issue of functional primacy of syntactic processing over discourse processing by investigating whether failed construction of local phrase structure using syntactic category information blocks, at least temporally, discourse referential processing.

Following the pioneering work of Van Berkum and colleagues, we will be using the Nref component to measure the processing of referential ambiguity (e.g., Nieuwland & Van Berkum, 2008; Van Berkum et al., 1999; see Van Berkum, Koornneef, Otten, & Nieuwland, 2007, for review). The Nref is a frontal, sustained negativity that emerges about 300 ms after noun onset. Although the Nref first appears at about the same time as another negative component, the semantic N400, the Nref differs in that it is sustained over half a second or more without a well-defined peak, and tends to be more frontal in scalp distribution. In our study, we used a full factorial design that crossed correctness of syntax (local phrase structure) with discourse-referential ambiguity. Stimuli were three-sentence discourses, as illustrated in Table 1.

---------- Insert Table 1 about here ----------

The subject nouns of the third sentences of the short discourses (*brother*) served as the critical words. There were neither syntactic category anomalies nor referential ambiguities for the critical words in the syntactically correct and referentially unambiguous (CONTROL) condition; the discourse context provided a single unique referent for the syntactically correct critical noun. For the referentially ambiguous only (REFERENTIAL) condition, the critical word had two equally eligible candidate referents. For the syntactically incorrect only (SYNTACTIC) condition, the degree adverb *hen* ('very') was inserted immediately before the critical noun, resulting in a syntactic category anomaly. This syntactic manipulation was also used in Zhang et al. (2010). In Chinese, *hen* can be followed by an adjective or a verb but not by a noun (Lü & Zhu, 1979). In the syntactically incorrect and referentially ambiguous (DOUBLE) condition, the critical noun had two equally eligible referents and *hen* appeared immediately before it.

We expected the REFERENTIAL condition to elicit an Nref, the sustained negative shift indexing the processing of referential ambiguity. For the SYNTACTIC condition, we expected a 300–500 ms left-lateralized negativity and a P600, as observed in previous studies (e.g., Zhang et al., 2010).

More importantly, if syntactic category processing indeed necessarily precedes discourse referential processing, the inability to construct local phrase structure would block, at least temporally, referential interpretations of NPs that contain syntactic category anomalies. In such a case, the ERPs for the DOUBLE condition should be the same as those for the SYNTACTIC condition, at least in the early time window, because the referential ambiguity would effectively be invisible. Thus, an interaction of referential ambiguity with syntactic correctness would be observed.

In contrast, if referential interpretations are functionally independent of the computation of local phrase structure, then referential processing should proceed in the absence of successful construction of local phrase structure, resulting in a main effect of referential ambiguity rather than its interaction with correctness of syntactic category. In that case, an Nref effect in addition to syntactic effects (left negativity in an early time window and P600) should be observed.

Method

Participants

After giving informed consent, sixteen students from Peking University participated in the experiment (mean age 21 years, range: 18-25 years; 8 females). One participant was replaced because of a relatively low (89%) accuracy on the probe verification task (see below). All were native speakers of Chinese, were right-handed, and had normal or corrected-to-normal vision.

Materials

The critical materials were 160 sets of Chinese short discourses consisting of three sentences (see Table 1 for examples). In each discourse, the first sentence introduced two human or object entities (e.g., “one brother and one sister” or “two brothers”), between which there was a clear contrast provided by the second sentence (e.g., “is very fat” and “is very thin”). The third sentence was the critical sentence, in which the subject NP was composed of the demonstrative pronoun *nage* (“that”) and a noun in the syntactically correct conditions, as “that brother”. For the syntactically incorrect conditions, the degree adverb *hen* (‘very’) appeared between the pronoun and noun, as “that very brother”, resulting in a syntactic anomaly at the noun (no any anomalies at *hen*).

The subject nouns of the third sentences served as the critical words for ERPs. They had a single unique referent in the referentially unambiguous conditions, but had two equally eligible candidate referents in the referentially ambiguous conditions. In addition, the critical words were lexically repeated for the same number of times (twice) in their preceding discourse context for each of the four conditions, to avoid lexical repetition effects.

The 160 sets of critical short discourses were assigned to four experimental lists using a Latin square procedure. For each list, the 160 critical items were pseudo-randomly mixed with 90 fully unproblematic filler short discourses, 50 of which had almost the same sentence construction as the critical items for the syntactically incorrect conditions, except for an adjective appeared between the degree adverb *hen* and the subject noun, to prevent participants from predicting the presence of a subsequent anomaly based on the reading of *hen*. The other 40 fillers had other sentence constructions.

Procedure

Participants were seated in a comfortable chair approximately 1 m from the computer screen in a dimly lit and sound-attenuated room. They read the discourses sequentially, as each word (or sometimes a short phrase) appeared in the center of the screen. Each trial started with a central fixation cross presented for 800 ms, followed by a 500 ms blank screen. Each word or short phrase was presented for 400 ms, with a 100-ms inter-stimulus interval. After the presentation of the last segment of the discourse, there was an 800-ms blank, followed two fifth of the time by a probe word. Participants were asked to read carefully and to judge whether the probe had been present in the preceding discourse by pressing a button.

The probe verification task was used to ensure that participants read attentively and that problematic discourses could also be tested. Of the probes, 50 percent were YES probes. The content words at each word position of the discourses served equally often as YES probes. The NO probes consisted of content words that were unrelated to the words in the discourse. The probe words of each category were evenly distributed across conditions. The probes remained on the screen until the participant had responded or for maximum of 3 s. The next trial began after a 1-s interval.

Each participant received only one of the four experimental lists. The total 250 discourses within each list were divided into five blocks of 50 trials. Prior to the experimental blocks, participants received a practice block of 12 trials. The experimental session lasted about 1 hr.

ERP Recording

The electroencephalogram (EEG) was recorded from 62 Ag/AgCl electrodes mounted in an elastic cap (Quik-Cap, NeuroScan Inc., Herndon, Virginia, USA). Recordings were referenced to the left mastoid but were re-referenced to linked mastoids offline. The horizontal electrooculogram (EOG) was recorded from electrodes placed at the outer canthus of each eye, and the vertical EOG was recorded from electrodes placed above and below the participants' left eye. Electrode impedances were kept below 5kΩ. The EEG and EOG were amplified with a band-pass from DC to 70 Hz and were recorded continuously with a digitization rate of 500 Hz. ERPs were additionally filtered off-line (5 Hz low pass, 24 dB/oct) for the plots only. All statistical analyses were performed on the original data.

ERP Data Analysis

ERPs time-locked to the critical words were computed for each participant, condition, and electrode site. We applied a detrending algorithm to correct for a common linear component caused by the slow voltage shifts that are common for DC recordings, as in some previous studies (e.g., Fiebach, Schlesewsky, & Friederici, 2002; Phillips, Kazanina, & Abada, 2005; Zhang et al., 2010). A 15-s time interval, ranging from the onset of the critical words to 15 s after them, was used to estimate the linear component. The subsequent analyses were based on 1,000-ms epochs, starting from the onset of the critical words. We used a 100-ms post-stimulus baseline because the word immediately preceding the critical word differed between the conditions containing syntactic anomaly and the conditions containing no such an anomaly (see Table 1). All epochs were evaluated individually for EOG or other artifacts. Epochs with amplitudes exceeding ±70 μV were excluded from the averages through artifact rejection. The overall rejection rate was 9.49%, equal for all four conditions.

We first chose two relatively large time windows on the basis of visual inspection and earlier studies (e.g., Van Berkum et al., 1999; Zhang et al., 2010): (a) 300–500 ms after the onset of the critical words both for left-lateralized negativity effects to syntactic anomalies and for the early part of Nref effects to referential ambiguity, and (b) 500–1000 ms for the later part of Nref effects as well as P600 effects. In addition, to observe more dynamic interplay between syntactic correctness and referential ambiguity, we chose 18 consecutive 50-ms time windows in the 100–1000 ms range (i.e., 100–150 ms, 150–200 ms, etc.). All statistical analyses were performed on the mean amplitudes in the selected time windows.

ERPs were analyzed separately for midline and lateral electrodes. Omnibus ANOVAs for midline electrodes included three within-subject factors: electrode (Fz/Cz/Pz), syntactic correctness (correct/incorrect), and referential ambiguity (ambiguous/unambiguous). Omnibus ANOVAs for lateral electrodes included four within-subject factors: hemisphere (left/right), region (anterior/central/posterior), syntactic correctness, and referential ambiguity. Crossing the variables of region and hemisphere yielded six regions of interest, with six electrodes for each region of interest: 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).

Only effects involving the factors syntactic correctness and referential ambiguity are reported. The Greenhouse-Geisser correction was applied when evaluating effects with more than one degree of freedom in the numerator. In these cases, the original degrees of freedom and the corrected mean square error and probability levels are reported.

Results

The overall average accuracy on the probe verification task was 98.00% (SD = 2.37%), equal for all four conditions, suggesting that participants read the stimuli attentively.

Figure 1 shows grand average ERPs elicited by the critical words for all four critical conditions. Figure 2 shows difference waves computed by subtracting the grand average ERP in the CONTROL condition from that in each of the three problematic conditions (REFERENTIAL, SYNTACTIC, and DOUBLE). In addition, Figure 3 shows the scalp distributions for the 300–500-ms and 500–1000-ms time windows for the difference waves in Figure 2.

---------- Insert Figures 1–3 about here ----------

As shown in Figures 1–2, the REFERENTIAL condition elicited a 300–1000 ms sustained negativity (Nref). The Nref has a broad distribution over the midline electrodes, and is most prominent at frontal and central sites (see Figure 3). In contrast, the SYNTACTIC condition elicited a left anterior negativity (LAN) in the 300–500-ms time window and a bilateral anterior negativity in the 500–1000-ms time window, as well as a 350–1000-ms positivity that was more pronounced over posterior sites (P600). More importantly, the DOUBLE condition elicited both LAN and Nref effects, resulting in a larger negativity over left anterior sites compared to both the REFERENTIAL and SYNTACTIC conditions. In addition, the DOUBLE condition also elicited a P600. These observations were statistically verified by ANOVAs performed on the mean amplitudes in the 300–500-ms, 500–1000-ms, and 18 consecutive 50-ms time windows, respectively. The results of the global ANOVAs for the 300–500-ms and 500–1000-ms time windows are shown in Table 2.

---------- Insert Table 2 about here ----------

The 300–500-ms Time Window

At the midline electrodes, the global ANOVA revealed a main effect of referential ambiguity, with a significant negativity for the conditions with referential ambiguities. In addition, there was an interaction of syntactic correctness with electrode, which was due to a positivity for the conditions with syntactic anomalies at Pz only, as expected for a P600 ($F(1, 15) = 6.76$, $p = 0.020$, $MSE = 5.22$).

At the lateral electrodes, the global ANOVA again revealed a main effect of referential ambiguity. This effect exhibited a (statistically borderline) interaction with hemisphere, but a significant negativity for the conditions with referential ambiguities was obtained in each hemisphere (left, $F(1, 15) = 12.58$, $p = 0.003$, $MSE = 0.58$; right, $F(1, 15) = 9.67$, $p = 0.007$, $MSE = 0.31$). In addition, there was an interaction of syntactic correctness, region, and hemisphere, which was due to a negativity at left anterior sites and a positivity at bilateral posterior and right central sites for syntactic anomalies (left anterior, $F(1, 15) = 5.15$, $p = 0.038$, $MSE = 1.99$; left posterior, $F(1, 15) = 7.93$, $p = 0.013$, $MSE = 1.92$; right posterior, $F(1, 15) = 14.60$, $p = 0.002$, $MSE = 1.55$; and right central, $F(1, 15) = 9.79$, $p = 0.007$, $MSE = 1.28$).

Most importantly, there was neither a referential ambiguity × syntactic correctness interaction, nor an interaction of referential ambiguity, syntactic correctness, and any location variable.

In sum, in the 300–500-ms time window, the referential ambiguity elicited a negativity (Nref) with a broad distribution. Crucially, the Nref effects were observed whether the local phrase structure was correct or not. In addition, the syntactic anomalies elicited a left anterior negativity (LAN) and a centro-posterior positivity (P600).

The 500–1000-ms Time Window

As shown in Table 2, at the midline electrodes, the global ANOVA revealed a main effect of referential ambiguity, with a significant negativity for the conditions with referential ambiguities. In addition, there was an interaction of syntactic correctness with electrode, which was due to a positivity for the conditions with syntactic anomalies at Pz only ($F(1, 15) = 22.66$, $p < 0.0005$, $MSE = 3.71$).

At the lateral electrodes, the global ANOVA revealed a referential ambiguity × region × hemisphere interaction, which was due to a significant negativity for the conditions with referential ambiguities at left posterior and right central sites (left posterior, $F(1, 15) = 17.00$, $p = 0.001$, $MSE = 0.33$; right central, $F(1, 15) = 7.74$, $p = 0.014$, $MSE = 1.01$). In addition, there was an interaction of syntactic correctness and region, resulting from an anterior negativity and a centro-posterior positivity to syntactic anomalies (anterior, $F(1, 15) = 5.06$, $p = 0.040$, $MSE = 1.52$; central, $F(1, 15) = 10.84$, $p = 0.005$, $MSE = 1.00$; posterior, $F(1, 15) = 42.17$, $p < 0.0005$, $MSE = 0.91$).

In sum, in the 500–1000-ms time window, the referential ambiguity elicited a negativity (Nref) that had a broad distribution at the midline sites and had a left posterior and right central distribution over lateral sites. Crucially, the Nref effects were observed whether the local phrase structure was correct or not. In addition, the syntactic anomalies elicited an anterior negativity and a centro-posterior positivity (P600). The anterior negativity, which was also observed in Zhang et al. (2010), may reflect either later processing of syntactic anomaly or some related processes such as memory storage cost that was caused by the missing of an adjective between *hen* (‘very’) and the critical noun (for sustained anterior negativity reflecting memory cost, see Fiebach et al., 2002; Münte, Schiltz, & Kutas, 1998).

The 18 Consecutive 50-ms Time Windows in the 100–1000-ms Range

At the midline electrodes, ANOVAs performed for these 50-ms time windows showed that from the 300–350-ms time window, the earliest window in which significant Nref effects were obtained, until the 500–550-ms time window, there was a main effect of referential ambiguity indicative of Nref effects ($F(1, 15) = 5.28\sim 16.38$, $ps < .05$). Crucially, in each 50-ms time window in the 300–550-ms range, there was neither a referential ambiguity × syntactic correctness interaction ($F(1, 15) = 0.01\sim 2.29$, $ps > .15$), nor an interaction of referential ambiguity, syntactic correctness, and electrode ($F(2, 30) = 0.01\sim 1.97$, $ps > .17$).

In the following two consecutive 50-ms time windows, there was an interaction of referential ambiguity with syntactic correctness (550–600-ms, $F(1, 15) = 7.04$, $p = 0.018$, $MSE = 11.50$; 600–650-ms, $F(1, 15) = 4.89$, $p = 0.043$, $MSE = 14.66$), due to referential ambiguity (Nref) effects obtained only when there were no syntactic anomalies. In each 50-ms window in the 650–1000-ms range, there was a main effect of referential ambiguity indicative of Nref effects ($F(1, 15) = 4.67\sim 8.89$, $ps < .05$), without interaction with syntactic correctness ($F(1, 15) = 0.54\sim 3.23$, $ps > .090$), or with syntactic correctness and electrode ($Fs < 1$).

At the lateral sites, from the 250–300-ms time window, the earliest window in which significant Nref effects were obtained, until the 700–750-ms window, there was either a main effect of referential ambiguity ($F(1, 15) = 4.56\sim 9.34$, $p = .007\sim .050$), or its interaction with hemisphere ($F(1, 15) = 7.38\sim 8.43$, $ps < .05$) or with region and hemisphere ($F(2, 30) = 3.58\sim 4.66$, $ps < .05$). Crucially, in each 50-ms time window in the 250–750-ms range, there was neither an interaction of referential ambiguity and syntactic correctness ($F(1, 15) = 0.03$~ 4.43, ps > .05), nor an interaction of referential ambiguity, syntactic correctness, and any location variable ($F = 0.01$~ 3.11, ps > .08).

In the 750–800-ms window, there was a three-way interaction of referential ambiguity, syntactic correctness, and hemisphere, $F(1, 15) = 4.60$, $p = 0.049$, $MSE = 1.28$, resulting from Nref effects obtained only when there were no syntactic anomalies and only over left hemisphere. Finally, in three 50-ms windows in the 800–1000-ms range, there was either a main effect of referential ambiguity ($F(1, 15) = 6.09$, $p = 0.026$, $MSE = 12.41$), or its interaction with region and hemisphere ($F(2, 30) = 4.05$~ 6.62, ps < .05).

In sum, significant Nref effects started to appear in the 300–350-ms and 250–300-ms time windows for the midline and lateral electrodes, respectively. More importantly, the main effect of referential ambiguity without interaction with syntactic correctness was obtained before their interaction was observed at both the midline and lateral sites. In addition, the interaction of referential ambiguity with syntactic correctness occurred during a short time window only (550–650 ms and 750–800 ms for the midline and lateral sites, respectively).

Discussion

The most important finding in the current study is that the Nref was found whether or not local phrase structure construction was possible. This finding suggests that the computation of local phrase structure does not necessarily precede discourse referential processing. We manipulated the correctness of syntactic category and discourse-referential ambiguity, and obtained both a main effect of syntactic correctness and a main effect of referential ambiguity, instead of an interaction between them, in both the 300–500-ms and 500–1000-ms time windows.

Qualitatively different ERP effects were observed for the two types of manipulations. Syntactic anomalies elicited a left anterior negativity (LAN) in the 300–500-ms time window and a bilateral anterior negativity in the 500–1000-ms time window, as well as a P600. These ERP responses are very similar to those observed in Zhang et al. (2010).

Referential ambiguities elicited a sustained negativity (Nref) with a broad distribution in the 300–500-ms time window. In the 500–1000-ms time window, the Nref effects had a broad distribution over the midline sites and had a left posterior and right central distribution over the lateral sites. The present Nref effects are very similar to those observed in previous studies in which no additional task demands were imposed (e.g., Nieuwland & Van Berkum, 2008; Van Berkum et al., 1999).

Crucially, the Nref effects to the processing of referential ambiguities were not affected by whether the local phrase structure was correct or not in the 300–500-ms and 500–1000-ms time windows. To gain insight into the dynamic interplay between syntactic correctness and referential ambiguity, we analyzed the ERPs in the 18 consecutive 50-ms time windows in the 100–1000-ms range. Significant Nref effects started to appear in the 250–300-ms time window. Very importantly, the interaction of referential ambiguity with syntactic correctness occurred only in later time windows (midline: 550–600 ms and 600–650 ms; lateral: 750–800 ms).

The present observations suggest that local phrase structure building based on syntactic category information is not a necessary prerequisite for discourse referential processing. Instead, referential interpretations can be functionally independent of the computation of local phrase structure. If the computation of local phrase structure must be completed before discourse-referential interpretations can be initiated, as assumed in syntax-first models (e.g., Frazier, 1987; Friederici, 2002; Mitchell et al., 1992), a failed computation of local phrase structure at the critical nouns occurring after the degree adverb *hen* should block, at least temporally, referential interpretations of these nouns. Thus, an interaction of referential ambiguity with syntactic correctness would be observed in the early time window of Nref effects. However, this is not the case. Our results therefore provide evidence against the syntax-first models.

Further studies should examine whether the present observation, that is, the absence of a functional primacy of syntactic category over discourse-referential processing for Chinese, can be generalized to other languages, especially those differing from Chinese in terms of syntactic properties. Note that Chinese, a non-Indo-European language with very limited inflections, does not generally use grammatical morphology to mark syntactic category or syntactic features such as case. Grammatical relations in Chinese therefore are cued mainly by word order, function words, lexical/semantic content, and discourse context. In contrast, in some Indo-European languages like German, grammatical morphology (e.g., inflectional or derivational affixes) and orthographic conventions (such as capitalizing all German nouns) mark the syntactic category of a word. These discrepancies in linguistic properties may result in the possibility that language comprehension in Chinese relies on discourse context to a larger degree compared to Indo-European languages, as proposed by some scholars (e.g., Xu, 1997). Future research needs to address whether or not linguistic properties can modify the functional independency of discourse referential processing.

Author Note

Jing Yu and Yaxu Zhang, Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, China; Julie E. Boland, Department of Psychology, University of Michigan.

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Jing Yu and Yaxu Zhang contributed equally to this work. Correspondence concerning this article should be sent to Yaxu Zhang, Department of Psychology, Peking University, Beijing, 100871, China, or via e-mail: yxzhang@pku.edu.cn

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Table 1

Design and Stimulus Examples for All Four Critical Conditions

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Syntactically correct, referentially unambiguous (CONTROL)

小明/有/一个/弟弟/和/一个/妹妹。/弟弟/很/胖，/妹妹/很/瘦。/那个/**弟弟**/昨天/刚来过。

Xiaoming/ has/ one/ brother/ and/ one/ sister./ The brother/ very/ fat,/ the sister/ very/ thin./ *nage* (DEM PRON, "that")/ **brother**/ yesterday/ just came by.

(Xiaoming has one brother and one sister. The brother is very fat and the sister is very thin. That **brother** just came by yesterday.)

Syntactically correct, referentially ambiguous (REFERENTIAL)

小明/有/两个/弟弟。/其中/一个/弟弟/很/胖，/另一个/很/瘦。/那个/**弟弟**/昨天/刚来过。

Xiaoming/ has/ two/ brothers./ of / one/ brothers/ very/ fat,/ the other/ very/ thin./ *nage* (DEM PRON, "that")/ **brother**/ yesterday/ just came by.

(Xiaoming has two brothers. One of the two brothers is very fat and the other is very thin. That **brother** just came by yesterday.)

Syntactically incorrect, referentially unambiguous (SYNTACTIC)

小明/有/一个/弟弟/和/一个/妹妹。/弟弟/很/胖，/妹妹/很/瘦。/那个/很/**弟弟**/昨天/刚来过。

Xiaoming/ has/ one/ brother/ and/ one/ sister./ The brother/ very/ fat,/ the sister/ very/ thin./ *nage* (DEM PRON, "that")/ *hen* ("very")/ **brother**/ yesterday/ just came by.

(Xiaoming has one brother and one sister. The brother is very fat and the sister is very thin. That very **brother** just came by yesterday.)

Syntactically incorrect, referentially ambiguous (DOUBLE)

小明/有/两个/弟弟。/其中/一个/弟弟/很/胖，/另一个/很/瘦。/那个/很/**弟弟**/昨天/刚来过。

Xiaoming/ has/ two/ brothers./ of / one/ brothers/ very/ fat,/ the other/ very/ thin./ *nage* (DEM PRON, “that”)/ *hen* (“very”)/ **brother**/ yesterday/ just came by.

(Xiaoming has two brothers. One of the two brothers is very fat and the other is very thin. That very **brother** just came by yesterday.)

Note. Examples are given in Chinese, with English literal glosses and translations. The critical words are in bold. DEM PRON = demonstrative pronoun.

Table 2

Overall Analyses of Variance for Two Time Windows (in Milliseconds) for Midline and Lateral Electrodes

Source	*dfs*	300–500			500–1000		
		F	*p*	*MSE*	*F*	*p*	*MSE*
Midline electrodes							
SYN	1, 15	3.58	0.078	15.06	9.37	0.008	9.56
REF	1, 15	16.77	0.001	4.84	7.97	0.013	7.38
SYN × Electrode	2, 30	5.97	0.019	3.75	16.87	<.0005	4.22
REF × Electrode	2, 30	1.41	0.260	0.88	< 1		
SYN × REF	1, 15	< 1			2.71	0.120	9.96
SYN × REF × Electrode	2, 30	< 1			< 1		
Lateral electrodes							
SYN	1, 15	2.78	0.116	11.56	6.85	0.019	8.76
REF	1, 15	12.46	0.003	4.74	5.53	0.033	7.43
SYN × Region	2, 30	13.39	0.001	4.73	33.94	<.0005	3.95
SYN × Hemisphere	1, 15	10.38	0.006	1.35	2.60	0.128	1.50
SYN × Region × Hemisphere	2, 30	5.75	0.018	0.34	1.03	0.357	0.29
REF × Region	2, 30	1.90	0.186	1.88	< 1		
REF × Hemisphere	1, 15	4.72	0.046	0.61	< 1		
REF × Region × Hemisphere	2, 30	< 1			5.03	0.017	0.30
SYN × REF	1, 15	< 1			1.47	.243	10.83
SYN × REF × Region	2, 30	< 1			< 1		
SYN × REF × Hemisphere	1, 15	< 1			3.20	0.094	0.99
SYN × REF × Region × Hemisphere	2, 30	< 1			< 1		

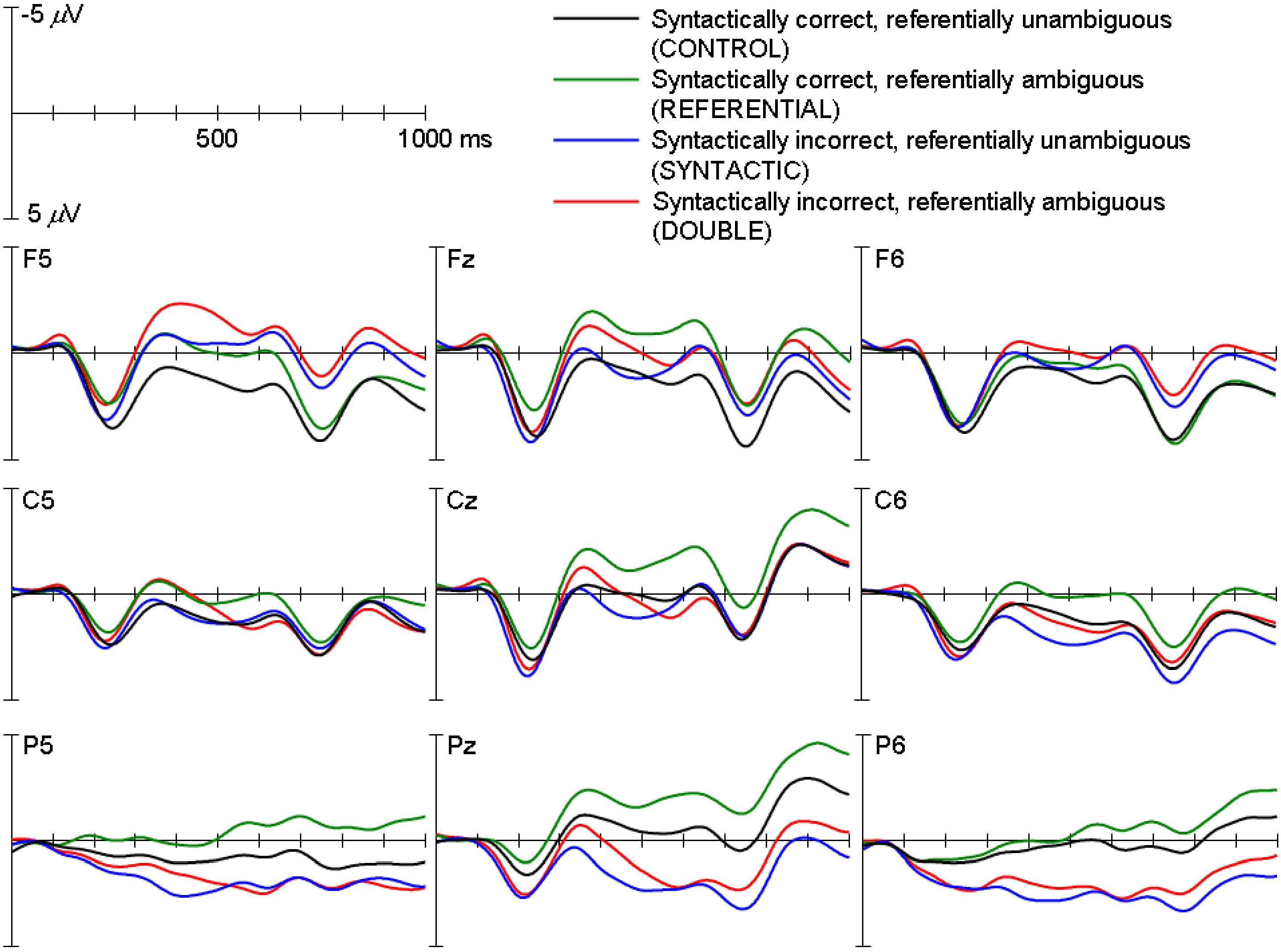
Note. SYN = syntactic correctness; REF = referential ambiguity.

Figure Captions

Figure 1. Grand average ERPs time locked to the onset of the critical nouns for all four critical conditions at 9 representative electrodes. In this and the following figure, negativity is plotted upwards and waveforms are filtered (5 Hz low pass, 24 dB/oct).

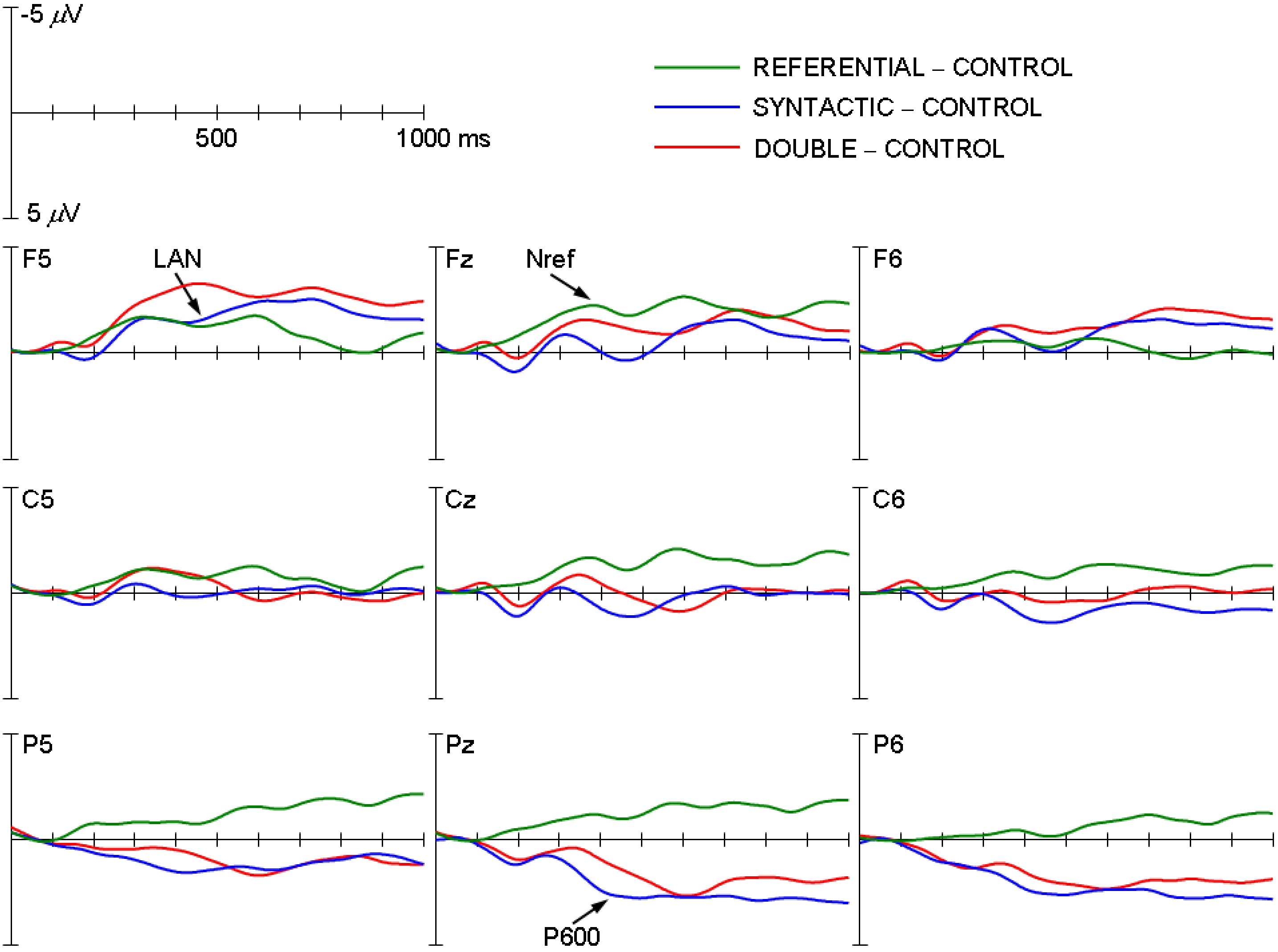
Figure 2. Difference waves computed by subtracting the grand average ERP in the CONTROL condition from that in the REFERENTIAL, SYNTACTIC, and DOUBLE condition, respectively, at 9 representative electrodes.

Figure 3. Scalp distributions for the 300–500-ms and 500–1000-ms time windows for the difference waves in Figure 2.



-5 µV
500
1000 ms
5 µV
Syntactically correct, referentially unambiguous (CONTROL)
Syntactically correct, referentially ambiguous (REFERENTIAL)
Syntactically incorrect, referentially unambiguous (SYNTACTIC)
Syntactically incorrect, referentially ambiguous (DOUBLE)
F5
Fz
F6
C5
Cz
C6
P5
Pz
P6

Figure 1



-5 µV
500
1000 ms
5 µV
REFERENTIAL – CONTROL
SYNTACTIC – CONTROL
DOUBLE – CONTROL
F5
LAN
Fz
Nref
F6
C5
Cz
C6
P5
Pz
P6
P600

Figure 2

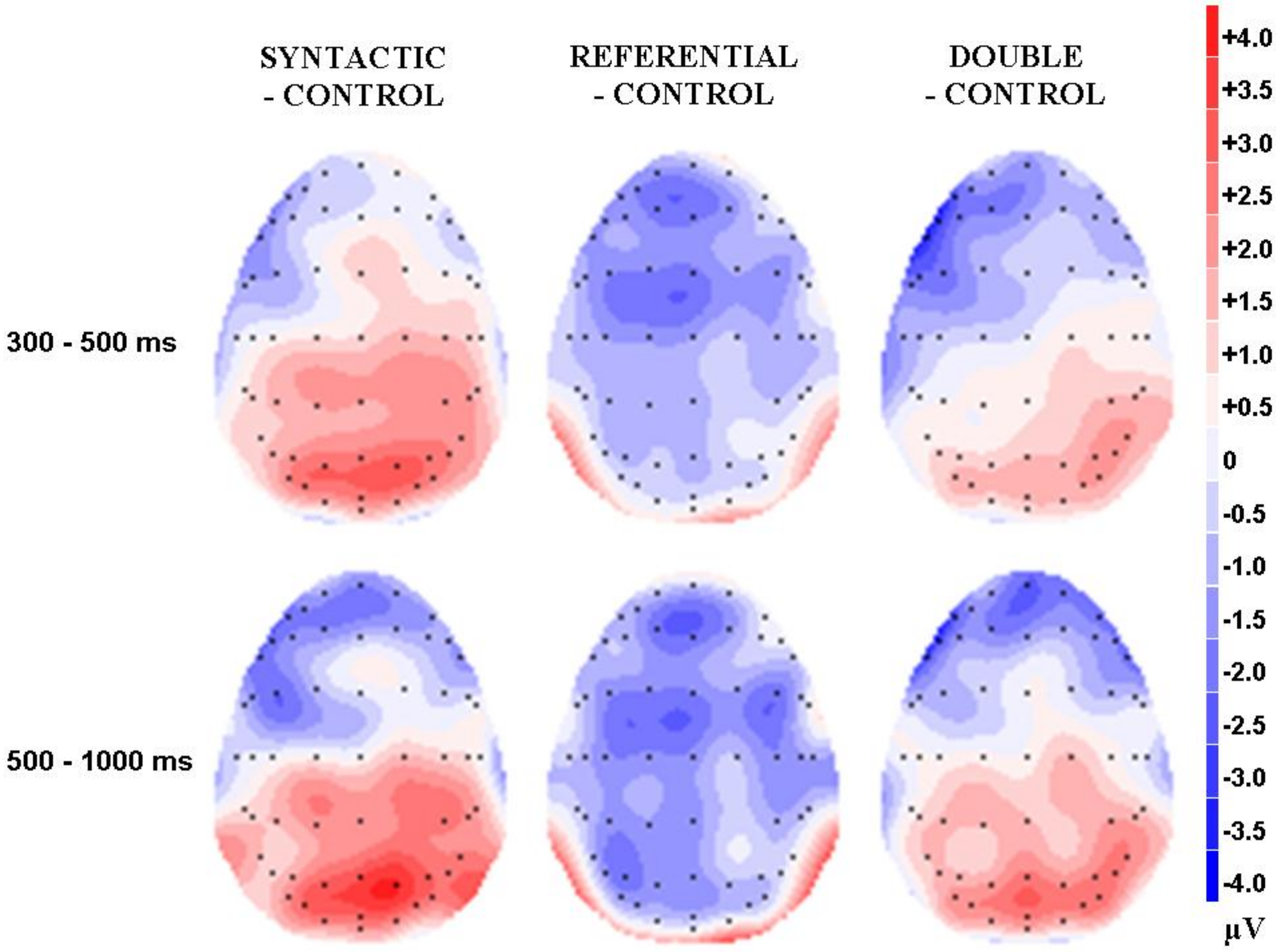

SYNTACTIC
- CONTROL
REFERENTIAL
- CONTROL
DOUBLE
- CONTROL
300 - 500 ms
500 - 1000 ms
+4.0
+3.5
+3.0
+2.5
+2.0
+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
µV

Figure 3