International Journal of Psychophysiology 69 (2008) 27–32

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

The effect of startle reflex habituation on cardiac defense: Interference between two protective reflexes

María Carmen Fernández [a,*], Jaime Vila [a], Ottmar V. Lipp [b], Helena M. Purkis [b]

[a] University of Granada, Spain
[b] University of Queensland, Australia

ARTICLE INFO

Article history:
Received 19 August 2007
Received in revised form 12 February 2008
Accepted 23 February 2008
Available online 4 March 2008

Keywords:
Cardiac defense
Eyeblink startle
Skin conductance
Habituation

ABSTRACT

The present study investigated the relationship between blink startle and cardiac defense, two protective reflexes that are said to be elicited by the transient and the sustained components, respectively, of high intensity stimuli. Three groups of participants were presented with three intense long lasting noise stimuli (500ms) after habituation training with 12 brief (50ms) high intensity noise bursts (High group), low intensity noise bursts (Low group) or high intensity visual stimuli (Light group). The transition from habituation to defense stimuli resulted in increased blink startles in groups Low and Light, but not in group High. A cardiac defense reflex, characterised by a short and long delayed increase in heart rate, was observed in group Light, but not in groups Low and High. This pattern of results indicates that habituation to startle eliciting stimuli will impair defense reflexes elicited on subsequent test trials and suggests some interrelation between the two reflex systems.

1. Introduction

One of the main contributions of psychophysiological research to the investigation of information processing has been in the detailed analysis of the non-specific, automatic responses to stimulus input that characterise the early stages of attentional processing. Sokolov (1963) in his seminal work distinguished orienting, defense, and adaptive reflexes as the initial responses to stimulus input. This scheme was extended by Graham (1992) who proposed that four basic reflexes are elicited by stimuli as a function of their intensity and their transient/sustained characteristics. Low intensity transients were said to elicit the transient detection reflex manifested, for instance, in startle prepulse inhibition whereas the sustained portion of low intensity stimuli elicits orienting. High intensity transients were said to elicit startle whereas sustained high intensity stimuli are said to elicit defense reflexes. As in Sokolov's typology, these reflexes are not seen as mutually exclusive, but may all be elicited by a single stimulus of appropriate characteristics with some reflexes dominating over others. An intense, long lasting stimulus with instant onset will, for instance, elicit defense and startle with defense dominating the overall response pattern. These reflexes have been the topic of much research in their own right (see for instance Siddle, 1983; Dawson et al., 1999). More recently, however, the two reflexes elicited by high intensity stimuli, startle and defense, have attracted researchers' interest because they are subject to modification by psychological background processes such as emotion.

Startle, operationalised as the contraction of the orbicularis oculi muscle, the eyeblink component of startle, is the most frequently investigated reflex in humans in recent years (see Blumenthal et al., 2005 for methodological considerations). Startle can be elicited by stimuli in any sensory modality (acoustic, visual, or electrocutaneous). The critical eliciting factor for startle is a very short stimulus risetime (shorter than 25ms), although the probability and amplitude of the reflex are enhanced by increasing stimulus intensity (Blumenthal, 1988; Blumenthal and Berg, 1986). Graham (1992) conceptualized startle as the manifestation of an interrupt that can trigger the allocation of attentional resources to the stimulus source.

Defense, most frequently operationalised as cardiac defense — i.e., the heart rate response to intense or aversive stimulation — , is seen as a protective reflex which in recent years has been well researched (Turpin, 1986; Turpin et al., 1999; Vila et al., 2007; Ramírez et al., 2005). Following Bond's (1943) first description of the heart rate response to intense acoustic stimulation in cats and dogs, cardiac defense in humans has been consistently described as a complex response with a short latency acceleration (peak around 3s), followed by a deceleration or return to baseline, and then a long latency acceleration (peak between 20 and 40s), finishing with a second deceleration. The response is elicited by intense acoustic and electrocutaneous stimulation but not by visual stimulation (Vila et al., 1992) and is significantly affected by stimulus duration. Only stimuli with durations of 500ms or longer elicit the entire response pattern. Cardiac defense is not affected by stimulus risetime as any risetime between 0 and 240ms elicits the full response pattern. In addition, the response tends to habituate

* Corresponding author. Facultad de Psicología, Campus La Cartuja s/n, 18011 Granada, Spain. Tel.: +34 958 243753; fax: +34 958 243749.
E-mail address: mcfersan@ugr.es (M.C. Fernández).

0167-8760/$ – see front matter
doi:10.1016/j.ijpsycho.2008.02.007

rapidly, the second acceleration/deceleration almost disappearing after the first stimulus presentation (Ramírez et al., 2005). These parametric characteristics of cardiac defense contrast markedly with those of eyeblink startle, which is dramatically affected by stimulus risetime, but not by stimulus duration (at least over 50ms), and which shows slow habituation. Given these differences, it seems not surprising that few studies have simultaneously examined cardiac defense and eyeblink startle.

However, recent studies of emotional processes suggest that startle and defense reflexes respond similarly to some experimental manipulations. If startle eliciting stimuli are presented during emotionally salient foreground stimuli, then the magnitude of the startle blink will covary with the valence of the foreground. It will be larger during unpleasant than during neutral stimuli, and smaller during pleasant than during neutral stimuli (Lang et al., 1990). Larger startles are also observed during visualization of fear evoking pictures as compared to non-fearful ones. A similar potentiation phenomenon has been reported for cardiac defense (Sánchez et al., 2002; Vila et al., 2003). Moreover, these parallels in fear potentiation of cardiac defense and eyeblink startle were found not only in response to consciously perceived emotional pictures, but also during subliminal presentations of phobic stimuli (Ruiz-Padial et al., 2005; Ruiz-Padial and Vila, 2007). These findings are consistent with the *reflex matching hypothesis* advanced by Lang and colleagues. This hypothesis poses that appetitive or defensive reflexes are facilitated if elicited while their respective motivational system is activated, for instance in response to a foreground stimulus such as a picture. Conversely, the reflexes will be inhibited if elicited while the opposite motivational system is activated. Thus, this motivational approach to startle and cardiac defense implies more communality among the two reflex systems which were previously conceptualised as distinct and with different functionalities.

The purpose of the present research was to further explore the communality among eyeblink startle and cardiac defense. In particular, this study explored the extent to which habituation of one reflex (eyeblink startle) will affect the elicitation of the second (cardiac defense). A brief, intense acoustic stimuli which reliably elicits blink startle does not elicit cardiac defense (Ramírez et al., 2005). Thus, habituation of participants' startle reflex should not affect the elicitation of cardiac defense if the two reflexes are mediated by independent reflex systems. If, however, there is some overlap among the two protective reflex systems, then habituation of one will affect the elicitation of the other. In order to control for the effects of exposure to acoustic stimuli and of exposure to intense stimuli, *per se*, two control groups were presented with low intensity acoustic stimuli or high intensity visual stimuli during habituation training. Low intensity acoustic stimuli served as control for differences in intensity within the same sensory modality. High intensity visual stimuli served as control for differences in sensory modality within the same subjective intensity. In addition to cardiac defense and eyeblink startle, the present study also monitored skin conductance and subjective ratings of startle and defense stimulus intensity. These measures would provide independent evidence of habituation and sensitization and for the success of the manipulation of stimulus intensity and modality during the habituation phase.

2. Method

2.1. Participants

Sixty-three students from the University of Queensland, with a mean age of 25.6years (standard deviation 6.82, range: 18–53years) volunteered participation and provided informed consent. The sample, which was recruited from the School of Psychology Research Participation Scheme, comprised 33 females. Participants received Australian $10 for participation. None of the participants had auditory or visual deficits or cardiovascular problems. Participants were allocated to three groups upon arrival at the laboratory such that the groups had approximately equal gender distributions (Low: 10:11m:f; High 10:12; Light 10:10).

2.2. Apparatus

Physiological responses — skin conductance, blink EMG, ECG, and respiration — were collected with a Biopac MP150 unit connected to an IBM compatible PC. Skin conductance was collected with two miniature Ag/AgCl electrodes filled with KY jelly and attached to the distal phalanges of the index and middle fingers of the preferred hand. Skin conductance was amplified with a GSR100C amplifier. Orbicularis oculi EMG was recorded with two miniature Ag/AgCl electrodes filled with standard electrode gel and attached to the skin overlaying the muscle under the left eye. One electrode was attached underneath the pupil and the second about 1cm lateral towards the outer cantus of the eye. A ground electrode was attached to the participants' forehead. EMG was amplified with a EMG100C amplifier with a gain of 500 and a band pass filter with a low cut off of 10Hz and a high cut off of 500Hz. The ECG, recorded via Ag/AgCl electrodes attached in an Einthoven lead II configuration, was amplified with an ECG100C amplifier. Respiration was recorded with a rubber strain gauge attached to the participants' lower chest and connected to a RSP100C amplifier. All physiological signals were collected with a sampling frequency of 1000Hz using AcqKnowledge373 data acquisition software.

Auditory stimuli were generated with a custom built white noise generator and presented through Sennheiser HD25-1 headphones. Auditory stimuli had an instantaneous rise time and were presented for 50ms during habituation training and for 500ms during the test for cardiac defense. Stimulus intensity during habituation was 65dBA in the low intensity condition and 105dBA in the high intensity conditions. All defense reflex eliciting stimuli were presented at 105dBA. Light stimuli were generated by a yellow 60W Osram strobe light placed 20cm in front of the participant and illuminated for 50ms. The stimulus sequence and stimulus timing were controlled by DMDX software (Forster and Forster, 2003) run on a second PC which also generated stimulus markers that were collected by the Biopac unit.

2.3. Procedure

Each participant attended an individual laboratory session that lasted approximately 45min. Upon arrival, the participant was informed that the purpose of the study was to record physiological data while she or he was resting during several minutes followed by the presentation of brief intense stimuli, such as lights and noises. No information on specific number, type, and sequence of the stimuli to be presented was given. After signing the informed consent form, an interview was conducted in order to ascertain age, visual or auditory deficits, and cardiovascular health. The participants were asked to clean skin areas to which skin conductance electrodes were to be attached and invited to take a seat in an adjoining participant room. Measurement devices were attached in the following order: respiration, electromyography, skin conductance, and electrocardiography. The fidelity of the physiological recordings was then checked, the headphones placed and the participant was left alone in the semi-darkened participant room. The psychophysiological test began with a 5min rest period followed by 12 habituation trials, with a variable inter-stimulus interval of 16–20s. Habituation stimuli were intense noise bursts in group 'High', low intensity noise bursts in group 'Low' and light stimuli in group 'Light'. Habituation was followed for all participants by the presentation of three defense trials with an inter-stimulus interval of 215s. The first defense trial began 20s after the last habituation trial. The test ended 215s after the last defense trial. During the test, participants were asked to breathe normally and maintain their eyes open looking at the light bulb located at a distance