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Research report

Shielding cognition from nociception with working memory

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ABSTRACT

Because pain often signals the occurrence of potential tissue damage, nociceptive stimuli have the capacity to capture attention and interfere with ongoing cognitive activities. Working memory is known to guide the orientation of attention by maintaining goal priorities active during the achievement of a task. This study investigated whether the cortical processing of nociceptive stimuli and their ability to capture attention are under the control of working memory. Event-related brain potentials (ERPs) were recorded while participants performed primary tasks on visual targets that required or did not require rehearsal in working memory (1-back *vs* 0-back conditions). The visual targets were shortly preceded by task-irrelevant tactile stimuli. Occasionally, in order to distract the participants, the tactile stimuli were replaced by novel nociceptive stimuli. In the 0-back conditions, task performance was disrupted by the occurrence of the nociceptive distracters, as reflected by the increased reaction times in trials with novel nociceptive distracters as compared to trials with standard tactile distracters. In the 1-back conditions, such a difference disappeared suggesting that attentional capture and task disruption induced by nociceptive distracters were suppressed by working memory, regardless of task demands. Most importantly, in the conditions involving working memory, the magnitude of nociceptive ERPs, including ERP components at early latency, were significantly reduced. This indicates that working memory is able to modulate the cortical processing of nociceptive input already at its earliest stages, and could explain why working memory reduces consequently ability of nociceptive stimuli to capture attention and disrupt performance of the primary task. It is concluded that protecting cognitive processing against pain interference is best guaranteed by keeping out of working memory pain-related information.

1. Introduction

Alleviating pain is a central question motivating many researchers in the field of pain research. The manipulation of attention is a potentially efficient method, partially constituting the common feature underlying the analgesic effect of hypnotic suggestion, meditation, cognitive behavioral therapy, etc. Several studies showed that distracting people from pain, i.e., directing attention away from a nociceptive stimulus, can decrease the perception of pain

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generated by that stimulus (see Van Damme et al., 2010 for a review).

The attention paid to a given stimulus depends on its salience (Egeth and Yantis, 1997). For this reason, nociceptive stimuli have a strong capacity to capture attention independently of voluntary control. Therefore, it was recently proposed that an efficient approach to reduce the attention paid to nociceptive stimuli should take into account the following three main factors (Legrain et al., 2009b). First, attention should be engaged in mental activities that are unrelated to pain and, more generally, to bodily sensations. Indeed, when performing a cognitive task, a mental set of information is defined to guide attention toward the stimuli that are relevant to the task (Folk et al., 1992). As a consequence, any sensory event sharing common features with the mental set will automatically attract attention. Therefore, the greater the segregation between competing task-relevant and task-irrelevant stimuli, the better attentional capture by irrelevant distracters is avoided. Second, the engagement of attention should be effortful: the more attention is loaded to perform a task, the less it will be prone to process distracter stimuli (e.g., see Allport, 1987; Lavie, 2005). Third, the engagement of attention should be controlled by executive functions in order to inhibit the interference of distracters (Posner and Petersen, 1990). Among the various executive functions, the role of working memory has been put forward (Olivers, 2008; Soto et al., 2008). Working memory contributes to optimize attention by keeping a memory trace of the attentional set during the achievement of the task (Desimone and Duncan, 1995) and by protecting task execution from the intrusion of distracters (Szmalec et al., 2011). Working memory was shown to facilitate the orientation of attention to any stimuli sharing common features of the task set (Downing, 2000; Soto et al., 2005; Soto and Humphreys, 2007). Moreover, working memory can control the intrusion of irrelevant distracters and, therefore, can protect task performance (SanMiguel et al., 2008), by reducing the cortical processing of the distracters (de Fockert et al., 2001; Berti and Schröger, 2003; SanMiguel et al., 2008). Conversely, such a control is less efficient if the resources of working memory are used in a second unrelated task (de Fockert et al., 2001; Lavie and de Fockert, 2005; Dalton et al., 2009).

Recently, we showed that the disruptive effect induced by nociceptive distracters, i.e., the decrease in task performance due to the interference from task-irrelevant nociceptive stimuli, can be reduced by working memory (Legrain et al., 2011a, 2011b). Indeed, when participants performed a visual task requiring the use of working memory, task-irrelevant nociceptive stimuli lost their ability to capture attention and to disrupt the task, as compared to conditions in which working memory was not used. In these experiments, we adapted a paradigm from research on auditory attention (Escera and Corral, 2007). In this paradigm, stimuli are delivered in pairs consisting of a task-irrelevant distracter immediately followed by a task-relevant target. In order to manipulate attentional capture and distraction, occasionally and unexpectedly, the standard distracter is replaced by a stimulus mismatching the standard distracters according to at least one parameter. In our experiments, task-relevant targets were visual stimuli and task-irrelevant distracters were tactile somatosensory stimuli occasionally replaced by a nociceptive somatosensory stimulus (Legrain et al., 2011a, 2011b). The low probability of occurrence of the mismatching distracter is an important factor since the novelty of a stimulus is a key factor determining stimulus salience and attentional capture (Näätänen, 1992; Escera and Corral, 2007). Indeed, it was shown that the ability of a nociceptive stimulus to capture attention is strongly determined by the context in which it occurs, such as its novelty (Legrain et al., 2009a, 2009b, 2011c). Comparing task performance when the visual targets were preceded by a standard tactile distracter versus a novel nociceptive distracter confirmed that the occurrence of novel nociceptive stimuli triggered an involuntary shift of attention and disrupted task performance, as indexed by the increased reaction times (RTs) to the visual targets preceded by a novel nociceptive distracter (Legrain et al., 2011a, 2011b). However, and most importantly, comparing task performance in conditions involving working memory and conditions not involving working memory, showed that the novel nociceptive stimuli lost their ability to disrupt task performance in the working memory condition, as revealed by the disappearance of the difference in RTs between the trials with standard tactile distracters and the trials with novel nociceptive distracters. This result suggests that working memory is able to suppress the attentional capture triggered by the novel nociceptive distracters and consequently, the disruptive effect on primary task performance. Another important point was the relative independency of the attentional control by working memory from task demands and attentional overload. Indeed, the reduction of distraction observed in the working memory conditions was significant both during high-demanding and low-demanding working memory tasks (Legrain et al., 2011a).

Here, using event-related brain potentials (ERPs) to sample stimulus-evoked cortical activity, we tested the hypothesis that suppression of distraction by working memory results in a reduction of the cortical processing of nociceptive inputs. More specifically, we predicted that nociceptive stimuli would elicit ERPs of reduced magnitude when participants rehearsed the properties of concurrent visual stimuli in working memory, as compared to conditions in which working memory was not engaged. Such as in our previous studies (Legrain et al., 2011a, 2011b), participants performed a task on visual target stimuli. The presentation of each visual target was shortly preceded by the presentation of a task-irrelevant somatosensory stimulus which was either a standard innocuous tactile stimulus in 83% of the trials or a novel nociceptive stimulus in the remaining 17% of trials. In the 0-back control conditions, participants were asked to perform the task on each visual target directly after its presentation. In the 1-back working memory conditions, participants were asked to respond based on the features of the visual target presented one trial before. Hence, participants were required to maintain information about the visual targets in working memory during the presentation of somatosensory distracters in the 1-back conditions but not in the 0-back conditions. As in our previous study (Legrain et al., 2011a), two different types of tasks were used in order to avoid the possible confounding effect of tasks demand and attentional load. In the first type of task, performing the working memory condition was more demanding than performing the control condition (matching