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Startle response and prepulse inhibition modulation by positive- and negative-induced affect

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ABSTRACT

The startle response, a set of reflex behaviours intended to prepare the organism to face a potentially threatening stimulus, can be modulated by several factors as, for example, changes in affective state, or previous presentation of a weak stimulus (a phenomenon termed Pre-Pulse Inhibition [PPI]). In this paper we analyse whether the induction of positive or negative affective states in the participants modulates the startle response and the PPI phenomenon. The results revealed a decrease of the startle response and an increase of the PPI effect when registered while the participants were exposed to pleasant images (Experiment 1), and an increase of the startle response and of the PPI effect when they were exposed to a video-clip of unpleasant content (Experiment 2). These data are interpreted considering that changes in affective states correlate with changes in the startle reflex intensity, but changes in PPI might be the result of an attentional process.

1. Introduction

Every organism with a complex nervous system is continuously processing numerous stimuli that compose a changing world in order to get a successful adaptation to the environment. From all those stimuli, only a few are relevant to adaptation, either because they are biologically relevant for survival, or they are neutral stimuli that consistently predict relevant outcomes.

Thus, for instance, when a stimulus reaches a determined level of intensity it induces a startle reflex, a response to a possible immediate threat intended to prepare the organism to face the possible consequences of such stimulus (e.g., Dawson et al., 1999; Eaton, 1984). Apparently, these reflex responses are fixed and appear in the same form when the intense stimulus is presented. However, a more detailed analysis reveals that startle responses change under different circumstances including repeated presentations (e.g., Geyer, and Braff, 1987; Sokolov, 1990), emotional changes (e.g., Bradley et al., 1999), or presentation of a weak stimulus that appears just before the more intense stimulus, a phenomenon termed Prepulse Inhibition (PPI) (e.g., Hoffman, and Searle, 1968; Graham, 1975). We will focus in this paper on the analysis of the modulation by positive and negative induced-affective states of the startle response to an intense auditory tone (see, for reviews, Bradley et al., 1999; Filion et al., 1998), and on the effect on PPI of the induction of such affective states (e.g., Hawk, and Cook, 2000).

Emotion has been often divided in two orthogonal factors, namely arousal and valence, both defined as a continuum that varies from calm to excitement and from positive to negative affect, respectively (Lang et al., 1993). There is empirical evidence of a diminished startle response to an intense stimulus when it is presented while the participants are being exposed to circumstances that favours a positive affect (e.g., Codispoti et al., 2001; Sutton et al., 1997), a state associated with the presence of pleasant events that generate feelings of satisfaction and happiness (e.g., Isen, 1999). On the other hand, the startle intensity during the induction of a negative affect – a state that includes an ample variety of emotional states linked to the presence of unpleasant events that induce feelings of anxiety, fear, or anger, among others (e.g., Clark and Watson, 1988) – increased (e.g., Hawk et al., 1992; Ehrlichman et al., 1995). These effects have been observed, both in non-human animals and in humans, independently of the stimuli used to induce the emotional state (Bradley et al., 1999).

In a typical example of an experimental situation designed to modulate the startle reflex to an auditory stimuli by the induction of induced affects, Vrana et al. (1988) programmed presentations of acoustic startle stimulus (95 dB, 50-ms white noise bursts) while the participants were viewing images with positive (smiling children, sex nudes, food, etc.), negative (mutilated bodies, snakes, guns, etc.) or neutral affective value (common household objects). The results showed a significant increase of the startle response to an auditory stimulus when it was presented during the presentation of the aversive images, and an attenuation of the startle response when it was presented in presence of the positive images. When the images were neutral, the startle magnitude was of intermediate intensity. These results have been interpreted as a result of a motivational priming effect that combines the appetitive or aversive valence of the reflex, and the current affective state of the individual (Lang et al., 1990). Thus, when the reflexes related to appetitive situations (including approach, attachment or consummatory behaviours) are activated, their intensity will be increased when the

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organism is engaged in a positive emotional state. Similarly, those reflexes linked to aversive situations (including avoidance, escape or defensive behaviours) will tend to increase when the subject is involved in a negative emotion. The theory also proposes an interpretation of those situations in which there are no correspondence between the affective situation and the type of reflex, by considering that aversive reflexes will be attenuated with positive emotions, and appetitive reflexes will be attenuated with aversive emotions (e.g., Bradley et al., 1999).

As mentioned above, another mechanism that modulates startle response intensity is the PPI effect, which induces a significant reduction of the startle response to an intense stimulus (pulse) by prior presentation of a less intense stimulus (prepulse) (see, for a review, Swerdlow et al., 1992). PPI has been considered as an example of sensorimotor gating, a process that blocks the processing of a stimulus in order to protect the processing of the stimulus that is already in progress (Braff and Geyer, 1990). Traditionally, PPI has been analysed in the framework of sensory and cognitive processes, while less attention has been paid to the role of affective factors.

In earlier studies analysing the effect of emotional variables on PPI positive, negative or neutral images were was used as prepulses, while the pulses were auditory stimuli (Bradley et al., 1993; Vanman et al., 1996). In some of the mentioned experiments, when the images used as prepulses were of aversive nature, PPI was reduced as compared with those trials in which the images used as prepulses were positive or neutral. However, several factors compromise an interpretation in terms of PPI of these results, since using the same stimulus for the induction of emotional states and as the prepulse makes difficult to distinguish whether the modulatory effect is due to sensorimotor gating or to a merely affective process. Moreover, the use in the mentioned experiments of lead intervals between prepulses and pulses ranging between 250 and 4450 ms makes it difficult to draw valid conclusions for the standard phenomenon of PPI with auditory stimuli in which typical lead intervals between prepulse and pulse presentations range between 30 and 240 ms (Braff et al., 2001a).

More recent experiments using affective pictures as prepulses and shorter lead intervals (ranging from 200 to 300 ms) did not clarify the relationship between induced-affect and PPI, because they showed either the absence of PPI effect (Stanley and Knight, 2004), significant PPI (Deuter et al., 2013), or even significant PPI when the images used as prepulses were of erotic nature, but the opposite effect (startle potentiation) when the images were threat scenes (Gard, Gard, Mehta, Kring, and Patrick, 2007).

On the other hand, those experiments that have used auditory stimuli both as pulses and prepulses, and induced the affective state of participants through an independent manipulation (e.g. featuring pictures of affective content) have not led either to conclusive results because, although the expected affective modulation of the startle response has been consistently observed, PPI remained intact (Hawk and Cook, 2000; Hawk, and Kowmas, 2003). However, the use of a within-subject procedure, in which the same subjects received sequential presentations of blocks of positive, negative and neutral images, could be inducing interferences between the different affective states that could be masking their modulatory effect on PPI.

In this paper we analyse the effect of inducing positive or negative affects on startle magnitude and PPI using a between-subject procedure to avoid the influence of possible residual emotional effects that can be affecting the results with the within-subject procedures. The standard procedure used to detect PPI combine auditory pulse-alone trials presentations, that allow detection of the startle response magnitude, while other trials consist in a low-intensity auditory stimulus (prepulse) preceding the pulse to induce PPI.

During startle response and PPI recording, participants were exposed to stimuli selected to induce positive or negative affective states (images in Experiment 1 and video clips in Experiment 2). From the experimental results described above we anticipate that the startle response to the pulse will increase for those participants in the negative affect condition, while it will decrease when exposed to the positive affect stimulation. With respect to the effect of affective states on the PPI, the hypotheses are less clear, because attending to previous experiments using standard auditory procedures to induce PPI there was no effect of positive- or negative-induced affects (e.g., Hawk and Cook, 2000; Hawk and Kowmas, 2003). Therefore, we do not anticipate any specific interaction between affective states and PPI, but we will consider the present experiment as an exploratory study intended to check the possible effect of different emotional states on sensorimotor gating.

2. Experiment 1

In our first experiment we used three sets of images of Positive (Pos), Negative (Neg), and Neutral (N) affective content selected from the International Affective Picture System (Lang et al., 1988). While the participants were exposed to the corresponding images they received the auditory stimuli intended to measure the startle response and the PPI effect. We used a between-subjects design in which each group was consistently exposed to a single category of affective stimuli (Pos, Neg, or N). In addition, in order to evaluate the subjective emotional state of the participants, we employed a scale designed for this purpose (Spanish version of PANAS, Joiner et al., 1997).

2.1. Method

2.1.1. Participants

Thirty volunteers ($n = 10$), 11 males and 19 females, participated in this experiment. Their ages ranged between 17 and 36 years. None of the participants reported any visual or hearing problem. All participants were informed of the type of stimulation used in the experiment, and provided signed informed consent before the start of the experimental manipulations. Seville University's ethical committee approved the study.

2.1.2. Materials

2.1.2.1. Questionnaire. Levels of induced affect were assessed with a Spanish version of the Positive and Negative Affect Schedule (PANAS; Sandin et al., 1999). This questionnaire is composed by 20 items, 10 each for the positive and negative scales, which can be rated on a scale from 1 (very slightly) to 5 (very much).

2.1.2.2. Affective stimuli. Three sets of 35 pictures each were selected from the IAPS to be presented for each of the induced affect condition.[1] The mean IAPS valences for the Pos, N and Neg set of pictures were 7.27, 5.14, and 2.79, respectively. Each image was presented for 5 s without any temporal interval between them, and the correspondent set of images was repeated three times in the same order to fit the entire duration of the experimental stage. Transition between images did not coincide with the occurrence of any auditory stimulus.

2.1.2.3. Prepulse and pulse stimuli. Acoustic stimuli were delivered binaurally using adjustable headphones (Sony model MDR-V50), connected to a MP150 control module (Biopac Systems Inc., Goleta, CA). The signal was sent with a high sampling rate of 50 kHz. The prepulse and the pulse stimulus consisted of a 75 dB (A) and 95 dB (A) broadband white noise with instantaneous rise time, lasting for 20 and 50 ms,

[1] IAPS picture numbers used in this study were: POSITIVE: 1019, 1111, 1112, 1274, 1280, 2095, 2692, 2694, 2710, 2717, 2730, 2751, 2900, 3000, 3069, 4621, 6242, 6244, 6311, 6555, 6561, 6562, 6831, 6940, 9120, 9340, 9409, 9417, 9423, 9426, 9428, 9570, 9594, 9429; NEGATIVE: 1340, 1463, 1603, 1722, 1750, 1920, 1999, 2071, 2165, 2209, 2224, 2303, 2311, 2344, 2345, 2352, 2530, 4532, 4601, 4614, 4624, 4640, 4641, 5270, 5450, 5480, 5721, 5760, 5833, 7220, 7230, 7270, 7330, 7430, 7508; NEUTRAL: 2580, 7000, 7009, 7025, 7055, 7059, 7100, 7150, 7175, 7180, 7185, 7187, 7190, 7192, 7211, 7224, 7235, 7236, 7247, 7248, 7490, 7491, 7545, 7546, 7547, 7550, 7705, 7950.