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Modulation of the ERP repetition effects during exposure to phobia-relevant and other affective pictures in spider phobia

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ABSTRACT

In the present study, dense sensor event-related potentials were measured in spider-phobic individuals and non-anxious controls during incidental encoding of phobia-relevant spider and standard neutral, unpleasant and pleasant pictures. Stimulus repetition effects were assessed by presenting each picture twice — in the first and in the second half of the session.

Repeated presentation of standard pleasant, unpleasant and neutral pictures resulted in a late ERP repetition effect that was similarly pronounced in both experimental groups and for all picture categories. Moreover, relative to non-fearful controls spider-phobic individuals showed an overall greater early ERP repetition effect starting at 180 ms after picture onset. At later stages of evaluative processing, repeated as compared with initial presentation of phobia-relevant spider pictures elicited reduced ERP amplitudes over centro-parietal sites (480–580 ms) in spider-phobic but not in control individuals. This pattern of results indicates that in small animal phobics long lasting exposure to their feared pictures leads to an increased mobilization of the perceptual analysis system, an effect that might help to improve emotional control and/or facilitate strategic avoidance of threat resulting in a diminished evaluative threat processing. This phobia-specific processing mechanism might prevent effective stimulus processing and hinder the habituation process during treatment.

1. Introduction

Fear is an aversive emotional state elicited by explicit threat that activates the defensive system of an organism. In people with specific phobia this defensive system exhibits an over-exaggerated response, as it is easily activated even by symbolic representations of phobia-relevant cues. Accordingly, when animal-phobic individuals are confronted with photographs of their feared stimuli the defensive system responds with marked somatic, autonomic, humoral, and motor changes to adjust to the threat. Moreover, phobic fear has been shown to modulate processes of stimulus perception and evaluation. For example, we recently reported (Michalowski et al., 2009) that spider phobia participants responded with overall larger P1 amplitudes than controls in a context in which phobia-relevant stimuli are likely to occur, an effect that suggests increased vigilance in this group. Moreover, in our study spider phobia participants exhibited a significantly enlarged early posterior negativity (EPN) during viewing of their feared material than controls. This latter effect might reflect an early involuntary "tagging" for preferential processing of feared pictures in later evaluative processing periods (Schupp et al., 2006) that has been repeatedly observed in several previous ERP studies as a pronounced late positive potential (LPP; Kolassa, et al., 2005; Michalowski et al., 2009; Miltner et al., 2005). Given the view that the extraction of meaning during the elaborated analysis of events is supposed to lead to the formation of inter-item associations and enhanced memory consolidation (Cowan, 1995; Craik and Lockhart, 1972; Craik and Tulving, 1975) these attentional effects might result in a preference for remembering fear-relevant events over non-feared events. However, our knowledge about the effects of fear on memory processes is still limited, even though information processing biases are thought to play an important role in the development and maintenance of anxiety disorders (Cameron, 1997; Mathews and MacLeod, 1987).

Previous studies on the relationship between emotion and explicit memory provided evidence of better memory performance for emotional relative to neutral stimuli in an immediate free recall (e.g., Bradley et al., 1992) and recognition tasks (Ochsner, 2000; Weymar et al., 2009). Moreover, numerous behavioral data indicate that this effect is most apparent for unpleasant when compared to pleasant and neutral words (for review see Cacioppo and Gardner, 1999) and pictures (Christianson and Fallman, 1990; Ochsner, 2000; Weymar et al., 2009), though there are mixed results in this regard (Ferre, 2003; Phelps et al., 1997). The benefit of enhanced memory for emotionally unpleasant events can be considered from a functional and evolutionary perspective: our survival as well as the survival of our ancestors depended on the ability to acquire functional behavioral patterns in life and death situations and to increase the chance that survival-relevant

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information would be available in the future (Dolan, 2002). The consequences of not recalling an aversive situation can be far more dangerous than the consequences of not recalling a positive one (Williams et al., 1997). From this point of view it is of considerable interest to determine to what extent the memory bias can also be observed for fear-inducing events. Given the motivational relevance of these events as well as previous experimental indications for their elaborated initial processing (Kolassa et al., 2005; Miltner et al., 2005; Michalowski et al., 2009), one would expect their better memory retrieval. However, there is a considerable amount of evidence that contradicts these expectations. Previous findings from phobic individuals did not find memory enhancing effects for phobia-relevant words when investigated with explicit memory tests such as recognition or recall (Kulas et al., 2003; Watts and Dalgleish, 1991; Wenzel et al., 2004). Keeping in mind that emotional arousal is expected to enhance memory effects (Bradley et al., 1992; Ochsner, 2000; Weymar et al., 2009), the failure to find corresponding results regarding the phobia-relevant stimuli in small animal phobics raises the possibility of an inadequate memory formation and an impaired quality of cognitive representations for fear-relevant materials in these persons. Williams et al. (1997) suggested that such inadequate memory formation would hinder recovery and interfere with exposure during treatment. However, it cannot be ruled out that prior failures to find consistent memory bias in phobias may be attributed to some methodological shortcomings of this research. First, given that phobic fear is typically triggered by an explicit threat the lack of memory enhancing effect in previous studies on spider phobia individuals might result from the rather low ecological validity of phobia-related words. Supporting this assumption Kindt and Brosschot (1999) reported that spider-phobic children rated fear-relevant pictures as more negative and arousing than fear-relevant words. Accordingly, to study the effect of phobic fear on memory it might be important to use stimuli that are more ecologically valid and anxiety-provoking such as photographs of fear-relevant objects. Second, explicit memory tests used in most previous studies might have been insufficient to explore the relationship between emotion and memory, since most of the information encoded in our memory system cannot be accessed through intentional recall and emotion should be considered as an unconscious process that does not always result in conscious experience (Carretie et al., 2005; LeDoux, 2000).

Considering the methodological shortcomings of previous memory studies from animal phobics, the goal of the current study was to test whether the use of spider photographs would strengthen memory effects in spider phobics and to provide a more direct insight into memory processing mechanisms by measuring event-related potentials (ERPs). Numerous researchers reported differences in the ERP waveform between items presented for the first time and items repeated after an interval of up to several minutes (for a review see Rugg and Allan, 2000). Most consistent findings regard the late ERP repetition effect observed as a positive deflection elicited over centro-parietal scalp areas with an onset latency of about 300 ms lasting until about 600 ms. Numerous experiments clearly demonstrated that this late ERP modulation can be observed for repeatedly displayed when compared to new words (Bentin et al., 1992; Rugg, 1995; Rugg et al., 1998) and pictures (Jordan and Thomas, 1999; Tapia et al., 2008). The enhancement of this late ERP component for repeatedly presented stimuli is thought to index the process of updating working memory during their semantic identification and evaluation (Donchin, 1981). Moreover, previous results from recognition tests suggest that the late ERP repetition effect is related to item recollection, that is, it is a sign that viewing item has been recognized as old on the basis of retrieval of a first presentation of this stimulus (Paller and Kutas, 1992; Rugg et al. 1996). Although less consistently, ERP repetition effects have been demonstrated, at an earlier, fleeting processing stage suggesting a considerable earlier time of the memory retrieval. Accordingly, greater ERP negativity has been observed for the second relative to the first stimulus presentation already around 200–300 ms after the stimulus onset at posterior sensor areas (Jordan and Thomas, 1999; Schweinberger et al., 1995). This early repetition effect has been generated even by semantically "meaningless" images distorted by a process of "pixilation" and was, thus, suggested to reflect recollection process of perceptual rather than semantic item properties (Jordan and Thomas, 1999; Schweinberger et al., 1995).

The early and late preferential processing of dangers that has repeatedly been observed in previous ERP studies exploring the time course of attention (e.g., Michalowski et al., 2009) seems to facilitate adaptive behaviour in a world where various stimuli compete for processing resources. Based on the evolutionary point of view, one would expect that successful adaptation also requires facilitated retrieval of emotionally-relevant cues at both early and late processing stages. In fact, previous ERP findings from the joint study of emotion and explicit memory indicated beneficial effect of emotion on ERP correlates of recognition memory (Dietrich et al., 2001; Dolcos and Cabeza, 2002; Palomba et al., 1997). Moreover, this effect was shown to be most pronounced for negative words (Inaba et al., 2005) as well as negatively valenced facial expressions (Johansson et al., 2004). These findings have been confirmed in a recent indirect memory study performed by Tapia et al. (2008). Using emotional and neutral pictures from the International Affective Picture System (IAPS; Lang et al., 2005) these authors showed that the effect of increased late positivity for old when compared to new pictures was most pronounced for unpleasant materials. Interestingly, in these studies emotion was observed to affect late but not early ERP correlates of memory retrieval. However, because differences in physical picture characteristics are known to strongly affect ERPs in the time window prior to 400 ms (Bradley et al., 2007) assessing memory effects by comparing one picture set (old) with another picture set (new) might have been a confounding factor in this research.

The main aim of the present study was to methodologically refine and extend previous research on memory bias in small animal phobics in order to determine phobia-specific memory processing mechanisms. First, given that previous studies utilized lexical materials that might have made less impact on phobic individuals than pictures of feared objects (Kindt and Brosschot, 1999), in the current study we used photographs of spiders to test whether this would strengthen memory effects in spider phobics. Second, since the information encoded in our memory system might be unavailable by explicit inspection we aimed to investigate indirect and involuntary memory effects measuring event-related brain potentials in a passive viewing paradigm. We extend previous research in these directions in order to explore whether we would find ERP correlates for increased memory in spider phobics during retrieval of spider pictures. Building upon previous research on ERP repetition effects as well as our knowledge about the time course of sensory processing (see above), we concentrated on early (perceptual) and late (conceptual) ERP correlates of memory retrieval. Especially, we aimed to provide an exploratory analysis of early and late ERP repetition effects in phobic and control individuals that were repeatedly exposed to phobia-relevant pictures (Schupp et al., 2006, Michalowski et al., 2009). Moreover, we expected to replicate previous results from explicit and implicit memory tests (Inaba et al., 2005; Johansson et al., 2004; Tapia et al., 2008) that showed an enhanced late ERP repetition effect for negatively valenced when compared to positively valenced and neutral cues by comparing ERPs elicited during passive viewing of the first and the second presentation of the same picture set consisting of unpleasant, pleasant and neutral IAPS pictures. As for phobia-relevant material, we also aimed to examine whether the effects of emotion on memory retrieval, as assessed with ERP repetition effects, can be observed during early perceptual processing of IAPS pictures. Especially, we expected that the appearance of "old" negatively valenced stimuli would result in their facilitated retrieval already at early processing stages, as indexed by larger early ERP repetition effect. No significant differences between