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Stimulus-Preceding Negativity and heart rate changes in anticipation of affective pictures

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Abstract

The aim of the present study was to investigate the affective modulation of the Stimulus-Preceding Negativity (SPN) and heart rate changes in anticipation of visual stimuli differing in emotional content. A S1–S2 task was employed with a word (S1) indicating the content of a subsequent emotional picture (S2). Both valence and arousal dimensions were manipulated by presenting positive and negative pictures, high and low in arousal. Irrespective of valence, the amplitude of the SPN resulted to be significantly larger preceding high rather than low arousal pictures, indicating that the SPN does reflect the intensity of the motivational engagement ascribed to affective stimuli. Heart rate responses showed a deceleration preceding S2, which was larger preceding high arousal stimuli in comparison with neutral stimuli. Results suggest a coherent response pattern in both cortical and peripheral measures during affective anticipation.

Keywords: Stimulus-Preceding Negativity; Heart rate; Anticipation; Emotion

1. Introduction

Emotional anticipation is an essential regulating factor of human behavior, enabling anticipation of positive outcomes and avoidance of danger. It helps us in the choice of alternative actions and possibly helps us to survive.

In psychophysiology, emotional anticipation can be investigated by means of slow cortical potentials, using a two-stimulus task, where a first stimulus (S1 or warning stimulus) indicates the occurrence of a second stimulus (S2 or imperative stimulus), which usually requires a motor response. A negative slow wave, known as Contingent Negative Variation (CNV; Walter et al., 1964), has been observed to develop in the interval between the two stimuli. When this interval is sufficiently long (2 or more seconds), the CNV consists of at least two waves: an early and a late wave (Connor and Lang, 1969; Loveless and Sanford, 1974a,b). The early wave is larger at fronto-central sites and has been associated with the properties of the first stimulus (Loveless and Sanford, 1974a,b), whereas the late wave is larger at centro-parietal sites and has been associated with expectancy (Loveless and Sanford, 1974a,b) and motor preparation (Rohrbaugh and Gaillard, 1983). The CNV late wave has also been observed when no motor response to the second stimulus is required. In these circumstances, however, the second stimulus has to be relevant enough to evoke a reliable anticipatory response. This is the case for emotional stimuli. When no motor response to the second stimulus is required, the CNV late wave is thought to reflect only the anticipatory processes related to the second stimulus, and it has been named Stimulus-Preceding Negativity (SPN; Brunia, 1988).

Several paradigms have been employed to investigate the SPN during emotional anticipation. The SPN has been identified by presenting an emotional stimulus (usually a picture) as S2, which was signaled by a neutral stimulus, such as a tone (Amrhein et al., 2005; Klorman and Ryan, 1980; Lumsden et al., 1986; Simons et al., 1979), by employing a threat-of-shock paradigm in which a threat cue was associated with the possibility of an electric shock delivery (Baas et al., 2002; Böcker et al., 2001), and by manipulating the emotional valence of a feedback about a previously performed task (usually a time estimation task) by means of rewards or punishments (Kotani et al., 2001, 2003; Ohgami et al., 2004).

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When visual emotional stimuli were employed as S2, only single comparisons have been assessed, i.e. positive pictures vs. neutral pictures or negative pictures vs. neutral pictures. Simons et al. (1979) showed male subjects pictures of nude females in comparison with neutral pictures and found a larger SPN prior to the emotional contents. Along with neutral pictures, Klorman and Ryan (1980) presented pictures depicting mutilated bodies, while both Amrhein et al. (2005) and Lumsden et al. (1986) presented stimuli with fear-related contents (e.g., snakes, spiders). Results generally indicated larger SPN amplitudes preceding emotional pictures, with only one study (Lumsden et al., 1986) reporting larger SPN amplitudes preceding neutral pictures.

The other paradigms employed in the literature are based on the delivery of a monetary reward (Kotani et al., 2001, 2003; Ohgami et al., 2004) or a punishment consisting of noise or painful stimuli, associated with the feedback about a previously performed task (Kotani et al., 2001) or following the presentation of a symbolic threat cue (Baas et al., 2002; Böcker et al., 2001). The results of these studies consistently indicate that the SPN is larger in reward than in no-reward conditions and in anticipation of a shock/noise presentation as compared with a neutral condition. The only study using both rewards and punishments (Kotani et al., 2001) did not directly compare these conditions.

The emotional value of the expected stimulus has been manipulated differently in the above-mentioned studies. Indeed, while in the feedback paradigms participants anticipate an outcome that depends on their task performance (i.e., they do not know exactly which stimulus will be presented trial by trial), in the threat-of-shock and in the picture-viewing paradigms participants are informed by the warning stimulus about the emotional content of the imperative stimulus.

The employment of a picture-viewing paradigm appears to be more suitable to investigate the anticipation of stimuli differing in emotional content. Indeed, it allows manipulating a specific emotional state in anticipation. Moreover, a number of studies indicated that the presentation of pictures varying in emotional content can reliably elicit pronounced affective reactions (e.g., Bradley et al., 1993, 2001). During picture processing, several psychophysiological measures show variations that are differently modulated by the pleasantness or the intensity of the emotional content (e.g. Bradley et al., 1993). These parameters are described in terms of valence and arousal dimensions, according to the dimensional model of emotion (e.g., Lang et al., 1993) and are supposed to be the most relevant parameters describing emotional experience. More specifically, valence is the affective dimension describing the pleasantness or unpleasantness of the emotional state and is supposed to be associated with the activation of the appetitive or the defensive motivational system, whereas arousal is the affective dimension related to the intensity of motivational activation and engagement (Bradley et al., 2001). These dimensions have never been manipulated in the study of anticipation by means of slow cortical potentials. Moreover, the cortical distribution of SPN in anticipation of emotional stimuli has not been fully investigated in the literature. In most picture-viewing paradigms, indeed, few midline electrodes have been employed (Lumsden et al., 1986; Klorman and Ryan, 1980; Simons et al., 1979). When the SPN distribution was investigated using reward–punishment paradigms (Kotani et al., 2001; Ohgami et al., 2004), it showed right lateralization; however the use of feedback in these studies suggests that this effect may not be specific of emotional anticipation but may rather be associated with the feedback itself. In fact, an SPN right lateralization in anticipation of a feedback has often been reported in the literature (Brunia et al., 2000; Damen and Brunia, 1985, 1987) but the same effect is not observed in anticipation of other kinds of stimuli (e.g., an instruction about a subsequent task or a probe in an arithmetic task).

Heart rate (HR) changes are another measure of anticipation which have been investigated along with cortical measures in few studies. These studies usually employed a two-stimulus paradigm with fairly long interstimulus intervals (e.g., Klorman and Ryan, 1980; Simons et al., 1979). Under these conditions, a classical triphasic HR waveform, including a first deceleration (D1), a mid-interval acceleration (A1) and a subsequent pronounced deceleration (D2), has frequently been observed. In reviewing some of these studies, Simons (1988) noted that the D2 component systematically occurs in a two-stimulus paradigm, during both cognitive and affective anticipations, and can develop independently of cortical negativity (Lacey and Lacey, 1974). On the other hand, in the absence of motor responses, cortical negativity clearly develops only in anticipation of affective stimuli. Simons then suggested that cardiac deceleration in the absence of cortical negativity could be an index of a merely cognitive anticipation while concurrent cardiac and cortical responses could more specifically indicate a state of emotional anticipation.

In the present study, both the SPN and HR changes have been recorded.

The general purpose of the study was to investigate emotional anticipation by analyzing the affective modulation of the SPN and HR changes to visual stimuli whose emotional content was signaled by congruent warning cues. An adapted form of the picture-viewing paradigm was employed by using a word (S1) naming the content of a subsequent picture (S2). Importantly, the use of such a paradigm allowed inducing a specific affective state during anticipation because participants knew which particular emotional stimulus they were going to face trial by trial.

The first aim was to manipulate the valence dimension by comparing the anticipation of positive and negative emotional stimuli within the same study. Although most of the above-mentioned studies demonstrated that negative and positive emotions elicited a larger anticipatory response in comparison with neutral stimuli, it is still unknown whether there are any differences in the SPN amplitude between positive and negative contents.

Moreover, this study was designed to verify whether the arousal level affected the modulation of the SPN. Since this dimension has never been systematically considered in previous studies, its contribution to the SPN modulation is still unknown.

Another purpose of the study was to investigate the cortical distribution of the SPN in anticipation of positive and negative emotional stimuli in order to clarify whether the right hemispheric preponderance normally recorded for the cortical distribution of the SPN in the reward–punishment paradigms might also be identified in anticipation of visual emotional stimuli.

This study was also aimed at exploring the cardiac response pattern in anticipation and its relationship with cortical responses.