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Immediate emotion-enhanced memory dependent on arousal and valence: The role of automatic and controlled processing ☆

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ABSTRACT

The phenomenon that emotional stimuli are better remembered than neutral ones is called emotion-enhanced memory (EEM). Previous studies have shown that both valence and arousal of stimuli contributed to EEM. Kensinger and Corkin (2004) proposed that the EEM dependent on arousal was associated with automatic encoding processes, whereas the EEM dependent on valence was associated with controlled encoding processes. Their experiment with negative words provided some evidence for this associative pattern. However, it is unclear whether the observed association that occurred with negative emotional stimuli could be replicated with positive emotional stimuli. To further examine this issue, two experiments were conducted to investigate the immediate EEM of emotional words in three different attention conditions using a divided attention (DA) paradigm. Results indicated that the immediate EEM dependent on valence was associated with controlled processing, while the immediate EEM dependent on arousal was not always associated with automatic processing. The immediate EEM dependent on arousal for negative stimuli was associated with automatic processing, whereas the immediate EEM dependent on arousal for positive stimuli was associated with controlled processing. Therefore, the immediate EEM dependent on arousal, whether it is associated with automatic or controlled processing, is moderated by the valence of stimuli.

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1. Introduction

Emotional stimuli are more easily remembered than neutral ones. This phenomenon is called emotion-enhanced memory (EEM) (LaBar & Cabeza, 2006; Phelps, LaBar, & Spencer, 1997; Talmi, Schimmack, Paterson, & Moscovitch, 2007). EEM has been observed in recognition, free recall and cued recall performances using various emotional stimuli types, from words and pictures to film clips (Bradley, Greenwald, Petry, & Lang, 1992; Buchanan & Adolphs, 2002; Burton et al., 2004; Denburg, Buchanan, Tranel, & Adolphs, 2003; Doerksen & Shimamura, 2001; Döhnel et al., 2008; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; MacKay et al., 2004; Richardson, Strange, & Dolan, 2004; Talmi et al., 2007). Existing studies have shown that EEM is driven by both the valence of stimuli and the arousal intensity of induced emotion (Kensinger, 2004; Kensinger & Corkin, 2003; LaBar, 2007). For instance, studies found that memory for highly arousing stimuli, especially highly arousing negative stimuli, is better than that for neutral ones. This suggests that arousal is a critical factor in enhancing memory (Anderson, Yamaguchi, Grabski, & Lacka, 2006; Canli, Desmond, Zhao, & Gabrieli, 2002; Dolcos & Denkova, 2008; Kensinger, Garoff-Eaton, & Schacter, 2007; Kensinger & Schacter, 2007; Mather & Sutherland, 2011; McGaugh, 2004). Other studies found that memory for negative or positive emotional stimuli is better than for neutral stimuli, even when the arousal intensity of such stimuli is low. This suggests that valence is another important factor in boosting memory performance (Berntsen, 2002; Kensinger, 2009; Kensinger & Corkin, 2003, 2004; Kensinger & Schacter, 2008; Kensinger et al., 2002; LaBar & Cabeza, 2006; Mickley & Kensinger, 2008; Ochsner, 2000; Talmi et al., 2007; Van Steenbergen, Band, & Hommel, 2010).

Neuroimaging studies have shown that arousal and valence influence emotional memory via modulation of distinct neural mechanisms (Kensinger & Corkin, 2004; Kensinger & Schacter, 2005; Murty, Ritchey, Adcock, & LaBar, 2010; Steinmetz & Kensinger, 2009). For arousing stimuli, the amygdala plays a critical role in EEM by modulating encoding processes, especially for negative arousing stimuli (Anderson et al., 2006; Kensinger & Schacter, 2005, 2006; Sharot, Delgado, & Phelps, 2004). The level of activation in the amygdala and hippocampus is proportional to the likelihood that emotionally arousing stimuli are remembered (Dolcos, Labar, & Cabeza, 2004; Kensinger & Corkin, 2004; LaBar & Cabeza, 2006; Phelps, 2004). In contrast, memory for

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negative nonarousing stimuli is boosted due to differential engagement of the prefrontal (PFC) network (Anderson et al., 2006; Kensinger & Corkin, 2004; Kensinger & Schacter, 2005), especially the right PFC (Davidson & Irwin, 1999).

Based on the findings of these neuroimaging studies, Kensinger and Corkin (2004) proposed that arousal and valence might play different roles in encoding processes contributing to the EEM via distinct neural routes. The EEM of a negative arousing stimulus is mediated by the amygdala-hippocampal network, which is associated with relatively automatic encoding processes, whereas, the EEM of a negative nonarousing stimulus is supported by a PFC-hippocampal network, which is associated with controlled encoding processes. Behavioral data using negative words by Kensinger and Corkin (2004) supported this associative pattern. However, the distinct neural mechanisms do not necessarily correspond with automatic and controlled processing in behavioral performance because the EEM of arousing stimuli does not solely depend on activation in the amygdala, and the EEM of nonarousing stimuli does not solely depend on prefrontal activation. Moreover, Kensinger and Corkin's study (2004) did not examine how automatic and controlled processing would contribute to the EEM dependent on arousal and valence in a positive stimulus condition. Therefore, more evidence is needed to clarify whether or not the EEM dependent on arousal is associated with automatic processing and whether or not the EEM dependent on valence is associated with controlled processing.

Beyond the research just discussed, related studies have shown that the cognitive processing and neural mechanisms of negative stimuli are different from those of positive stimuli (Christianson, 1992; Clark-Foos & Marsh, 2008; Kern, Libkuman, Otani, & Holmes, 2005; Steinmetz, Addis, & Kensinger, 2010; Talmi et al., 2007). For instance, Steinmetz et al. (2010) found that, in contrast to processing of negative stimuli, the amygdala was activated when processing positive low-arousing stimuli and amygdala efferents weakened as arousal increased for positive stimuli. Electrophysiological evidence has also shown that threat-related stimuli may elicit an early enhanced encoding (amplitude enhancement on frontal sites), and this early effect might be processed unconsciously relative to happy and neutral stimuli (Eimer, Kiss, & Holmes, 2008; Righi et al., 2012). Talmi et al. (2007) argued that attention mediation can completely account for the effect of positive emotion on memory, but the influence of negative emotion on memory is not significantly mediated via attention. Moreover, from an evolutionary perspective, the biological information attached to positive and negative stimuli is different from each other (Bradley & Lang, 2007; Lang, 2010). Prior research on the relation between emotional valence and goals has suggested that people feel negative emotion when goals are threatened and feel positive emotion when goal attainment is anticipated or has been achieved (Levine & Edelstein, 2009). The information relevant to uncompleted goals tends to be well remembered whereas information relevant to completed goals tends to be forgotten (Förster, Liberman, & Higgins, 2005). Taken together, the growing body of evidence indicates that the cognitive processing of negative stimuli differs from that of positive stimuli. Accordingly, the associative pattern between the EEM dependent on arousal or valence and the automatic or controlled processing for negative emotional stimuli might be different from that for positive emotional stimuli.

Recently, the contributions of automatic and controlled processing to the EEM have been reported in other studies. For example, Talmi et al. (2007, 2012), distinguished between immediate and delayed EEM (referring separately to memory tested immediately, or at relatively short delays and at long delays, such as hours or even days, as each is believed to depend on different processes). They found that immediately positive EEM was completely mediated by secondary-task performance (controlled attention) during encoding, but immediately negative EEM was not. Kern et al. (2005) reported that in contrast to full attention, divided attention would adversely impact neutral and positive arousing words more than negative words. Chainay, Michael, Vert-pré, Landré, and Plasson (2012) reported that the effect of emotion on immediate memory enhancement may depend on the intentionality to encode for positive pictures. Pottage and Schaefer (2012) found that visual attention and automatic preattentive processing both play important roles in the immediate EEM for negative pictures. Maddox, Naveh-Benjamin, Old, and Kilb (2012) found that automatic processing contributes to immediate EEM for positive words as well as for negative words. Talmi et al. (2013) found that food images had parallel effects on attention and memory for hungry participants, which implies that superior memory for food images is not mediated by the attention devoted to them. However, the studies mentioned above simply investigated the effect of emotionality on immediate EEM, and did not distinguish the EEM effects dependent on arousal and valence. Therefore, it is difficult to infer from them which processes, automatic or controlled, contributed to the immediate EEM dependent on arousal and valence of stimuli.

The present study examined the contributions of automatic and controlled processing to the immediate EEM dependent on arousal and valence, especially for positive emotional stimuli. The negative/positive arousing, negative/positive nonarousing, and neutral Chinese words were employed in the experiment. To control the residual processing resources involved in the immediate EEM, three different attention conditions which included FA (full attention), easy DA (divided attention with an easy concurrent secondary task) and difficult DA (divided attention with a difficult concurrent secondary task) were designed. The effect of valence was investigated by comparing recognition memories for nonarousing and neutral words. Similarly, the effect of arousal was investigated by comparing recognition memories for arousing and nonarousing words.

2. Experiment 1: the role of automatic and controlled processing in the immediate EEM of negative words

To further test the particular contributions of automatic and controlled processing to the immediate EEM dependent on arousal and valence for negative stimuli, Experiment 1 replicated Kensinger and Corkin's study (2004) with Chinese words. In Experiment 1, negative arousing, negative nonarousing, and neutral Chinese words were used as experimental materials. Participants were first asked to learn negative arousing, negative nonarousing, and neutral Chinese words under three different attention conditions, and then were instructed to complete a recognition test. We hypothesized that there are no differences between recognition memories for negative arousing words under the three attention conditions, but that there are differences between the recognition memories for negative nonarousing and neutral words under three attention conditions. Namely, the immediate EEM of negative arousing words was observed under full and divided attention, but the immediate EEM of negative nonarousing words reduced or eliminated under divided attention.

2.1. Method

2.1.1. Participants

Participants included ninety right-handed university students (45 men, 45 women; average age = 20.16 years, range 19–24 years). All participants were Chinese native speakers, with no history of psychiatric or neurological disorders. All participants had normal or corrected-to-normal vision.

2.1.2. Materials

Ninety six Chinese words including 32 negative arousing words (e.g., 血迹/*bloody*, 魔鬼/*devil*), 32 negative nonarousing words (e.g., 厕所/*toilet*, 阴暗/*gloom*), and 32 neutral words (e.g., 作家/*author*, 规范/*criterion*) were selected from Chinese Affective Words System (CAWS) (Wang, Zhou, & Luo, 2008) as experimental materials employed in Experiment 1. To control the influence of word length and word frequency on immediate EEM, all selected words were disyllabic and were matched by their

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