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Weakening of recognition memory caused by task-irrelevant emotional encoding context can be modulated by individuals' inhibitory control

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ABSTRACT

Previous studies have demonstrated weakened memory performance caused by emotional encoding contexts. However, whether and how an individual's inhibitory control ability modulates this emotional context effect remains unclear. The present study adopted a study-test paradigm with words as studied items and emotional pictures as backgrounds to address this question. The behavioral results showed that, for participants with low control ability (LCA) but not those with high control ability (HCA), the positive high-arousing context impaired word recognition performance compared to neutral and positive low-arousing contexts. Event-related potential (ERP) data at encoding indicated a significant emotional context effect after 150 ms post-stimulus and HCA participants demonstrated more negative ERPs than LCA participants in frontal sites during 300–500 ms. ERP results at retrieval revealed that the late positive component old/new effect in a positive high-arousing context appeared only in HCA participants. These results suggest that HCA participants can better suppress interference from emotional context at encoding and thus perform recall effectively at retrieval.

1. Introduction

In real life, learning and remembering take place within contexts, some of which might interfere with learning and recall activities. Previous studies have shown that performance impairment may be more severe when context distractors are emotional rather than neutral. For example, Rimmele, Davachi, Petrov, Dougal, and Phelps (2011) found that recognition accuracy for frame colors surrounding negative scenes was lower than for frame colors surrounding neutral scenes. Some studies (e.g., Kim, Vossel, & Gamer, 2013; Touryan, Marian, & Shimamura, 2007) showed impaired memory for items that were peripheral to negative emotional pictures. Zhang, Liu, An, Yang, and Wang (2015) found that, compared with neutral contexts, task-irrelevant emotional contexts impaired memory for items centrally superimposed onto background pictures.

Theoretically, if irrelevant contexts can easily capture individuals' attention and thus interfere with item learning and memory, individuals will invoke inhibitory control mechanisms to disengage from distractors or avoid attending to them in the first place. This inhibitory control can be either an automatic or active process (Geng, 2014). Because individual differences in inhibitory control are readily apparent, we anticipate that the lower an individual's control ability, the more obvious the weakening in memory performance caused by the emotional encoding context. To our knowledge, however, no research has directly tested this hypothesis; thus, whether or how inhibitory control ability may affect recognition memory in an emotional encoding context is unclear. The present study attempts to provide experimental evidence for this hypothesis by examining how inhibitory control ability modulates the effects of emotional encoding context on recognition memory.

Memory retrieval involves two distinct processes: familiarity and recollection (Jacoby, 1991; Rugg & Curran, 2007; Yonelinas, 2002). *Familiarity* occurs when people find an item familiar but cannot recall detailed information about it; *recollection* occurs when people can correctly recognize the learned item and recall the details of the encoding context. Event-related potential (ERP) studies using recognition tasks have showed that ERP waveforms elicited by correctly classified old items (i.e., those learned in the encoding phase) are more positive than waveforms elicited by correctly classified new items (i.e., those not seen in the encoding phase); this is referred to as the old/new effect (Rugg & Curran, 2007). Two old/new effects are thought to index familiarity and recollection, respectively. The earlier frontal old/new effect reflected by a negative component (FN400) that peaks around 400 ms post-stimulus can be attributed to familiarity; the parietal old/new effect representing recollection is reflected by a late positive component (LPC) peaking at approximately 600 ms (Curran & Hancock, 2007; Rugg & Curran, 2007). In addition, a late post-retrieval old/new effect reflected by a late slow wave (LSW) in the frontal area observed after

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about 700 ms post-stimulus is interpreted as monitoring and evaluation of the retrieved information (Rugg et al., 1998; Rugg & Allan, 2000; Rugg & Wilding, 2000; Zhang et al., 2015).

In general, individuals' memory performance relies heavily on the quality of their memory encoding. Numerous studies have investigated the processing of emotional stimuli employing ERPs and demonstrated that emotion can modulate ERP amplitudes (e.g., Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Keil et al., 2002; Schupp et al., 2000). Earlier (< 300 ms) ERP emotion effects have been found to reflect attention orientation for unpleasant pictures; later (> 300 ms) ERP emotion effects have been linked to the influence of emotion on mental resource allocation and memory formation (see Olofsson, Nordin, Sequeira, & Polich, 2008). In the present work as well as in prior research (Zhang et al., 2015), the authors examined memory for neutral words superimposed onto emotional pictures at encoding. Study-phase ERPs were expected to reflect the processing of studied words and emotional backgrounds. We proposed that earlier emotion effects might reflect the influence of emotional context on word identification, whereas later emotion effects might indicate the effects of emotional context on mental resource allocation and memory formation.

Some research has investigated the effects of emotional context on memory retrieval using ERP measurement, but results have been inconsistent. For example, Smith, Dolan, and Rugg (2004) found that the most evident ERP effects of emotional contexts (i.e., negative and positive) emerged around 800 ms post-stimulus compared with a neutral context, reflecting an emotional modulation in post-retrieval processing. Additionally, a small effect of emotional context emerged during the 300–500 ms interval, indicating that items paired with emotional contexts at encoding acquired some emotional attributes of these contexts and did not depend upon conscious recollection of the contexts. Jaeger, Johnson, Corona, and Rugg (2009) explored ERP correlates of the retrieval of neutral objects paired with negative or neutral scenes at encoding over short and long study-test delays. They observed a sustained positive-going modulation in ERPs elicited by objects paired with negative scenes relative to neutral contexts from around 200 ms post-stimulus under the short delay and a different ERP emotional effect (in terms of polarity and scalp distribution) under the long delay. Jaeger et al. suggested that the effect of emotional context on retrieval might be modulated by an emotion-specific consolidation mechanism.

Recent work from Zhang et al. (2015) investigated the influences of task-irrelevant emotional encoding contexts on recognition memory of neutral words. ERP results at encoding demonstrated that, compared with items presented in a neutral context, items in positive and negative high-arousing contexts elicited more positive ERPs from 150 ms – 1000 ms post-stimulus, likely reflecting an automatic process of attention-capturing in high-arousing contexts as well as a conscious and effortful process of overcoming interference of high-arousing contexts. ERP results at retrieval demonstrated that significant FN400 old/new effects occurred in the negative low-arousing, positive, and neutral context conditions but not in the negative high-arousing condition. Moreover, the LPC old/new effect in the negative high-arousing condition was smaller than in the positive high-arousing and low-arousing conditions. These results imply that the emotional encoding context might influence familiarity as well as recollection processes.

The present study adopted a paradigm similar to that in Zhang et al. (2015). Emotional and neutral pictures were used as encoding contexts, and Chinese words were used as items in the study-test task. The present study and that by Zhang et al. (2015) each manipulated the arousal level (high vs. low) of emotional pictures. Zhang et al. (2015) employed positive and negative contexts and found that the negative and positive high-arousing contexts impaired word recognition compared with the neutral context. However, the current study only employed positive contexts and expected the positive high-arousing context to impair word recognition compared with the neutral context, replicating the results of Zhang et al. (2015). More importantly, the present study used ERP measurements to further explore how inhibitory control modulates the effect of positive encoding contexts.

The positive context condition used in the current study was based on two considerations. First, we set out to design a simpler experiment with fewer context conditions. Second, although Zhang et al. (2015) noted that the negative and positive high-arousing contexts each impaired word recognition performance compared with the neutral context, a significant FN400 old/new effect occurred in the positive high-arousing condition but not in the negative high-arousing condition. Moreover, the LPC old/new effect in the negative high-arousing condition was smaller than in the positive high-arousing condition. To better examine the potential modulation of inhibitory control ability on FN400 and LPC old/new effects under emotional contexts, the present study employed a positive context.

In sum, this study aimed to test the modulatory roles of individuals' inhibitory control ability on recognition memory under task-irrelevant positive encoding contexts using behavioral and ERP measurements. The main research question was “Which ERP component might be influenced by inhibitory control ability and emotional encoding context?” in an effort to infer whether and how inhibitory control ability affects the encoding process and familiarity, recollection, or the post-retrieval process at retrieval relative to the emotional encoding context. Because emotional pictures as contexts only occurred in the encoding stage, we proposed that inhibitory control ability would first affect the encoding process and then result in different memory performance and ERP patterns at retrieval.

Because items and emotional contexts were displayed simultaneously during the study, participants needed to employ an inhibitory control mechanism to overcome interference from emotional contexts to encode items. The stronger the interference, the greater the role of inhibitory control. Thus, we predicted that individuals' inhibitory control would impact the ERPs in the encoding process and modulate ERPs of retrieval, especially in the high-arousing context that could more easily capture individuals' attention and thus interfere with item learning and memory compared with the neutral context. Moreover, the familiarity process is somewhat implicit, whereas recollection involves conscious retrieval (Curran, 2000; Curran, Tepe, & Piatt, 2006; Rugg & Curran, 2007). Previous research showed that explicit but not implicit memory might be more easily influenced by processing level (Graf, Squire, & Mandler, 1984). As different degrees of suppressing distractors among participants with different levels of control ability may lead to diverse item-processing levels under emotional contexts during encoding, we predicted that inhibitory control would indirectly influence the LPC old/new effect representing recollection.

2. Methods

2.1. Participants

Initially, 96 undergraduate students completed the Stroop task which is typical measure of inhibitory control ability (Schmid, Kleiman, & Amodio, 2015). Participants who received the first 27% of control ability score (CAS) were considered to have low control ability (LCA), and those who received the last 27% of CAS were considered to have high control ability (HCA). Forty students (20 LCA, 20 HCA; mean age = 25.12 years, SD = 1.83; 9 men) were selected to participate in the experiment and received monetary compensation. The respective CASs (mean ± SD) of LCA and HCA participants were 131.73 ± 33.75 and 36.24 ± 21.75, with a significant difference between the LCA and HCA groups [$t(38) = -10.636$, $p < 0.001$]. All participants were right-handed, native Chinese speakers, and had normal or corrected-to-normal vision. Each participant signed an informed consent form. Ethical approval from the University was obtained.

2.2. Measure and stimuli

Participants' inhibitory control ability was measured using the