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Cardiac defense response as a predictor of fear learning

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ABSTRACT

Prior studies have demonstrated that differences in activation of the defensive motivational system – as indexed by cardiac responses to the CS+ during aversive conditioning – are related to differences in the acquisition of two-levels-of-learning: cognitive (contingency learning) and emotional (fear learning). Here we further explored these differences using an independent psychophysiological test to assess cardiac reactivity – Cardiac Defense Response (CDR) – prior to the aversive conditioning task. Participants were then classified as accelerators or decelerators based on the CDR second accelerative component. Both groups showed contingency learning, as indexed by greater skin conductance changes to CS+ than to CS− during acquisition and by consistent contingency awareness ratings after the conditioning task. However, only accelerators showed affective fear learning, as indexed by greater blinks to CS+ than to CS− during (acquisition) and after (extinction) aversive conditioning. These results extend evidence about differences in the two-levels-of-learning in aversive conditioning as a function of defensive reactivity, and suggest that the CDR second accelerative component could be a reliable predictor of fear learning.

1. Introduction

One of the most important emotions for survival is fear, an aversive emotional state elicited by external threatening cues that activate the aversive/defensive motivational system — one of the two basic motivational systems in the brain (the other one is the appetitive) that evolved from primitive neural circuits in mammals (e.g., Lang et al., 1997). Founded on protective and escape reflexes that underlie unpleasant affects, the aversive motivational system prepares the organism to get away, motivates avoidance, and shows high plasticity (Öhman and Mineka, 2001). The latter is probably one of the most outstanding attributes of the system, as it enables previously innocuous stimuli that were associated with threatening outcomes to activate the aversive motivational system by themselves. Indeed, classical aversive conditioning allows the quantification of learned fear by means of measuring the extent to which an a priori neutral stimulus that has been paired with an aversive stimulus is able to *turn on* the aversive motivational system (cf. Hamm and Weike, 2005).

It must be noted, though, that humans participating in a typical aversive conditioning task do not always acquire fear responses. Öhman and Mineka (2001) and, more recently, Hamm and Weike (2005) have suggested the existence of two-levels-of-learning in aversive conditioning. According to these authors, when humans are subjected to paired presentations of a conditioned stimulus (CS+) and an aversive unconditioned stimulus (US), they separately acquire the stimulus contingency awareness and the emotional response to the CS+. Therefore, participants may learn that the CS+ predicts the occurrence of the US on a cognitive level without learning to fear the CS+ on an emotional level. In this case, participants acquire knowledge of the CS+/US contingency relationship (similar to contingency learning observed in animals; see Rescorla, 1988), but the CS+ does not gain the affective properties to activate the aversive system (Weike et al., 2007).

The existence of these two levels of learning has been demonstrated in several studies where participants were classified on the basis of reactivity of their aversive motivational system, as indexed by heart rate acceleration (high reactivity) or heart rate deceleration (low reactivity) in response to the CS+ during the acquisition phase. These studies found that both accelerators and decelerators acquired – on a cognitive level – contingency learning, as indexed by skin conductance CS+/CS− differentiation during acquisition (Hamm and Vaitl, 1996; Hodes et al., 1985) and by reported contingency awareness (Moratti et al., 2006). However, only accelerators acquired – on an emotional level – affective fear learning, as indexed by heightened startle reflex potentiation to the CS+ during acquisition and even extinction (Hamm and Vaitl, 1996) and by CS+ affective valence ratings devaluation (Hamm and Vaitl, 1996; Hodes et al., 1985). The main caveat to these studies is that they used the same stimulus (the CS+) both to obtain cardiac responses in which participant classification was based on, and to observe the effect of this classification on the other conditioning measures.

The conclusions of these studies would be strengthened if assessment of the aversive motivational system reactivity (i.e., classification of participants as accelerators or decelerators) was based on a task completely independent of the conditioning task. One such

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option would be the psychophysiological reactivity test (Vila et al., 1992), where the presentation of an aversive, discrete, intense, and unexpected (usually auditory) stimulus prompts a specific phasic cardiac reactivity pattern known as Cardiac Defense Response (CDR). The CDR includes two distinct accelerative components with decelerative components after each acceleration – relative to the pre-stimulation baseline (usually 15-s), – and lasts for 80-s after stimulus presentation (Ramírez et al., 2005; Vila and Fernández, 1989; Vila et al., 1992). This cardiac reactivity pattern is interpreted as a sequence of heart rate changes with both accelerative and decelerative components, with both parasympathetic and sympathetic mediating mechanisms (Fernández and Vila, 1989a; Reyes del Paso et al., 1993), and with both attentional (first acceleration/deceleration component) and emotional (second accelerative component) significance. This pattern seems to reflect the transition from attention to action (Vila et al., 2003). Due to its emotional significance, our study was focused on the second accelerative component, which peaks during the 20 to 45-s interval after stimulus presentation. This component has been interpreted motivationally as reflecting the mobilization of the organism's resources to give a defensive coping response (Fernández and Vila, 1989a) and seems to reflect the activation of the defensive motivational system (Cook and Turpin, 1997; Turpin, 1986; Turpin et al., 1999). Furthermore, research seems to suggest that the presence or absence of the second accelerative component of the CDR implies qualitative differences between subjects (Eves and Gruzelier, 1984; Pérez et al., 1999), thus identifying individuals with high or low reactivity, respectively, of the aversive motivational system (cf. Fernández and Vila, 1989b; Sánchez-Navarro et al., 2006).

The aim of this study was to further investigate whether differences in the reactivity of the aversive motivational system – as indexed here by long-latency CDR patterns – lead to different levels of learning (cognitive, emotional) in an aversive conditioning experiment. Previous investigations have explored this issue using the same stimulus (CS+) both as a criterion to establish the experimental groups (based on short-latency cardiac reactivity patterns) and as a cue to examine conditioning (fear–startle potentiation and electrodermal changes). In our study, we tried to solve this issue by using an independent test of phasic cardiac reactivity (the CDR) in order to separate the composition of the experimental groups from the physiological measurement in the conditioning task. On a cognitive level, we predicted that both accelerators and decelerators would learn the CS+/US contingency relationship, reflected by the presence of conditioned electrodermal changes when exposed to the CS+ during acquisition, though greater resistance to extinction in front of CS+ was also expected for accelerators but not decelerators (cf. Hodes et al., 1985). Additionally, we expected that both groups would report contingency awareness (Moratti et al., 2006). On an emotional level, we predicted that only accelerators would acquire and maintain conditioned fear responses when exposed to the CS+, as evidenced by fear–startle potentiation and heart rate acceleration to CS+ compared to CS− during acquisition and extinction, and would show an affective valence devaluation of CS+ in post-conditioning ratings (cf. Hamm and Vaitl, 1996; Hodes et al., 1985).

2. Materials and methods

2.1. Participants

Participants were 73 psychology undergraduates (6 men) from the Jaume I University of Castellón (Spain) aged between 21 and 32 ($M = 24.17$; $SD = 2.31$). None were undergoing psychiatric or pharmacological treatment, and none presented visual or auditory deficits. Because of computer or experimenter errors, data for some participants were lost. Final Ns were as follows: skin conductance, $n = 71$; eyeblink EMG, $n = 65$; heart rate, $n = 73$; valence ratings, $n = 70$; arousal ratings, $n = 73$ and contingency ratings, $n = 73$.

Participants were classified as accelerators or decelerators based on the presence or absence of the second accelerative component of the CDR obtained in a psychophysiological reactivity test that was conducted before the conditioning task. It consisted of a rest period of 6-min, followed by a recording of 80-s after a white noise presentation (500-ms, 110 dB and instantaneous risetime). Visual inspection of individual waveforms confirmed that all participants showed a first acceleration followed by a first deceleration or return to baseline within the 10-s after stimulus presentation, as usual for these early components. In addition, as expected, there were individual differences in the second acceleration appearing within 20 to 45-s after stimulus presentation.

Ward's hierarchical clustering method (recommended for producing cluster with roughly the same number of observations in relatively small data tables; cf. Milligan and Isaac, 1980) was used to conduct a cluster analysis on the second by second heart rate changes during the 20 to 45-s interval after the stimulus onset. For consistency with previous research, a three-cluster solution was first tested, but it was rejected because of an imbalanced distribution of participants among the resulting groups (2 extreme accelerators, 32 accelerators, and 39 decelerators). Finally, two groups of participants with distinct cardiac reactivity patterns were obtained based on the two-cluster solution: accelerators ($n = 40$), participants who showed clear heart rate acceleration during this interval, and decelerators ($n = 33$), participants who showed a decelerative pattern during this interval (see Fig. 1).

Statistical analyses confirmed that accelerators and decelerators differed significantly in parameters Y and A2 – the first being indicative of goodness of whole CDR waveform, and the second being a quantitative index of the CDR second accelerative component – (Vila and Fernández, 1989).[1] Thus, accelerators showed a better whole CDR waveform than decelerators (Y Means = 30.82 and 15.87, respectively; $t[71] = 24.87$, $p < .0005$), and also a higher second cardiac acceleration (A2 Means = 8.31 and 0.37, respectively; $t[71] = 37.60$, $p < .0005$).

2.2. Materials and design

The differential aversive conditioning task consisted of 5 practice trials followed by habituation (1 block of trials), acquisition (2 blocks of trials), and extinction (3 blocks of trials) phases. Each block consisted of 4 CS+ and 4 CS− presented in a pseudorandom order, with no more than two consecutive presentations of each CS type. Practice trials consisted of 2 CS+, 2 CS− and 1 non-paired US delivered during the ITI between a CS− and a CS+, presented in a pseudorandom order.

Each trial consisted of a 6-s presentation of an affective picture selected from the International Affective Picture System (IAPS: Lang et al., 2005) that served as conditioned stimuli. Half of the participants ($n = 38$) viewed 2 erotic pictures (# 4670 and 4672; man–woman couples in sexual attitude), whereas the other half ($n = 35$) viewed 2 threatening pictures (# 6250 and 1300; front aiming gun and threatening dog, respectively), each pair being matched for valence and arousal ratings according to the Spanish norms (Moltó et al., 1999; Vila et al., 2001). Specific pictures that served as CS+/CS− were counterbalanced across subjects,[2] and projected onto a screen (with a maximum size of 120 cm × 85 cm) using a Toshiba TLP-T50 slide

[1] The Y parameter is a quantitative index of the presence or absence of an adequate CDR pattern. $Y = A1 - D1 + 2A2$, where A1 is the mean of the 3 consecutive highest heart rate change values within seconds 1 to 4 after onset, D1 is the mean of the 3 consecutive lowest heart rate change values within seconds 5 to 20 after onset, and A2 is the mean of the 6 consecutive highest heart rate change values within seconds 15 to 45 after onset.

[2] Cluster membership was unrelated to the content of the CSs that the participants received: roughly half of the participants in each experimental group viewed erotic pictures (20 accelerators and 18 decelerators) and the other half viewed threatening pictures (20 accelerators and 15 decelerators).