RESEARCH ARTICLE

Semantic Processing Persists despite Anomalous Syntactic Category: ERP Evidence from Chinese Passive Sentences

Yang Yang[1], Fuyun Wu[1]*, Xiaolin Zhou[2,3,4]*

1 Institute of Linguistics, Shanghai International Studies University, Shanghai, 200083, China, **2** Center for

might simply be due to some idiosyncrasies of Chinese grammar, rather than reflecting the predictions of the two parsing models.

Second, results of some Chinese ERP studies might be subject to different interpretations. For instance, in an auditory ERP study on the BA construction, Ye et al. [24] treated syntactic-category anomaly by deleting the object NP after BA and semantic anomaly by violating the semantic selection of the verb, as in the combined anomalies (e.g., , 'Exploiting the forest, the lumberjack BA (pine trees) cut'). They found broad negativities in the 300–500 ms range (N400) after the onset of the critical verb. But given that the critical verb occurred at the end of the sentence, such negativities could be related to sentence-final wrap-up processes [29]. Furthermore, Chinese is a tonal language and has many homophones, which means that different words share the same pronunciation. Given the auditory modality used in this study, the negativities could be partly due to semantic confusion caused by homophone activation.

Third, in terms of ERP experimental design, the criterion for syntactic category violation is less straightforward in Chinese than in strong configurational languages such as German. This applies to several studies including Wang et al. [28]. In the Chinese passive BEI construction, where the theme/patient precedes BEI, and the agent occurs after BEI. They created combined anomalies by using an intransitive verb (e.g. 'sobbed'), which violated both (sub)categorization selection and semantic selection (given the preceding agent NP), as in 'The lost children were sobbed to mountain areas by outlaws'. The assumption here was that incorrect verb transitivity (verb-subcategorization violation) involves both syntactic violation and semantic mismatch. Wang et al. [28] observed an N400-P600 pattern in this condition. However, one might argue that this verb-subcategorization violation should not, in a strict sense, be considered as syntactic category violation, and hence the pattern of effect should not be taken as evidence against the syntax-first view. Indeed, this N400-P600 response for subcategorization violation has been demonstrated in several previous studies, including the study by Friederici herself [30].

Leaving aside the problematic manipulation of verb (in)transitivity, Zhang and colleagues' work on the BA construction appears to be especially enlightening [25,26]. In Experiment 1 of Zhang et al. [26], they created combined anomalies by replacing the post-adverbial verb (e.g., 'peel') with a noun (e.g. 'piano'), thereby violating both word category and semantic selection of a verb that is highly expected (given the syntactic frame of the BA construction and the preceding adverb 'slowly'), as in (Li Wei BA fresh pears slowly piano-le$_{PERF}$ two, 'Li Wei piano-ed two fresh pears slowly'). The N400 effect was found in combined anomalies, indicating that semantic integration persisted even when syntactic category-based structure building presumably failed. Yet given that the BA construction tested in Zhang et al. is specific to Chinese, their conclusion might not be generalized unless further evidence is obtained using some construction commonly shared between Chinese and German.

In the current study, we aimed to overcome the above difficulties, including the 'comparability' problem, by focusing on Chinese passive sentences, which structurally resemble German passives. Both languages use the general formula Patient NP + BEI/Von + Agent NP + VP to express 'That piece of glass is carefully wiped by Jiangna', as shown by the following grammatical Chinese passive sentence (1a) and its German counterpart (1b):

1. a. nakuai boli bei Jiangna zixide cashi le. that-CL glass BEI Jiangna carefully wipe-ASP.
   b. Jene Scheibe wurde von Jiangna sorgfältig geputzt. that glass by Jiangna carefully wiped.

We adopted the same design as Zhang et al. [26] on the BA construction by manipulating semantic consistency (consistent vs. inconsistent) and syntactic category (noun vs. verb) of the critical verb. We hypothesized that semantic anomaly would elicit an N400 effect, and syntactic-category anomaly would elicit a P600 effect. Critically, for combined anomalies, there would be no N400 effects according to the syntax-first model, but according to interactive/concurrent models, it would result in a strong N400 effect.

Method

Participants

Twenty-eight right-handed undergraduate and graduate native Chinese speakers from Peking University or neighboring universities were paid to participate in the experiment. Four were excluded from data analysis due to excessive eye or head movements artifacts (over 40% trials). The remaining 24 participants (13 female) aged between 19 and 25 years, with a mean age of 21.6 (SD = 1.86) years. No participants reported any cognitive or psychiatric disorders or vision deficit (after correction). Informed written consent was obtained from each participant before the test. This study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Department of Psychology, Peking University.

Materials and norming tests

In our study, the structure of the passive stimuli is "Det + NP1 (inanimate) + BEI + NP2 (animate) +ADV + *V/N* + Le (PERF) + FreqAdv". We added an aspect marker-*le* and an adverbial modifier after the critical verb for two reasons. First, sentences can continue after the critical verb, allowing us to avoid the sentence-final wrap-up effects. Second, Chinese passive structures typically denote completion of an action [31,32], thus an aspect marker and a frequency-denoting adverbial modifier can convey a sense of completion associated with the verbs. All two-character human names serving as agent NPs are taken from Jiang and Zhou [33], with word frequencies and number of strokes well controlled across conditions.

All sentences were visually presented segment by segment (see Table 1, the word between two slashes presented as one segment in one screen). We manipulated the verb's semantic consistency (SEM) to its argument/patient NP (consistent vs. inconsistent) and its syntactic category

Table 1. Exemplar stimuli for the four critical conditions, with English translations.

a. CORRECT	那 /玻璃/被/蒋娜/仔细地/擦拭/了多遍。
	Det/glass/ BEI/ Name/carefully/***wipe***/ASP/many times.
	(That piece of glass is carefully ***wiped*** by Na Jiang many times.)
b. SEMANTIC	那个/方案/被/胡▫/仔细地/擦拭/了/多遍。
	Det/plan/ BEI/ Name/carefully/***wipe***/ASP/many times.
	(That plan is carefully ***wiped*** by Jie Hu many times.)
c. SYNTACTIC	那 /玻璃/被/蒋娜/仔细地/抹布/了/多遍。
	Det/glass/ BEI/ Name/carefully/***dishcloth***/ASP/many times.
	(That piece of glass is carefully ***dishcloth*** by Na Jiang many times.)
d. COMBINED	那个/方案/被/胡▫/仔细地/抹布/了/多遍。
	Det/plan/ BEI/ Name/carefully/***dishcloth***/ASP/many times.
	(That plan is carefully ***dishcloth*** by Jie Hu many times.)

The critical words are in bold.

doi:10.1371/journal.pone.0131936.t001

(SYN) (verb vs. noun), yielding four conditions in Table 1: CORRECT (SEM+, SYN+), SEMANTIC (SEM-, SYN+), SYNTACTIC (SEM+, SYN-), and COMBINED (SEM-, SYN-).

F e N e e . We conducted five pretests to check various properties of the stimuli. The first test was conducted on all syntactic-category anomalous sentences (in the SYNTACTIC and COMBINED conditions), in which the critical region was a noun. A group of 20 participants who did not participate in the ERP test were asked to make the sentences more natural or acceptable by changing whichever word(s) they thought necessary. On average, 99% of the time participants correctly identified the anomalous nouns, and changed them to transitive verbs. These results showed that participants detected the syntactic-category anomaly at the critical region and expected the words to be verbs.

To further quantify the degree of semantic anomaly across conditions, we conducted a second pretest on comprehensibility/semantic acceptability of the critical sentences. A different group of 32 participants were asked to judge the comprehensibility of each sentence on a 5-point scale, with 1 meaning completely incomprehensible and 5 quite comprehensible. Table 2 shows the mean ratings in the four conditions. A repeated measures ANOVA with semantic consistency and syntactic category as two within-participant factors showed a significant effect of semantic consistency, $F(1, 31) = 662.64$, $p < 0.001$, a significant main effect of syntactic category, $F(1, 31) = 143.42$, $p < 0.001$, and a significant interaction between them, $F(1, 31) = 57.92$, $p < 0.01$. Further analysis showed that the comprehensibility scores differed between conditions, even for the smallest difference between SEMANTIC and COMBINED conditions, $F(1, 31) = 41.14$, $p < 0.001$.

The third pretest was on cloze probability of the critical verbs. Another group of 20 participants were asked to complete sentence fragments "Det + NP1 (inanimate) + BEI + NP2 (animate) + ADV . . ." with the first appropriate words coming into their minds. Results showed that while the verbs used in the CORRECT condition had a cloze probability of 21%, critical words in the other three conditions all had a cloze probability of zero.

The fourth pretest was on semantic relatedness between the critical words used in each condition and the words with the highest production rate in the above cloze probability test. The purpose of this pretest was to provide evidence for an account of N400 effects in different conditions (See Discussion). Twenty-two participants were asked to rate on a 7-point scale (1 = completely unrelated, 7 = most highly related) the semantic relatedness between the critical words and the produced words. The mean rating scores for the four conditions are presented in Table 2. A repeated-measures ANOVA with semantic consistency and word category as two within-participant factors showed a significant main effect of semantic consistency $F(1, 21) = 322.00$, $p < 0.001$, a significant main effect of word category, $F(1, 21) = 31.54$, $p < 0.001$, and a significant interaction between them, $F(1, 21) = 5.72$, $p < 0.05$. Further tests showed that while the small difference between CORRECT and SYNTACTIC reached significance, $F(1, 21) = 18.86$, $p < 0.001$, so did the smallest difference between SEMANTIC and COMBINED, $F(1, 21) = 6.80$, $p < 0.05$.

Table 2. Mean scores of sentence comprehensibility rating (on a 5-point scale), cloze probability for the critical words, the semantic relatedness between the critical words, the mostly produced words in the cloze probability test (on a 7-point scale) and the plausibility of the construction (standard deviations in parentheses).

	CORRECT	SEMANTIC	SYNTACTIC	COMBINED
Comprehensibility	4.69 (0.29)	1.92 (0.52)	3.30 (0.50)	1.64 (0.38)
Cloze probability	21%	0%	0%	0%
Semantic relatedness	4.76 (0.19)	2.40 (0.18)	4.12 (0.23)	2.20 (0.16)
Plausibility of construction	4.57 (0.08)	4.57 (0.08)	1.97 (0.11)	1.97 (0.11)

doi:10.1371/journal.pone.0131936.t002

To further determine the validity of our stimuli, we conducted the fifth pretest on sentence congruency related to our phrasal structure, in order to make sure that the transitive verbs could indeed be used in the BEI constructions, and that the counterpart nouns used in the SYNTACTIC condition really did not make sense in such structures. The phrasal segments (e.g., "被. . .仔细地擦拭", *BEI. . .carefully wipe*) were rated on a 5-point scale by another group of 34 participants regarding how plausible it was to use the phrasal segments to construct a congruent sentence (ranging from 1 = extremely implausible to 5 = fully plausible). A repeated measures ANOVA revealed a significant main effect of condition, F (1, 33) = 219.30, $p < 0.001$. Post-hoc Bonferroni comparisons showed that the mean score of the noun in SYNTACTIC and COMBINED (mean = 1.97, SD = 0.11) was significantly lower than that of the transitive verbs in CORRECT and SEMANTIC (mean = 4.57, SD = 0.08).

Ma e a . Each participant read 160 critical sentences, with 40 in each condition. Word frequencies and strokes of critical words and Patient NPs were well matched across conditions ($p > .1$). In addition, 220 filler items were used to prevent participants from developing test-taking strategies. Eighty were correct BEI sentences with two NPs varied in their animacy status. These sentences were included to equate the numbers of the correct and incorrect BEI sentences overall and to offset the inanimate-animate configuration used in the critical sentences. The remaining 140 fillers were of different syntactic structures, including the BA construction, simple SVO sentences, topicalization, and complex clauses.

Four lists were created using a Latin Square design. In each list, 160 critical sentences and 220 fillers were pseudo-randomized, such that no more than 4 BEI sentences and no more than two critical sentences of the same condition appeared consecutively.

Procedure

Participants sat approximately 100 cm away from a CRT computer screen in a dim and sound-proofing room. They were instructed to move their head and body as little as possible and to keep their eyes fixated on a cross sign at the center of the computer screen before the onset of each sentence. Sentences were presented in white against black background segment by segment. Each segment was presented for 400 ms followed by a blank screen lasting 400 ms. Trials were separated by a 2000 ms interval.

Participants were instructed to read all trials attentively for comprehension. About one third of the trials (80 critical sentences and 50 fillers) were followed by a cue "?", upon which participants need to judge the correctness of the sentence by pressing one of the two response buttons. The cue remained on the screen for a maximum of 3000 ms until participants responded. The cues were pseudorandomized such that 1) at least one cue appeared in every 5 consecutive sentences; 2) for answers, at most three "Yes" or "No" occurred consecutively (if responded correctly).

mastoids. The vertical electro-oculogram (VEOG) was recorded from electrodes placed above the right eye. The horizontal EOG (HEOG) was recorded from electrodes placed at the outer cantus of left eye. Electrode impedance was kept below 5 kΩ. The biosignals were amplified with a band pass from 0.016 to 100 Hz and digitized on-line with a sampling frequency of 500 Hz. ERPs were additionally filtered for plots with 20Hz low pass. The ocular artifacts were corrected automatically, with both VEOG and HEOG as common reference and blink detection by algorithms implemented in Brain Vision Analyzer. The original ERP data and the data produced during the analysis can be found in Harvard Dataverse Database (doi:10.7910/DVN/28781).

ERP analysis

ERPs were computed for each sentence type, electrode site, and participant. Sentences contaminated by excessive movement artifacts (mean voltage exceeding ±100 μV) or incorrectly judged were excluded before averaging. The overall trials rejection rate was 11.3% across all 24 participants and conditions. The mean rejection rate for each condition was 13.3% (SD = 0.14) for CORRECT, 12.3% for SEMANTIC (SD = 0.14), 9.2% (SD = 0.09) for SYNTACTIC and 10.5% (SD = 0.14) for COMBINED.

Analyses were based on the critical verbs in the critical sentences. Since the critical words were preceded by different words in different conditions (see Table 1), we used a post stimulus-onset baseline covering 100 ms post critical-word-onset, following Friederici et al. [22]. Subsequent analyses were based on 800 ms-epochs post onset of the critical words. Two time windows were chosen on the basis of visual inspection and previous studies [15] [25]: (1) 300–500 ms time window for possible N400 effects; (2) 500–800 ms for possible P600 effects. A repeated measures analyses of variance (ANOVAs) were conducted on the average ERP amplitudes in the two time windows with following within-subjects factors: semantic consistency (SEM+, SEM-), syntactic category (SYN+, SYN-), hemisphere (left, middle and right) and region (anterior, central and posterior). Crossing the factors of hemisphere and region produced nine regions of interest (ROI), each with 6, 4, or 2 electrodes, including left anterior (F1, F3, F5, FC1, FC3, FC5), left central (C1, C3, C5, CP1, CP3, CP5), left posterior (P1, P3, P5, PO3), middle anterior (FZ, FCZ), middle central (CZ, CPZ), middle posterior (PZ, POZ), right anterior (F2, F4, F6, FC2, FC4, FC6), right central (C2, C4, C6, CP2, CP4, CP6) and right posterior (P2, P4, P6, PO4). Mean amplitudes were averaged over electrodes in each ROI for statistical purpose. Comparisons were planned for each ROI if interactions reached significance. The Greenhouse-Geisser correction was applied when the evaluated effects had more than one degree of freedom in the numerator. For planned comparisons, the probability levels were Bonferroni-adjusted.

Results

Behavior results

The overall response accuracy rate was 91.6% across all four conditions: 87.7% for the correct sentences (SD = 0.1); 89.2% for the semantic anomaly condition (SD = 0.1); 93.8% for the syntactic-category anomaly condition (SD = 0.09); 96% for the combined anomalies (SD = 0.06). A repeated-measures ANOVA with semantic consistency and word category as two within-participant factors showed only a significant main effect of syntactic category, $F(1, 23) = 14.59$, $p < 0.01$, with the accuracy higher for sentences in the SYNTACTIC and COMBINED conditions than for sentences in the CORRECT and SEMANTIC conditions. We did not measure RTs in this study, following Friederici et al. [22] and Zhang et al. [26]. RTs were not informative

in the current study as they were recorded long after the presentation of each sentence. In general, behavioral results showed that participants were attentive to the task.

ERP data

As shown in Fig 1 and Fig 2, in the 300–500 ms time window, compared with the CORRECT sentences, anomalous sentences in all the other three conditions (SYNTACTIC, SEMANTIC and COMBINED) elicited larger negativities (N400 effects). These effects had somewhat different distributions over the scalp (Fig 2), with the effect for SYNTACTIC predominantly on the left hemisphere and the effect for COMBINED over the whole scalp. In the time window of 500–800 ms, compared with the CORRECT sentences, sentences in the SYNTACTIC and COMBINED conditions elicited larger positivities (P600) in the centro-posterior areas whereas the effect for the SEMANTIC conditions was more left-lateralized. Statistical analyses confirmed these observations.

The 300–500 [illegible] e [illegible] d [illegible]. A repeated-measures ANOVA revealed a main effect of semantic consistency, $F(1, 23) = 22.2$, $p < 0.01$, suggesting that sentences in the SEMANTIC and COMBINED conditions evoked a larger N400 than sentences in the CORRECT and

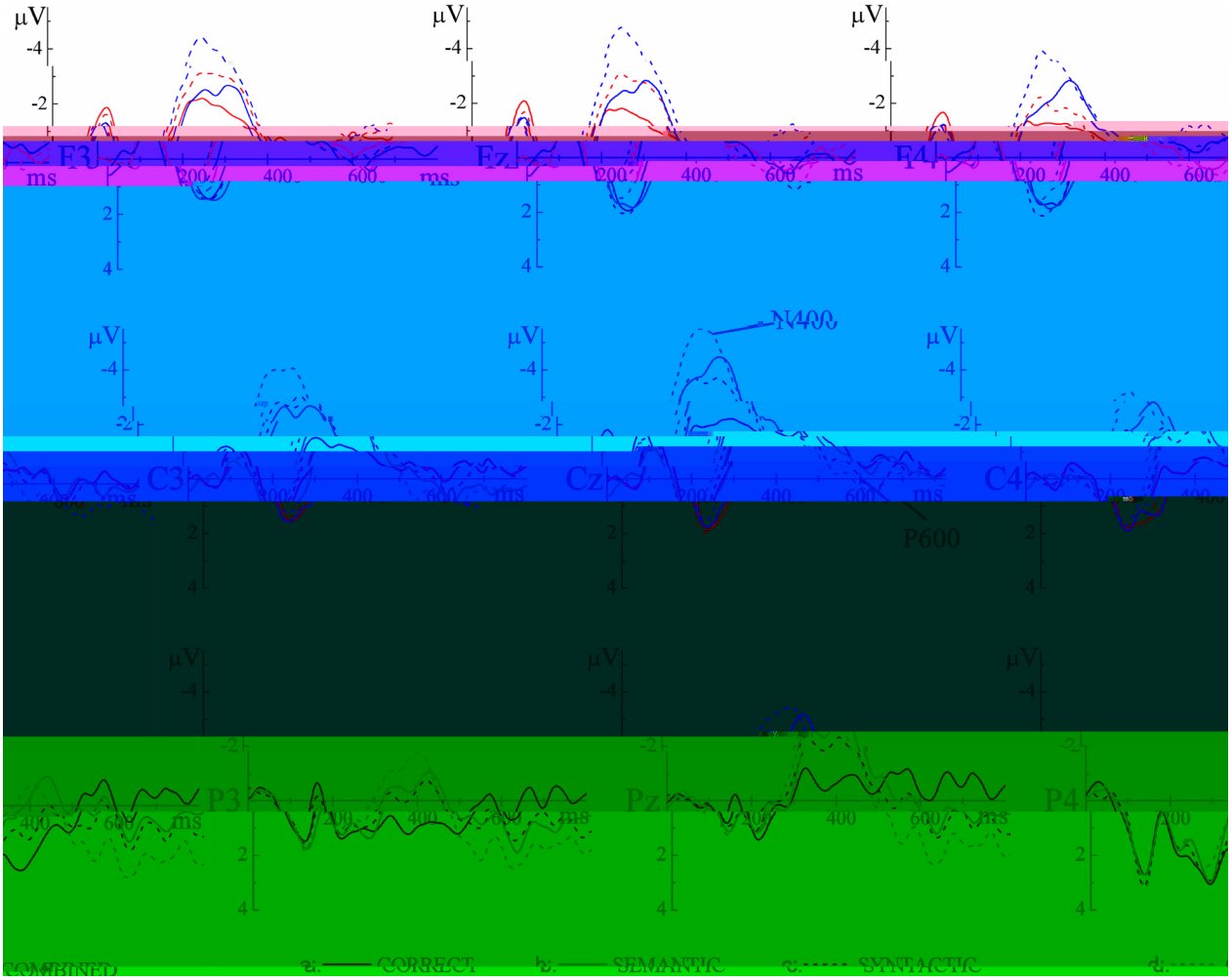

Fig 1. Grand average ERPs at 9 exemplar electrodes time-locked to the onset of the critical words for the four experimental conditions.

doi:10.1371/journal.pone.0131936.g001

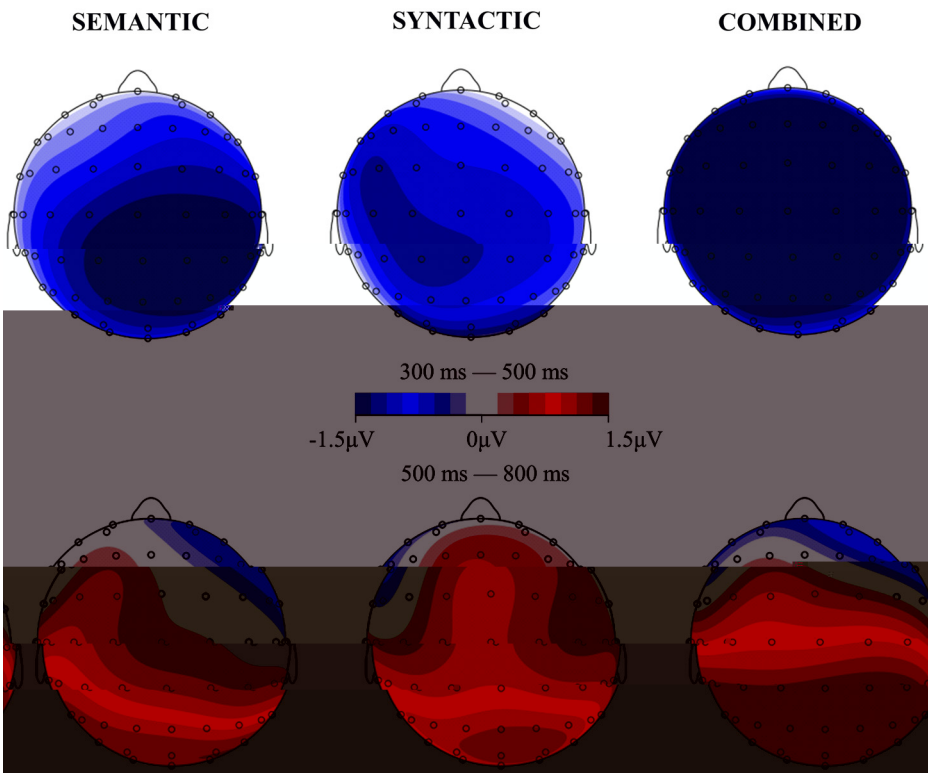

Fig 2. Topographic distributions of the mean ERP differences at the 300–500 ms and 500–800 ms windows, respectively. The three anomalous conditions were all compared with the CORRECT condition.

doi:10.1371/journal.pone.0131936.g002

SYNTACTIC conditions. This effect did not interact with syntactic category, $F(1, 23) = 0.341$, $p > 0.1$, but interacted with hemisphere and region, $F(4, 92) = 4.167$, $p < 0.01$, indicating that the size of the main effect of semantic consistency varied over different scalp areas (Fig 2). Importantly, the main effect of syntactic category also reached significance, $F(1, 23) = 16.41$, $p < 0.05$, with sentences in the SYNTACTIC and COMBINED conditions evoking more negative responses than sentences in the CORRECT and SEMANTIC conditions. This effect interacted with hemisphere and region, $F(4, 92) = 2.31$, $0.05 < p < 0.1$, indicating that the size of this varied over different scalp areas.

To better understand the N400 effects for the three types of anomalous sentences, we conducted separate comparisons between the SYNTACTIC, SEMANTIC and COMBINED conditions and the CORRECT condition. Compared with the sentences in the CORRECT condition, sentences in the SEMANTIC condition elicited more negative responses, $F(1, 23) = 10.11$, $p < 0.01$, and this N400 effect interacted with hemispheres, $F(2, 46) = 5.06$, $p = 0.01$ and region, $F(2, 46) = 3.35$, $p < 0.05$. It is clear from Fig 2 that the N400 effect was the strongest in the right centro-posterior regions. Sentences in the SYNTACTIC condition also elicited more negative responses, $F(1, 23) = 6.96$, $p < 0.05$. Moreover, sentences in the COMBINED condition elicited the most negative responses, $F(1, 23) = 33.753$, $p < 0.001$, with the effect appearing all over the scalp sites (Fig 2).

Given that the N400 effect appeared in all three anomalous conditions, we further examined the relative magnitude of the effect in each condition. A repeated-measures ANOVA was conducted on the ERP responses in the three anomalous conditions after subtracting the ERP responses in the CORRECT condition. The difference between the effects for the SEMANTIC

and SYNTACTIC conditions did not reach significance, $F(1, 23) = 1.17$, $p > 0.1$, although it did interact with hemisphere and region, $F(4, 92) = 2.46$, $p = 0.05$. Detailed analyses for ROIs showed that the N400 effect was stronger for the SEMANTIC condition than for the SYNTACTIC condition in middle posterior, right central and right posterior areas ($p < 0.05$ or $0.05 < p < 0.1$). Importantly, the N400 effect for the COMBINED condition was larger than the effect for either the SEMANTIC or SYNTACTIC conditions: $F(1, 23) = 3.19$, $0.05 < p < 0.1$, and $F(1, 23) = 6.74$, $p < 0.05$, respectively (Fig 2).

The 500–800 ms window. A repeated-measures ANOVA revealed a significant main effect of syntactic category, $F(1, 23) = 8.178$, $p < 0.01$, with syntactically anomalous sentences in the SYNTACTIC and COMBINED conditions being more positive than sentences in the CORRECT and SEMANTIC conditions. This effect interacted with hemisphere, $F(2, 46) = 3.29$, $p < 0.05$, and region, $F(2, 46) = 10.2$, $p < 0.01$, respectively. Separate analyses were conducted for each ROI. The syntactic category effect reached significance in all centro-posterior ROIs, including left central, left posterior, middle central, middle posterior, right central and right posterior, $Fs(1, 23) > 4.44$, $ps < 0.05$.

Importantly, although the main effect of semantic consistency was not significant in this window, $F(1, 23) = 1.913$, $p > 0.1$, it interacted with hemisphere and region, $F(4, 92) = 3.09$, $p < 0.05$. Detailed analyses in each ROI found an overall semantic consistency effect in left posterior, middle posterior and right posterior regions, $Fs(1, 23) > 6.8$, $ps < 0.05$.

To better understand the P600 effects for the anomalous sentences, we conducted a further analysis comparing the SYNTACTIC, SEMANTIC and COMBINED conditions separately with the CORRECT condition. Results showed that, compared with the CORRECT condition, P600 in the right

9[(d)219(with)-225.6(s1Tf18.)-229.70060TD2[(d)-14.4(ur1.1966-223.2(i22.3(1(

Discussion

The main goal of this study was to test whether Chinese sentence processing was consistent with the syntax-first model by using the BEI construction, a passive structure that has not been extensively studied but is most comparable to the German passive. Overall, we found both N400 and P600 effects for sentences with semantic anomaly, with syntactic category anomaly, or with combined anomalies. Our results replicate and extend findings from previous Chinese ERP studies that used different structures [24–27] and present a solid piece of evidence against the syntax-first model.

The present findings demonstrate the importance of probing processing differences from a cross-linguistic perspective. By using passive sentences, we ruled out the potential confound of sentence structure in the previous ERP studies on Chinese. As stated in the introduction, evidence supporting the syntax-first model comes mainly from German passive structures [15,16,22]. However, existing ERP results in Chinese that conflict with this model could be attributed to the idiosyncrasies of the Chinese language. By using the Chinese BEI structure that closely resembles the German passive structure, we obtained a pattern of effects that supports existing ERP work on the BA construction and offers converging evidence that semantic processing in Chinese does not need to be licensed by syntax.

After controlling for structural differences between the two languages, what is the real reason behind the fact that Chinese ERP studies are inconsistent with the syntax-first model? As Zhou, Ye, Cheung and Chen [34] stated, it is likely that there exist language-specific cognitive processes. Thus, one possibility is that processing models may take into account and incorporate typological differences between languages. Consider German again. As a strong configurational language, its rich morphological cues (e.g. inflectional affixes) explicitly mark different syntactic information such as tense, case, and number. Moreover, syntactic categories such as nouns (which are capitalized in written German) or verbs are easy to visually identify by their morphological forms. Therefore, it is possible that syntactic structure building based on syntactic categories is fast and even automatic. In contrast, Chinese is an isolating language that is impoverished in morphological inflections. Often, comprehenders cannot detect the syntactic category of a Chinese word simply by its form, and the boundaries between nouns and verbs as syntactic classes in Chinese are by no means distinct [35,36]. Without explicit grammatical cues, syntactic structure building for a Chinese sentence relies mainly on the processing of the lexical and contextual meaning of each individual word [28]. Therefore, it seems plausible that semantic information, rather than syntactic information, has primacy in Chinese. As stated in Kuperberg [37], a semantic memory-based analysis and possibly a semantically-driven combinatorial thematic analysis can temporarily dominate online sentence comprehension.

Four findings in the current study are particularly worth discussing. First, as shown in Fig 1, in the 300–500 ms time window, responses to sentences with combined anomalies were more negative than responses to sentences with only a semantic anomaly or only a syntactic anomaly. This was consistent with the rating test in which sentences with combined anomalies were rated as more difficult to comprehend than sentences with single anomalies (Table 2). As discussed in the introduction, the absence of N400 effects in the COMBINED condition is taken as evidence for the syntax-first model, because the unsuccessful syntactic processing entirely blocks access to lexical/semantic processing. However, in our study, we found N400 effects in the COMBINED condition, leading us to conclude, reflecting Zhang et al. (2010), that syntactic category violation does not prevent access to lexical semantics of the target word; but it would make the semantic integration of this word into the sentence context more difficult. Another source of increased N400 responses in the COMBINED condition could come from the semantic relatedness between the critical words and the words that would be expected in the context

(although these words were not presented). Federmeier and Kutas [38] demonstrated that words that were expected with respect to sentential context but were from the same semantic category as the expected words elicit reduced N400 responses, compared with words that were expected and were from different categories. This finding was interpreted as reflecting the impact of context-independent long-term memory structure on sentence processing: semantic features shared between the target words and the unexpected but related words are activated by sentence context, facilitating to a certain degree the integration of the former with the context. For the present study, although the critical words and the most expected words were largely from the same category (verbs for the SEMANTIC condition) or from different categories (nouns vs.4a6b3,wTACthe 31(words)-222COMBINED.5(proceMANTIC)-2s),225.9(4(degy.1(to)-2ne.1(

pre-tests and the negativities in the SYNTACTIC condition (see above discussion). It is possible that the interplay of syntax and semantics is asymmetric during online processing, but more work is needed in order to fully understand the underlying mechanism.

To conclude, the current study on Chinese passive sentences is consistent with studies on other Chinese structures [24–28] and demonstrates an N400 effect for sentences with both semantic anomaly and syntactic category anomaly, indicating that semantic processing persists in face of anomalous syntactic structure. Claims of syntactic category processing primacy do not apply to Chinese.

Acknowledgments

We gratefully acknowledge Drs. Yingyi Luo and Xiaoming Jiang for help with the experimental design, Prof. Chenglin Zhou and Mr. Biye Wang for assistance in ERP data reanalysis, Philip

16. Hahne A, Friederici AD. Differential task effects on semantic and syntactic processes as revealed by ERPs. Cogn. Brain Res. 2002; 13: 339–356.
17. Kaan E, Harris A, Gibson E, Holcomb P. The P600 as an index of syntactic integration difficulty. Lang. Cogn. Process. 2000; 15: 159–201.
18. Friederici AD, Hahne A, Mecklinger A. Temporal structure of syntactic parsing: Early and late event-related brain potential effects. J. Exp. Psychol. Learn. Mem. Cogn. 1996; 22(5): 1219–1248. PMID: 8805821
19. Friederici AD, Steinhauer K, Frisch S. Lexical integration: Sequential effects of syntactic and semantic information. Mem. Cogn. 1999; 27: 438–453.
20. Friederici AD, Frisch S. Verb argument structure processing: The role of verb-specific and argument-specific information. J. Mem. Lang. 2000; 43, 476–507.
21. Angrilli A, Penolazzi B, Vespignani F, De Vincenzi M, Job R, Ciccarelli L, et al. Cortical brain responses to semantic incongruity and syntactic violation in Italian language: an event-related potential study. Neurosci. Lett. 2002; 322(1): 5–8. PMID: 11958830
22. Friederici AD, Gunter C, Hahne A, Mauth K. The relative timing of syntactic and semantic processes in sentence comprehension. NeuroReport. 2004; 15:165–169. PMID: 15106851
23. Isel F, Hahne A, Maess B, Friederici AD. Neurodynamics of sentence interpretation: ERP evidence from French. Biol. Psychol. 2007; 74: 337–346. PMID: 17011692
24. Ye Z, Luo Y, Friederici AD, Zhou X. Semantic and syntactic processing in Chinese sentence comprehension: Evidence from event-related potentials. Brain Res. 2006; 1071: 186–196. PMID: 16412999
25. Yu J, Zhang Y. When Chinese semantics meets failed syntax. NeuroReport. 2008; 19: 745–749. doi: 10.1097/WNR.0b013e3282fda21d PMID: 18418250
26. Zhang Y, Yu J, Boland JE. Semantics does not need a processing license from syntax in reading Chinese. J. Exp. Psychol. 2010; 36: 765–781.
27. Zhang Y, Li P, Piao Q, Liu Y, Huang Y, Shu H. Syntax does not necessarily precede semantics in sentence processing: ERP evidence from Chinese. Brain Lang. 2013; 126: 8–19. doi: 10.1016/j.bandl.2013.04.001 PMID: 23648559
28. Wang S, Mo D, Xiang M, Xu R, Chen H. The time course of semantic and syntactic processing in reading Chinese: Evidence from ERPs. Lang. Cogn. Process. iFirst. 2012; 1–20.
29. Hagoort P. Interplay between syntax and semantics during sentence comprehension: ERP effects of combining syntactic and semantic violations. J. Cogn. Neurosci. 2003; 15: 883–899. PMID: 14511541
30. Osterhout L, Holcomb PJ, Swinney DA. Brain potentials elicited by garden-path sentences: Evidence of the application of verb information during parsing. J. Exp. Psychol. Learn. Mem. Cogn. 1994; 20: 786–803. PMID: 8064247
31. Lu J. Some Issues of passive sentences of mandarin Chinese. Chin. Linguist. 2004; 8: 9–15.
32. Huang Y, Yang S, Gao L, Zhang W, Cui X. The L2 acquisition of Chinese Bei construction. Chin. Teach. World. 2007; 80: 76–90.
33. Jiang X, Zhou X. Processing different levels of syntactic hierarchy in sentence comprehension: An ERP study on Chinese. Neuropsychologia. 2009; 47: 1282–1293. doi: 10.1016/j.neuropsychologia.2009.01.013 PMID: 19428392
34. Zhou X, Ye Z, Cheung H, Chen H. Processing the Chinese language: An introduction. Lang. Cogn. Process. 2009; 24: 7–8, 929–946.
35. Shen J. Hanyu Lide Mingci He Dongci [Nouns and verbs in Chinese]. Hanzangyu Xuebao [J. Sino-Tibatan Lang.]. 2007; 1: 27–47.
36. Shen J. My view of word classes in Chinese. Lingusit. Sciences. 2009; 1: 1–12.
37. Kuperberg GR. Neural mechanisms of language comprehension: Challenge to syntax. Brain Res. 2007; 1146: 23–49. PMID: 17400197
38. Federmeier KD, Kutas M. A rose by any other name: long-term memory structure and sentence processing. J. Mem. Lang. 1999; 41: 469–495.
39. Chow W, Phillips C. No semantic illusions in the "Semantic P600" phenomenon: ERP evidence from Mandarin Chinese. Brain Res. 2013; 1506: 76–93. doi: 10.1016/j.brainres.2013.02.016 PMID: 23422676
40. Kim A, Osterhout L. The independence of combinatory semantic processing: Evidence from event-related potentials. J. Mem. Lang. 2005; 52: 205–225.
41. Stroud C, Phillips C. Examining the evidence for an independent semantic analyzer: an ERP study in Spanish. Brain Lang. 2012; 120 (2): 108–126. doi: 10.1016/j.bandl.2011.02.001 PMID: 21377198

42. Zhou X, Jiang X, Ye Z, Zhang Y, Lou K, Zhan W. Semantic integration processes at different levels of syntactic hierarchy during sentence comprehension: An ERP study. Neuropsychologia. 2010; 48: 1551–1562. doi: 10.1016/j.neuropsychologia.2010.02.001 PMID: 20138898

43. Jiang X, Zhou X. Multiple semantic processes at different levels of syntactic hierarchy: Does the higher-level process proceed in face of a lower-level failure? Neuropsychologia. 2012; 50: 1918–1928. doi: 10.1016/j.neuropsychologia.2012.04.016 PMID: 22561886