The Cognitive Load Affects the Interaction Pattern of Emotion and Working Memory

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ABSTRACT

Emotion might selectively affect spatial and verbal cognitive activities and the selective interaction pattern could be modulated by cognitive load. To test the hypotheses, the authors used event-related potentials (ERPs) technique to investigate the interaction pattern of emotion and working memory (WM) by typical WM n-back tasks with low and high cognitive loads. In the 0-back task, late ERP components for both spatial and verbal WM were affected by induced emotional states consistently. However, in the 2-back task, they could clearly observe that induced emotional states selectively affected ERPs for spatial WM, but not for verbal WM. These results suggested that the interactive pattern of emotion and WM was modulated by cognitive load. In the condition of low cognitive load, interaction of emotion and WM was similar and nonspecific. However, with the increasing of cognitive load, interaction of emotion and WM became specific and selective. ERP results suggested that attention resource competition could be the underlying neutral mechanism of the selective interactive pattern between emotion and WM.

Keywords: Cognitive Load, Emotion, Event-Related-Potentials, Event-Related-Potentials Technique, Working Memory

INTRODUCTION

In cognitive science (Baddeley, 1992; Sweller, 1988) and cognitive informatics (Wang, 2003, 2007; Wang et al., 2006, 2009), processing efficiency theory suggests that effects of negative emotion (i.e., anxiety) on cognitive performance may be mediated by effect on working memory (WM) (Eysenck & Calvo, 1992). It is easy to explain that anxious individuals may care more about anxiety responses unrelated to the current task (i.e., compulsive thought, negative cogni-
tion), which would distract attention and consume the limited WM resource. As a result, there is a low efficiency of cognition in anxious individuals. WM refers to a system used for the temporary storage and manipulation of information, which is deemed necessary for a range of more complex cognitive activities (Baddeley, 1992). Baddeley (1992) has hypothesized that WM is composed of three major components that can work independently of one another: (i) a verbal WM system; (ii) a visuo-spatial WM system; (iii) a central executive that determines which information is made available for conscious processing by exerting control over voluntary action. The verbal WM system involves a phonological loop, and visuo-spatial WM is thought to involve a buffer responsible for the initial registration of non-verbal material called visuo-spatial sketchpad. However, more recent studies suggest that spatial and verbal WM may be differentially affected by affects in healthy people, and possibly spatial WM is more vulnerable to negative emotion (Lavric, Rippon, & Gray, 2003; Li, Chan, & Luo, 2010; Li, Li, & Luo, 2005b, 2006). This implies that the modulation of cognition by affect is not a global effect but may involve specific neurocognitive mechanisms. However, it is not known which neural mechanisms are involved in this selective modulation.

Recently, Event-related potentials (ERPs) studies also found this selective effect between emotion and working memory and implied the underlying neural mechanism. ERPs are voltage fluctuations that are associated in time with some physical or mental occurrence. These potentials can be recorded from the human scalp and extracted from the ongoing electroencephalogram (EEG) by means of filtering and signal averaging. Because the temporal resolution of these measurements is on the order of milliseconds, ERPs can accurately measure when processing activities take place in the human brain. The spatial resolution of ERP measurements is limited both by theory and by our present technology, but multichannel recordings can allow us to estimate the intracerebral locations of these cerebral processes (Picton et al., 2000). When ERPs were first used to study issues in the domain of cognitive neuroscience, they were primarily used as an alternative to measurements of the speed and accuracy of motor responses in paradigms with discrete stimuli and responses. In this context, ERPs have two distinct advantages. First, an overt response reflects the output of a large number of individual cognitive processes, and variations in reaction time (RT) and accuracy are difficult to attribute to variations in a specific cognitive process. ERPs, in contrast, provide a continuous measure of processing between a stimulus and a response, making it possible to determine which stage or stages of processing are affected by a specific experimental manipulation. A second advantage of ERPs over behavioral measures is that they can provide an online measure of the processing of stimuli even when there is no behavioral response. Thus, the ability to covertly monitor the online processing of information is one of the greatest advantages of the ERP technique (Luck, 2005).

For example, in Li et al.’s ERP study (2006), there wasn’t significant interaction effect between emotion and working memory type (spatial and verbal working memory) on accuracy and RT. However, they found that in the parietal cortex, P300 amplitudes of spatial WM tasks were reduced by the participants’ negative emotional states significantly. Whereas in verbal WM tasks, this kind of influence was absent, which was interpreted in term of the reliance of threat-evoked anxiety and spatial WM on a common visuo-spatial attention mechanism (Lavric et al., 2003; Li et al., 2006, 2010). Because negative affects automatically draw visuo-spatial attention (e.g., attention to threat) (Li, Li, & Luo, 2005a; Mathews, Mackintosh, & Fulcher, 1998; Mathews & Mackintosh, 1998), which most likely represents an exacerbation of the normal increase in visuo-spatial attention in the presence of an exogenous threat. Attention may well represent the point of overlap between anxiety and spatial WM, because there appear to be visuospatial attentional demands during spatial WM that are not present during verbal WM. In particular, in verbal WM tasks letters are presented on the screen in either upper or lower case, which encourages one
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