Can pragmatic inference benefit from topic prominence? ERP evidence from *Mandarin Chinese*

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ABSTRACT

This study investigated how pragmatic inference making is modulated by information structure in preceding text. We created three types of two-clause structures in which the interpretation of a critical word in the second clause was dependent on the engagement of pragmatic inference as well as a successful establishment of a referential relation between the target word and an intended antecedent in the preceding text. An enhanced P600 response was elicited by target words when the intended referent was in non-topic position compared to topic position or sub-topic position. Moreover, a reduced N400 was elicited by the target word when the intended referent in the preceding clause was in non-topic position, compared to topic position. These findings suggest that building inferential relations can benefit from information structural prominence of topicality.

1. Introduction

During communication, speakers want their utterance to be appropriately interpreted. However, there is almost always more information conveyed than actually said. In many cases, the ideas expressed by a speaker may not be explicitly stated. Under such circumstances, an inferential process is initiated to bridge a current idea with a prior statement. Bridging inference is a device by which pragmatic enrichment takes place and discourse coherence is achieved (Irmer, 2009). For instance, in sentence (1), there is no explicit antecedent for the referential expression "the black swan", its interpretation, therefore, must be retrieved from the explicit statement of a related entity "a ballet".

(1) I went to see a ballet last night. *The Black Swan* was marvelous.

A world knowledge-based inferential process enables listeners to access the assumption that the name of the ballet is called "The Black Swan". In such cases, the generation of pragmatic inferences can greatly facilitate the process of establishing a situational model, though extra processing cost is required. A number of empirical studies have been carried out to examine the relationship between inferential process and on-line sentence processing (Bettinsoli, Maass, Kashima, & Suitner, 2015; Burkhardt, 2006; Hirotani & Schumacher, 2011; Kuperberg, Paczynski, & Ditman, 2011; Yang, Perfetti, & Schmalhofer, 2007). These studies, however, have mainly focused on how the different degrees of semantic association affect the establishment of pragmatic inference. Unlike these

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studies, the main purpose of our study is to shed light on how pragmatically-based information status (e.g., topichood vs. objecthood) affects inference making during sentence comprehension. Before we present our design, we first introduce the concept of topic and its relation with discourse coherence. Then we review the literature on the electrophysiological correlates of pragmatic inference during sentence processing, as well as on how inference making is modulated by semantically- and structurally-based constraints.

1.1. The notion of topic and discourse coherence

The information status of discourse constituents is conceived as a gradient representation of discourse salience that is attributed to information structural notions such as topic-comment and given-new (Burmester, Spalek, & Wartenburger, 2014). Topic is defined as the most prominent sentence/discourse entity indicating what the utterance is about, and establishing shared information between the speaker and the addressee (i.e., givenness; Li & Thompson, 1989; Reinhart, 1981). Structurally, a topic tends to be associated with an early and prominent syntactic position, i.e., the highest position in a syntactic tree (Cowles & Ferreira, 2011; Lambrecht, 1994; Xu & Zhou, 2016), which is typically a noun phrase (NP) subject (an object can also be topicalized) that names what the clause/sentence is about. At the discourse level, topic encodes the discourse-pragmatic notion of aboutness and relevance, in addition to definiteness and givenness (Colonna, Schimke, & Hemforth, 2012; Lambrecht, 1994; Reinhart, 1981). In particular, as the first element of a sentence, topic provides an anchoring point from which an upcoming referential expression is inferred and hence defines the perspective from which the reader/hearer will process the following utterance (Vallduvi & Engdahl, 1996), and therefore is more accessible in the reader/listener's mental model relative to other non-topic entities (e.g., object). Given its prominent status in discourse, a topic entity is argued to be highly accessible as an indirect antecedent for bridging inference (Matsui, 1993). A topic entity is normally a preferential candidate for the subsequent referential expression (co-reference) and topic continuation is regarded as an important principle to maintain discourse coherence during both utterance comprehension (Cowles, Walenski, & Kluender, 2007; Kaiser, 2011; Stevenson, Nelson, & Stenning, 1995) and production (Cowles & Ferreira, 2011).

1.2. Electrophysiological correlates of pragmatic inference

The involvement of pragmatic inference during sentence comprehension can facilitate the construction of a coherent discourse representation, and lead to faster and better comprehension performance. Electrophysiological studies have shown an attenuated N400 (a negative deflection, between 300 and 500 ms post-onset of a target word, which is linked, among other things, to lexical-semantic integration) for sentences where pragmatic inference was straightforward, as compared to those where such processes were difficult or impossible (Hirotani & Schumacher, 2011; Kuperberg et al., 2011), suggesting that the process of establishing a coherent sentence representation can benefit from pragmatic inference. Nonetheless, the N400 has also been interpreted to reflect memory (lexical-semantic) retrieval (Brouwer, Fitz, & Hoeks, 2012; Federmeier & Kutas, 1999; Federmeier & Laszlo, 2009; Kutas & Federmeier, 2011), with its (smaller) size indexing the ease with which lexical information is retrieved from the lexicon.

However, although pragmatic inference can facilitate sentence comprehension, making a pragmatic inference is not itself without cost, it slows down sentence processing, as it takes extra time and cognitive resources (e.g., working memory capacity, Clark & Sengul, 1974; Haviland & Clark, 1974; Van den Broek, Beker, & Oudega, 2015). For instance, Yang et al. (2007) observed a larger N400 in response to a target word when its interpretation was dependent on an inferential process (e.g., "… the bomb hit the ground. The *explosion* …") than when morphological (their term is "referentially explicit" e.g., "… the bomb hit the ground and **exploded**. The *explosion* …") or conceptual associations existed between them (e.g., "… the bomb hit the ground and **blew up**. The *explosion* …"). Difficulties in establishing pragmatic inference during sentence processing have also been reflected by the P600 (e.g., Burkhardt, 2006; Davenport & Coulson, 2011), a late positivity which was initially interpreted to reflect syntactic processing (Osterhout & Mobley, 1995; Osterhout, Holcomb, & Swinney, 1994) and more recently has been described as reflecting reinterpretation or updating of discourse representations (Brouwer et al., 2012; Burkhardt, 2006; Hung & Schumacher, 2012; Kaan, Dallas, & Barkley, 2007; Steinhauer & Connolly, 2008). Burkhardt (2007) measured ERPs on target words (e.g., 'pistol') following contexts which have different inferential relations with the target word (e.g., "Yesterday, a Ph.D. student was shot/killed/found dead/downtown"), a larger positivity (P600) was obtained on target words when an inferential process was necessary (under 'killed' context) compared to cases in which they were not (the 'shot' context) due to the explicit semantic association, probably because processing an inferential reference requires more cognitive effort to update the discourse model than processing an overt reference.

Pragmatic inference is subject to both lexical-semantic and structural constraints (Van den Broek et al., 2015). In a number of recent studies (e.g., Burkhardt, 2006; Haviland & Clark, 1974; Kuperberg et al., 2011; Stafura & Perfetti, 2014; Stafura, Rickles, & Perfetti, 2015; Yang et al., 2007), semantic association across clauses/sentences was manipulated. Most of these studies adopted a word-to-text processing paradigm in which the integration of a target word of a second sentence/clause into the existing representation (i.e., the initial sentence/clause) was dependent on the degree to which the preceding sentence/clause contained an antecedent that had a semantic association with the target word. Using this paradigm combined with a meaning judgment task, Stafura and Perfetti (2014) examined how inference was modulated by different degrees of semantic association between a target word and the preceding text. While the target word (e.g., the "rain") was preceded either by a strongly (" …, dark clouds began to gather, and it started to **storm**. The *rain* …") or a weakly associated prime (" …, dark clouds began to gather, and it started to **shower**. The *rain* …"), both resulted in reduced N400 responses relative to the baseline condition (in which the target word had no readily-available referent in the preceding text), a larger N400 reduction was observed in strong association conditions than weak association ones over some sites (e.g., left parietal electrodes), suggesting that pragmatic inference can benefit from semantic association. Moreover, the direction of the association can also affect pragmatic inference as well (Stafura et al., 2015). Backward

association (from target to text, e.g., "when the bear was awoken by the wandering chipmunk, he was filled with <u>anger</u>. The *rage* …") resulted in larger P600, as well as N400, responses than the forward association (from text to target, e.g., "when the bear was awoken by the wandering chipmunk, he was filled with <u>rage</u>. The *anger* …"). The ERP modulations were attributed to different load on memory system—backward inference is assumed to be less sensitive to memory capacity than forward inference.

Apart from semantic constraints, drawing pragmatic inference is also affected by structural constraints. In an off-line sentence comprehension task (asking *How much do you think the action is due to the subject/object?*), Bettinsoli et al. (2015) explored how word order variation influences causal interpretation of an event. Consistent with other studies (e.g., Kandylaki, 2011; Li & Zhou, 2010), the authors found that participants were more likely to attribute the cause of an event (e.g., the teacher has criticized the student) to the element that occurs in the first rather than in later (2nd or 3rd) sentential positions, indicating a preferential causal attribution for the first over the second mentioned element, due to the more salient status of the sentence-initial than the sentence-medial elements in a sentence. More importantly, in one recent ERP study using a word-text processing paradigm, Burkhardt and Roehm (2007) investigated how inferential processing is modulated by the structural salience of the contextual sentence. The target word (in sentence (3)) was preceded either by a salient structure (only one potential referent with no coordination) like (2a), or a less salient structure (two potential referents with coordination) like (2b). A more pronounced N400 was observed (on '*midwife*') if the inferential relation involved a less salient referent (2b) compared to the inferential relation that contained a highly salient referent (2a). This seems to suggest that pragmatic inference can benefit from structural aspects of prominence.[1]

(2a) Gerhard/filmte/erstmals/eine Geburt/für/Arte. (with no coordination)
   Gerhard/filmed/for the first time/a <u>childbirth</u>/for/Arte.
(2b) Erwin/filmte/erstmals/eine Geburt/und/eine Beerdigung. (with coordination)
   Erwin/filmed/for the first time/a <u>childbirth</u>/and/a funeral.
 (3) Er/berichtete,/dass/die Hebamme/äußerst/freundlich/war. (target sentence)
   He/reported/that/the <u>midwife</u>/extremely/friendly/was.

It should be noted that the notion of structural constraint has a closer association with pragmatic than lexical-semantic information. In many cases, structural manipulations, such as word order variation, can lead to a change in an entity's pragmatic and information status, especially in languages with flexible word orders (e.g., Chinese, Xu, 2015; LaPolla, 1995; Finnish, Järvikivi, van Gompel, Hyönä, & Bertram, 2005). However, up until now, existing ERP studies were mainly concerned with how pragmatic inference is modulated by lexical-semantic associations or purely structural differences, it remains unclear how pragmatic inference is constrained by pragmatic information.

Taken together, existing evidence from ERP studies indicates that inference making during sentence processing can facilitate the on-line establishment of a coherent mental representation. Drawing a pragmatic inference is also a strategic and resource-consuming mental operation, and is modulated by a number of constraints including semantic as well as structural factors. However, the existing studies reviewed were mainly concerned with how pragmatic inference is modulated by semantic associations or structural differences, it remains unclear how pragmatic inference is modulated by pragmatically encoded information status, in particular that which is realized through structural manipulations.

1.3. The present study

In contrast to the above mentioned studies in which different levels of lexical-semantic association between the target word and the preceding text were manipulated, the present study focused on how pragmatically-based information status influences the establishment of a bridging inferential relation. More specifically, we want to examine whether and how establishing inference during word-to-text integration process is modulated by the information status of an intended referent (e.g., topic antecedent vs. non-topic antecedent). To this end, we manipulated the information status of the referent while keeping the semantic associations between target and the intended antecedent completely constant.

Chinese is claimed to be a topic-prominent language (Huang, Li, & Li, 2009; Li & Thompson, 1976, 1989), in which topic-comment is a canonical information structure in addition to subject-verb-object (SVO) structure. As a topic-prominent language, Chinese uses topicalization to a greater degree than other non-topic-prominent languages (Li, 1996). However, in contrast to other languages (e.g., German, Japanese) in which topic can be realized through morphological devices such as case marking (e.g., Hirotani & Schumacher, 2011), topic information in Chinese is not realized morphologically. Instead, topichood in Chinese is typically indicated using pragmatic or discourse devices. In many situations, especially in the written form, topic is identified based on word order alone. For instance, although both sentence (4) and (5) are acceptable in Chinese, the NP, "the book" conveys different linguistic functions in (4) and (5). While "the book" (书) plays a patient role and acts as an object in (4), it acts as sentence topic in (5) even if it plays the same patient role. This is because "the book" is in the prominent sentence-initial position and is interpreted as the shared information between the speaker and the addressee in (5), but not in (4). It is thus assumed that the entity ("the book") is more salient in discourse in sentence (5) than in sentence (4).

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[1] However, as suggested by an anonymous reviewer it could also be that the difference between conditions is linked to the level of semantic richness they contained, as one condition contained one semantic element and the other two.

(4) 小王看完了书.

     Xiaowang has read book (SVO)

     Xiaowang has read the book.

(5) 书小王看完了.

     Book Xiaowang has read (OSV)

     Xiaowang has read the book.

(6) 小王书看完了.

     Xiaowang book has read (SOV)

     Xiaowang has read the book.

Another important feature of Chinese topic structure is that Chinese can support more than one topic entity in a single sentence (Xu & Liu, 2007). Taking sentence (6) as an example, in addition to the main topic (i.e., "Xiaowang") of the sentence, "the book" is regarded as the second topic (or sub-topic) of the sentence as it is in second position, before the verb "read", and it is also treated as the shared information between speaker and hearer (Xu & Liu, 2007; Xu, 2015). As a consequence, "the book" (sub-topic) is believed to be more salient in sentence (6) than in sentence (4). According to Chao (1968), at least 50% of Chinese sentences can be analyzed as having topic-comment structure, in which a topic establishes a reference point upon which the rest of the sentence (i.e. comment) is centered. Thus, Chinese provides us with a good opportunity to test the influence of topic structure on sentence processing in more natural contexts than in other subject-prominent languages.

Similar to previous studies using word-to-text processing paradigms (e.g., Burkhardt, 2006; Stafura & Perfetti, 2014; Yang et al., 2007), we created two-clause sentences which contained two critical words: an antecedent word in the first clause and a target word in the initial position of the second clause. The first clause distinguished three types of information structures (SVO, SOV, and OSV), with the intended antecedent (the Object) embedded in these clauses bearing three different types of information status (objecthood, sub-topichood, and topichood). According to the immediate integration hypothesis of sentence processing (Koornneef & Van Berkum, 2006; Traxler, Bybee, & Pickering, 1997; Yang et al., 2007), if information structure indeed affects the on-line establishment of a coherent mental representation, it should exert an immediate influence on the integration of the initial word of the second clause. Specifically, if inference making can benefit from topic prominence, integration of the target word into the mental model will be easier in a topic referential sentence compared to a non-topic referential one, and even in sub-topic referential sentences compared to non-topic referential ones, and thus result in attenuated P600 responses in the former than the later cases. As for the N400 effect, we have two different predictions. According to the integration account (Hagoort, Hald, Bastiaansen, & Petersson, 2004; Kuperberg et al., 2011), topic-shift would lead to difficulties in semantic integration, and thereby gave rise to larger N400 responses for non-topic inferential sentences (i.e., SVO structure) compared to topic inferential sentences. Alternatively, according to the retrieval account (Brouwer et al., 2012), these non-topic inferential sentences should elicit reduced N400 responses in comparison with topic inferential sentences, because the former is easier to retrieve than the later due to the benefits of a short-distance dependency.

2. Methods

2.1. Participants

Thirty-eight native Chinese speakers from Nanjing Normal University, Nanjing, China participated in this study. The data from five participants were excluded due to EEG artifacts (*n* = 4), or because they did not complete the task (*n* = 1), resulting in 33 participants in the final ERP data analyses (13 women, their age ranged from 19 to 28 years with a mean of 23.1 years). All of them were right-handed and had normal or corrected-to-normal vision. None of them had a history of neurological or psychiatric disorders. None had participated in stimuli development tasks described below. Participants gave informed consent before the experiment. This study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Nanjing Normal University.

2.2. Design and materials

Ninety triplets of two-clause sentences were constructed, as illustrated in Table 1. For each triplet, the target clause (second clause) was kept identical in all three conditions, whereas the initial clause has identical constituents but their order of mention was not the same, due to manipulation of the information status of the critical antecedent (e.g., *morning newspaper*). Specifically, the intended antecedent of the target embedded in the initial clause could occur either in sentence-initial position, sentence-medial position or sentence-final position, and correspondingly functions as the topic, the sub-topic and the non-topic (i.e., object), as demonstrated in 7(a), 7(b), and 7(c), respectively (Xu & Liu, 2007). Note however that although the initial (target) word of the second clause ("the fire") had no explicit semantic/lexical association with the constituents in the preceding clause, it could be linked with the intended antecedent and the preceding text by drawing a pragmatic inference, since there was an indirect referential relation between the target and the intended antecedent (based on real world knowledge and context). For each condition, successful integration of the target word of the second clause into the existing discourse representation depended on the generation of an inference to bridge the gap between the target and the meaning of the preceding text. In particular, integration difficulty was expected to be largely dependent on the degree to which a pragmatic inference was generated, which, in turn, was mainly constrained by the information status of the intended referent.

Table 1
Experimental conditions and exemplar sentences with literal translations and glosses.

Conditions	Examples
Topic	(7a) 早报/爷爷/已经读过了, 大火/得到了/控制. *Zaobao yeye yijing duguole, dahuo/dedaole/kongzhi* morning-newspaper/Grandpa/has-read, fire/has-been/put-out Grandpa has read the morning-newspaper; the fire has been put out.
Sub-topic	(7b) 爷爷/早报/已经读过了, 大火/得到了/控制. *Yeye zaobao yijing duguole, dahuo/dedaole/kongzhi* Grandpa/morning-newspaper/has-read, fire/has-been/put-out Grandpa has read the morning-newspaper; the fire has been put out.
Non-topic	(7c) 爷爷/已经读过了/早报, 大火/得到了/控制. *Yeye yijing duguole zaobao, dahuo/dedaole/kongzhi* Grandpa/has-read/morning-newspaper, fire/has-been/put-out Grandpa has read the morning-newspaper; the fire has been put out.

For the ERP experiment, each experimental sentence in a triplet was assigned to a different testing list with a Latin-square design, such that each list had 30 different sentences per condition and each subject see only one sentence of each triplet. Moreover, in order to encourage the reader to read the sentence naturally without developing strategies, 180 filler sentences were constructed, including 150 sentences with similar two-clause structures as the experimental conditions (with the initial clause having either SVO, SOV, or OSV structure) but either a pronoun (120 sentences; e.g., *she*, as in "*Xiaoli* lost her bank card, *she* didn't buy anything today") or a function word (30 sentences; e.g., *then, but, once*, etc.) occupied the initial position of the second clause, and 30 sentences in which there was a close semantic association between the critical word and the potential referent (e.g., *The patient* was in low spirits, *the doctor* encouraged her to cheer up). All sentences in each list were pseudo-randomized, with the restriction that no more than three consecutive sentences were of the same type and no more than three consecutive sentences were expected to generate a "yes" or "no" response (see Procedures below).

The stimulus materials underwent three separate pretests, including a semantic association judgment test (forced choice test), a sentence completion test, and a sentence acceptability rating test. The forced choice and the sentence completion tests were developed to test (1) whether bridging inference was engaged after onset of the target words, and (2) the potential association between the target word and the preceding context (e.g., NP1, NP2, and the initial clause). In both tests, the first clause as well as the target word of the second clause was presented as a whole, while the sentence constituents after the target noun were deleted. In the forced-choice test, thirty-three participants were randomly assigned one of three counterbalanced lists (with only one of the three conditions for a given target). They were asked to select the antecedent noun that was most closely related to the target word. Three choices were provided, namely the initial noun (NP1), the second noun (NP2), and a third noun not mentioned in the context (a person or a thing). In the sentence completion test another thirty-two participants were asked to write a meaningful continuation to the fragment of each testing sentence. There was no time or word limit, but the completed sentences were to be as natural and reasonable as possible. The completion responses were coded into three types: mainly related with (1) the inanimate object-noun in the initial clause (e.g., 老赵租好了办公室, 地板是红色的/Laozhao has rented an office, the carpet is red.); (2) the whole initial clause (e.g., 小明从来不玩电脑, 游戏容易上瘾/Xiao Ming never uses computers; the games are easily addictive.); (3) other words/sentences not explicitly mentioned in the text (e.g., 小明从来不玩电脑, 游戏也不玩/Xiao Ming never uses computers, the games he doesn't play either.). Compared with the forced choice test, the sentence completion test is less influenced by task and therefore is more ecological.

Results from the forced choice test (see Table 2) showed that the target nouns of the second clause were more closely related with the object referent (inanimate noun) than either the subject referent (i.e., animate noun, OSV: $t(32) = 5.23$, $p < .001$; SOV: $t(32) = 7.26$, $p < .001$; SVO: $t(32) = 7.77$, $p < .001$) or the outside-context referent (OSV: marginally significant, $t(32) = 1.64$, $0.05 < p < .1$; SOV: $t(32) = 2.97$, $p < .01$; SVO: $t(32) = 3.1$, $p < .01$). The percentage of subject reference or outside-context reference, however, was not different across conditions (for subject reference, $ps > 0.3$; for outside-context reference, $ps > 0.6$), although the percentage of object reference was larger in OSV sentences than in SVO ones ($p < .05$), suggesting that the possibility of linking the target noun with the outside-context referent (the possibility of drawing outside-context inference) was equal across conditions.

Results from the sentence-completion task in Table 3 show that completion of the second clause was more likely related with the

Table 2
Percentage linking of the target noun with the inanimate object-noun, the animate subject-noun, or a third unmentioned referent in the forced choice test.

	object-noun	subject-noun	outside-context referent
Topic	0.46 ± 0.19	0.19 ± 0.18	0.35 ± 0.23
Sub-topic	0.51 ± 0.18	0.16 ± 0.16	0.33 ± 0.20
Non-topic	0.52 ± 0.19	0.16 ± 0.16	0.32 ± 0.22

Table 3
The possibility (percentage) of linking the second clause with the inanimate object-noun in the initial clause, the whole initial clause, or other words/sentences not explicitly mentioned in the text in the sentence completion test.

	object-noun	whole clause	other words/sentences
Topic	0.31 ± 0.12	0.56 ± 0.16	0.09 ± 0.10
Sub-topic	0.32 ± 0.14	0.52 ± 0.16	0.14 ± 0.13
Non-topic	0.35 ± 0.15	0.58 ± 0.14	0.06 ± 0.08

whole first clause (e.g., *Grandpa has read the morning-newspaper*) rather than a single referent, i.e., the object noun (e.g., *morning-newspaper*), in all three conditions. Pair-wise *t*-tests from the sentence completion test failed to show differences across the three conditions, neither for linking the target to the whole clause (*ps* > 0.5), nor for linking it to the single object noun (*ps* > 0.7), suggesting that the probability of drawing pragmatic inference in these three conditions is the same. Thus, readers continue the sentences based on the entire sentence rather than individual words (i.e., inanimate object nouns). This result differs from those found in the forced choice test, which showed that the target word was most closely related with the inanimate noun. Both lines of evidence suggest that although the target words are most closely related to the inanimate nouns (object noun), readers tend to connect the target word with the whole preceding clause rather than a single word. This means that interpretation of the target word depends on a bridging inference that links it with the existing event representation, rather than a purely-lexical semantic association between the target word and a given antecedent.

Additionally, in order to examine to what extent each of the experimental sentences was acceptable, an off-line sentence acceptability test was conducted prior to the ERP experiment. For this task, the critical sentences, together with filler sentences, were divided into three versions using a Latin-square procedure. Twenty-four students were randomly assigned to one of the three versions and were asked to judge the acceptability of each of the sentences using a 7-point Likert Scale (1 indicating the least acceptable and 7 indicating the most acceptable). The mean acceptability score for experimental stimuli was 4.7 (SD = 1) for the OSV sentences, 4.3 (SD = 1) for the SOV sentences, and 5.2 (SD = 0.8) for the SVO sentences. Repeated measures ANOVA showed a significant main effect of experimental condition, $F(1,23) = 15.28$, $p < .001$. Post-hoc pair-wise comparisons showed that SVO sentences were more acceptable than either the OSV sentences, $t(23) = 2.85$, $p < .03$, or the SOV sentences $t(23) = 5.2$, $p < .01$. Moreover, OSV sentences were more acceptable than SOV ones $t(23) = 3.0$, $p < .03$.

2.3. Procedures

Participants sat in a comfortable chair in a dimly lit room and were instructed to read each sentence carefully. Each trial began with a fixation cross ('+') at the center of the screen for 500 ms, followed by a blank screen for 500 ms. Then the initial clause was presented on the screen (the screen included the entire clause). After reading the first clause, the participant immediately pressed the space bar to initiate the second clause, which was presented word-by-word at the center of the screen. Each segment was presented for 400 ms followed by a 400 ms blank screen. The final segment of each sentence was followed by a yes/no comprehension question that probed sentence comprehension (e.g., "*Has the fire been put out?*"). Assignment of left/right hands to yes/no responses was counterbalanced across participants.

Participants performed a practice block of 20 sentences that had similar structures as the test stimuli. In the experiment, the test stimuli were divided into four blocks and the participant had an average break of about three minutes between each block. The whole experiment lasted about 2.5 h on average, including electrode installation.

2.4. EEG recording and data analysis

EEG activity was recorded from 63 electrodes in a secured elastic cap (Electro-cap International) and Electrode impedances were kept below 5 kΩ. The EEGs were referenced online to the tip of nose and re-referenced offline to the algebraic average activity measured in the left and right mastoids (TP9 and TP10). The vertical electrooculogram (VEOG) was monitored from electrodes located above the right eye and the horizontal electrooculogram (HEOG) from electrodes located at the outer canthus of the left eye. EEG signals were filtered using a bandpass of 0.016–70 Hz, and digitized at a sampling rate of 500 Hz. Trials with absolute values greater than 60 μV were excluded from further analysis. Trials with ocular artifacts were corrected using an independent component analysis (ICA) approach (Jung et al., 1998; Makeig, Bell, Jung, & Sejnowski, 1996).

For each sentence, a 900 ms ERP epoch was extracted for the initial word of the second clause (e.g. "fire"). As the difference in word-order prior to the target, a 0.1–20 Hz band-pass filter rather than the pre-stimulus baseline correction was adopted. The very mild high-pass filter procedure can remove slow voltage shifts and avoid causing the baseline artifact at the same time (see Widmann, Schröger, & Maess, 2014; Wolff, Schlesewsky, Hirotani, & Bornkessel-Schlesewsky, 2008). Trials with incorrect responses were eliminated from data analysis, and the remainder were screened for drift artifacts. The mean number of trials included for EEG analysis was 27.9 for the topic condition, 28.5 for the sub-topic condition, and 28.2 for the non-topic condition. There was no significant difference between conditions, *ps* > 0.1.

On the basis of visual inspection as well as the previous literature concerning inferential processing (e.g., Burkhardt, 2006; Cohn & Kutas, 2015; Dröge, Fleischer, Schlesewsky, & Bornkessel-Schlesewsky, 2016; Xu, Jiang, & Zhou, 2015), the 350–450 ms as well as

450–800 ms time windows were selected for statistical analysis of the N400 and P600 components. Analyses of variance (ANOVAs) were conducted on mean ERP amplitudes in these two time windows, with *experimental condition* (topic, sub-topic, and non-topic), and topographical factors as within-participant variables. For the midline analysis, the topographic factor was *region* [three levels: anterior (Fz and FCz), central (Cz and CPz), and posterior (Pz and POz)]. For the lateral analysis, the topographic factor was *region* (three levels: anterior vs. central vs. posterior) and *hemisphere* (two levels: left vs. right). The factors *region* and *hemisphere* were crossed, resulting in six regions of interest: left frontal (F1, F3, F5, FC1, FC3 and FC5), left central (C1, C3, C5, CP1, CP3 and CP5), left posterior (P1, P3, P5, PO3, and PO7), right frontal (F2, F4, F6, FC2, FC4 and FC6), right central (C2, C4, C6, CP2, CP4 and CP6) and right posterior (P2, P4, P6, PO4, and PO8). Mean amplitudes over electrodes in each region of interest were entered into ANOVAs. Post-hoc comparisons with Bonferroni correction were carried out and the Greenhouse-Geisser correction was performed when appropriate.

3. Results

3.1. Behavioral results

Average comprehension question accuracy was 98.7% (Mean = 29.5, SD = 0.86) for the topic-referential condition, 98.8% (Mean = 29.6, SD = 0.55) for the sub-topic referential condition, and 97.6% (Mean = 29.3, SD = 1.12) for the non-topic referential condition. An ANOVA with experimental condition as a within-subject factor failed to show any significant effect of condition, $F(2,64) = 2.02$, $p > .1$, suggesting that participants can process these sentences equally well.

3.2. ERP results

The grand averaged ERPs, time-locked to the target words, are shown in Fig. 1. As can be seen in Fig. 1, target words in the non-topic condition elicited a larger P600 compared to those in the topic condition or sub-topic condition. Additionally, a reduced N400 was elicited by the target word when the intended referent in the preceding clause was in non-topic position, compared to topic position. The scalp topographies in Fig. 2 depict the differences on the target words between the non-topic and the topic/sub-topic conditions, as well as between the sub-topic and the topic conditions in the 350–450 ms and 450–800 ms time windows, respectively.

3.2.1. 350–450 ms time window (N400)

Mean amplitudes recorded at the lateral and midline electrodes were analyzed separately. Repeated-measures ANOVAs with *condition*, *region* and *hemisphere* as within-subject variables showed a significant main effect of *condition* [lateral: $F(2,64) = 3.16$, $p < .05$, $\eta^2 = 0.09$; midline: $F(2,64) = 2.34$, $0.05 < p < .1$, $\eta^2 = 0.07$]. No other effects were significant.

Follow-up pairwise-comparisons showed that the non-topic condition induced a reduced N400 compared to the topic condition [lateral: $t(32) = 2.46$, $p < .05$; midline: $t(32) = 1.96$, $.05 < p < .1$] but not the sub-topic one, $ps > 0.1$.
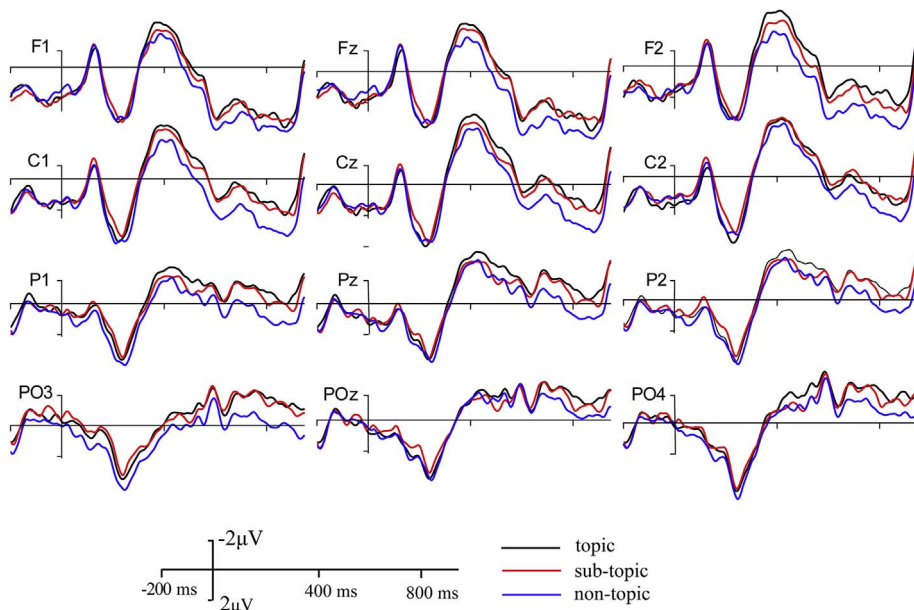

Fig. 1. Grand average ERPs time-locked to the onset of the target words in the second clause for the topic condition, sub-topic condition, and non-topic condition.
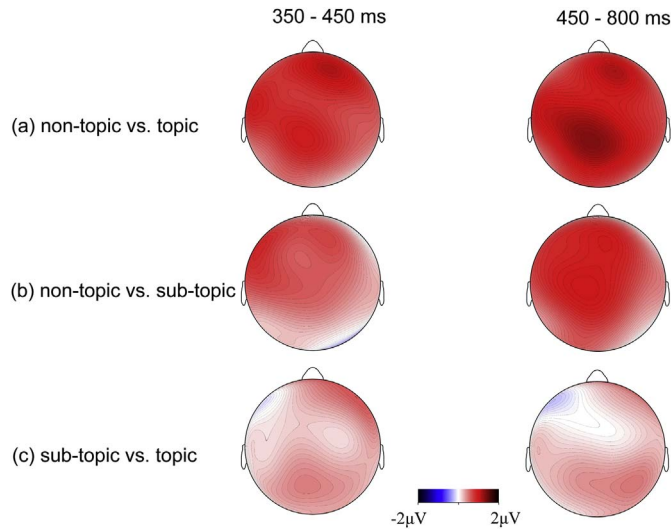
Fig. 2. Topographic maps for the difference waves resulting from the subtractions of ERPs for topic condition from that for non-topic condition (a), ERPs for sub-topic condition from that for non-topic condition (b), and ERPs for topic condition from that for sub-topic condition (c) in the 350–450 ms and 450–800 ms time window, respectively.

3.2.2. 450–800 ms time window (P600)

Repeated-measures ANOVA with *condition*, *region*, and *hemisphere* (only in the lateral analysis) as within-subject variables showed a significant main effect of *condition* [lateral: $F(2,64) = 6.49$, $p < .005$, $\eta^2 = 0.17$; midline: $F(2,64) = 6.01$, $p < .005$, $\eta^2 = 0.16$]. No other effects were significant, $ps > 0.1$.

Follow-up pairwise-comparisons showed that the non-topic condition elicited a larger P600 than either the topic condition [lateral: $t(32) = 3.98$, $p < .005$; midline: $t(32) = 3.80$, $p < .005$], or the sub-topic condition [lateral: $t(32) = 2.46$, $p < .05$; midline: $t(32) = 2.36$, $p < .05$], whereas there was no difference in the P600 elicited in the topic and the sub-topic conditions, $ps > 0.3$.

4. Discussion

This study investigated the impact of information structure (topic structure vs. non-topic structure) on inference making during sentence comprehension. An enhanced P600 was observed at target words (NPs) when the intended referent in the preceding clause was in non-topic position compared to topic or sub-topic positions, when the potential interference from distance was excluded. In contrast, a reduced N400 was observed on the target word when the intended referent was in non-topic position, compared to topic position. These findings suggest that building an inferential relation during discourse processing can benefit from information structural prominence (topichood).

4.1. N400 and semantic processing

A larger N400 is observed in response to sentences with various types of semantic or pragmatic incoherence (Hagoort et al., 2004; Kutas & Hillyard, 1980). The N400 has also been observed in situations where there is no semantic or pragmatic incoherence, but where an inferential process has to be employed to build a coherent sentence representation (e.g., Burkhardt & Roehm, 2007). The size of N400 effect has traditionally been interpreted to reflect the relative difficulty of semantic integration processing (Hagoort et al., 2004; Kuperberg et al., 2011). Alternatively, the amplitude of N400 has also been interpreted as reflecting the ease of retrieving lexical information from long-term memory (Brouwer et al., 2012; Federmeier & Kutas, 1999; Federmeier & Laszlo, 2009). According to the later account, the more difficult the retrieval process, the larger the N400 amplitude will be. As for the present study, given that the same critical antecedent-target word pairs were used, the lexico-semantic information between the target word and the intended referent in preceding text remains identical across conditions. The difference in N400 amplitude, therefore, is less likely to be associated with the lexically-based integration process. In particular, according to the integration account, if the difference in N400 amplitude is associated with semantic integration, topic-inferential relations should result in reduced N400s relative to the non-topic inferential conditions, because integrating a semantically salient entity (topic) should be easier than integrating a semantically less salient entity (object). However, the fact that an enhanced, rather than a reduced N400, was found for topic-inferential relations than non-topic-inferential ones goes against this explanation. Instead, the difference in N400 amplitude was more plausibly related to retrieval processing difficulties — that is, retrieving lexical information from long-term memory and linking it to the target word. Consistent with this interpretation, a number of ERP studies found a correlate between the N400 amplitude and the distance between an anaphora and its potential referent. For instance, Hammer, Jansma, Lammers, and Münte (2008) found that long-distance

referential relations resulted in increased N400 responses in comparison with short-distance referential relations, due to the increased effort when linking a pronoun with a less accessible antecedent. In the same vein, in our study the establishment of a link was easier for non-topic referential relations than for topic-referential relations, because of the stronger activation of the antecedent in the shorter distance dependency than the long distance dependency, and thus resulted in a reduced N400 in the non-topic referential relation, compared to the topic referential relation.

4.2. P600, pragmatic inference, and sentence integration processing

In contrast to previous studies (Kuperberg et al., 2011; Yang et al., 2007), a sustained positivity (P600) in addition to an N400 was observed when participants were establishing a bridging inference. The P600 component has been found across languages for a large variety of linguistic anomalies including syntactic violations (Hagoort, Brown, & Groothusen, 1993; Osterhout & Mobley, 1995; Xu, Jiang, & Zhou, 2013), syntactic ambiguities ("garden path" sentences; Osterhout et al., 1994), or even thematic violations (e.g., "The hearty meal was devouring …"; Kim & Osterhout, 2005), and has been interpreted to reflect repair or reanalysis. However, the P600 effect observed in this study cannot be grouped in this class of phenomena, since neither syntactic nor semantic anomalies or ambiguities were present. Instead, the P600 is more likely associated with ease of integration (Brouwer et al., 2012; Hoeks & Brouwer, 2014; Wang & Schumacher, 2013), namely integrating an indirectly (inferentially) associated relation into discourse. According to the integration account, the P600 amplitude is associated with the effort engaged to establish a coherent discourse representation, irrespective of whether there is an overt anomaly or not. The more demanding integration is, the larger the amplitude of the P600.

The observation of a P600, however, is inconsistent with a few previous studies of pragmatic inference in which only an N400 component was reported (Kuperberg et al., 2011; Yang et al., 2007; Nieuwland, 2013, but see Davenport & Coulson, 2011 who observed a P600 in addition to an N400 when building a novel meaning mapping, e.g., the mapping between the concept *cardboard box* and *boat* in "The clever boys used a cardboard box as a boat, …"). One interpretation for the observation of late positivity may be related with the manipulation of topic structure. Given its prominent status in discourse, the integration of a topic entity (given information) into discourse is less costly than integration of a non-topic entity (new information), since the later would lead to topic shift or topic incoherence. Previous studies have repeatedly shown that topic shift during sentence or discourse processing gives rise to P600 response, reflecting effort on updating the discourse model (Burkhardt, 2006; Hirotani & Schumacher, 2011; Xu, 2015). Here, topic inconsistency in the non-topic referential condition makes pragmatic inference more demanding, and hence generated a larger P600. Note that the P600 modulation cannot be explained by distance-based differences (e.g., difference in working-memory load) between the target word and the referent, because, if distance matters, a smaller rather than larger P600 response should be observed at the non-topic target word, as a short referential dependency usually leads to attenuated rather than increased P600 response (Hammer et al., 2008; Xu et al., 2015). Furthermore, the P600 effect cannot be explained in terms of differences in acceptability either. If sentence acceptability is the key factor, a reduced P600 response should be found for non-topic-referential sentences (e.g., SVO sentence) rather than the topic referential sentences, since the former are more acceptable than the later. However, the finding of an enhanced P600 for non-topic over topic referential sentences goes against this interpretation.[2] Finally, the P600 modulation cannot be attributed to lexical-semantic associations between target words and antecedents. First, at the lexical-level, the same word pairs (the same target-antecedent words) were used in each triplet of experimental materials. Second, at the sentence-level, the results from both the forced choice and the sentence completion showed that the preceding context and the mention-order exert no influence on semantic associations between targets and antecedents. This provided further evidence to support our arguments that the observed P600 modulation was mainly attributable to discourse-level inference rather than purely lexical-semantic associations.

The larger P600 in non-topic-referential condition could be related to processing costs involved in establishing pragmatic inference while integrating the target word with the preceding text representation. As demonstrated previously, an enhanced P600 was regularly observed in situations where new discourse entities are introduced or bridging inference must be drawn to achieve discourse coherence, reflecting the increased processing costs in updating the discourse model (Burkhardt, 2006; Burmester et al., 2014; Hirotani & Schumacher, 2011; Kaan et al., 2007; Xu et al., 2013). As for the present study, although inferential processes are required to establish a coherent mental model for all three experimental conditions, the cognitive effort needed for successful pragmatic inference is not equal. For topic referential sentences, given that the antecedent word (e.g., *Xiaowang*) occurs in the sentence-initial position and is what the following utterance is about (i.e., aboutness), it is thus highly accessible in readers' mental models. A bridging inference under such circumstance can easily be established. For the non-topic referential sentence, however, the integration process may have been more difficult, because the antecedent word occurs in a less prominent sentence-final position and acts as a sentence object. Its accessibility status in discourse, therefore, is relatively lower than the initial NP (e.g., *morning newspaper* in sentence 7a). This lower status increases the cost of bridging inference and consequently leads to increased brain activity.

Previous ERP studies (Stafura & Perfetti, 2014; Stafura et al., 2015) have shown that increased semantic association between the target word and the preceding text leads to an N400 reduction, because a stronger semantic association can facilitate pragmatic inference. However, the facilitation observed here cannot be based on a stronger semantic association, but rather is due to pragmatically-based information status, namely the more prominent status of topic entities over non-topic entities. Moreover, the present study is also different from Burkhardt and Roehm's (2007) study in which the referent's salience status was mainly realized through

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[2] As can be seen in Fig. 1, although a tendency for a larger P600 for the sub-topic sentence compared to the topic sentence seems consistent with the acceptability account (OSV sentences are more acceptable than SOV ones), the difference between these two conditions did not reach significance.

structural manipulation (a coordinate structure vs. non coordinate structure). While one referent was available in the non-coordinate structure, two were available in the coordinate structure. The referential ambiguity in coordinate structure may have significantly increased retrieval costs and thus resulted in an increased N400.

4.3. The N400-P600 complex and neurolinguistic models of sentence processing

The finding of both N400 and P600 components in response to pragmatic inference processing can be interpreted within the framework of two-stage models of sentence processing (e.g., Brouwer & Hoeks, 2013; Brouwer et al., 2012). According to the Retrieval-Integration model proposed by Brouwer et al. (2012), sentence processing is composed of a memory retrieval process and a subsequent integration process. The retrieval process is reflected by the N400, which is modulated by the ease with which lexical and semantic information can be retrieved from long-term memory, and is followed by the integration of each constituent into a coherent syntactic and mental representation, which can be reflected by modulations of the P600. The short distance between the target word and the intended antecedent in the non-topic condition (relative to the topic condition) led to a stronger memory representation of the preceding referent. Consequently, the retrieval process was much easier in the non-topic condition than the topic one and thus resulted in a reduced N400. However, although retrieval processes benefited from this short-distance, the integration process apparently did not. Instead, compared to the long-distance dependencies (the topic as well as sub-topic condition), the integration of short-distance dependencies into the discourse representation was more demanding, because the non-topic referent is pragmatically as well as structurally less prominent in discourse than either the topic entity or the sub-topic entity. More effort was thus required to integrate the entities with the less salient information, resulting in larger P600s. This seems to indicate that information-structural prominence takes precedence over linear effects in establishing inferential coherence. Thus, the final integration process benefits less from distance than from the information status of referents.

5. Conclusion

By manipulating the information status of an intended antecedent of referential expressions, we examined how their interpretation was modulated by the information structure of an intended antecedent. While a reduced N400 was elicited by a referential expression when the intended referent was in non-topic position compared to topic position, an enlarged P600 was elicited by the referential expression when the intended referent was in non-topic position compared to topic or sub-topic positions. These findings suggest that establishing inference can benefit in different ways from the status of information structure.

Acknowledgements

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jneuroling.2017.12.004.

References

Bettinsoli, M. L., Maass, A., Kashima, Y., & Suitner, C. (2015). Word-order and causal inference: The temporal attribution bias. *Journal of Experimental Social Psychology, 60*, 144–149. http://dx.doi.org/10.1016/j.jesp.2015.05.011.

Brouwer, H., Fitz, H., & Hoeks, J. (2012). Getting real about semantic illusions: Rethinking the functional role of the P600 in language comprehension. *Brain Research, 1446*, 127–143. http://dx.doi.org/10.1016/j.brainres.2012.01.055.

Brouwer, H., & Hoeks, J. C. J. (2013). A time and place for language comprehension: Mapping the N400 and the P600 to a minimal cortical network. *Frontiers in Human Neuroscience, 7*, 758. http://dx.doi.org/10.3389/fnhum.2013.00758.

Burkhardt, P. (2006). Inferential bridging relations reveal distinct neural mechanisms: Evidence from Event-related brain potentials. *Brain and Language, 98*, 159–168. http://dx.doi.org/10.1016/j.bandl.2006.04.005.

Burkhardt, P. (2007). The P600 reflects cost of new information in discourse memory. *NeuroReport, 18*(17), 1851–1854. http://dx.doi.org/10.1097/WNR.0b013e3282f1a999.

Burkhardt, P., & Roehm, D. (2007). Differential effects of saliency: An event-related brian potential study. *Neuroscience Letters, 413*, 115–120. http://dx.doi.org/10.1016/j.neulet.2006.11.038.

Burmester, J., Spalek, K., & Wartenburger, I. (2014). Context updating during sentence comprehension: The effect of aboutness topic. *Brain and Language, 137*, 62–76. http://dx.doi.org/10.1016/j.bandl.2014.08.001.

Chao, Y. R. (1968). *A grammar of spoken Chinese.* Berkeley: University of California Press.

Clark, H. H., & Sengul, C. J. (1974). In search of referents for nouns and pronouns. *Memory & Cognition, 7*(1), 35–41. http://dx.doi.org/10.3758/BF03196932.

Cohn, N., & Kutas, M. (2015). Getting a cue before getting a clue: Event-related potentials to inference in visual narrative comprehension. *Neuropsychologia, 77*, 267–278. http://dx.doi.org/10.1016/j.neuropsychologia.2015.08.026.

Colonna, S., Schimke, S., & Hemforth, B. (2012). Information structure effects on anaphora resolution in German and French: A crosslinguistic study of pronoun resolution. *Linguistics, 50*(5), 991–1013. http://dx.doi.org/10.1515/ling-2012-0031.

Cowles, H. W., & Ferreira, V. S. (2011). The influence of topic status on written and spoken sentence production. *Discourse Processes, 49*, 1–28. http://dx.doi.org/10.1080/0163853X.2011.635989.

Cowles, H. W., Walenski, M., & Kluender, R. (2007). Linguistic and cognitive prominence in anaphor resolution: Topic, contrastive focus and pronouns. *Topoi, 26*, 3–18. http://dx.doi.org/10.1007/s11245-006-9004-6.

Davenport, T., & Coulson, S. (2011). Predictability and novelty in literal language comprehension: An ERP study. *Brain Research, 1418*, 70–82. http://dx.doi.org/10.1016/j.brainres.2011.07.039.

Dröge, A., Fleischer, J., Schlesewsky, M., & Bornkessel-Schlesewsky, I. D. (2016). Neural mechanisms of sentence comprehension based on predictive processes and decision certainty: Electrophysiological evidence from non-canonical linearizations in a flexible word order language. *Brain Research, 1633*, 149–166. http://dx.doi.org/10.1016/j.brainres.2015.12.045.

Federmeier, K. D., & Kutas, M. (1999). A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language, 41*, 469–495.

Federmeier, K. D., & Laszlo, S. (2009). Time for meaning: Electrophysiology provides insights into the dynamics of representation and processing in semantic memory. In B. H. Ross (Vol. Ed.), *Psychology of learning and motivation: Vol. 51*, (pp. 1–44). Burlington: Academic Press.

Hagoort, P., Brown, C. M., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language & Cognitive Processes, 8*, 439–483. http://dx.doi.org/10.1080/01690969308407585.

Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science, 304*, 438–441.

Hammer, A. H., Jansma, B. M., Lammers, M., & Münte, T. F. (2008). Interplay of meaning, syntax and working memory during pronoun resolution investigated by ERPs. *Brain Research, 1230*, 177–191. http://dx.doi.org/10.1016/j.brainres.2008.07.004.

Haviland, S. E., & Clark, H. H. (1974). What's new ? Acquiring new information as a process in comprehension. *Journal of Verbal Learning and Verbal Behavior, 13*, 512–521. http://dx.doi.org/10.1016/S0022-5371(74)80003-4.

Hirotani, M., & Schumacher, P. B. (2011). Context and topic marking affect distinct processes during discourse comprehension in Japanese. *Journal of Neurolinguisitics, 24*, 276–292. http://dx.doi.org/10.1016/j.jneuroling.2010.09.007.

Hoeks, J., & Brouwer, H. (2014). Electrophysiological research on conversation and discourse processing. In T. Holtgraves (Ed.). *Oxford University handbook of language and social cognition* (pp. 365–386). Oxford, UK: Oxford University Press.

Huang, C. T. J., Li, Y. H. A., & Li, Y. (2009). *The syntax of Chinese.* Cambridge: Cambridge University Press.

Hung, Y. C., & Schumacher, P. B. (2012). Topicality matters: Position specific demands on Chinese discourse processing. *Neuroscience Letters, 511*, 59–64. http://dx.doi.org/10.1016/j.neulet.2012.01.013.

Irmer, M. (2009). *Bridging inferences in discourse interpretation*Doctoral Dissertation, Leipzig.

Järvikivi, J., van Gompel, R. P., Hyönä, j., & Bertram, R. (2005). Ambiguous pronoun resolution: Contrasting the first-mention and subject-preference accounts. *Psychological Science, 16*, 260–264.

Jung, T. P., Humphries, C., Lee, T. W., Makeig, S., McKeown, M. J., Iragui, V., et al. (1998). Extended ICA removes artifacts from electroencephalographic recordings. *Advances in Neural Information Processing Systems, 10*, 894–900.

Kaan, E., Dallas, A. C., & Barkley, C. M. (2007). Processing bare quantifiers in discourse. *Brain Research, 1146*, 199–209. http://dx.doi.org/10.1016/j.brainres.2006.09.060.

Kaiser, E. (2011). Focusing on pronouns: Consequences of subjecthood, pronominalisation, and contrastive focus. *Language & Cognitive Processes, 26*, 1625–1666. http://dx.doi.org/10.1080/01690965.2010.523082.

Kandylaki, K. D. (2011). *Causality of the subject: Event initiator and its effect on processing.* Philipps University of Marburg.

Kim, A., & Osterhout, L. (2005). The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language, 52*, 205–225. http://dx.doi.org/10.1016/j.jml.2004.10.002.

Koornneef, A. W., & Van Berkum, J. J. A. (2006). On the use of verb-based implicit causality in sentence comprehension: Evidence from self-paced reading and eye tracking. *Journal of Memory and Language, 54*, 445–465. http://dx.doi.org/10.1016/j.jml.2005.12.003.

Kuperberg, G., Paczynski, M., & Ditman, T. (2011). Establishing causal coherence across sentences: An ERP study. *Journal of Cognitive Neuroscience, 23*, 1230–1246. http://dx.doi.org/10.1162/jocn.2010.21452.

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62*, 621–647. http://dx.doi.org/10.1146/annurev.psych.093008.131123.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials relfect semantic incongruity. *Science, 207*, 203–205.

Lambrecht, K. (1994). *Information structure and sentence form: Topic, focus, and the mental representation of discourse referents.* Cambridge: Cambridge University Press.

LaPolla, R. J. (1995). Pragmatic relations and word order in Chinese. In P. Downing, & M. Noonan (Eds.). *Word order in discourse* (pp. 297–329). Amsterdam: John Benjamins Publishing Company.

Li, W. D. (1996). *Second language acquisition of topic-comment structures in Mandarin Chinese*Ph.D. Dissertation. University of Alberta.

Li, C. N., & Thompson, S. A. (1976). Subject and topic: A new typology of language. In C. N. Li (Ed.). *Subject and topic* (pp. 457–489). New York, NY: Academic Press.

Li, C. N., & Thompson, S. A. (1989). *Mandarin Chinese: A functional reference grammar.* Berkeley: University of California Press.

Li, X., & Zhou, X. (2010). Who is *ziji*? ERP responses to the Chinese reflexive pronoun during sentence comprehension. *Brain Research, 1331*, 96–104. http://dx.doi.org/10.1016/j.brainres.2010.03.050.

Makeig, S., Bell, A. J., Jung, T. P., & Sejnowski, T. J. (1996). Independent component analysis of electroencephalographic data. *Advances in Neural Information Processing Systems, 8*, 145–151.

Matsui, T. (1993). Bridging reference and the notion of 'topic' and 'focus'. *Lingua, 90*, 49–68.

Nieuwland, M. S. (2013). "If a lion could speak…": Online sensitivity to propositional truth-value of unrealistic counterfactual sentences. *Journal of Memory and Language, 68*, 54–67. http://dx.doi.org/10.1016/j.jml.2012.08.003.

Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden-path sentences: Evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(4), 786–803.

Osterhout, L., & Mobley, L. A. (1995). Event-related brain potentials elicited by failure to agree. *Journal of Memory and Language, 34*, 739–773. http://dx.doi.org/10.1006/jmla.1995.1033.

Reinhart, T. (1981). Pragmatics and linguistics, an analysis of sentence topics. *Philosophica, 27*, 53–94.

Stafura, J. Z., & Perfetti, C. A. (2014). Word-to-text integration: Message level and lexical level influences in ERPs. *Neuropsychologia, 64*, 41–53. http://dx.doi.org/10.1016/j.neuropsychologia.2014.09.012.

Stafura, J. Z., Rickles, B., & Perfetti, C. A. (2015). ERP evidence for memory and predictive mechanisms in word-to-text integration. *Language, Cognition and Neuroscience, 30*(10), 1273–1290. http://dx.doi.org/10.1080/23273798.2015.1062119.

Steinhauer, K., & Connolly, J. F. (2008). Event-related potentials in the study of language. In B. Stemmer, & H. A. Whitaker (Eds.). *Handbook of the cognitive neuroscience of language* (pp. 91–104). New York: Elsevier.

Stevenson, R. J., Nelson, A. W. R., & Stenning, K. (1995). The role of parallelism in strategies of pronoun comprehension. *Language and Speech, 38*(4), 393–418. http://dx.doi.org/10.1177/002383099503800404.

Traxler, M. J., Bybee, M. D., & Pickering, M. J. (1997). Influence of connectives on language comprehension: Eye-tracking evidence for incremental interpretation. *The Quarterly Journal of Experimental Psychology, 50*, 481–497. http://dx.doi.org/10.1080/027249897391982.

Vallduvi, E., & Engdahl, E. (1996). The linguistic realization of information packaging. *Linguistics, 34*, 459–519.

Van den Broek, P., Beker, K., & Oudega, M. (2015). Inference generation in text comprehension: Automatic and strategic processes in the construction of a mental representation. In E. J. O'Brien, A. E. Cook, & R. F. Lorch (Eds.). *Inferences during reading* (pp. 94–121). Cambridge, UK: Cambridge University Press.

Wang, L., & Schumacher, P. B. (2013). New is not always costly: Evidence from online processing of topic and contrast in Japanese. *Frontiers in Psychology, 4*, 1–20. http://dx.doi.org/10.3389/fpsyg.2013.00363.

Widmann, A., Schröger, E., & Maess, B. (2014). Digital filter design for electrophysiological data – a practical approach. *Journal of Neuroscience Methods, 250*, 34–46.

Wolff, S., Schlesewsky, M., Hirotani, M., & Bornkessel-Schlesewsky, I. (2008). The neural mechanisms of word order processing revisited: Electrophysiological evidence from Japanese. *Brain and Language, 107*, 133–157.

Xu, X. D. (2015). The influence of information status on pronoun resolution in Mandarin Chinese: Evidence from ERPs. *Frontiers in Psychology, 6*, 873. http://dx.doi.org/10.3389/fpsyg.2015.00873.

Xu, X. D., Jiang, X. M., & Zhou, X. L. (2013). Processing biological gender and number information during Chinese pronoun resolution: ERP evidence for functional differentiation. *Brain and Cognition, 81*, 223–236. http://dx.doi.org/10.1016/j.bandc.2012.11.002.

Xu, X. D., Jiang, X. M., & Zhou, X. L. (2015). When a causal assumption is not satisfied by reality: Differential brain responses to concessive and causal relations during sentence comprehension. *Language, Cognition and Neuroscience, 30*(6), 704–715. http://dx.doi.org/10.1080/23273798.2015.1005636.

Xu, L. J., & Liu, D. Q. (2007). *Topic structure and function* (in Chinese)Shanghai: Shanghai Education Press.

Xu, X. D., & Zhou, X. L. (2016). Topic shift impairs pronoun resolution during sentence comprehension: Evidence from event-related potentials. *Psychophysiology, 53*, 129–142. http://dx.doi.org/10.1111/psyp.12573.

Yang, C. Y., Perfetti, C. A., & Schmalhofer, F. (2007). Event-related potential indicators of text integration across sentence boundaries. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(1), 55–89. http://dx.doi.org/10.1037/0278-7393.33.1.55.