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Event-related brain potentials and affective responses to threat in spider/snake-phobic and non-phobic subjects

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Abstract

We investigated cortical responses and valence/arousal ratings of spider phobic, snake phobic, and healthy subjects while they were processing feared, fear-relevant, emotional neutral, and pleasant stimuli. Results revealed significantly larger amplitudes of late ERP components (P3 and late positive complex, LPC) but not of early components (N1, P2, N2) in phobics when subjects were processing feared stimuli. This fear-associated increase of amplitudes of late ERP components in phobic subjects was maximal at centro-parietal and occipital brain sites. Furthermore, phobics but not controls rated feared stimuli to be more negative and arousing than fear-relevant, emotional neutral, and pleasant stimuli. Since late ERP components and valence/arousal ratings were only significantly increased when phobic subjects but not when healthy controls were processing feared stimuli, the present data suggest that P3 and LPC amplitudes represent useful neural correlates of the emotional significance and meaning of stimuli.

Keywords: ERP; Valence; Arousal; Animal phobia; Fear

1. Introduction

Phobic fear in humans is more frequently elicited by objects like snakes, spiders, or rodents than by any other object of our every-day environment (Agras et al., 1969; Marks, 1969). Fear of these stimuli represents the core group of animal phobias with almost equal prevalence among different populations (9–14%) and a clear dominance in females. Whether this preference of phobic responses to a subgroup of animals is based on phylogenetic preparedness (Seligman, 1971; McNally, 1987; Öhman et al., 1995) or due to other evolutionary-based information processing systems in the human brain (LeDoux, 1996) or whether it is the result of conditioning or otherwise acquired cognitive schemata (Beck and Emery, 1985) and memory functions (Bower, 1981; Williams et al., 1997; Lang et al., 2000) is still a matter of debate. However, there is general agreement that the presence of these stimuli in the environment of phobics grants these objects salient meaning by significantly pulling subjects attention towards them, increasing arousal and negative emotional feelings of threat and the induction of flight/fight responses (Williams et al., 1997; Lang et al., 2000).

In the past, evidence for the salience of threatening stimuli was demonstrated by a number of studies indicating that the processing/encoding of such stimuli is significantly biased in clinically anxious subjects and subjects with high-trait anxiety scores (Williams et al., 1997). Researchers became particularly interested to disentangle individual differences of involuntary attention to threat and demonstrated that attention of anxious subjects is automatically pulled to threatening stimuli (MacLeod, 1991, 1999; MacLeod and Mathews, 1991; Logan and Goetsch, 1993; Williams et al., 1997). Results were based on different information processing paradigms including dichotic-listen-

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ing tasks (Mathews and MacLeod, 1986), the emotional Stroop test (Williams et al., 1996), the dot-probe-paradigm (MacLeod et al., 1986), and an emotional version of the Eriksen-flanker task (Streblow et al., 1985; Lavy et al., 1993). As a general result of these studies, it was shown consistently that the attention of subjects with anxiety or fear is automatically allocated to threatening stimuli at early stages of information processing. Furthermore, it was shown that this early allocation of attention happens particularly when stimuli are strongly related to subjects' individual anxious concern (Logan and Goetsch, 1993; Williams et al., 1997) and when stimuli are presented outside of subjects attentional focus (Fox, 1996; Miltner et al., 2004). Additionally, studies by Öhman and coworkers (Öhman and Soares, 1993; Öhman et al., 1995) have shown that peripheral nervous system activity in animal phobics is significantly increased when subjects are exposed either to masked or unmasked feared stimuli as compared to neutral stimuli or stimuli related to other phobic fears (Öhman and Soares, 1998). From these and additional studies, Öhman and Mineka (2001) concluded that attention to feared stimuli is guided by latent dispositions and/or by memory networks and top-down controlled attentional sets that involuntarily and automatically allocate subjects attention towards threat. This priority processing finally lends these stimuli salient and significant emotional meaning.

Despite the fact that cognitive paradigms and investigations on peripheral nervous system activities have greatly supported the presence of a selective encoding bias in phobic subjects, only little is known, how the brain of phobic subjects organizes this biased processing. Only few studies have tested the neural correlates of this biased, salient, and automatic processing of threatening stimuli by means of brain electrical event-related potentials (ERPs, i.e., the P1, N1, P2, P3, the late positive complex (LPC)). While the amplitude, latency, and topographic distribution of the P1 and N1 component in response to visual stimuli were demonstrated to represent correlates of different early selective attentional operations (Hillyard and Picton, 1979; Hansen and Hillyard, 1980), late components like the P3 and the LPC were demonstrated to be affected by the probability of an event's occurrence and its relevance to the observer's task (Johnson, 1986). Additionally, P3 amplitude is significantly affected by the amount of attention being spent to a stimulus at later stages of information processing and is a significant correlate of different memory encoding operations (Johnson, 1986). Furthermore, P3 amplitude has been shown to be sensitive to the amount of subjects' intentional engagement towards a stimulus and its demand characteristics (Johnson, 1986). Finally, and most important for the present study, it was shown that P3 amplitude is systematically affected by the individual meaning of a stimulus, i.e., by its emotional arousal and individual valence (Begleiter et al., 1967; Hömberg et al., 1981; Johnston et al., 1986; Farwell and Donchin, 1991; Naumann et al., 1997; Palomba et al., 1997; Schupp et al., 2000). These studies consistently indicate that P3 and LPC amplitudes are largest in response to those stimuli that subjects rate as emotionally meaningful and arousing.

Furthermore, in a recent study by Pauli et al. (1997), P3 amplitude was used to investigate whether brain electrical activities of subjects with panic disorders are affected differently by stimuli whose meaning reflects critical concerns associated with emotional stress as compared to emotional neutral stimuli. Using body-related and non-somatic words, presented tachistoscopically to 15 panic patients and 15 healthy controls at each subject's perceptual threshold for correctly identifying 50% of neutral words, it was demonstrated that panic patients recognized more body-related words than non-body-related words. Furthermore, compared to words not related to individual concerns, body-related words were associated with larger P3 amplitudes than non-body-related words. In healthy controls, no equivalent difference in word identification or in P3 amplitude was observed. When LPC activities to body-related and non-body-related words were compared, panic patients additionally showed larger positive slow waves than healthy controls.

With reference to the study by Pauli et al. (1997), the present study examined which ERP amplitude (N1, P2, N2, P3, LPC) is significantly increased when phobic subjects are processing visual stimuli related to their own specific phobic fear as compared to stimuli depicting objects of non-personal meaning or to objects with emotionally neutral or positive meaning.

When P3 amplitude and the magnitude of LPC are signatures of salience and threat, we should obtain significant larger P3 and LPC amplitudes when phobic subjects are processing images related to their personal concerns than to stimuli evaluated as fearful by others or when processing neutral or positive stimuli. Control subjects, having been selected to be free of any phobia, should not show this enhancement of P3 amplitude in response to spider or snake stimuli. Responses to these stimuli should be like those observed for neutral or pleasant slides. In terms of the N1 component, which is considered to represent a signature of early processes related to attention (Hillyard and Picton, 1979; Hansen and Hillyard, 1980), we should obtain similar differences between stimulus categories and groups with larger N1 amplitudes in phobic subjects when processing objects of personal concern as compared to the stimuli from the other categories. Similar results are expected for the late positive complex.

2. Methods

2.1. Subjects

Subjects were recruited from the student population of the University of Jena by means of handouts and posters.