International Journal of Psychophysiology 94 (2014) 329–335

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Resting heart rate variability and the startle reflex to briefly presented affective pictures ☆

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ARTICLE INFO

Article history:
Received 25 March 2014
Received in revised form 6 October 2014
Accepted 7 October 2014
Available online 16 October 2014

Keywords:
Startle reflex
Heart rate variability
Emotion
Unconscious

ABSTRACT

We have previously shown that persons with low HRV showed potentiated startle responses to neutral stimuli. In the present study we replicated our prior findings and extended them to examine the effects of HRV on the startle magnitude to pictures that were presented outside of conscious awareness. A total of 85 male and female students were stratified via median split on their resting HRV. They were presented pictures for 6 s or for 30 ms. Results indicated that the high HRV group showed the context appropriate startle magnitude increase to unpleasant foreground. The low HRV group showed startle magnitude increase from pleasant to neutral pictures but no difference between the neutral and unpleasant pictures. This pattern of results was similar for the 30 ms and the 6 s conditions. These results suggest that having high HRV may allow persons to more efficiently process emotional stimuli and to better recognize threat and safety signals.

1. Introduction

Individual differences in physiology have been associated with a range of cognitive, affective and behavioral processes including psychopathology. Such individual differences may help to better characterize persons with various disorders and thus provide important insights into their etiology and treatment. Two physiological variables that have been investigated in this context are the emotion modulated startle response (SR) and heart rate variability (HRV).

The emotion modulated SR has proven to be a reliable and robust indicator of affective responding. Importantly, individual differences exist in the SR (Vaidyanathan et al., 2009). In persons without obvious pathology startle responses in the presence of unpleasant foregrounds are potentiated and responses in the presence of pleasant foregrounds attenuated relative to neutral foregrounds. However in persons with various pathologies this normal pattern may be altered. For example, in persons with simple phobias or high trait negative affect, SR in the presence of phobic specific or unpleasant foregrounds may be exaggerated (Hamm et al., 1997). Similarly Patrick and others have shown that persons scoring high on psychopathic traits may show attenuated SR in the presence of unpleasant foregrounds (e.g.,Vaidyanathan et al., 2009). Recently, a growing body of literature suggests that persons that show potentiated SR in the presence of neutral foregrounds or during the inter-trial intervals may have or be at risk for the development of at least certain anxiety disorders (Craske et al., 2012). Thus the pattern of SR responses to various foregrounds may provide useful information about the types of deficits or disorders the individual may manifest.

Similarly individual differences in resting HRV have been used to characterize persons with or at risk for the development of various disorders. Low resting HRV has been related to a range of psychopathologies including depression, anxiety, and schizophrenia as well as various pathophysiologies such as cardiovascular disease and diabetes (Clamor et al., 2014; Thayer et al., 2010). Recently it has been shown that low resting HRV was characteristic of a range of anxiety disorders including generalized anxiety disorder, panic disorder, social anxiety disorder, and obsessive–compulsive disorder (Pittig et al., 2013). In addition we have recently shown that low resting HRV was prospectively related to elevated anxiety symptom scores in a college sample (Gillie et al., 2012). Interestingly, to date, few studies have examined resting HRV and emotion modulated SR in the same study.

In one study that examined the relationship between resting HRV and SR we showed that individual differences in resting HRV were associated with differences in the pattern of emotion modulated startle responses (Ruiz-Padial et al., 2003). Specifically, those individuals in the highest quartile of HRV showed the expected startle potentiation to unpleasant pictures and the expected startle attenuation to the pleasant pictures whereas those in the lowest quartile failed to show this expected pattern. Importantly, the persons in the lowest quartile showed similarly large startle responses to the neutral as well as the unpleasant pictures. These results suggested that those persons with low HRV showed undifferentiated responses to neutral and unpleasant pictures

☆ Author notes: The present research was supported by a grant from the Spanish Ministry of Science and Innovation (PSI2009-12368) and another from the Spanish Ministry of Economy and Competitiveness (PSI2012-37090).

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http://dx.doi.org/10.1016/j.ijpsycho.2014.10.005
0167-8760/

Table 1
Mean age (and standard deviation) of each group of participants.

	High HRV			Low HRV			TOTAL
	Female	Male	Combined	Female	Male	Combined	
Conscious (N = 44)	21.09 (2.58) (N = 11)	20.92 (2.19) (N = 12)	21 (2.33) (N = 23)	20.27 (1.90) (N = 11)	19.9 (1.10) (N = 10)	20.09 (1.55) (N = 21)	20.57 (2.03)
Non Conscious (N = 41)	21.91 (1.30) (N = 11)	19.75 (1.49) (N = 8)	21 (1.73) (N = 19)	21 (1.41) (N = 8)	22.07 (3.65) (N = 14)	21.68 (3.03) (N = 22)	21.36 (2.51)
TOTAL			21 (2.06)			20.91 (2.52)	20.95 (2.29)

and may have difficulty recognizing "safety" signals. The notion that persons with, or at risk for, various psychopathological conditions have an impaired ability to recognize "safety" signals is gaining support in the literature (Bishop et al., 2004; Craske et al., 2012; Lissek et al., 2005; Melzig et al., 2009; Maier et al., 2006; Thayer et al., 2012). Specifically, numerous researchers have reported that these at-risk individuals may be over generalizing the threat they perceive in the environment leading to less context appropriate responses. That those persons show threat responses to neutral stimuli is in accordance with our notion that the default response to uncertainty is the so-called "default stress response" (Thayer et al., 2012; Verkuil et al., 2010).

We have previously shown that persons with low resting HRV lack the necessary restraint to produce a context appropriate response and instead emit the default stress response in the presence of non-threatening or "safe" contexts (Thayer et al., 2000; Melzig et al., 2009; Park et al., 2013). Thus in the present experimental setting we hypothesized that such persons would show exaggerated startle responses not so much to aversive contexts but to neutral contexts. In our prior study this was found in response to foreground stimuli that were presented over a wide range of picture viewing durations including some that we thought to be outside of conscious awareness. However if our hypothesis about the default stress response is correct, we should see this also when stimuli are clearly outside of conscious awareness as this would be evidence of the early, initial "default" response.

The further investigation of the effects of resting HRV on startle responses to emotional stimuli is called for in order to clarify the nature of the modulatory effects of HRV on startle responses under a range of conditions not previously investigated in the same study. As we have described in detail previously (Ruiz-Padial et al., 2003), the neural circuitry of the startle reflex suggests that the affective modulation is achieved via a pathway involving the central nucleus of the amygdala (CNA). The CNA is further modulated by inhibitory inputs from the prefrontal cortex (see Thayer & Lane, 2009 for a detailed description of this circuitry). Importantly, we have shown repeatedly that HRV is related to activity in the prefrontal cortex and to emotion regulation (e.g., Thayer et al., 2012; Lane et al., 2013; Allen et al., in press). Thus, we expect, and have previously shown, that individual differences in HRV should be related to the emotional modulation of the SR (Ruiz-Padial et al., 2003; Melzig et al., 2009).

In our prior study we included a range of picture viewing durations some of which we thought to be outside of conscious awareness. In the present study we chose one subliminal picture viewing duration and hypothesized that persons with low resting HRV would respond to neutral as well as aversive foregrounds with similar startle responses even when those stimuli are presented very briefly and with a backward mask so that participants can not consciously report the nature of the foreground stimulus.

In addition, there were several other limitations to our prior study of HRV and startle which we hoped to rectify as well. First, in the prior study all participants were female. Thus one could not ascertain that the findings would generalize to males. Therefore in the present study approximately equal numbers of females and males served as participants. Furthermore, in the prior study no measures of psychological individual differences such as measures of personality were included. Recent research suggests that the nature of the SR response in the presence of an unpleasant foreground varies as a function of a bipolar dimension of trait fear with fearful individuals showing potentiated SR to unpleasant pictures whereas fearless/psychopathic individuals showing attenuated SR to unpleasant pictures (Vaidyanathan et al., 2009). However those studies have not included measures of resting HRV. Importantly, numerous studies have shown that psychopathic traits may be identified using the five-factor model of personality (see Lynam and Derefinko, 2006 for a comprehensive review). Thus it is possible that the combination of measures of personality and resting HRV might help to clarify the nature of the SR response of low HRV persons to unpleasant and neutral pictures. Therefore in the present study all participants completed the NEO-FFI (Costa and McCrae, 1992) and at least we could examine the major dimensions of personality as a possible explanation for our prior findings.

2. Method

2.1. Participants

Participants were 85 students of the University of Jaén (41 female) with a mean age of 20.95 (sd = 2.29). They were distributed into two groups (conscious and non conscious) according to the duration of the picture that produced an ineffective and effective masking effect, respectively. Moreover, they were classified into high and low HRV groups using a median split on their baseline HRV (see Table 1 for details on each group). However HRV was also analyzed as a continuous variable. They were given course credit for their participation. None was undergoing psychiatric or pharmacological treatment. All participants had normal or corrected to normal vision and hearing. This study was reviewed by the local institutional review board and all participants gave their written informed consent.

2.2. Materials and design

Forty-five pictures (15 pleasant, 15 neutral and 15 unpleasant) were selected from the International Affective Picture System slides on the basis of their valence and arousal ratings from the Spanish norms (Moltó et al., 1999).[1] Each picture was presented for 6 s in the Conscious group and for 30 ms in the Non-conscious group (Ruiz-Padial et al., 2011). The pictures were followed by a 100 ms mask consisting of an image that did not contain a recognizable object (see Fig. 1). This mask had a backward masking effect only in the Non-conscious group.

[1] The IAPS pictures used in this study were: Pleasant: 4607, 4608, 4631, 4652, 4653, 4658, 4659, 4660, 4664, 4670, 4672, 4680, 4690, 4800, 4810; Neutral: 7000, 7002, 7010, 7025, 7030, 7035, 7040, 7050, 7060, 7170, 7205, 7207, 7217, 7224, 7820; and Unpleasant: 3010, 3030, 3053, 3060, 3110, 3140, 3160, 3190, 3210, 3230, 3250, 3300, 3350, 3400, 9400. Based on the Spanish norms the Pleasant [mean (sd) = 6.9 (0.56)], Neutral [mean (sd) = 5.14 (0.30)], and Unpleasant [mean (sd) 2.2 (.91)] slides differed significantly from each other on valence, Pleasant versus Neutral, $F(1,42) = 56.8$, $p < 0.001$, Pleasant versus Unpleasant, $F(1,42) = 401.0$, $p < 0.001$, Neutral versus Unpleasant, $F(1,42) = 155.9$, $p < 0.001$. Both the Pleasant [mean (sd) = 6.7 (0.40)], and Unpleasant [mean (sd) = 6.9 (0.68)] slides differed significantly on arousal from the Neutral [mean (sd) = 3.2 (0.48)] slides, $F(1,42) = 324.3$, $p < 0.001$, and $F(1,42) = 364.9$, $p < 0.001$, respectively, but did not differ from each other, $F(1,42) = 1.2$, $p = 0.28$.