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rTMS ON LEFT PREFRONTAL CORTEX CONTRIBUTES TO MEMORIES FOR POSITIVE EMOTIONAL CUES: A COMPARISON BETWEEN PICTURES AND WORDS

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Abstract—The present research explored the cortical correlates of emotional memories in response to words and pictures. Subjects' performance (Accuracy Index, AI; response times, RTs; RTs/AI) was considered when a repetitive Transcranial Magnetic Stimulation (rTMS) was applied on the left dorsolateral prefrontal cortex (LDLPFC). Specifically, the role of LDLPFC was tested by performing a memory task, in which old (previously encoded targets) and new (previously not encoded distractors) emotional pictures/words had to be recognized. Valence (positive vs. negative) and arousing power (high vs. low) of stimuli were also modulated. Moreover, subjective evaluation of emotional stimuli in terms of valence/arousal was explored. We found significant performance improving (higher AI, reduced RTs, improved general performance) in response to rTMS. This ''better recognition effect'' was only related to specific emotional features, that is positive high arousal pictures or words. Moreover no significant differences were found between stimulus categories. A direct relationship was also observed between subjective evaluation of emotional cues and memory performance when rTMS was applied to LDLPFC. Supported by valence and approach model of emotions, we supposed that a left lateralized prefrontal system may induce a better recognition of positive high arousal words, and that evaluation of emotional cue is related to prefrontal activation, affecting the recognition memories of emotions.

Key words: emotion, word, picture, memory, DLPFC, rTMS.

INTRODUCTION

The topic of where memories for emotional pictures and words could be represented in the brain was explored only in a few cases (Gray et al., 2002). Some studies explored the cortical correlates of emotional cue encoding or retrieval process, taking into account different material types. Indeed in some cases non-verbal emotional stimuli (faces, scenes, pictures etc.) were considered (Balconi et al., 2009b, 2010; Zhang et al., 2012); in a limited number of cases also emotional verbal material was used (Ramponi et al., 2011; Balconi and Ferrari, 2012; Balconi and Cobelli, 2014).

An interesting approach, based on the circumflex model (Davidson, 1992a,b, 2004; Davidson and Irwin, 1999; Bradley and Lang, 2007; Balconi et al., 2009b), focused on the interaction between emotions and memories, with particular reference to the effect of emotional content in recognizing stimuli, taking into account the valence (positive vs. negative) and the arousal degree (high vs. low) of the emotional cues (Cahill and McGaugh, 1995; Keil et al., 2001; Balconi and Ferrari, 2012). In fact, it was observed that arousal and valence of material to be encoded/retrieved may affect subjects' responsiveness to these emotional cues (Hariri et al., 2000; Grimm et al., 2012).

From a neuropsychological point of view, models for the processing of emotional information have suggested that a network of interconnected neuroanatomical regions, including the amygdala, hippocampus, thalamus, anterior cingulate cortex, and prefrontal cortex (PFC), cooperate to process emotional information and emotional memories (LeDoux et al., 1990; Davis, 1992; Balconi and Ferrari, 2013; Vanderhasselt et al., 2013; Skipper and Olson, 2014). Regions known to participate in the formation of emotional memories, such as the basolateral amygdala, also promote brain activation (with increased gamma-band oscillations) throughout cortical and subcortical circuits (Headley and Paré, 2013). It was also suggested that top-down control by the amygdale on the PFC allows for the cognitive modulation of emotional processes by frontal brain structures, and the PFC could be crucial for mechanisms underlying the regulation of emotion, such as the inhibition of emotional information or the regulation of specific control monitoring on interference effects (Hariri et al., 2000; Kalish and Robins, 2006).

Moreover several studies have shown that the PFC plays a crucial role in the integration of different aspects of memory and emotional regulation by managing the cognitive control over emotional stimuli and emotional behavior (Knight et al., 1999; Miller and Cohen, 2001;

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Abbreviations: AI, Accuracy Index; DLPFC, dorsolateral prefrontal cortex; LDLPFC, left dorsolateral prefrontal cortex; LPFC, lateral prefrontal cortex; PFC, prefrontal cortex; RTs, response times; rTMS, repetitive Transcranial Magnetic Stimulation; tDCS, transcranial direct current stimulation; TMS, Transcranial Magnetic Stimulation.

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Kalish and Robins, 2006; Balconi, 2013). Specifically regarding the memory task, neuropsychological and lesion studies have documented the involvement of the frontal lobes in recognition memory. Neuroimaging, Transcranial Magnetic Stimulation (TMS), and transcranial direct current stimulation (tDCS) research has shown that the dorsolateral prefrontal cortex (DLPFC) is involved in the recognition process (Sandrini et al., 2003; Turriziani et al., 2010; Javadi and Walsh, 2011; Balconi and Ferrari, 2012). With regard to the contribution of these brain areas in specific memory tasks, neuroimaging studies have shown increased activation of the DLPFC during tasks that require the organization of information and the need to manage the relationships between memory cues. This process of manipulation promotes the strengthening of inter-item associations, resulting in enhanced memory formation (Blumenfeld and Ranganath, 2006).

Some main factors, able to modulate and interfere with the memory process within the PFC, were also considered in previous research: the specific processing phase (encoding vs. retrieval); the type of material (word vs. pictures); and the emotional meaning (in term of valence and arousal) of the material. About the former factor it was observed that prefrontal left and right lateralization was respectively related to encoding and retrieval phase (ERA model, Tulving, 1984). For example, Gagnon in two experimental studies (Gagnon et al., 2010, 2011) using both verbal and non-verbal stimuli, observed how in the encoding phase only TMS of the left DLPFC was able to interfere with both accuracy and response times (RTs). In the retrieval phase, instead, stimulation of the right DLPFC was able to affect the accuracy and the RTs of the memory performance.

On the other hand, about the stimulus material (linguistic vs. nonlinguistic) effect, some recent study compared stimulus processing based on picture vs. word (Hinojosa et al., 2009). It seems that, under some circumstances, the processing of affective information captures attention with more biologically relevant stimuli, independently of the stimulus type. Moreover, Kensinger and Schacter (2006) found that for both pictures and words, the amygdala, the dorsomedial prefrontal cortex (PFC), and the ventromedial PFC responded equally to all high-arousal items, regardless of valence. In contrast, laterality effects in the amygdala were based on the stimulus type (word = left; picture = bilateral) and valence effects were most apparent when the individuals processed pictures. Focalizing on the memory construction, several authors (Balconi and Ferrari, 2012). reported that the right DLPFC, but not the left, contributes to the encoding of visual-object associations (Epstein et al., 2002) and the left but not the right DLPFC plays a crucial role in the encoding of verbal material (Balconi and Pozzoli, 2009; Balconi and Ferrari, 2012), supporting the theories of material specificity. However, no specific research was designed to directly compare the effect of linguistic vs. non-linguistic stimuli during a recognition task, taking into account the lateralized cortical and sub-cortical contribution.

Finally, factors specifically related to the stimulus, beyond their verbal/non-verbal nature, may determine the different involvement of the DLPFC in memory processes. Type of the emotional content may modulate the cortical asymmetry. Several studies provide evidence for the hypothesis of the ‘‘valence model’’, which states that withdrawal-related emotional cues are located in the right hemisphere whereas approach-related emotional cues are biased to the left hemisphere (Epstein et al., 2002). Focusing on the TMS technique, Balconi and Ferrari (2012) found an increased facilitation of the retrieval of positive emotional words (in terms of reduced RTs) under stimulation of the left DLPFC during the retrieval phase. On the contrary, the memory performance relative to negative information was not influenced by left frontal stimulation.

However, previous research did not directly explore the effect of valence and arousal, taking into account the different types of material (such as verbal or non-verbal) to be encoded and retrieved (Balconi and Cobelli, 2014). Secondly, the lateralization effect (left vs. right DLPFC) was not systematically analyzed. Indeed, a currently debated critical point is the distinct contributions of the left versus the right DLPFC for emotional cues, and specifically emotional picture/word recognition. Significant evidence has been reported in favor of both the left and the right DLPFC playing roles in retrieving emotional stimuli.

To answer to these questions, the present study analyzed the role of the prefrontal network (DLPFC) on emotional memory performance with specific focus on the cortical lateralization effect (prefrontal left hemisphere) when subjects engaged in memory recognition of emotional figures or words. We tested retrieval of different material, verbal-nonverbal, taking into account the emotional valence (positive vs. negative). We currently have only a limited understanding of how prefrontal areas accomplish both emotional valence and memory functions in recognition. Thus, in the present research we focused on the potential effects of the DLPFC on the emotional pictures vs. word recognition process because prefrontal areas may affect emotional memories that elicit specific responses during the recognition phase.

The valence model was proposed to explain the relationship between emotional information processing and a frontal left/right hemispheric lateralization effect (Davidson et al., 1999; Balconi et al., 2009a). Thus, the different effects of the left and right DLPFC on memory recognition may be due to the emotional valence of the stimuli and to the distinct contributions that the two hemispheres may have in manipulating stimuli from different emotional categories. Moreover, the arousal feature could contribute to increasing this lateralization effect. As shown by previous research, affectively arousing information may enhance the formation of semantic representations during lexical (word) encoding. It can be concluded that affective arousal is associated with activation of widespread networks, which act to optimize sensory and cognitive processing (Keil, 2006). Indeed, on the basis of prioritized sensory analysis for affectively relevant stimuli, subsequent steps such as working memory may be adjusted to meet the adaptive requirements of the situation perceived.