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False memories to emotional stimuli are not equally affected in right- and left-brain-damaged stroke patients

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ABSTRACT

Previous research has attributed to the right hemisphere (RH) a key role in eliciting false memories to visual emotional stimuli. These results have been explained in terms of two right-hemisphere properties: (i) that emotional stimuli are preferentially processed in the RH and (ii) that visual stimuli are represented more coarsely in the RH. According to this account, false emotional memories are preferentially produced in the RH because emotional stimuli are both more strongly and more diffusely activated during encoding, leaving a memory trace that can be erroneously reactivated by similar but unstudied emotional items at test. If this *right-hemisphere hypothesis* is correct, then RH damage should result in a reduction in false memories to emotional stimuli relative to left-hemisphere lesions. To investigate this possibility, groups of right-brain-damaged (RBD, $N = 15$), left-brain-damaged (LBD, $N = 15$) and healthy (HC, $N = 30$) participants took part in a recognition memory experiment with emotional (negative and positive) and non-emotional pictures. False memories were operationalized as incorrect responses to unstudied pictures that were similar to studied ones. Both RBD and LBD participants showed similar reductions in false memories for negative pictures relative to controls. For positive pictures, however, false memories were reduced only in RBD patients. The results provide only partial support for the right-hemisphere hypothesis and suggest that inter-hemispheric cooperation models may be necessary to fully account for false emotional memories.

1. Introduction

Emotional stimuli are remembered better and more vividly than non-emotional stimuli (Hamann, 2001; Kensinger, 2004). This phenomenon, known as the *emotional enhancement of memory*, has been replicated across a range of paradigms and stimulus types (e.g., Borsutzky, Fujiwara, Brand, & Markowitsch, 2010; Bradley, Greenwald, Petry, & Lang, 1992; Kensinger & Corkin, 2004; Nagae & Moscovitch, 2002; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008) and is particularly robust for arousing events (e.g., Anderson, Yamaguchi, Grabski, & Lacka, 2006; Christman, Propper, & Dion, 2004; Ochsner, 2000; Schaefer, Pottage, & Rickart, 2011).

However, not all aspects of memory are enhanced by emotional stimuli (Bradley et al., 1992). Peripheral features of visual scenes are remembered less well when an emotional item is present in the scene than when only non-emotional items are present (Kensinger, Garoff-Eaton, & Schacter, 2007a; Talmi et al., 2008). In addition, memory for scene details can be impaired by emotionality, even when these details belong to a central element of the scene (Adolphs, Denburg, & Tranel, 2001; Denburg, Buchanan, Tranel, & Adolphs, 2003). For example, participants may remember well a picture of a dead body compared to a picture of a living person (*gist* memory), but they may remember less well the spatial orientation of the body than the orientation of the living person (memory for scene *details*) (Adolphs, Denburg, et al., 2001; but see Kensinger, 2009, for a different perspective).

Perhaps more surprisingly, emotional stimuli can also induce more false memories than non-emotional stimuli (Dehon, Laroi, & Van der Linden, 2010; Porter, Spencer, & Birt, 2003). For example, Porter et al. (2003) showed negative, positive or neutral pictures to different groups of participants and asked them a few questions,

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some of which contained misleading information about the pictures (e.g., that there was a large animal). When asked to recall the pictures 1 h later, twice as many participants in the negative group falsely recalled the misleading information compared to participants in the positive and neutral groups. This apparent paradox – that negative emotion can simultaneously improve and impair memory – has been repeatedly found in recognition memory experiments with word stimuli (Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008; Grassi-Oliveira, Gomes, & Stein, 2011; Maratos, Allan, & Rugg, 2000), even when potential confounds, such as concreteness or semantic cohesiveness, are taken into account (Dehon et al., 2010; McNeely, Dywan, & Segalowitz, 2004). Thus, results from studies using words and complex scenes suggest that highly arousing negative stimuli can increase both true and false memories.

Research into the neural correlates of emotional memories (LaBar & Cabeza, 2006) and false memories (Schacter & Slotnick, 2004) started uncovering a network of brain structures that are commonly involved in these phenomena, including amygdala, hippocampus, pre-frontal, orbitofrontal and parietal cortices. Less is known, however, about the neural structures underlying *false emotional memories* and whether or not, like emotional processing, these networks show some degree of *lateralization*. In the following, we briefly review the literature implicating right-hemisphere structures in both emotional processing and false memories and outline the main goals and hypotheses of the present study.

1.1. Right hemisphere and emotional processing

The right brain hemisphere (RH) has been consistently linked to a preferential processing of emotional stimuli in comparison to the left hemisphere (LH) (Abbott, Cumming, Fidler, & Lindell, 2013; Borod, Bloom, Brickman, Nakhutina, & Curko, 2002; Demaree, Everhart, Youngstrom, & Harrison, 2005; Kucharska-Pietura, 2006; Witteman, van Ijzendoorn, van de Velde, van Heuven, & Schiller, 2011). However, there is still debate about which processes (expression vs. perception) and types (negative vs. positive) of emotion are best supported by right-hemisphere networks. For emotional perception, two main hypotheses have been put forward. The *right-hemisphere hypothesis* posits that the RH specializes in processing both positive and negative emotions (e.g., Borod et al., 2002). The *valence-specific hypothesis*, on the other hand, posits that the RH specializes in negative emotions, whereas the LH specializes in positive emotions (e.g., Davidson, 1992).

Consistent with the right-hemisphere hypothesis, Borod et al. (1998) found that perception of emotional faces, prosody and written words was impaired in right-brain-damaged patients compared to left-brain-damaged patients and healthy controls, who did not differ from each other. Similarly, Alves, Aznar-Casanova, and Fukusima (2009) showed that perception of emotional faces in healthy participants was faster when the faces were presented to participants' RH (via their left visual field) than when the faces were presented to participants' LH (via their right visual field), suggesting that emotional stimuli are preferentially processed in the RH.

By contrast, Natale, Gur, and Gur (1983) showed that participants judged faces with negative expressions as more negative when they were presented to the RH than when they were presented to the LH. Conversely, participants judged faces with positive expressions as more positive when they were presented to the LH than when they were presented to the RH. These results directly supported the valence-specific hypothesis. Additional evidence for the valence-specific hypothesis came from neuroimaging and electrophysiological studies. Canli, Desmond, Zhao, Glover, and Gabrieli (1998) found in a functional magnetic resonance imaging (fMRI) study that brain activation was stronger in the RH when participants saw a sequence of negative pictures and stronger in the LH when they saw a sequence of positive pictures. Likewise, Davidson (1992) found in several electroencephalogram (EEG) studies that brain activity was higher in right frontal electrodes when participants reacted to negative film clips and higher in left frontal electrodes when they reacted to positive clips.

More recent results, however, suggest that these hypotheses may not capture the complexity of emotional processing. In an fMRI study, Killgore and Yurgelun-Todd (2007) presented sad and happy chimeric faces very briefly to normal participants who were only required to determine the sex of the face (but were not asked to make any overt emotional judgement). The pattern of brain activations, which was linked to the non-conscious perception of affective faces presented to either hemisphere, showed that not only the RH was more responsive than the LH to both face types (a result consistent with the right-hemisphere hypotheses) but also that the LH was more responsive to sad faces than to happy faces (a result inconsistent with both the right-hemisphere and the valence-specific hypotheses).

More surprisingly, Paradiso, Anderson, Ponto, Tran, and Robinson (2011) reported a group of patients with stable right-hemisphere lesions who showed an impairment relative to healthy controls in their ability to judge the emotionality of positive pictures but no impairment in their ability to judge negative pictures, a result that supports only partially the right-hemisphere hypothesis and directly contradicts the valence-specific hypothesis.

Taken together, these results indicate a lack of consensus regarding laterality and emotional processing, which might be a result of different experimental paradigms, sample characteristics and stimulus types across studies. However, as most evidence supports a *relative specialization* of the RH towards emotion perception (Abbott et al., 2013; Adolphs, Jansari, & Tranel, 2001; Borod et al., 2002; Charbonneau, Scherzer, Aspirot, & Cohen, 2003; Kucharska-Pietura, Phillips, Gernand, & David, 2003; Nijboer & Jellema, 2012), we adopt this view to derive our predictions.

1.2. Right hemisphere and false memories

In addition to its role in emotional processing, the RH has also been implicated in the production of false memories (e.g., Marchewka, Jednorog, Nowicka, Brechmann, & Grabowska, 2009; Westerberg & Marsolek, 2003). Patients undergoing the intracarotid amobarbital sodium procedure, which selectively anesthetizes only one hemisphere at a time, show a marked increase in false alarms during recognition memory tests following LH injection (Loring, Lee, & Meador, 1989). That is, patients incorrectly say more often that an unstudied test item has been studied when the RH is operational and the left is anesthetized than when the LH is operational and the right is anesthetized, suggesting that false alarms are generated by processes at play in the RH.

Patients with RH lesions, particularly in frontal regions, have also been shown to produce more false memories than controls in studies using words (Delbecq-Derouesne, Beauvois, & Shallice, 1990), faces (Rapcsak, Polster, Glisky, & Comer, 1996), and pictures (Schacter, Curran, Galluccio, Milberg, & Bates, 1996). Consistent with these results, a structural neuroimaging study has shown that healthy participants who generated the highest levels of false memories in a recognition memory test using pictures also possessed the lowest densities of gray matter in their right frontal gyrus (Marchewka et al., 2009).

In healthy participants, most evidence that the RH is preferentially involved in producing false memories comes from studies combining the divided visual field technique (Bourne, 2006) with the DRM paradigm (Roediger & McDermott, 1995). In the DRM paradigm, participants study lists of words (e.g., *candy*, *sugar*, *tooth*) that are all related to a single unstudied word (e.g., *sweet*). In a