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The effect of conceptual priming on subsequent familiarity: Behavioral and electrophysiological evidence

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ABSTRACT

Previous studies on the neural mechanisms of how priming influences subsequent recognition memory have mainly focused on repetition priming, whereas the neural mechanisms of how conceptual priming affects subsequent recognition memory is still not clear. The present study investigated the electrophysiological correlates of how conceptual priming influences subsequent recognition memory. The behavioral results showed that conceptual priming only affected subsequent familiarity. The ERP results showed that conceptual priming was associated with reduced N400, and that the N400 conceptual priming effect predicted the behavioral effect of conceptual priming on subsequent familiarity. These results indicated that conceptual priming could influence subsequent familiarity by facilitating semantic processing in the encoding phase.

1. Introduction

The distinction between implicit and explicit memory is one of the most fundamental advances in contemporary memory research (Schacter, 1994). Implicit memory refers to the influence of prior episodes on current behavior without intentional retrieval. Priming is one of the most well-known implicit memory, involving improved performance in a cognitive task, e.g., faster response time or greater accuracy, driven by prior access to the same (repetition priming) or semantically related (conceptual priming) information (Paller, Voss, & Boehm, 2007; Schacter & Buckner, 1998). Explicit memory involves the conscious and intentional retrieval of past events and information (Dew & Cabeza, 2011; Schacter & Buckner, 1998). Recognition memory is one kind of explicit memory, referring to the conscious discrimination between previously studied and novel information (Voss & Gonsalves, 2010). According to the dual-process models of recognition memory, recognition memory can be subdivided into two distinct processes: familiarity and recollection (for review, see Yonelinas, 2002). Recollection refers to the recognition of prior event with recall of its context or other relevant information, whereas familiarity refers to the recognition of prior event without such recall (Mandler, 1980; Yonelinas, 2002).

Studies on the relationship between recognition memory and priming have mainly focused on whether they are supported by the same memory system and underlying neural processes (e.g., Dew & Cabeza, 2011; Henke, 2010; Squire, 2004; Wang, Li, Gao, & Guo, 2018; Wang, Li, Gao, Xiao, & Guo, 2015; Wang, Ranganath, & Yonelinas, 2014). The account of multiple memory systems posits that priming and recognition memory depend on different memory systems (for review see Dew & Cabeza, 2011). In contrast, the single memory system theory posits that priming and recognition depend on the same memory system (e.g., Berry, Shanks, & Henson, 2008). Thus investigating how processing fluency induced by priming interacts with recognition memory retrieval is very important for our understanding of the memory mechanisms (e.g., Lucas, Taylor, Henson, & Paller, 2012; Wang et al., 2018). Notwithstanding the extensive investigation of the interaction between priming and recognition memory in the retrieval phase, another fundamental question regarding whether priming can interact with recognition memory by influencing memory encoding has attracted relatively little attention in the past (Wagner, Maril, & Schacter, 2000).

Previous studies on the effect of priming on memory encoding has mainly focused on how repetition priming in the encoding phase influences subsequent recognition memory. In one fMRI study, Wagner et al. (2000) asked subjects to re-perform the same semantic task after a long lag (25 -h) or a short lag (3-minute) in an incidental re-encoding phase and then took the final recognition test after two days. They found that the behavioral (reduced reaction times) and neural priming effects (reduced brain activities in the left inferior prefrontal cortex)

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were greater for the words repeated after a short lag, albeit the recognition performances were worse for these words. The behavioral and neural priming effects were negatively related to the subsequent high confidence recognition memory for words repeated after a long-lag. Some later studies also found that repetition priming might impair the subsequent memory (e.g., Li, Gao, Wang, & Guo, 2015; Li, Wang, Gao, & Guo, 2016; Xue et al., 2010, 2011). These findings suggested that repetition priming can affect the subsequent recognition memory by hindering episodic encoding (for null or oppsite effect see Gagnepain et al., 2011; Gagnepain, Lebreton, Desgranges, & Eustache, 2008; Miyoshi, Minamoto, & Ashida, 2014; Stark, Gordon, & Stark, 2008).

Priming could also be induced by the prior presentation of a semantically related concept, which is referred as conceptual (or semantic) priming (e.g., Schacter & Buckner, 1998). Repetition priming might facilitate the processing of multiple levels, e.g., perceptual, semantic, etc., whereas conceputal priming mainly influences the semantic processing. Given these mechanismic differences between repetition and conceptual priming, conceputal priming might affect subsequent memory differently compared with repetition priming, and they can rely on different neural mechanisms. Previous studies have found that conceputal priming had different effects on the recognition memory retrieval compared with repetition priming, wherein the repetition priming influences familiarity and the conceptual priming influences recollection (e.g., Li, Taylor, Wang, Gao, & Guo, 2017; Taylor, Buratto, & Henson, 2013; Taylor & Henson, 2012; Wang et al., 2018). However, it is still unclear whether conceptual priming influences subseqent memory differently when compared to the repetition priming.

The present study aimed to examine the effects of conceptual priming on subsequent recognition memory by using masked conceptual priming paradigm in the encoding phase. In a typical masked conceptual priming experiment, a masked prime item, which is either semantically related (primed item, e.g., apple-orange) or unrelated to the target item (unprimed item, e.g., throat-horse), is briefly presented before the target item (Van den Bussche, Van den Noortgate, & Reynvoet, 2009). The remember/know (R/K) paradigm (Migo, Mayes, & Montaldi, 2012; Tulving, 1985) was used in the test phase to investigate whether conceptual priming influences subsequent familiarity or recollection. ERPs were recorded during the study and test phase to explore the electrophysiological correlates of how conceptual priming affects the subsequent recognition memory.

Previous research showed that masked conceptual priming was associated with the N400 priming effect from 300 to 500 ms after stimulus onset, in which the amplitude of N400 was larger for the unprimed than the primed items (e.g., Kiefer, 2002; Kiefer & Spitzer, 2000; but see Brown & Hagoort, 1993; Holcomb & Grainger, 2009 for null result). Given that N400 potential is an index of sematic processing (Kutas & Federmeier, 2011; Kutas & Hillyard, 1980), the N400 conceptual priming effect might reflect more efficient semantic processing for the primed items. Intriguingly, some studies also found that the subsequent familiarity was predicted by the magnitude of semantic processing in the encoding phase (Meyer, Mecklinger, & Friederici, 2007; Meyer, Mecklinger, & Friederici, 2010), which suggested that conceptual priming might influence subsequent familiarity.

ERP studies using the DM (difference based on subsequent memory) paradigm (Paller, Kutas, & Mayes, 1987; for review, see Paller & Wagner, 2002) to investigate the ERPs associated with memory encoding have found that the ERPs around 300–500 ms in the encoding phase was related to subsequent familiarity (e.g., Duarte, Ranganath, Winward, Hayward, & Knight, 2004; Mangels, Picton, & Craik, 2001; Yovel & Paller, 2004). Some studies also posited that the ERPs around 300–500 ms at encoding might reflect semantic processing during memory encoding and was not predictive of subsequent recollection (e.g., Cansino, Trejo-Morales, & Hernandez-Ramos, 2010). Thus, these ERP results suggested that conceptual priming might influence subsequent familiarity but not recollection.

According to the above review, we predicted that masked conceptual priming in the encoding phase was associated with N400 priming effect (e.g., Kiefer, 2002; Kiefer & Spitzer, 2000) and that conceptual priming in the encoding phase might reduce subsequent familiarity but have no effect on subsequent recollection.

2. Material and methods

2.1. Participants

Eighteen students (13 females, 19–25 years old, all right handed) from Capital Normal University participated in the experiment. All participants signed an informed consent form and were paid for their participation. This research was approved by the Human Research Ethics Committee of Capital Normal University.

2.2. Materials

Stimuli were 300 conceptually related two-character Chinese word pairs (half living and half nonliving, mean total strokes: 17(± 4(M ± SD)), mean word frequency: 36 (± 30) occurrence per million for primes and 35(± 25) occurrence per million for targets (Liu et al., 1990)). The criteria of conceptual relatedness was defined according to Taylor and Henson (2012), i.e., taxonomic category (e.g., apple–orange), attributes or functions (e.g., beauty-rose), typical context (e.g., Africa-lion), part–whole relationship (e.g., sport-tennis), or lexical interchangeability (e.g., apology-excuse). The old/new status and priming/unpriming status of the stimuli sets were counterbalanced across participants. Another 28 word pairs were used as the filler and practice stimuli.

2.3. Procedure

The experiment consisted of an incidental study phase and a test phase (consisting of two test blocks). In the study phase, participants were asked to judge whether the target word conveyed a living or nonliving concept. A practice block (consisted of 16 trials) was administered before the formal study block to help participants adjust to the procedure in the study phase. The study block consisted of 200 (target) words, with two filler words each presented at the beginning and the end of the block to avoid the primacy and recency effects. Each word was preceded by the brief presentation of a masked prime word, which was either conceptually related (primed trials, 50%) or unrelated to (another unrelated word in unprimed condition, unprimed trials, 50%) the target word.

They were then told about the surprise memory test and given instructions for R/K/New responses immediately after the study phase. A practice test with 10 words (6 from the practice block and 4 unstudied words) was administered before the test phase. Participants were asked to report why they made R or K responses to ensure that they understood the instructions and did not confuse R and K responses with confidence ratings (Wang & Yonelinas, 2012). Each test block consisted of 150 words (100 studied and 50 unstudied). Participants were asked to indicate whether they had seen the target words in the study phase by responding old (seen) and new (not seen). If they responded old, they were prompted to report whether they recollected the test item (e.g., they could recall how the word looked on the screen or they could recall what they thought of when they read the word) or just felt the item was familiar (they could not recall any information associated with the studied word). Presentation (Neurobehavioral Systems, Inc) was used to present the stimuli and collect responses.

Participants were seated on a sofa about 70 cm from the monitor (17″, 1024 × 768 resolution, 85-Hz refresh rate). Stimuli were presented in white against black background in the center of the screen. In the study phase, each trial began with a cross fixation presented randomly between 1506 and 2000 ms. A forward mask (##) was then presented for 306 ms, followed by a prime word for 35 ms and a backward mask (##) for 70 ms. The target word was presented for 1506 ms immediately after the backward mask. Participants were not informed about the presentation of the masked words during the experiment. They were told that the flickering symbols were presented to obtain baseline electroencephalographic (EEG) activities. In the test phase, each trial began with a cross fixation presented randomly between 1506 and 2000 ms, followed by the target word for 506 ms. Then a 2000 ms blank screen was presented after the target word, during which participants made the old / new judgment. If participants made an old judgment, the prompt "remember or familiar" (in Chinese) was presented until participants made the R/K judgment. However, the label K was used following the previous literature. If they responded new or failed to respond within 2000 ms, the next trial was presented. Subjects were debriefed about the presentation of the masked prime word and were asked to report whether they had noticed the presentation of the masked prime word during the experiment. Four of them reported that they noticed there were words presented between the flickering symbols in some trials, but only one of them reported to be able to identify or read the seen prime words in some trials, the remaining reported that they were unable to identify or read the seen prime word.[1]

2.4. EEG recording

The EEGs were recorded with 64 Ag/AgCl electrodes positioned in a nylon electrode cap by Neuro Scan system (NeuroScan Inc. Sterling, Virginia, USA). The EEGs were recorded with a band pass of 0.05–100 Hz (0.05–30 Hz filtered in offline analysis), and sampled at a rate of 500 Hz. All channels were referred to the left mastoid electrode and re-referenced to averaged mastoids in offline analysis. Electrodes were placed above and below the center of left eye and on the canthi to record vertical and horizontal electro-oculograms (EOG). EOG blink artifacts were corrected using a linear regression estimate (Semlitsch, Anderer, Schuster, & Presslich, 1986). Electrode impedance was kept below 5 kΩ during the experiment. EEGs were segmented into epochs from 100 ms prior to stimulus onset (for baseline correction) to 900 ms after stimulus onset. Epochs containing artifacts exceeding ± 75μV were excluded from ERP averaging.

For the analysis of ERP data in the test phase, two midline electrode clusters were selected in the analysis of the ERPs based on previous studies (Li et al., 2015; Lucas et al., 2012). The clusters were frontal: F1, FZ, and F2 and parietal: P1, PZ, and P2. Statistical comparisons were performed using repeated-measures ANOVA or paired *t-test* (criterion $p = 0.05$). Greenhouse-Geisser correction was used where appropriate and Bonferroni-correction was used in Post-hoc comparisons.

3. Results

3.1. Behavioral data

3.1.1. Study phase

Paired *t-test* was conducted on reaction times (RTs) and accuracy of the living/nonliving judgment to primed and unprimed words to examine the effect of masked conceptual priming on the performance of the participants. Participants responded faster to primed words than unprimed words (676 (± 56) ms vs 698(± 50) ms, $t\,(17) = 5.92$, $p < 0.001$, $d = 1.81$). However, there was no difference between the accuracy to primed and unprimed words (0.96 (± 0.03) vs. 0.96 (± 0.02), $t\,(17) = 0.32$, $p = 0.755$, $d = 0.08$).

3.1.2. Test phase

The raw proportions of responses in each condition are depicted in Table 1. Familiarity was calculated according to the independent know procedure (IK procedure, Yonelinas and Jacoby (1995), in which familiarity was calculated as "proportions of K responses / (1 - proportions of R responses)" in the analysis of the behavioral data in the test phase to compensate the underestimation of familiarity in R/K paradigm (e.g., Wagner, Gabrieli, & Verfaellie, 1997; Yonelinas, 2002). Overall accuracy (Pr, calculated as the proportion of Hits minus the proportion of False Alarms, Snodgrass and Corwin (1988) was 0.35 (± 0.11) for R and 0.31 (± 0.12) for IK. The Prs of R and IK were both significantly greater than zero ($t\,(17) = 12.72$, $p < 0.001$, $d = 3$ and $t\,(17) = 11.06$, $p < 0.001$, $d = 2.6$, respectively), which suggested that participants responded above chance level in the test phase. Two-way ANOVA involving response type (R/IK) and priming status (primed/unprimed in the study phase) was conducted on proportions of R and IK to studied items to investigate the effect of masked conceptual priming on subsequent recollection and familiarity.

The two-way ANOVA revealed a significant two-way interaction ($F\,(1,\ 17) = 7.32$, $p = 0.015$, $\eta_p^2 = 0.3$). Proportions of IK responses to unprimed words were significantly greater than primed words ($t\,(17) = 2.33$, $p = 0.032$, $d = 0.55$), whereas proportions of R responses were not significantly different between primed and unprimed words ($t\,(17) = 0.67$, $p = 0.513$, $d = 0.15$). These results indicated that masked conceptual priming affected subsequent familiarity but not recollection.

The Two-way ANOVA involving response type (R/K) and priming status (primed/unprimed in the study phase) was also conducted on the RTs to R and K hits. The two-way ANOVA revealed a significant main effect of response type ($F\,(1,\ 17) = 19.69$, $p < 0.001$, $\eta_p^2 = 0.54$), which indicated that RTs to R responses were faster than RTs to K responses. Neither the main effect of priming status nor the two-way interaction was significant ($ps > 0.1$, $\eta_p^2 s < 0.12$), which indicated that masked conceptual priming had no significant effect on RTs of subsequent familiarity and recollection (RTs to each condition were as follow: Primed R-hits: 850(± 117)ms, Primed K-hits: 1006(± 182)ms, Unprimed R-hits: 857(± 126)ms, and Unprimed K-hits: 976(± 217) ms).

3.2. ERP data

3.2.1. Study phase

A time window of 300–500 ms (N400) were taken to index the masked conceptual priming effect based on previous studies (Li et al., 2017; Wang, Li, Gao, Xiao et al., 2015) and the observation of ERP waveforms. The ERP waveforms and topographic map of N400 priming effect are presented in Fig. 1. A two-way ANOVA, involving priming status (primed/unprimed) and electrode cluster (frontal/parietal) was performed on the mean amplitudes of N400 to primed and unprimed words to investigate the priming effect. Mean numbers of artifact-free trials for primed and unprimed conditions were 93(Range: 72–100) and 94(82–100) respectively.

300–500 ms The two-way ANOVA revealed a significant two-way interaction ($F\,(1,\ 17) = 5.91$, $p = 0.026$, $\eta_p^2 = 0.26$). Amplitudes of

Table 1
Mean percentage of responses in each condition in the test phase.

Study status	Priming status	Remember	Know	IK	New
Studied	Primed	41(11)	26(10)	45(15)	33(12)
	Unprimed	39(13)	29(12)	48(14)	31(11)
Unstudied		4(3)	15(8)	16(9)	81(10)

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[1] Current data could not give a valid conclusion on how the awareness of the prime affects the results as the number of subjects who were aware of the prime was relatively small (only 1). We suspect that the awareness of the prime should enlarge the effect of conceptual priming on subsequent familiarity as masked priming effect is usually larger when the prime could be consciously observed than not (Holcomb, Reder, Misra, & Grainger, 2005).

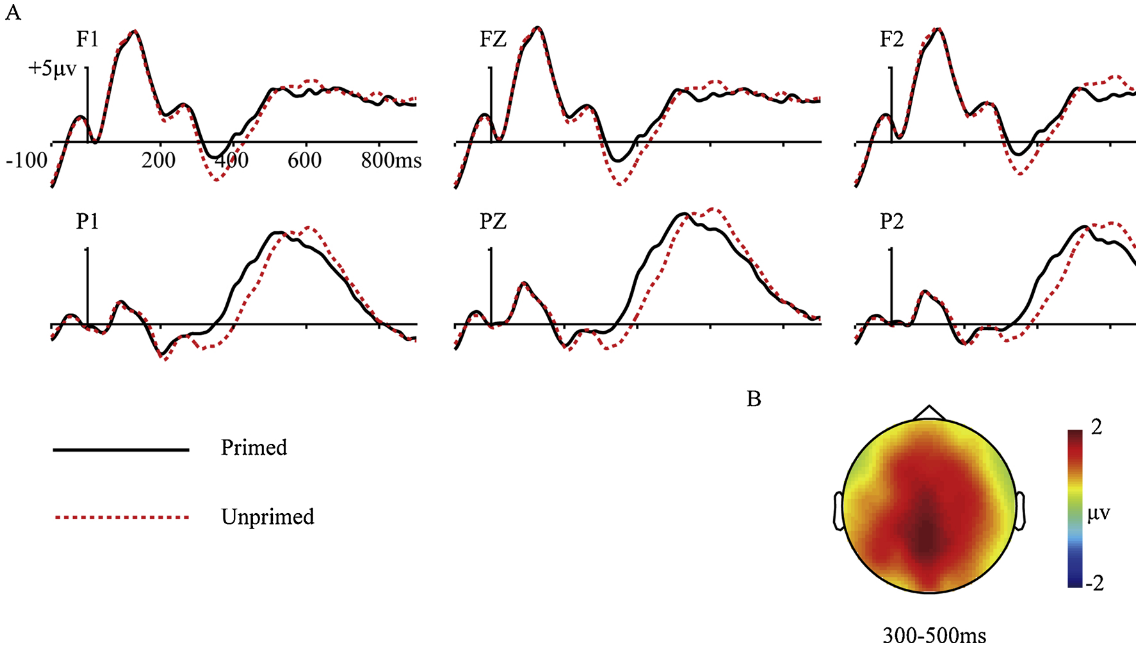

Fig. 1. Grand-averaged ERP waveforms for primed and unprimed words in the study phase.
A) Grand-averaged ERP waveforms for primed and unprimed words in the study phase; B) The topographic maps for the N400 priming effects (ERPs to primed words minus ERPs to unprimed words) between 300–500 ms.

unprimed words were more negative than primed words at frontal (t (17) = 2.71, $p =$ 0.015, d = 0.64) and parietal electrode cluster (t (17) = 4.11, $p =$ 0.001, d = 0.97). These results suggested that this priming effect was parietal maximum distributed as depicted in Fig. 1B.

Across-participant correlation analyses were conducted to investigate the relationship between N400 priming effect in the study phase and behavioral priming effect on subsequent familiarity and recollection. The N400 effect was calculated as amplitude of ERP to primed words minus amplitude of ERP to unprimed words averaged across frontal and parietal electrode cluster. The behavioral priming effect on subsequent memory (R or K) was calculated as proportions to unprimed (in the study phase) words minus proportions to primed words in the test phase. The N400 priming effect was significantly correlated with the priming effect on subsequent familiarity (n = 18, r = 0.65, p = 0.004; see Fig. 2), but it was not correlated with the priming effect on subsequent recollection (n = 18, r = 0.24, $p =$ 0.338).

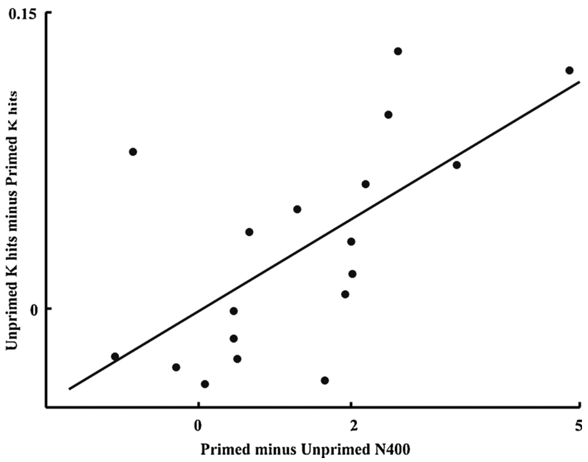

Fig. 2. Across-participant correlation between the effect of conceptual priming on subsequent familiarity and the N400 effect in the study phase.

3.2.2. *Test phase*

3.2.2.1. Basic memory effects. A time-window of 300–500 ms and a time-window of 500–800 ms were taken to indexed FN400 effect and parietal LPC effect respectively based on previous studies (e.g., Rugg et al., 1998). Grand-averaged ERP waveforms of R hits, K hits, and CRs, and topographic maps of FN400 and LPC effects are shown in Fig. 3A and B. ERPs were collapsed across prime type and priming status to compare ERPs for R hits, K hits, and correct rejections (CRs) to analyze the primary memory effects. ERPs associated with familiarity was compared between K hits and CRs and recollection was compared between R hits and K hits. A two-way ANOVA involving response type (R/K/CR) and electrode cluster (frontal/parietal) was performed separately for mean amplitude between 300–500 ms and 500–800 ms. Mean numbers of artifact-free trials for R, K, and CR were 76(41–139), 51(20–109), 73(53–90) respectively.

300–500 ms The two-way ANOVA revealed a significant main effect of response type (F (2, 34) = 7.3, p = 0.002, η_p^2 = 0.3). The interaction between response type and electrode cluster was not significant (F (2, 34) = 0.17, p = 0.838, η_p^2 = 0.01). Amplitudes of ERPs to R hits were not different from K hits ($p >$ 0.1, d = 0.08). Amplitudes of ERPs to R hits and K hits were more positive than CRs (all $ps < 0.05$, $ds > 0.75$). However, the topographic map in Fig. 3B indicated that the FN400 effect between K hits and CRs was fronto-central distributed.

*500–800*ms The two-way ANOVA revealed a significant main effect of response type (F (2, 34) = 7.48, $p =$ 0.003, η_p^2 = 0.31). The interaction between response type and electrode cluster did not reach significant (F (2, 34) = 2.18, $p =$ 0.141, η_p^2 = 0.11). Amplitudes of ERPs to R hits were more positive than K hits and CRs (all $ps < 0.05$, $ds > 0.64$). Amplitudes of K hits were not different from CRs ($p >$ 0.1, d = 0.34). However, the topographic map in Fig. 3B indicated that the LPC effect between R hits and K hits was centro-parietal distributed.

3.2.2.2. Effect of masked repetition priming on subsequent old/new effects. Analyses were conducted on ERP responses to R hits and K hits as a function of priming status to examine which old/new effect was influenced by masked conceptual priming in the study phase. Data from 2 subjects were excluded from these analyses for less than 16

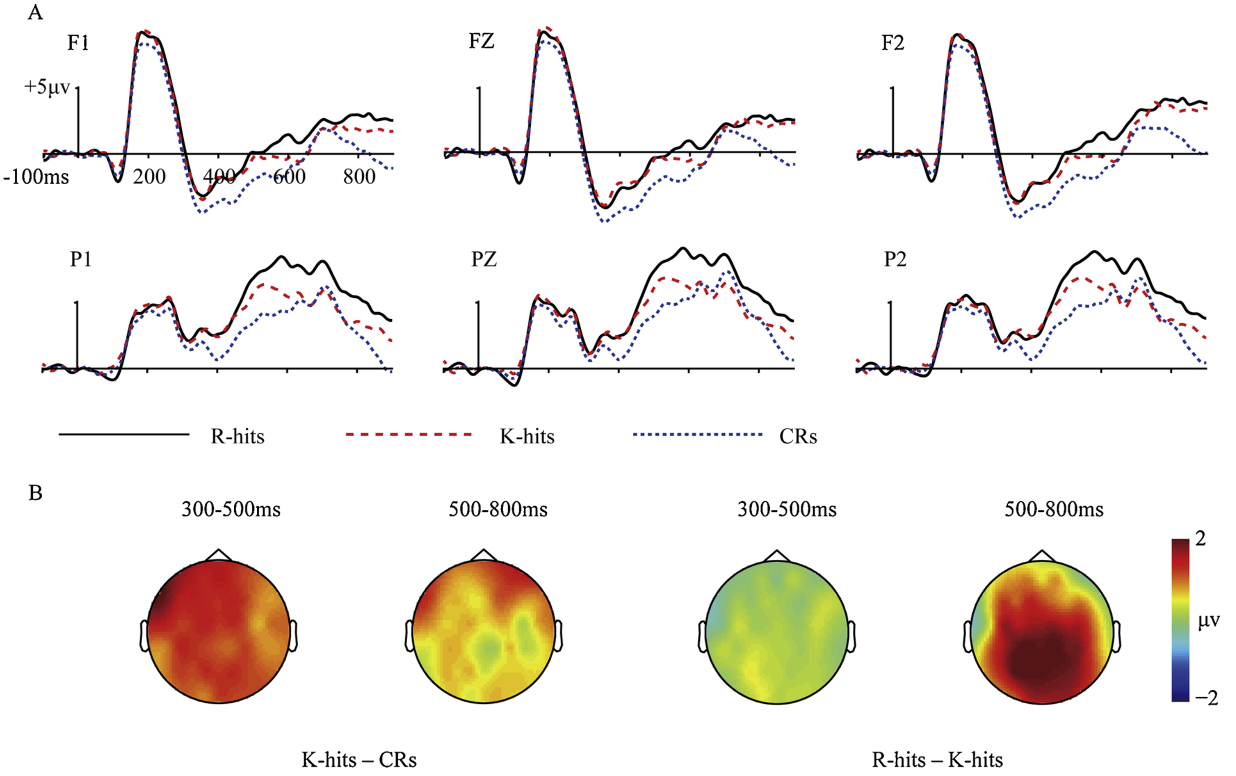

Fig. 3. ERP waveforms and topographic maps for basic memory effects.
A) Grand-averaged ERP waveforms for R hits, K hits, and CRs; B) topographic maps for FN400 ("K-hits – CRs" at 300–500 ms) and LPC ("R-hits – K hits" at 500–800 ms) old/new effects.

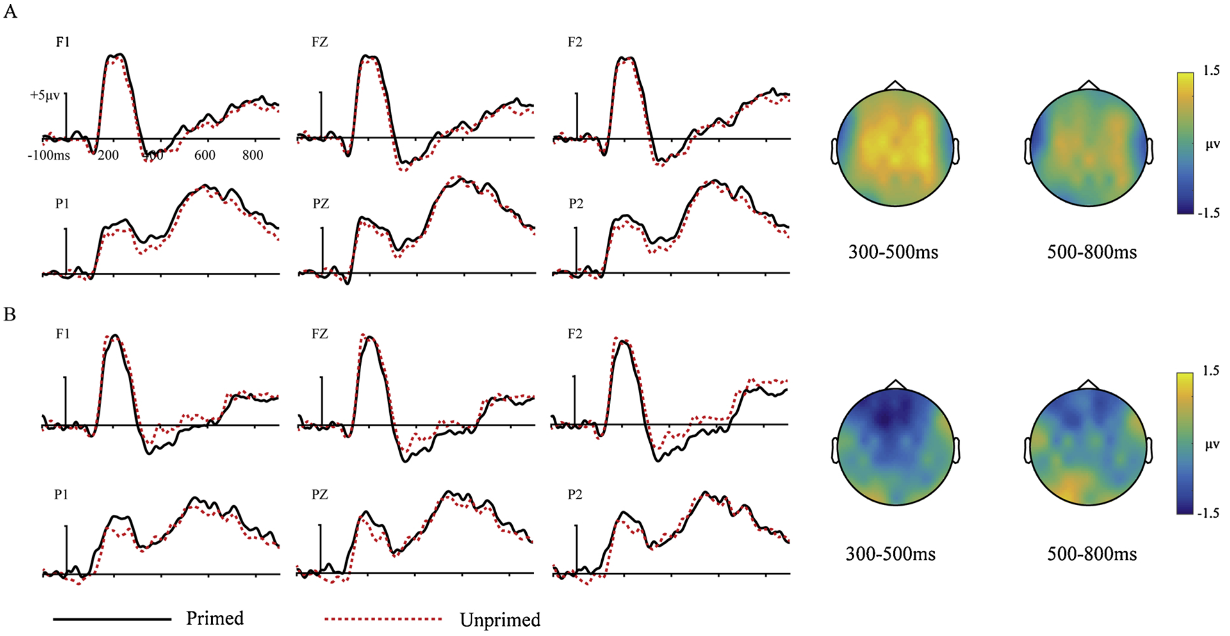

Fig. 4. Grand-averaged ERP waveforms for the R hits and K hits as a function of prime status and topographic maps of the priming effects.
A) Grand-averaged ERP waveforms and topographic maps for priming effects (Primed hits – Unprimed hits) on the R hits for the FN400 and the LPC; B) grand-averaged ERP waveforms and topographic maps for priming effect (Primed hits – Unprimed hits) on the K hits for the FN400 and the LPC.

artifact-free trials in any condition. A three-way ANOVA, involving response type (R/K), priming status (primed/unprimed in the study phase) and electrode cluster (frontal/parietal), was conducted for ERPs during 300–500 ms (FN400) and 500–800 ms (LPC) separately. Grand-averaged ERP waveforms for primed and unprimed R and K hits are shown in Fig. 4. Mean numbers of artifact-free trials for primed R and K hits are 35(23–49) and 26(16–51) respectively, and mean numbers of artifact-free trials for unprimed R and K hits were 35(16–54) and 29(16–58) respectively.

For the FN400, the three-way ANOVA revealed a significant three-way interaction between response type, priming status and electrode cluster (F (1, 15) = 5.17, $p =$ 0.038, $\eta_p^2 = 0.26$). No two-way interactions were significant (all $ps > 0.1$, all $\eta_p^2 < 0.6$). Subsequent analyses revealed that ERP amplitudes to primed R hits were not significantly different from unprimed R hits at frontal and parietal electrode cluster ($t\ (15) = 1.14$, $p = 0.273$, $d = 0.29$; $t\ (15) = 1.36$, $p = 0.195$, $d = 0.34$), whereas ERP amplitudes to primed K hits were less positive than unprimed K hits at frontal electrode cluster ($t\,(15) = 2.41$, $p = 0.029$, $d = 0.6$) but not at parietal electrode cluster ($t\,(15) = 0.19$, $p = 0.847$, $d = 0.05$). For the LPC, the main effect of priming type was not significant ($F\ (1, 15) = 0.02$, $p = 0.88$, $\eta_p^2 = 0.002$). No three-way or two-way interactions were found to be significant (all $ps > 0.1$, all $\eta_p^2 < 0.08$). These results indicated that masked conceptual priming in the study phase only increased the FN400 old/new effect for K hits.

4. Discussion

The present study used masked conceptual priming paradigm in the study phase and R/K paradigm in the test phase to investigate the effects of conceptual priming on subsequent recognition memory. The behavioral results revealed that the ratio of familiarity to previously primed items was reduced compared with previously unprimed items, whereas the ratio of recollection to previously primed items was not significantly different from previously unprimed items. The ERP results in the study phase revealed that conceptual priming was correlated with reduced N400 and the N400 priming effect was predictive of the effect of conceptual priming on subsequent familiarity.

The present study showed that conceptual priming affected the subsequent familiarity. However, some studies found that repetition priming affected the subsequent recollection but not familiarity (e.g., Gagnepain et al., 2011, 2008; Li et al., 2015, 2016). These results indicated that the two types of priming might affect subsequent recognition memory through different mechanisms. We speculate that these differences might be explained by the mechanic differences between these two kinds of priming. Previous studies suggested that repetition priming affects the subsequent memory via processes associated with episodic encoding (Gagnepain et al., 2011; Li et al., 2016; Wagner et al., 2000), which is supposed to affect recollection more than familiarity. Conceptual priming mainly affects the semantic process which might be predictive of the subsequent familiarity but not of recollection (Meyer et al., 2007, 2010; Xu, Qin, Li, & Guo, 2015). Future studies might examine underlying mechanisms of the two types of priming in memory by directly comparing how repetition and conceptual priming affect the subsequent memory using behavioral and neuroimaging methods.

The RTs for primed words were faster than unprimed words, which implicated that the semantic processing of primed words was facilitated compared to unprimed words. Consistent with the behavioral priming effect, the ERP results revealed that the N400 was less negative for the primed words compared with the unprimed words in the study phase, which was consistent with the previous studies (e.g., Kiefer & Spitzer, 2000; Li et al., 2017; Wang, Li, Gao, Xu, & Guo, 2015). In addition, the N400 priming effect was significantly correlated with the effect of conceptual priming on subsequent familiarity, which indicated that more negative N400 in the encoding phase was associated with greater subsequent familiarity (Mangels et al., 2001). According to the automatic spreading account, the semantic access to the primed words was facilitated because its semantic nodes are partially activated by the spreading of the related prime word (Collins & Loftus, 1975; Kiefer, 2002). As there was no such activation for the unprimed words, more effort was devoted to get semantic access to the unprimed words, resulting in greater sematic processing and subsequent familiarity. This interpretation is also consistent with the findings showing that tasks with desirable difficulty can lead to better subsequent memory performances (Bjork, 1994; Gao et al., 2016; Jia, Gao, Cui, & Guo, 2018). Conceptual priming had no effect on subsequent recollection because the previous studies suggested that the ERPs around N400 time-window in the encoding phase could not support encoding processes that distinguish subsequent familiarity and recollection (e.g., Cansino et al., 2010).

We prospect that the perirhinal cortex (PRc) might be the brain region responsible for the effects of conceptual priming on subsequent familiarity. First, PRc is related to semantic processing. Intracranial recording studies investigating the brain regions associated with semantic processing found that greater activities in anterior medial temporal lobe (including PRc) were associated with enhanced semantic processing (McCarthy, Nobre, Bentin, & Spencer, 1995; Meyer et al., 2005). Second, PRc is associated with conceptual priming. Dew and Cabeza (2013) found that the activities of PRc for primed items were reduced in the masked conceptual priming paradigm. Wang et al. (2014) found that PRc could support both conceptual priming and familiarity. These results suggested that PRc might be the brain region associated with facilitated semantic processing induced by conceptual priming.

The results of the present study are also in reconcile with the previous studies investigating the relationship between semantic processing and subsequent familiarity (Meyer et al., 2007, 2010). Meyer et al. (2007) presented subjects with sentences with semantically correct or incorrect final word in an incidental study phase and found that the correct final word induced greater N400 compared to the incorrect final word. They also found that the amplitude of N400 in the encoding phase, which was supposed to reflect semantic integration processing, was negatively correlated with the amplitude of the FN400 in the test phase. They concluded that the magnitude of semantic processing in the encoding phase were negatively associated with the subsequent familiarity. In a later study using similar paradigm with R/K paradigm in the test phase, they found that semantic processing in the encoding phase affected subsequent familiarity but not recollection (Meyer et al., 2010). Meyer et al. (2010) also found that enhanced semantic processing was associated with stronger activities in anterior MTL which includes PRc. These results also supported our assumption that the PRc was responsible for the effects of conceptual priming on subsequent familiarity. Conceptual priming was also indexed by N400 effect in the present study, which suggested that semantical violation in sentences and conceptual priming might affect subsequent familiarity via similar mechanism.

The results of the present study could contribute to the understanding of the relationship between conceptual priming and recognition memory. Previous studies on the relationship between recognition memory and conceptual priming have focused mainly on whether they are supported by the same underlying neural processes. For example, some studies found that familiarity based recognition memory might be supported by overlapping brain region that induces conceptual priming (e.g., Lucas et al., 2012; Wang, Lazzara, Ranganath, Knight, & Yonelinas, 2010, 2014; Wang, Li, Gao, Xiao et al., 2015; Wang, Li, Gao, Xu et al., 2015; Wang & Yonelinas, 2012). However, some studies found that conceptual priming and familiarity are supported by different brain regions (e.g., Levy, Stark, & Squire, 2004; Voss, Reber, Mesulam, Parrish, & Paller, 2008). The results of the present study suggested that conceptual priming could also interact with familiarity by affecting semantic processing in the encoding phase, which provided new insights on the relationship between familiarity and conceptual priming.

Although we found that the FN400 was more positive for unprimed items (in the study phase), which was consistent with the behavioral effects of priming on the subsequent familiarity as FN400 was supposed to reflect familiarity based on previous studies (Rugg & Curran, 2007; Rugg et al., 1998). The FN400 was found to be associated with right dorsolateral prefrontal cortex and the right intraparietal sulcus as suggested by a recent study combing EEG and fMRI recording (Hoppstädter, Baeuchl, Diener, Flor, & Meyer, 2015). However, some recent studies posited that the FN400 is associated with conceptual priming but not familiarity (Gao, Hermiller, Voss, & Guo, 2015; Hou, Safron, Paller, & Guo, 2013; Paller et al., 2007). The present results cannot rule out the possibility that the FN400 may reflect conceptual priming (e.g., Paller et al., 2007; Voss, Lucas, & Paller, 2012) because the present study used word as stimuli, which would induce conceptual priming in the test phase, and conceptual priming and familiarity might be affected similarly by manipulations in the encoding phase (for review, see Paller et al., 2007; Yonelinas, 2002). Therefore, the present study could not rule out the possibility that the effect of conceptual priming on the FN400 might reflect the effect of conceptual priming on subsequent conceptual processing of the test items.

Some single process theories posited that the R and K responses in the R/K paradigm were only different in confidence (e.g., Dunn, 2004, 2008), although the R/K paradigm was widely used in memory studies to separate familiarity and recollection in the test phase (for review, see Migo et al., 2012). In order to get a purer index of familiarity and recollection by using the R/K paradigm, we asked subjects to report their reasons for R and K responses in the practice phase and emphasized on the differences between confidence and between R and K to make subjects not confuse R and K with confidence (e.g., Wang & Yonelinas, 2012; Yonelinas & Parks, 2007). The analysis of ERP old/new effects also supported the distinction between the R and K responses. Therefore, the behavioral effects of conceptual priming on familiarity should be valid in the present study.

In sum, the present study extended the view on the relationship between conceptual priming and recognition memory by showing that conceptual priming can interact with recognition memory by reducing subsequent familiarity. The analysis of ERPs in the study phase revealed that conceptual priming can facilitate the semantic processing of the target items which results in worse subsequent familiarity.

Declaration of Competing Interest

None.

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Appendix A

Examples of word pairs used in the study.

Prime	Target
刀子(knife)	匕首(dagger)
雪茄(tobacco)	香烟(cigar)
教室(classroom)	讲台(platform)
戒指(ring)	项链(necklace)
扣子(button)	纽扣(button)
木工(carpenter)	木匠(carpenter)
皇上(king)	国君(king)
水塘(pond)	青蛙(frog)
婚礼(wedding)	新娘(bride)
蚂蚱(locust)	蟋蟀(cricket)

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