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Research article

High working memory load impairs the effect of cognitive reappraisal on emotional response: Evidence from an event-related potential study

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HIGHLIGHTS

- The high-load WM task impairs the efficacy of simultaneous reappraisal.
- The low-load WM task does not influence reappraisal efficacy.
- Emotion-enhanced LPP is not influenced by the WM load.

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ABSTRACT

This study investigates how the working memory (WM) load influenced the efficacy of cognitive reappraisal, a frequently used strategy for emotion regulation. In a dual-task paradigm, the participants were required to perform a high-load or a low-load memory task and simultaneously reappraise aversive pictures with a negative or a neutral meaning. In the low-load condition, we found that the amplitude of emotion-enhanced late positive potential (LPP) was significantly decreased by neutral reappraisal compared to negative reappraisal. In the high-load condition, this regulatory effect of reappraisal disappeared. These results suggest that successful reappraisal relies on cognitive resources and WM processes. If the necessary resources involved in reappraisal are over-depleted by a concurrent memory task, the reappraisal effect will be impaired. Moreover, we found that emotion-enhanced LPP was significant in both of the high-load and low-load tasks, which suggests that emotional electrocortical response may not be susceptible to the available resources.

1. Introduction

Emotion regulation refers to a set of processes that aim to influence the intensity and temporal dynamics(e.g., duration, rise time) of emotional responses in behavioral, experiential and physiological domains [1]. It is significantly important in mental health [2]. However, the cognitive profile that may affect the efficacy of emotion regulation remains open to investigation.

It has been proposed that, as a series of goal-directed processes, emotion regulation may critically rely on working memory (WM) [3]. Clinical studies have supported this statement, finding that mood disorders such as depression typically involve difficulty in performing WM tasks [4–6]. The deficit in regulating negative emotions in depressed individuals is found to be related to the malfunction of the lateral frontal cortex [7], which is an overlapping area recruited by both of emotion regulation [8] and WM processes [9].

To reveal the function of WM in effective regulation, studies have focused on the relationship between WM capacity and the result of emotion regulation. Among the multiple strategies of emotion regulation, cognitive reappraisal is often investigated for its distinct regulatory effect on emotional feelings, behaviors [10] and

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neural activities [11]. Cognitive reappraisal is a strategy of interpreting emotional stimuli in an alternative manner, such as the use of a less emotionally disturbing meaning, to change the emotional significance of the situation [1]. Studies have found that people with higher WM capacity are more successful in reducing negative emotional responses through reappraisal [12,13].

However, how WM influences the emotional responses in an emotion regulation task remains unknown; this knowledge would promote our understanding of the role of WM in emotion regulation. The first goal of the present study is to investigate this issue by using a dual-task paradigm [14]. The participants were required to simultaneously perform two tasks, i.e., a WM task and a reappraisal task. According to Baddeley and Hitch, WM is a resource-limited system, and the simultaneous performance of the two tasks would introduce the competition for cognitive resources if they involve the same processes [15]. We manipulated the load of the WM task to introduce different levels of the competition for resources. In the concurrent reappraisal task, the participants were required to reappraise aversive pictures with neutral or negative meanings. If reappraisal involves WM processes, its regulatory efficacy would be impaired when it was accompanied by a high-load WM task compared to a low-load task, because the former would deplete more resources and cause insufficiency of resources for reappraisal.

The event-related potentials (ERPs) were employed as the measure in our study because ERPs provide an opportunity to reveal the neural mechanisms and the time course of emotion regulation. The late positive potential (LPP), a central-parietal component, was analyzed. The LPP amplitude is typically enhanced by emotional stimuli compared to neutral stimuli 300 ms after the stimuli onset. It is considered to reflect the attention to and perceptual processing of emotional stimuli [16,17], and its amplitude can be reduced by effective reappraisal [17]. In addition to being regulated by the emotional valence and arousal of the stimuli, the amplitude of the LPP has been found to be modulated by the WM load. In a study, compared to the low-load task, the simultaneous high-load task decreased the LPP amplitude evoked by pictures, whether their contents were neutral or aversive [18].Thus, to isolate the effect of emotion from that of WM load on the LPP, the larger amplitude for the aversive pictures in the negative or neutral reappraisal than that for the neutral pictures with the same load was used as the emotion-enhanced electrocortical response in different reappraisal types. Further, the reappraisal efficacy was indicated by the difference in the emotion-enhanced amplitude of the LPP between the two reappraisal types.

The examination of the reappraisal efficacy relies on a significant emotional response in both load tasks. Since if emotion generation is interrupted and emotion-enhanced LPP is eliminated by the simultaneous (high-load) task, the reappraisal efficacy cannot be investigated. Thus, the present study also tests the effect of the WM load on emotion-enhanced LPP to ensure that aversive pictures elicited significantly larger LPPs than neutral pictures in both load tasks.

2. Methods

2.1. Participants

A total of 26 female university students (mean age = 21 years, range = 19–24 years) participated in the experiment. All were right-handed and reported normal or corrected-to-normal vision, no history of neurological or psychiatric disorders and no use of any medication during the experiment. The Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences, approved this study, its participant-recruitment procedure, and its methodology.

2.2. Materials and design

A total of 180 pictures were selected from the International Affective Picture System (IAPS) [19], comprising 120 aversive and 60 neutral pictures. The aversive pictures were more unpleasant (mean = 3.03, SD = 0.97) than the neutral pictures (mean = 5.61,SD = 0.95) according to normative ratings. The emotional arousal of the aversive pictures (mean = 5.52, SD = 0.87) was also higher than that of the neutral pictures (mean = 3.51, SD = 1.18).

A total of 180 sets of items were used as memory materials, and each set was paired with an IAPS picture. Under the high-load condition, the memory set consisted of three words and three symbols (e.g., ¨$ # &¨). The participants had to memorize all six items. Under the low-load condition, the memory set involved three words and three "X"s. The participants only needed to memorize the words.

The words that paired with the symbols or "X"s in each set described the situation of the target picture. All of the words were different from each other, and each was a frequently used word comprising two Chinese characters.

For the aversive pictures, 120 sets of words were selected and used to describe the situation in the pictures. Under the negative reappraisal condition, the words highlighted the negative aspects of the picture (e.g., "cancer disease weakness" for a picture in which a weak patient is lying on a hospital bed), whereas under the neutral reappraisal condition, the words described the picture in an emotionally attenuated manner (e.g., "safe withdraw fortunate" for a picture in which passengers are exiting from a smoking plane). The descriptions in the negative and neutral reappraisal types were expected to help the participants up- and down-regulate their emotional response respectively [20–22]. Presenting the descriptions before emotional stimuli is considered to be a reappraisal method with improved precision compared to requiring the participants to generate reappraisal meanings by themselves, because it could exclude the confounding effect of using other strategies (e.g., detachment or attention deployment) in a reappraisal task.

For the neutral pictures, only neutral reappraisal was included. 60 sets of neutral words that described the situation in the pictures were used.

Overall, there were four conditions for the aversive pictures: high-load with a negative reappraisal task, high-load with a neutral reappraisal task, low-load with a negative reappraisal task, and low-load with a neutral reappraisal task. The valence and arousal of the pictures were counterbalanced across conditions. For the neutral pictures, two conditions were involved, high-load and low-load. Each condition had 30 trials.

2.3. Procedure

The experimental materials were presented on a computer monitor. All participants were seated 60–80 cm away from the computer in a dimly lit room. They were required to memorize the items and recognize them after an interval of picture presentation. They were also instructed to use the presented words to reappraise the target picture.

A typical trial is shown in Fig. 1. It began with a cross, which was displayed for 1000 ms. Then, the memory materials, i.e., words on the upper portion of the screen and symbols or "X's on the bottom portion, were presented for 4000 ms, followed by a blank screen displayed for a random time period of 500, 750 or 1000 ms. Afterward, an aversive or neutral picture was presented for 3000 ms. The following item was a word or a symbol for recognition. The participants were asked to decide whether it had been presented before and to quickly respond by pressing a key when a dot appeared. For half of the participants, "j' indicated the 'yes' response and "f" indicated the "no" response, and the other half, vice versa. The accuracy (ACC) and the reaction time (RT) for each trial were recorded. After