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Research paper

Updating emotional information in daily language comprehension: The influence of topic shifts

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ABSTRACT

Tracking and updating emotional information in daily language use is essential for successful comprehension and communication. Using an event-related potential technique, we investigated how the updating of emotional information was influenced by changes in topic with two-pair conversational discourses. The first pair established a topic and a kind of emotional information. The second pair either maintained or changed the topic of the first pair. The description of the topic within the second pair contained a critical word that either maintained or shifted the emotional valence of the first pair. Event-related potentials (ERPs) were recorded for both the topic words and the emotion words. We found that the topic-shifted words elicited a larger P2, a larger N400, and a larger late positive component (LPC) than the topic-maintained words. More importantly, we found that emotion updating elicited an enhanced sustained N400 in the topic-maintained discourses. On the other hand, emotion updating induced a pronounced LPC in the topic-shifted discourses. These results suggest that topic shift captures more cognitive resources for its own processing and new substructure building, which further affects the processing of emotion updating. Our findings demonstrated an active use of topic information in guiding emotion updating during natural language comprehension.

1. Introduction

The tracking and updating of emotional information is essential for language comprehension. When reading stories or engaging in conversation comprehension, readers can track the dynamic changes of emotion information and update their situation model (de Vega, 1996; Ferstl, Rinck, & Cramon, 2005; Komeda & Kusumi, 2006). Moreover, natural conversations are often organized around certain topics, which stand out as a significant cause of emotional changes in human conversation (Kim, Bak, & Oh, 2012a, 2012b; Norgaard, 2006). Both topic and emotion are essential for the building of story schema or discourse representation (Miall, 1988, 1989, 2011; Gernsbacher, 1997; Van den Broek, Young, Tzeng, & Linderholm, 1999, pp. 71–98). In the present study, we used the event-related potentials (ERPs) technique to study whether and how the updating of emotional information is affected by topic organization during the comprehension of natural discourses.

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1.1. Emotion updating in discourse comprehension

Emotional information has been deemed as salient information within sentence and discourse context (Hinojosa, Méndez-Bértolo, & Pozo, 2012; Holt, Lynn, & Kuperberg, 2009). During sentence or discourse comprehension, emotional words take priority over neutral words. This can be demonstrated by enhanced perceptual processing (larger P1/N1) (Kissler & Herbert, 2013; Mareike, Werner, & Annekathrin, 2012; Sass et al., 2010; Wang, Zhu, Bastiaansen, Hagoort, & Yang, 2013; Zhang et al., 2014), more detailed semantic analysis (larger N400) (Ding, Wang, & Yang, 2015; Holt et al., 2009), and more elaborative emotional evaluation (larger LPC) (Delaney-Busch & Kuperberg, 2013; Holt et al., 2009).

In studying the processing of emotional words in discourse context, many studies have focused on the updating of emotional information. These studies have shown that readers make inferences about protagonists' emotion (for example, "sad") while reading stories (de Vega, 1996; Gernsbacher, Goldsmith, & Robertson, 1992; Gernsbacher, Hallada, & Robertson, 1998; Gygax, Garnham, & Oakhill, 2004; Gygax, Oakhill, & Garnham, 2003). This inference processing is online (Marotto, Barreyro, Cevasco, & van den Broek, 2011) and automatic (Gernsbacher et al., 1992, 1998). In addition, readers can keep track of the emotional information contained (for example, "failure") in discourses. Once emotional incongruence has occurred, readers will encounter integration or updating difficulty (Baetens, Van der Cruyssen, Achtziger, Vandekerckhove, & Van Overwalle, 2011; Bartholow et al., 2001, 2003; Leuthold, Filik, Murphy, & Mackenzie, 2012; Wang, Bastiaansen, & Yang, 2015). A large number of studies have examined this emotion updating process. Previous behavioral studies have shown that the reading times for emotion-shifted sentences are longer than those for emotion-maintained sentences. It indicates that readers keep track of emotional changes during narrative comprehension and update their mental model correspondingly (Komeda & Kusumi, 2006; Lu & Ma, 2011; Mulcahy & Gouldthorp, 2016).

Using the ERP technique, several studies have explored the time course and cognitive mechanisms of emotion comprehension (e.g., Baetens et al., 2011; Bartholow et al., 2001; Delaney-Busch & Kuperberg, 2013; León, Díaz, de Vega, & Hernández, 2010; Leuthold et al., 2012; Wang et al., 2015). In these studies, emotion updating was mainly manipulated in such a way that the emotional critical words were either consistent or inconsistent with preceding discourse contexts. It has been consistently found that emotionally incongruent information elicited enhanced brain responses more so than emotionally congruent information, although the manifestation of this incongruence effect might vary in ERP components across studies.

There are studies that reported early brain components for emotional incongruency (León et al., 2010; Leuthold, Kunkel, Mackenzie, & Filik, 2015). In León et al. (2010), the researchers used long stories describing some emotional events of the protagonist as context (e.g., *Carlos is away from home. He learned that there had been a great flood in his town. Carlos immediately tried to call his family and friends, but the phones did not work. The Embassy of his country did not have any news, either …*). They manipulated the target sentences to be either consistent (*Carlos was feeling more and more **desperate***) or inconsistent (*Carlos was feeling really **calm***) with the previous context. They found that compared to the emotion-congruent critical words, the emotion-incongruent critical words elicited earlier response, i.e., larger N1/P2 and larger N400 amplitudes.

There are also other studies that reported larger P300 or larger late positivity for emotional incongruence (Bartholow et al., 2001; Van Duynslaeger, Sterken, Van Overwalle, & Verstraeten, 2008; Van Duynslaeger, Van Overwalle, & Verstraeten, 2007). For instance, Van Duynslaeger et al. (2008) used stories that depicted someone's emotional behavior as context (e.g., *Tolvan smiles at everyone on the way to work. Whenever it snows, Tolvan shovels her elderly neighbor's walk …*). They manipulated target sentences to be either consistent (*Tolvan gave her sister a **hug***) or inconsistent (*Tolvan dared the stranger to **fight***) with the previous context. Their results showed larger P300s or larger late positivity for emotional incongruence.

In contrast to the aforementioned studies, there are other studies that found both N400 and LPC effects for emotional incongruence (Baetens et al., 2011; Leuthold et al., 2012; Moreno & Rivera, 2013; Moreno & Vázquez, 2011). For example, Baetens et al. (2011) used stories that depicted someone's emotional behavior as context. They matched the form of the target sentences and the characteristics of the critical words (e.g., "*Tolvan gave her sister a **hug/slap***"). Their results showed larger N400 and LPC for emotionally inconsistent information.

Together, these ERP findings have shown larger N100/P200, N400, and P300/LPC for emotional incongruence. The ERP patterns indicate that emotion updating may contain various stages of processing. According to previous studies, the N100/P200 may indicate early expectation of emotional information (León et al., 2010), and the N400 is related to semantic analysis for emotional words and integrating emotional information into discourse context (Baetens et al., 2011; León et al., 2010; Leuthold et al., 2012; Wang et al., 2015). In addition, the P300/LPC is associated with the late stage of evaluation and sustained analysis of emotional information (Baetens et al., 2011; Bartholow et al., 2001; Leuthold et al., 2015; Wang et al., 2015), increased demand for building a situational model or making emotional inferences (Leuthold et al., 2012), and updating of emotional information in working memory (Van Duynslaeger et al., 2007, 2008).

The aforementioned studies have revealed how emotion information is updated during discourse comprehension. However, when readers construct a mental representation of a discourse, not only discourse content is concerned, e.g., emotion information, but also discourse structures (Sanders & Maat, 2006; Yang & Yang, 2012). Discourses are organized and unfolded by various discourse structures, and many comprehension processes are influenced by discourse structure. One of the most important aspects of discourse structure is topic information, which we will introduce in the next section.

1.2. The role of topic structure in discourse comprehension

As a global discourse factor, topic is seen as a matter of standing interest (Xu & Zhou, 2015). Topic serves to enhance cognitive prominence (Cowles, Walenski, & Kluender, 2007) and has a privileged cognitive status relative to other sentential entities in

constraining the upcoming information (Xu & Zhou, 2015). Numerous studies on discourse comprehension have emphasized topic structure, which describes the relation between sentence topics (generally topic-maintained and topic-shifted) as a significant discourse structure that affects language comprehension (e.g., Anderson, Garrod, & Sanford, 1983; Katherine S. Binder, 2003; Katherine S Binder & Morris, 1995; Hoeks, Vonk, & Schriefers, 2002; Hung & Schumacher, 2012, 2014; Hyönä, 1994, 1995; Lorch, Lorch, & Mogan, 1987; Lorch Jr, Lorch, & Matthews, 1985; Lorch Jr, Lorch, & Mogan, 1987a, b; Murray & McGlone, 1997; O'Brien, Duffy, & Myers, 1986; Xu & Zhou, 2015; Yang, Chen, Chen, Xu, & Yang, 2013). Earlier studies on text comprehension (Hyönä, 1994, 1995; Lorch et al., 1987; Lorch Jr et al., 1985) found that reading times for topic-shifted sentences were longer than for topic-maintained sentences. It was named the topic shift effect. In addition, some studies revealed that topic shift resulted in longer times for anaphor processing (e.g., Anderson et al., 1983; O'Brien et al., 1986).

The effect of topic structure has also been explored in recent ERP studies. Hung and Schumacher (2012, 2014) adopted simple conversation pairs to observe the ERP response at the topic position [e.g., *Speaker A: What about **Zhangsan*** (topic shift)/***Lisi*** (topic continuity)? *Speaker B: **Lisi** beat Zhangsan.*]. ERP response was recorded at the position of the "Lisi" mentioned by Speaker B, which varied as topic shift/topic continuity according to Speaker A's remarks. They found that topic shift brought about larger P200, N400, and P600 than topic continuity. The larger P200 elicited by topic shift was deemed as coding processes for the graphic features of the shifted topics. The N400 effect was interpreted as the expectation-based process for the unexpected topic shifts. The pronounced P600 was seen as discourse-internal reorganization demands and the cost of discourse updating.

In addition to studies on the pure effects of topic shift, the processing of topic shift has been shown to influence other cognitive processes during on-line comprehension, such as anaphor processing and semantic integration. Xu and Zhou (2015) found that pronouns in topic-shift condition elicited a larger P600 than in topic-continuity condition. It demonstrates that topic shift requires more processing costs in the resolution stage (late stage) of referential processing. Yang et al. (2013) found that semantic violation evoked an N400 effect in both the topic-shift and topic-continuation conditions, but a late positivity (P600) effect was found only in the topic-shift condition. The P600 effect was interpreted as the reorganization or updating of discourse representation.

To sum up, these studies have shown that topic shifts can bring about increased processing demands for its own processing, as evidenced by longer reading times and enhanced ERP components for topic shifts. Furthermore, the processing of topic shifts can also affect other cognitive processes during on-line comprehension. According to a classical theory of discourse comprehension, the Structure Building Framework (Gernsbacher, 1996, 1997), readers build global coherent representations of the discourse when reading texts. They tend to map new information onto a present representation. If the new information cannot be mapped onto the present representation, readers shift to building a new substructure to represent the new information. Thus, the processes can result in the processing demands of topic shift and its subsequent effects on other cognitive processes.

Though topic structure plays an important role in discourse comprehension, very few studies have investigated the effect of topic structure on emotion updating processing. This is problematic for at least two reasons. For one, a full account of discourse comprehension should take into consideration not only content information, but also structural variations (Sanders & Maat, 2006; Yang & Yang, 2012). Moreover, topic and emotion are highly intertwined, and topic has been recognized as a significant cause of emotion change in natural discourse (Kim, Bak, & Oh, 2012a, 2012b; Norgaard, 2006). Topic and emotion both are salient information during discourse comprehension (Cowles et al., 2007; Hinojosa et al., 2012), and both are important for discourse representation. Thus, in the present study, we aimed to investigate whether and how emotion updating would be influenced by topic structure. Knowledge of this question is of special interest in that it can advance our understanding of how the two kinds of important information of discourse (i.e., topic and emotion) are used for comprehending natural discourse.

1.3. Present study and hypotheses

To this end, we constructed short conversational discourses and crossed the two factors of topic structure and emotion state in a factorial design. Here topic structure refers to the maintenance/change of the person or object talked about in the conversation (Hung & Schumacher, 2012, 2014). In addition, we investigated emotion updating by manipulating emotion state, i.e., either maintaining or changing emotional valence (positive or negative) throughout the conversation. Here, the emotion state refers to emotional valence contained in the sentences, such as "theft." These manipulations resulted in four experimental conditions: topic-maintained/emotion-maintained (TM-EM), topic-maintained/emotion-shifted (TM-ES), topic-shifted/emotion-maintained (TS-EM), topic-shifted/emotion-shifted (TS-ES).

The target sentence for the four conditions was the same, e.g., "Xiao Lin often has theft behavior" (see Table 1). The topic of the target sentence ("Xiao Lin") either maintained ("Xiao Lin") or shifted from the topic of the first conversational pair ("the dormitory"). The emotional valence of the target sentence (negative, "theft") either maintained (negative, "hypocritical," "shabby") or changed (positive, "enthusiastic," "comfortable") the emotional valence in the first conversational pair. For the target sentence, we recorded ERP responses at two positions. One was the topic position ("Xiao Lin"), where the topic shift effects could be observed. The other was the critical-word position ("theft"), where we could explore the effect of topic structure on emotion updating.

Note that unlike previous studies in which emotional updating was manipulated with emotional violation paradigm (Baetens et al., 2011; Delaney-Busch & Kuperberg, 2013; León et al., 2010, 2015; Leuthold et al., 2012; Van Duynslaeger et al., 2007, 2008), we shifted the emotional valence of the critical words without causing a semantic violation in our stimuli. This is important in that it allows us to study the emotional updating effect without the confounding effect of semantic violation.

For the topic position, based on previous studies that found the topic shift effects (Hung & Schumacher, 2012, 2014), we expected larger P200, N400, and LPC components for topic shift compared to topic maintenance. More importantly, given that topic structure has been found to affect the processing of discourse contents (e.g., Xu & Zhou, 2015; Yang et al., 2013), we expected that topic

Table 1
Example of experimental stimuli.

	Topic-maintained	Topic-shifted
Emotion-maintained	A:小霖怎么样？(A: How about Xiao Lin?) B:为人很虚伪。(B: He is very hypocritical.) **A:哦。/据说/小霖/经常/有/偷窃/行为。 (A: Oh./Heard of/Xiao Lin/often/has/*theft*/behavior.)** B:哦，是吗？(B: Oh, is it so?)	A:宿舍怎么样？(A: How about the dormitory?) B:破旧得很呢。(B: It is very shabby.) **A:哦。/据说/小霖/经常/有/偷窃/行为。 (A: Oh./Heard of/Xiao Lin/often/has/*theft*/behavior.)** B:哦，是吗？(B: Oh, is it so?)
Emotion-shifted	A:小霖怎么样？(A: How about Xiao Lin?) B:为人很热情。(B: He is very enthusiastic.) **A:哦。/据说/小霖/经常/有/偷窃/行为。 (A: Oh./Heard of/Xiao Lin/often/has/*theft*/behavior.)** B:哦，是吗？(B: Oh, is it so?)	A:宿舍怎么样？(A: How about the dormitory?) B:舒适的很呢。(B: It is very comfortable.) **A:哦。/据说/小霖/经常/有/偷窃/行为。 (A: Oh./Heard of/Xiao Lin/often/has/*theft*/behavior.)** B:哦，是吗？(B: Oh, is it so?)

Note. The materials are originally in Chinese. The critical sentences are in bold, and the critical words are in italics and underline. The slashes between words in the critical sentences indicate how the critical sentences were divided for word-by-word presentation. The word-by-word English translations are presented in brackets.

structure would affect emotion updating at the target word position. If, as suggested by previous studies, in the topic-maintained condition, comprehenders map upcoming information to the current discourse representation while in the case of topic shifts, comprehenders shift to building a new substructure for the new topic (Gernsbacher, 1996, 1997), then there will be less cognitive resources left for emotion updating in the topic-shifted discourses than in the topic-maintained discourses. Consequently, for the topic-maintained discourses, we expected that readers would have adequate resources for emotion updating, which might be reflected by early detection of emotional valence change (N1/P2/N400) and later updating of emotional representation (LPC/P300). However, for the topic-shifted discourses, as the processing of topic shifts might take up readers' cognitive resources for new substructure building, the earlier processing (i.e., the detection of emotional valence change) of the emotion information might be suppressed and the emotion updating process might be delayed, reflected by the absence of early ERP components, i.e., N1/P2/N400, and the presence of a late positivity effect.

2. Methods

2.1. Ethics statement

All participants signed a written informed consent in accordance with the Declaration of Helsinki. The ethics committee of the Institute of Psychology, Chinese Academy of Sciences, approved this study, its participant-recruitment procedure and its methodology.

2.2. Participants

Twenty-eight undergraduate and graduate students participated in the experiment (thirteen females, mean age = 21.6 years; range = 18–28 years). All were right-handed native Mandarin Chinese speakers with normal or correct-to-normal vision. They reported no reading problems, neurological impairment, or psychiatric disorder. All participants were paid for their participation. The data of six participants (four males) were excluded because of poor signal-to-noise ratios. The analysis reported here was performed on the data from 22 participants (mean age 21.6 years, range = 18–28; 11 males).

2.3. Materials

We constructed 160 sets of two-pair conversational discourses, which contained two speakers (A and B) and had an A-B-A-B structure. Speaker A firstly established a topic (e.g., *Xiao Lin* or *the dormitory*) and Speaker B talked about something containing positive (*very enthusiastic or very comfortable*) or negative (*very hypocritical or very shabby*) emotional information. Then Speaker A talked about something concerning *Xiao Lin*, which resulted in topic-maintained or topic-shifted discourse structure along with the previous contextual topic (*Xiao Lin* or *the dormitory*). In addition, the information expressed by speaker A about *Zhang Lei* in the second pair contained a critical emotional word, e.g., *theft,* which either maintained or shifted the emotional valence of the first pair (emotion-maintained or emotion-shifted). Thus, four conditions were constructed between the two conversational pairs. The critical words were the same among the four conditions, with half positive and half negative critical words (to exclude confounding of valence processing). The critical words were located in the second sentences of Speaker A, followed by one or two words that were the same among the four conditions. In addition, in order to make the whole conversation natural, we added a short response from Speaker B after the target sentence, which was identical among the four conditions. An example of the experimental stimuli for each condition is shown in Table 1.

The 160 sets of discourses were divided into four versions, using a Latin square design to ensure that each discourse set was only presented once per version. Each version contained 40 discourses per condition. To each version 160 fillers were added. Eighty fillers with similar structures to the four experimental conditions (20 fillers per condition) was used to balance the topic type of target

Table 2
Pretests results of the stimuli.

Conditions	Cloze probability	Plausibility	First-pair arousal
TM-EM	2.0% (0.086)	5.88 (0.77)	5.05 (0.68)
TM-ES	1.5% (0.068)	5.79 (0.61)	5.10 (0.64)
TS-EM	2.3% (0.074)	5.84 (0.41)	5.10 (0.63)
TS-ES	2.1% (0.098)	5.84 (0.39)	5.16 (0.65)

Note. Data are expressed as mean (*SD*). SD represents the standard deviation.
TM-EM: topic-maintained/emotion-maintained; TM-ES: topic-maintained/emotion-shifted.
TS-EM: topic-shifted/emotion-maintained; TS-ES: topic-shifted/emotion-shifted.

sentences, half with person (e.g., "Xiao Lin") and half with nonperson (e.g., "The school") as the topic. Eighty fillers with various syntactic structures were added in order to increase the ecological validity of the present study. For 40 fillers, Speaker A asks "what's up/what happened" or "what are you talking about" without an apparent topic in the first conversation pair. For the other 40 fillers, Speaker introduces one event with a topic in the first conversation pair (e.g., "I just baked a loaf of bread"). Among these 80 fillers, the topic and emotion information of 40 fillers were constructed according to the four experiment conditions (10 fillers per condition) and 40 fillers were constructed as emotional neutral (20 fillers with topic maintenance and 20 fillers with topic shift). Among the 320 sets of discourses, one-third of them (spreading out in all conditions) were followed by a comprehension question, which was either about the main idea or detailed information of the discourse. These questions were used to ensure that the participants would read attentively for comprehension.

2.3.1. Pretests of materials

Three pretests were conducted to match the cloze probability and plausibility of the materials among conditions (to exclude possible confounding factors) and to assess the emotionality (valence and arousal) of the materials (to ensure the effectiveness of the manipulation for emotion state). In the cloze probability test, we removed the critical words and the subsequent words from the discourses and asked 24 participants to complete the critical sentence with the first words that came to mind. In the plausibility pretest, 24 participants who did not participate in the cloze probability test rated the plausibility of the discourses on a scale from 1 (*most implausible*) to 7 (*most plausible*). Participants were assigned one of the four versions. Repeated measures analyses of variance (ANOVAs) for the 160 experimental items revealed that the main effect of topic structure, the main effect of emotion state, and the interaction between them were not significant in the two pretests, $Fs < 1.4$. Table 2 presents the mean scores and standard deviations.

In the emotional valence and arousal pretest, another 24 participants who did not take part in the above pretests were asked to rate the valence and arousal conveyed by the critical sentence (the second sentence spoken by Speaker A) and the first conversational pair. The valence was rated on a scale of −3 (*most negative*) to 3 (*most positive*), and the arousal was rated on a scale of 1 (*least arousing*) to 7 (*most arousing*).

We first analyzed the emotional valence and arousal of the critical sentences (half positive and half negative; see Table 3 for valence scores). The valence of the positive critical sentences [Mean (*SD*) = 1.81 (0.33)] was more positive than that of the negative critical sentences [Mean (*SD*) = −1.99 (0.42)]. The arousal rating scores of all the critical sentences were greater than 4 [Mean (*SD*) = 5.1 (0.63)]. These results suggest that the stimuli met the requirement of our manipulation for critical sentences.

Then we analyzed the arousal and valence of the first conversational pair. The arousal rating scores of the four conditions were 5.05 (0.68), 5.10 (0.64), 5.10 (0.63), and 5.16 (0.65) for TM-EM, TM-ES, TS-EM and TS-ES, respectively [expressed as Mean (*SD*); see Table 2]. Repeated measures ANOVA for the arousal showed that none of the main effect of topic structure, the main effect of emotion state, and the interaction between them, was significant ($Fs < 1.7$), indicating that arousal rating scores among the four conditions were matched. For the emotional valence of the first conversational pair, discourses with the positive and the negative critical words were analyzed respectively. For the 80 discourses with positive critical words, the emotional valence (see Table 3 for valence rating scores) for the emotion-maintained condition [topic-maintained: Mean (*SD*) = 1.89 (0.42), topic-shifted: Mean (*SD*) = 1.93 (0.40)] differed significantly from the emotion-shifted condition [topic-maintained: Mean (*SD*) = −1.89 (0.48), topic-shifted: Mean (*SD*) = −1.93 (0.49)]. Repeated measures ANOVA showed that the main effect of emotion state was significant

Table 3
Results of pretests for emotional valence.

CW	Target sentence	First-pair			
		TM-EM	TM-ES	TS-EM	TS-ES
Positive	1.81 (0.33)	1.89 (0.42)	−1.89 (0.47)	1.93 (0.40)	−1.93 (0.49)
Negative	−1.99 (0.42)	−1.92 (0.52)	1.96 (0.40)	−1.84 (0.46)	1.99 (0.39)

Note. Data are expressed as mean (*SD*). SD represents the standard deviation. The valence rating scale was −3 (most negative) to 3 (most positive).
CW: critical words. TM-EM: topic-maintained/emotion-maintained.
TM-ES: topic-maintained/emotion-shifted; TS-EM: topic-shifted/emotion-maintained; TS-ES: topic-shifted/emotion-shifted.

[$F_{(1,79)} = 5144.82$, $p < .001$, $\eta_p^2 = 0.985$]. Neither the main effect of topic structure nor the interaction between them was significant ($Fs < 1$). It was the same pattern for the 80 discourses with the negative critical words. The emotional valence for the emotion maintained condition [topic-maintained: Mean (SD) = −1.92 (0.52), topic-shifted: Mean (SD) = −1.84 (0.46)] was significantly different from that for the emotion-shifted condition [topic-maintained: Mean (SD) = 1.96 (0.40), topic-shifted: Mean (SD) = 1.99 (0.39)]. Repeated measures ANOVA revealed that the main effect of emotion state was significant [$F_{(1,79)} = 5867.37$, $p < .001$, $\eta_p^2 = 0.987$]. Neither the main effect of topic structure nor the interaction between them was significant ($Fs < 1$). These results showed that the stimuli met the requirement of our manipulation for the first conversational pair.

2.4. Procedure

Participants sat in comfortable chairs in a sound-attenuating, shielded room and were instructed to read each discourse carefully for comprehension. The discourses were presented visually in the center of the computer screen. Each trial started with a fixation cross (+) displayed for 1000 ms in the center of the screen. Then the first conversational pair appeared on the screen, sentence by sentence. Participants were asked to press the space bar when they finished reading each sentence of the first conversational pair. Subsequently, the critical sentence was presented word by word, with each word displayed for 400 ms, followed by a blank screen for 400 ms. Then the response sentence by Speaker B appeared for 1000 ms. After that, three question marks (???) were presented for 500 ms as a cue for the upcoming comprehension question (after 1/3 trials) or "space." If it was a question, participants were asked to press "*F*" or "*J*" on the keyboard within 10 s, with "*F*" and "*J*" signaling false and true, respectively. If it was "space," participants were asked to press the space bar to continue. Then a blank screen lasting 1000 ms was presented as inter-stimuli interval.

The stimuli were divided into four blocks. Each block lasted about 10 min, with a short break between blocks. The discourses were presented in a pseudo-random order, and no more than three discourses for the same condition were presented in succession. Before the formal experiment, there was a practice round of 16 trials to familiarize participants with the procedure.

2.5. Electrophysiological recording and analysis

ElectroEncephaloGraphy (EEG) data was recorded with 64 Ag/AgCl electrodes mounted on an elastic cap (10–20 system), using a SynAmps amplifier and Scan 4.3 Acquisition Software (Neuroscan Labs, TEXAS, USA). The data was collected at a sampling rate of 500 Hz with a bandpass of 0.05–100 Hz. Electrodes were referenced online to the left mastoid and re-referenced offline to the average of both left and right mastoids. An electrode between Fz and FPz electrodes served as the ground. Horizontal electrooculograms (HEOG) were monitored through two electrodes placed at the outer canthus of each eye. Vertical electrooculograms (VEOG) were recorded via two electrodes above and below the left eye. Electrode impedances were kept below 5 kΩ.

Two positions were recorded for the EEG data: the topic position ("Xiao Lin"), and the target position ("theft"). The EEG data were preprocessed offline and ERPs were computed with the Edit program in Scan 4.3 (Neuroscan Labs, TEXAS, USA). After rejecting apparent artifacts of muscle actions, we corrected the vertical eye movements (Semlitsch et al., 1986). The EEG data were first low-pass filtered (30 Hz, 24 dB/oct) and then high-pass filtered (0.05 Hz, 24 dB/oct) to remove slow drifting. Given that different contexts occurring prior to the critical sentence among conditions could have caused a potential baseline difference, we used high-pass filtering to replace baseline correction (see Tanner, Morgan-Short, & Luck, 2015; Widmann, Schröger, & Maess, 2015; and Wolff, Schlesewsky, Hirotani, & Bornkessel-Schlesewsky, 2008; for methodological details). After filtering, the EEG data were segmented from 200 ms prior to the onset of the critical word to 1000 ms after the onset of the critical word at both the topic position and the target position. Trials contaminated with artifacts (excessive amplitude exceeding ± 75 μV) were rejected automatically. Then by trial-by-trial visual inspection, we excluded trials with apparent artifacts (such as electrode drifting, and very large alpha waves). Subsequently, for the topic position, on average 67 and 65 trials were left for the TM and the TS condition, respectively. For the target position, on average 31, 32, 32, and 33 trials were left for the TM-EM, TM-ES, TS-EM, and TS-ES conditions, respectively. Finally, average ERPs were calculated for each condition at each electrode and for each participant.

Grand average waveforms were computed through all trials per condition for the 22 participants. For the topic position, based on visual inspection and previous studies on topic shift (Hung & Schumacher, 2012, 2014; Xu & Zhou, 2015; Yang et al., 2013), we selected the time window of P200 (180–270 ms), N400 (300–480 ms), and LPC (550–800 ms) for statistical analysis. We performed repeated measures ANOVAs with topic structure (topic-maintained/topic-shifted), Anteriority (anterior/central/posterior), and Laterality (left/middle/right) as independent variables. The electrodes selected for statistical analysis are shown in Fig. 1. Overall ANOVAs were followed up by simple effect tests where there were interactions with the topic structure. For the critical words position, based on visual inspection and previous studies on emotional processing (Baetens et al., 2011; Chen, Zhao, Jiang, & Yang, 2011; Ding et al., 2015; Ding, Wang, & Yang, 2016; León et al., 2010; Leuthold et al., 2015), we selected the time windows of P200 (180–300 ms), N400 (300–500 ms), and LPC (500–1000 ms) for statistical analysis. We performed repeated measures ANOVAs with topic structure (topic-maintained/topic-shifted), emotional state (emotion-maintained/emotion-shifted), Anteriority (anterior, central, posterior), and Laterality (left, middle, right) as independent variables. The electrodes selected for statistical analysis are shown in Fig. 1. Overall ANOVAs were followed up by simple effect tests where there were significant interactions with the critical manipulations (topic structure, emotional state). All pair-wise comparisons were corrected by the Bonferroni correction method. The Greenhouse-Geisser correction was performed (Greenhouse & Geisser, 1959) when the degree of freedom in the numerator was larger than one, and the result of the sphericity test was significant. In these cases, we reported the original degrees of freedom and corrected p values.

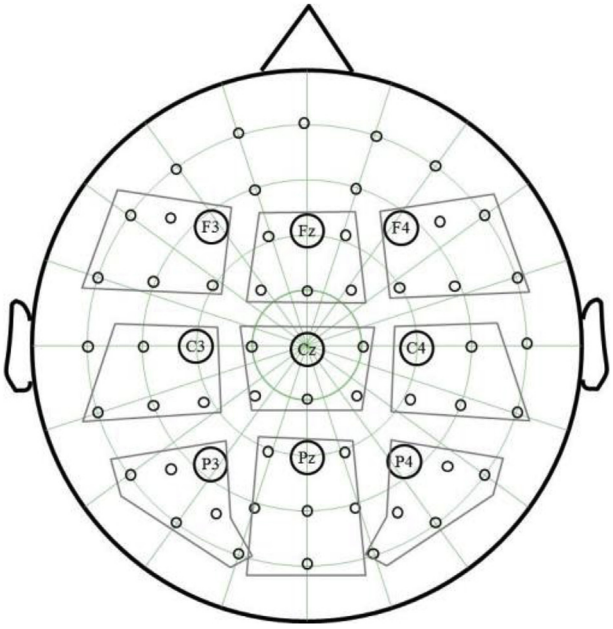

Fig. 1. Electrode layout on the scalp. The nine regions present the electrodes selected for statistical analysis, with one electrode encircled by thicker line in each region for displaying grand average waveforms. The electrodes selected for the nine regions are as follows: left-anterior (F3/F5/F7/FC3/FC5/FC7), left-central (C3/C5/CP3/CP5/CP7), left-posterior (P3/P5/PO5/PO7/O1), middle-anterior (Fz/FCz/F1/FC1/F2/FC2), middle-central (Cz/CPz/C1/CP1/C2/CP2), middle-posterior (Pz/POz/Oz/P1/PO1/P2/PO2), right-anterior (F4/F6/FC4/FC6/FC8), right-central (C4/C6/CP4/CP6/CP8), right-posterior (P4/P6/P8/PO6/PO8/O2).

3. Results

3.1. Behavioral results

The mean accuracy rates were over 87.2% (ranging from 75% to 94%) for the comprehension questions, indicating that the participants were reading attentively for comprehension.

3.2. Event-related potential (ERP) results

3.2.1. ERP results at the topic position

Fig. 2A displays the grand average ERP waveforms triggered by the topic words in different conditions. The topographic distributions of the topic shift effects are shown in Fig. 2B.

In the time window of P200 (180–270 ms), the interaction between topic structure and anteriority was significant [$F_{(2,\ 42)} = 4.10$, $p = .028$, $\eta_p^2 = 0.163$]. Simple-effect tests showed that topic shift elicited a larger P200 than topic maintenance at the anterior region [$F_{(1,\ 21)} = 5.61$, $p = .028$, $\eta_p^2 = 0.211$]. No significant effect at the central region [$F_{(1,\ 21)} = 3.05$, $p = .096$, $\eta_p^2 = 0.127$] and the posterior region [$F_{(1,\ 21)} = 0.85$, $p = .368$, $\eta_p^2 = 0.039$] was found. No other effects were significant ($ps > 0.05$).

In the time window of N400 (300–480 ms), the main effect of topic structure was significant [$F_{(1,\ 21)} = 10.09$, $p = .005$, $\eta_p^2 = 0.325$]. Pair-wise comparison showed that topic shift elicited a larger N400 than topic maintenance. No other interaction effects were found to be significant ($ps > 0.05$).

In the time window of LPC (500–800 ms), the main effect of topic structure was significant [$F_{(1,\ 21)} = 6.41$, $p = .019$, $\eta_p^2 = 0.234$]. Pair-wise comparison showed that topic shift elicited a larger LPC than topic maintenance. No other interaction effects were found to be significant ($ps > 0.05$).

3.2.2. ERP results at the critical word position

Fig. 3A displays the grand average ERP waveforms triggered by the critical words in different conditions. The topographic distributions of emotion shift effect in the topic-maintained and topic-shifted discourses are shown in Fig. 3B.

In the time window of P200 (180–300 ms), the interaction between topic structure and laterality was significant [$F_{(2,\ 42)} = 4.34$, $p = .029$, $\eta_p^2 = 0.171$]. Simple-effect tests showed no significant topic shift effect at the left region, the middle region or the right region ($ps > .05$). No other effects were significant ($ps > .1$).

In the time window of N400 (300–500 ms), the interaction between topic structure and emotion state was significant [$F_{(1,21)} = 4.41$, $p = .048$, $\eta_p^2 = .174$]. Simple-effect tests showed that emotion shift elicited a larger N400 than emotion maintenance in the topic-maintained discourses [$F_{(1,21)} = 6.40$, $p = .019$, $\eta_p^2 = .234$]., while no significant effect in the topic-shifted discourses

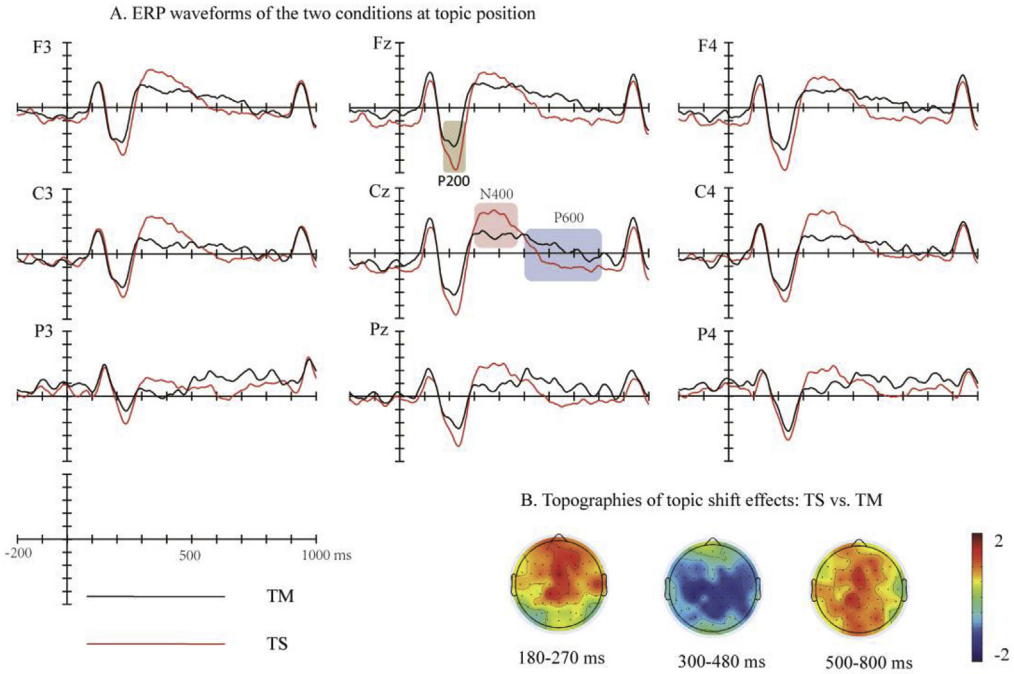

Fig. 2. ERP waveforms at the topic position. (A) Grand average waveforms elicited by the two conditions (topic-maitennace and topic shift) at the selcted electrodes. TM represents topic-maintained and TS represents topic-shifted. (B) Topographies showing the average amplitude voltage differences between the topic-maintained condition and the topic-shifted condition.

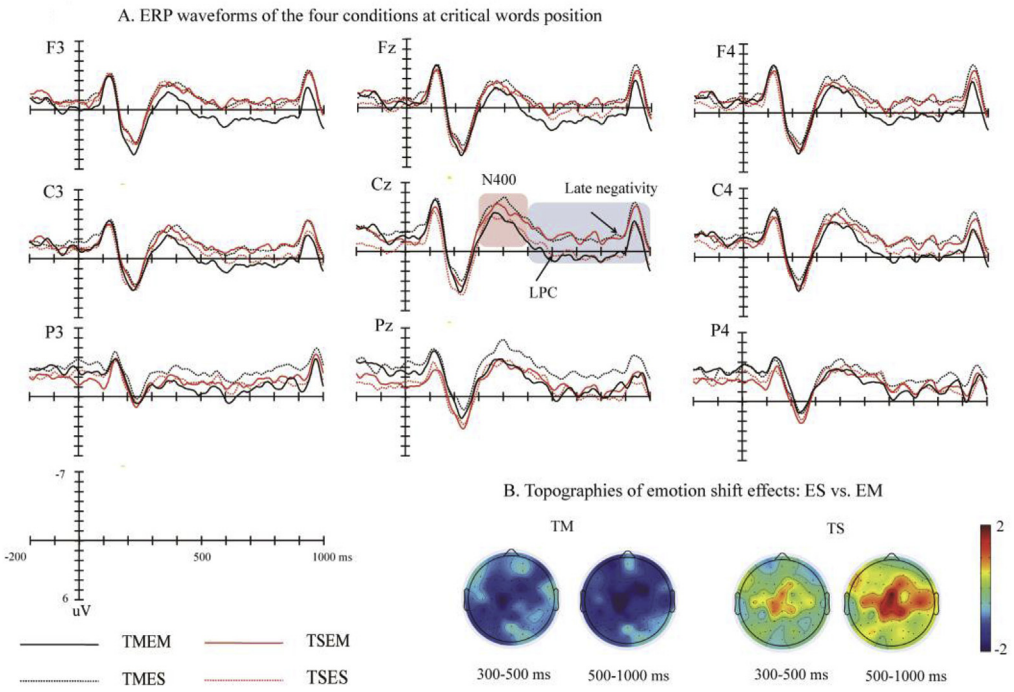

Fig. 3. ERP waveforms at the critical word position. (A) Grand average waveforms elicited by the four conditions at the selcted electrodes. TMEM represents topic-maintained/emotion-maintained, TMES represents topic-maintained/emotion-shifted, TSEM represents topic-shifted/emotion-maintained and TSES represents topic-shifted/emotion-shifted. (B) Topographies at the critical word postion. Topographies showing the average amplitude voltage differences between emotion-shifted (ES) and emotion-maintained (EM) in the topic-maintained condition (TM) and in the topic-shifted condition (TS).

was found [$F_{(1,21)} = 0.027$, $p = .872$, $\eta_p^2 = .001$]. No other effects were significant ($ps > .05$).

In the time window of 500–1000 ms, the interaction between topic structure and emotion state was significant [$F_{(1,21)} = 10.97$, $p = .003$, $\eta_p^2 = .343$]. The three-way interaction of topic structure, emotion state and anteriority was also significant [$F_{(2, 42)} = 3.38$, $p = .043$, $\eta_p^2 = 0.139$]. Simple-effect tests showed that the interaction between topic structure and emotion state was significant at the anterior region [$F_{(1,21)} = 9.93$, $p = .005$, $\eta_p^2 = .321$], the central region [$F_{(1,21)} = 13.78$, $p = .001$, $\eta_p^2 = .396$], and the posterior region [$F_{(1,21)} = 6.52$, $p = .018$, $\eta_p^2 = .237$]. At the anterior region, simple-simple-effect tests showed emotion shift elicited a larger late negativity than emotion maintenance in topic-maintained discourses [$F_{(1,21)} = 7.06$, $p = .015$, $\eta_p^2 = .252$], but no significant effect was found in topic shifted discourses [$F_{(1,21)} = 2.96$, $p = .100$, $\eta_p^2 = 0.124$]. At the central region, simple-simple-effect tests showed that emotion shift elicited a larger late negativity than emotion maintenance in the topic-maintained discourses [$F_{(1,21)} = 8.32$, $p = .009$, $\eta_p^2 = .284$], while emotion shift elicited a larger late positivity than emotion maintenance in the topic-shifted discourses [$F_{(1,21)} = 5.67$, $p = .027$, $\eta_p^2 = .213$]. At the posterior region, simple-simple-effect tests showed that emotion shift elicited a larger late negativity than emotion maintenance in the topic-maintained discourses [$F_{(1,21)} = 5.62$, $p = .027$, $\eta_p^2 = .211$], but no significant effect was found in the topic shifted discourses [$F_{(1,21)} = 0.994$, $p = .330$, $\eta_p^2 = .045$]. No other effects were significant ($ps > .05$).

4. Discussion

The aim of the study was to explore how emotion updating was influenced by topic structure and its underlying cognitive mechanisms. We found that the topic-shifted words elicited a larger P2, a larger N400 and a larger late positive component (LPC) than the topic-maintained words. More importantly, we found that topic structure and emotion state interacted at the early (300–500 ms) and late (500–1000 ms) stage. In the topic-maintained discourses, emotion shift induced a larger N400 and a larger late negativity than emotion maintenance. However, emotion shift only elicited an enhanced LPC effect in the topic-shifted discourses. These results indicate that readers were sensitive to both emotion and topic changes in natural conversation processing, and that topic information had a dynamic influence on emotion updating. We discuss these results in more detail below.

4.1. The topic shift effects at the topic position

For the topic position, topic shifts brought a larger P2, a larger N400 and a larger LPC than topic maintenance. These results compare favorably with previous studies that reported the topic shift effect (Hung & Schumacher, 2012, 2014), and provide strong evidence that topic shifts engage more cognitive processing than topic maintenance. Based on the Structure Building Framework, when the topic shifts, the global coherent representation of a discourse could be temporarily interrupted and readers have to allocate cognitive resources to build a new substructure for the new topic (Gernsbacher, 1996, 1997). Accordingly, the larger P200 for topic shifts might reflect the initial coding process for the graphic features of the shifted topic (Hung & Schumacher, 2012, 2014; Liu, Perfetti, & Hart, 2003), and the enhanced N400 might be ascribed to the semantic processing of the new topic (Hung & Schumacher, 2012, 2014). The larger LPC, however, could reflect the updating of discourse structure when readers shifted to building a new substructure for the new topic (Yang et al., 2013).

Following Hung and Schumacher (2012, 2014), the topic maintenance in the present study was manipulated by repeating the subject of the first conversation pair. One might argue that the observed ERP effects at the topic position may be confounded by the difference in the repetitiveness of the topic words between the topic-maintained and topic-shifted conditions. However, the findings in Hung and Schumacher (2012, 2014) have suggested that the observed ERP effects for topic processing are not merely a repetition effect. Hung and Schumacher (2012, 2014) set up three conditions: topic maintenance, topic shift, and novel topic. In the novel topic condition, no topic has been established by the prior context, e.g., A: What's wrong? B: Zhangsan beats Lisi. They found a less pronounced N400 for novel topic over topic shift and a more pronounced N400 for novel topic than for topic maintenance. These results demonstrate the worthiness of topic. They imply that the observed ERP effects are not merely repetition effects but rather context-induced topicality processing. In the present study, the effects observed at the topic position might not completely exclude word repetition effects. However, context-induced topicality processing also contributed to the observed effects as indicated in the studies of Hung and Schumacher (2012, 2014). Thus, the effects observed in the topic position might reflect both the repetition effect and the topic shift effect.

4.2. Emotional updating effects in the topic-maintained discourses

We found a larger N400 and a larger late negativity (a prolonged N400) for emotion shift than emotion maintenance in the topic-maintained discourses. These results indicate that in the topic-maintained discourses, emotional valence change could be rapidly detected at early stage and the changed emotional information could be mapped onto the same topic in the two conversation pairs at the late stage.

The emotion-shifted words elicited an immediate N400 effect, which is consistent with amount of studies (Baetens et al., 2011; León et al., 2010; Leuthold et al., 2012; Wang et al., 2015). In previous studies, the N400 effect was linked to rapid detection of emotional change (León et al., 2010; Wang et al., 2015) and increased integration and sematic memory efforts (Baetens et al., 2011; Leuthold et al., 2012). In the present study, the N400 effect may indicate that the emotional valence change can be rapidly detected in topic-maintained discourses. Meanwhile, more efforts of semantic analysis and semantic integration for the emotion-shifted words were demanded than the emotion-maintenance words.

It is interesting that a late negativity effect rather than a LPC effect was found for emotion updating in topic-maintained discourses. Late negativity following an N400 effect has been interpreted as a reinterpretation process or secondary semantic integration after an initial failure to reach meaning (Arzouan, Goldstein, & Faust, 2007; De Grauwe, Swain, Holcomb, Ditman, & Kuperberg, 2010; Rutter et al., 2012), and a second-pass process to re-interpret the initially constructed semantic representation (Jiang, Li, & Zhou, 2013; Jiang & Zhou, 2015). Consistent with such interpretations, in the present study, upon encountering critical words in the emotion-shift condition, readers may adopt a re-interpretation strategy to map the incoming emotional information onto the topic. That is, readers may reorganize or expand new emotional information of the topic. Unlike previous ERP studies using emotion-violation paradigm, the present study adopted emotion-shift paradigm without apparent semantic violation. Therefore, the late negativity effect might reflect enriched emotional representation with various information of the maintained topic.

Alternatively, given similar topographic distributions of the late negativity effect and the N400 effect, the late negativity could be interpreted as a sustained N400 effect. In previous studies, a sustained N400 effect has been observed when comprehenders detect a mismatch between the expected and encountered word forms (Tromp, Peeters, Meyer, & Hagoort, 2018), when readers need to deactivate the irrelevant meaning and activate the relevant meaning of a word (Kotchoubey & El-Khoury, 2014), or when a persistent attempt is needed for integration (Rodríguez-Gómez, Martínez-García, Pozo, Hinojosa, & Moreno, 2018). Relating these findings to the current study, the nature of the sustained N400 effect in our study could reflect the detection of emotion change and the subsequent persistent attempt to map the current emotional information onto the previous representation. It is possible that in topic-maintained discourses, readers have adequate processing resources for the emotional information processing. Thus, they could immediately detect the emotional valence change in the emotion-shifted condition. Once the emotional valence change was detected, more semantic analysis and contextual semantic retrieval in memory was required to attempt to map the current emotional information onto the previous representation. As the mapping of emotion-shifted words was more difficult than emotion-maintained words, more efforts were required for emotion-shifted words, leading to a larger sustained N400.

4.3. Emotional updating effects in the topic-shifted discourses

For the topic-shifted discourses, unlike the topic-maintained discourses, no N400 effect of emotion updating was found, suggesting that in the topic-shifted discourses, readers overpassed earlier detection of emotional valence change and lexical sematic analysis for the emotion-shifted words. It is possible that as the topic shifted, readers had to build a new substructure for the new topic, leading to less attention resources for emotion processing. Thus, in the topic shift discourses, readers may overpass immediate emotional valence change detection and detailed lexical sematic processing for emotion-shifted words.

In the topic-shifted discourses, only a LPC component was found for emotion updating. Previous studies have found that LPC is highly sensitive to emotional stimuli, including isolated emotional words (Citron, 2012; Kissler, Assadollahi, & Herbert, 2006) and emotional words in discourse context (Fields & Kuperberg, 2012; Holt et al., 2009). The LPC is thought to associate with a re-allocation of attentional resources and a sustained evaluation of the motivational significance of the emotional stimulus (Hajcak, Weinberg, MacNamara, & Foti, 2012). In some cases, the LPC is sensitive to emotional valence information—evidence of negativity bias (Fields & Kuperberg, 2012; Holt et al., 2009) and positivity bias (Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Winkler, & Junghofer, 2009). In the present study, the LPC in topic-shifted discourses may reflect that readers were sensitive to emotional valence change for the emotion-shifted words and they reallocated attentional resources to evaluate the motivational significance of the emotional stimulus.

The LPC is often viewed as part of P300 family of ERP components, which indicates updating of the contextual information in working memory (Donchin & Coles, 1988). In discourse contexts, many studies have found the LPC effect for emotional updating (Baetens et al., 2011; Bartholow et al., 2001; Leuthold et al., 2015; Wang et al., 2015), with inconsistent emotional information elicited a pronounced LPC effect. The LPC effect for emotion updating has been associated with the evaluation and sustained analysis of emotional conflicts (Baetens et al., 2011; Bartholow et al., 2001; Leuthold et al., 2015; Wang et al., 2015), and the increased demand of building a situational model or making emotional inferences (Leuthold et al., 2012). Therefore, in the present study, the LPC effect for emotional updating could also be interpreted as increased demanding for analyzing the emotion-shifted words to build a coherent mental representation. Taken together, the LPC effect for emotion updating in topic-shifted discourses may reflect that readers detected the emotional valence change for emotion-shifted words and reallocated attentional resources to build a coherent mental representation in working memory.

Compared with the N400 effect and the continued late negativity effect observed in the topic-maintained discourses, the delayed time window of the LPC component in the topic-shifted discourses could be an indication that topic shifts delayed the updating of emotional information. This delayed effect could be caused by the new substructure building process initiated by topic shifts. According to the Structure Building Framework (Gernsbacher, 1996, 1997), when readers encountered topic shift, they shifted to building a new substructure about the new topic. Only after they have laid a new foundation for the new topic can the incoming information be mapped onto the new topic. Thus, it is quite reasonable that emotion updating was delayed in the topic-shifted discourses.

5. Conclusions

Our study found that topic structure influenced the updating of emotional information during conversation processing. The results implicated that processing of different kinds of important information in discourse, such as topic and emotion, may compete for the same cognitive resources during discourse comprehension. Our findings establish topic structure as an important factor in guiding the

tracking and updating of emotional information in daily language use.

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