Modulation of the Time Course of Cardiac Chronotropic Responses During Exposure to Affective Pictures

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Abstract

One of the most important topics in attentional and emotional modulation of cardiac responses is time course of cardiac chronotropic response. The reason lies in dual innervation of heart, which leads to occurrence of several phases of cardiac response during exposure to affective stimuli, determined by the balance of sympathetic and parasympathetic influences. Cardiac chronotropic reactivity thus represents quite effective measure capable to trace the moment when attending and orienting processes (i.e., sensory intake of stimulus) prime relevant behavioral response (i.e., emotion with approach or avoidance tendencies). The aim of this study was to find the time course of heart rate (HR) responses typical for negative (disgust, surprise, fear, anger) and positive (happiness, pleasant erotic) affective pictures and to identify cardiac response dissociation for emotions with different action tendencies such as "approach" (surprise, anger, happiness) and "avoidance" (fear, sadness, disgust). Forty college students participated in this study where cardiac responses to slides from IAPS intended to evoke basic emotions (surprise, fear, anger, sadness, disgust, happiness, pleasant-erotic). Inter-beat intervals of HR were analyzed on every 10 sec basis during 60 sec long exposure to affective visual stimuli. Obtained results demonstrated that differentiation was observed at the very first 10 s of exposure (anger-fear, surprise-sad, surprise-erotic, surprise-happiness pairs), reaching the peak of dissociation at 30 s (same pairs plus surprise-disgust and surprise-fear) and was still effective for some pairs (surprise-erotic, surprise-sad) even at 50 s and 60 s. Discussed are potential cardiac autonomic mechanisms underlying attention and emotion processes evoked by affective stimulation and theoretical considerations implicated to understand the role of differential cardiac reactivity in the behavioral context (e.g., approach-avoidance tendencies, orienting-defense responses).

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Introduction

Issues on attentional and emotional modulation of cardiac responses were intensively explored in current research studies [3-6, 10-14, 16, 22, 27, 31-36], since many questions of cardiac reactivity to affective stimulation are not yet solved. One of the most important topics is a time course of cardiac chronotropic response, first of all due to dual sympathetic and parasympathetic innervation of heart which leads to occurrence of several phases of cardiac response during exposure to an affective stimulus [2, 7, 20, 25-26, 34]. Cardiac chronotropic reactivity thus represents quite effective measurement capable to detect the moment when orienting process (attention and perception of stimulus), primes relevant motivational response (emotion with approach or avoidance tendencies) [18, 32-33].

Issues of the degree of association of cardiac rhythm with entire emotional reactivity, and the extent of reflection of other psychological processes such as attention are quite complex [6, 12]. In our studies [31-32] we had results indicating that some of emotion-related phasic heart rate reactions could be interpreted as an orienting response. Exposing subjects to affective stimuli, we observed distinct HR decelerative response indicating an orienting and attention [31-32]. There existed as well a possibility that passive viewing of IAPS pictures, which we generally view as aversive (negative valenced) may actually evoke positive emotional engagement and continued motivated attention. Those processes might be seen either in cardiac response dynamics [19].

Vila *et al* .,(1996) described autonomic mechanisms underlying the cardiac defense response in humans evoked by intense affective stimulation and later clearly confirmed the specifics of HR response as consisting of four consecutive components: the first and short-term acceleration that peaks around 3rd sec, followed by a deceleration that generally surpasses that of baseline, and the second and long-term acceleration that peaks around 30th sec, ending with the second deceleration. Analysis of the autonomic space underlying the observed HR changes showed a sequential pattern of sympathetic-parasympathetic interaction along the four components of the response with co-inhibition (1st acceleration), co-activation (1st deceleration), sympathetic activation - parasympathetic inhibition (2nd acceleration), and sympathetic inhibition - parasympathetic activation (2nd deceleration) [36]. The finding of a vagal dominance during the first components of response, restraining the sympathetic influences, and reciprocal interaction during the last two components, with sympathetic dominance, gives support to the idea that the defense reaction in natural settings follows a sequential process with initial phases in which attentional factors predominate, directed to detailed processing of the stimulus, and later phrases in which motivated actions predominate, directed to overt behaviors of "fight-or-flight " type or emotional response with detectable autonomic responses, even if active coping is not available [6, 12, 27, 33-36] . Similar ideas were expressed in Lang' s "defense cascade" concept [18]. According to author [18] initially attentive process has to be associated with parasympathetic domination in autonomic system, however later sympathetic system becomes involved and dominates when action is imminent (or action tendency is finally formed).

Cardiac responses are involuntary responsive to emotional stimulation. The manifestations of cardiovascular responses provide objective indications of changing psychological status during occurrence of emotion. Heart rate is one of the best discriminators of emotions, especially sensitive to valence dimension of emotional response [1-3, 7-8, 23, 28-30].

Heart rate (HR) data in studies of psychophysiology of emotion are not uniform in different experimental designs. Facial expression studies have shown acceleration of HR [8, 21], as well as did imagery and affective situation design [1, 28, 30]. Affective visual stimulation yielded more mixed results. HR acceleration to visual traumatic stimuli was reported for all subjects by some authors [3], and for phobic individuals only by others[13-14]. Nevertheless in passive viewing situation HR has shown to vary more strongly with valence during affective picture stimuli [5, 22]. Short-term HR response showed deceleration for all affective pictures, which was greater for unpleasant pictures and least for pleasant pictures [5, 16, 31]. HR deceleration to negative film stimulation and slides of negative emotional scenes was also reported by several researchers [5, 11, 13-14]. Attention (as orienting response component) and emotions (as defense response component) may interact during affective picture viewing and this interference should also be regarded during HR deceleration interpretation, since effects of above processes are not easy to separate [10, 12, 15, 22, 31 ,36].

Heart rate showed differentiation for sadness-disgust, disgust-anger, and fear-surprise pairs, being thus reviewed by Cacioppo *et al.* (1993) as one of the best discriminators. But, on another hand in the same review there had been reported results indicating rather low reproducibility of HR to differentiate happiness-surprise, sadness-anger, sadness-fear, anger-fear, or surprise-disgust pairs [2]. This problem could be explained perhaps by overlooking of dynamics of cardiac responses, because cardiac patterns may not be described by only gross output measures of an end-organ responses (e.g., HR), particularly for antagonistically innervated organs (i.e., heart) [2,20]. Emotional stimuli do not invariantly evoke reciprocal activation of sympathetic and parasympathetic branches, and thus resulting response of such measure as cardiac chronotropy could be determined by several combinations of ANS influences [20]. This effects was described for cardiac response to intense stimuli by Vila [34-36]. It is possible that emotions (e.g., disgust) or an early components of emotion (e.g., attention) could be differentiated by cardiac responses, if the central point has been done on cardiac rhythm changes in time rather than on HR as such .

The aim of this study was to find time course of heart rate responses typical for negative (disgust, surprise, fear, anger) and positive (happiness, pleasant erotic) affective pictures and to identify cardiac response dissociation for emotions with different action tendencies such as approach (surprise, anger, happiness) and avoidance (fear, sadness, disgust).

Methods

Forty two college students (20-26 years old) participated in the study. After passing psychometric tests, brief introduction to experimental situation and attachment of electrodes subjects were placed in recliner-chair in sound-proof room with dim lights and were instructed to sit with eyes open and watch the screen where pictures had to be presented by Kodak slide-projector. Initial baseline measurements of physiological signals were taken. Then 7 slides for 7 discrete emotions were selected from the International Affective Picture System (IAPS) [20]. The IAPS numbers for pictures used were: happiness (i.e., happiness nurturant) #2340, sadness #2800, disgust #3140, surprise #3170, exciting (i.e., pleasant erotic) # 4460, anger #6540, fear #3110. The slides were counterbalanced for each subject to avoid order bias.

Physiological signal was acquired by BIOPAC MP100WS hardware with AcqKnowledge III (v.3.5) software. Three Ag/AgCl electrodes were fixed for measurement of Lead I electrocardiogram (ECG). ECG was acquired with sampling rate 512 *Hz*. Heart rate (HR) and inter-beat intervals (IBI) were calculated for each 10 sec of exposure to stimulus (total 60 sec) and 30 sec long inter-trial resting baselines. Changes of parameters were computed as compared to relevant baselines and as tonic IBI levels.

Statistical analysis was performed by SPSS package using t-test for paired samples.

Results

Cardiac responses in surprise and fear emotions demonstrated significant changes of IBI from baseline during whole period of exposure to IAPS slides. Comparison of HR responses of these two emotions nevertheless showed dissociation on 20 s of stimulation (Fig. 1). IBI increase was quite similar for first 10 sec, namely 27.73 (standard error 7.16) ms and 23.52 (8.21) ms in fear. Other emotions did not demonstrate significance of cardiac responses (Fig.2-4). Clear dissociation of time course of HR response was observed within some negative emotions elicited by affective visual stimulation, such as fear and anger (Fig. 2). These emotions have different action tendencies, in particular anger is usually considered to be approach type emotion, whereas fear - avoidance. Anger as an emotion associated mostly with "fight-or-flight" (or in other words defense response) demonstrated very short-term and non-significant orienting manifested in increase of IBI on 8.40 ms in the first 10 sec. Fear usually is described either as an emotion with behavioral inhibition manifestations.

Surprise in our study demonstrated steady HR deceleration (expressed in IBI increase) and could be more relevant to orienting response in its classical terms (modulated mainly by attentional demands) and thus represents quite useful reference for comparison with typical approach (positive emotions : happiness, pleasant-erotic) or avoidance (negative emotions: disgust, sadness) behavioral tendencies. Comparison of surprise with positive and negative valence emotions are shown on Figures 3-4. Sadness, disgust and anger were featured by surprisingly similar cardiac response profiles during the first 30 s of exposure (Figure 4). Tonic HR level comparisons between emotions yielded quite same results as phasic HR response and are not reported here.

Discussion

Obtained results (Figures 1-4) demonstrated that dissociation of IBI was observed at the very first 10 s of exposure (anger-fear, surprise-sad, surprise-erotic, surprise-happiness pairs), reaching the peak of differentiation at 30 sec (same pairs plus surprise-disgust and surprise-fear) and was still effective for some pairs (surprise-erotic, surprise-sad) even at 50 sec and 60 sec.

Potential cardiac autonomic mechanisms underlying attention and emotion processes evoked by affective stimulation should be sought inunderstanding of the role of differential cardiac reactivity in the behavioral context (e.g., approach-avoidance tendencies, orienting-defense responses dichotomy etc.). Cardiovascular changes in response to external stimuli have been considered in general to be indicative of psychological processes related to the facilitation or inhibition of information processing [12, 15, 22]. Briefly, according to Vila et

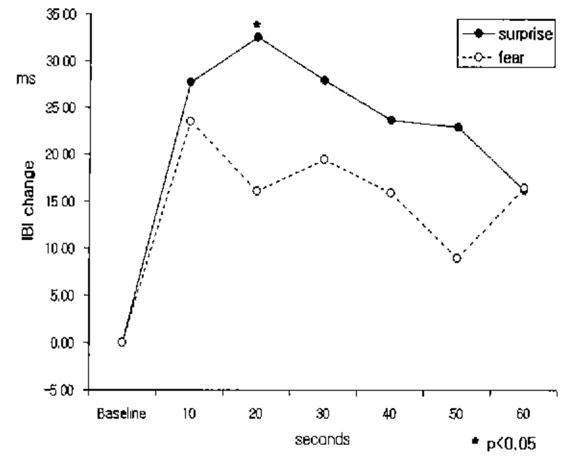

Figure 1. Cardiac response dynamic profile in surprise and fear during IAPS stimulation (N=42). Mean IBI changes on 10s basis are presented. Responses show clear dissociation at 20s and convergence at 60s.

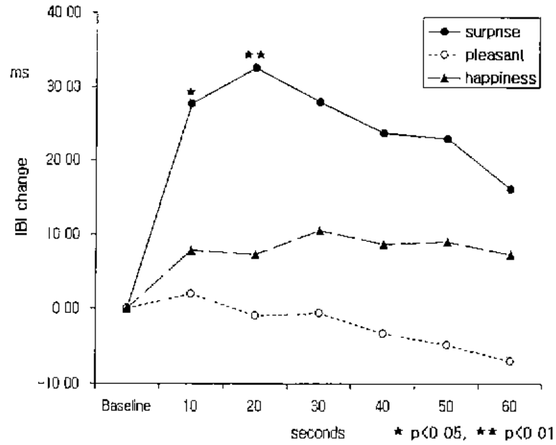

Figure 3. Cardiac response time course in surprise and positive emotions (pleasant-erotic, happiness). Mean IBI changes in 42 subjects. Surprise as an emotion with strong attentional and orienting components (IBI decrease) dissociates from both positive emotions from 10s.

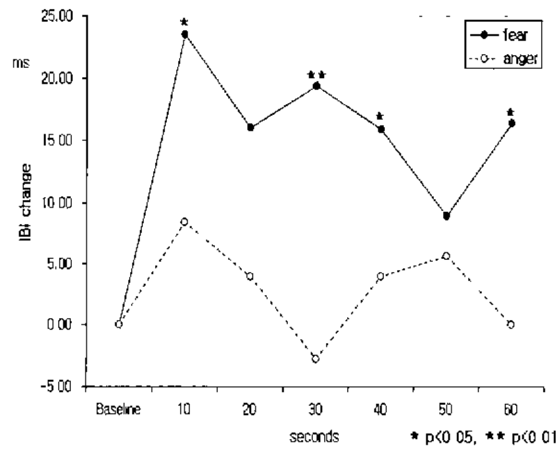

Figure 2. Time course of cardiac response in fear and anger during IAPS stimulation. These negative emotions with different motivational behavioral tendencies (fear-avoidance; anger-approach) demonstrate dissociation of IBI responses from 10s and differentiate conditions.

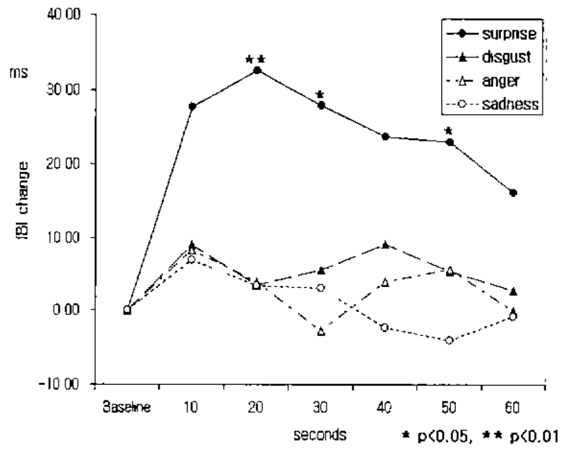

Figure 4. Cardiac response time course in surprise and negative emotions (sadness, anger, disgust). Mean IBI changes in 42 subjects. Surprise differentiate from negative emotions. All negative valence emotions have extremely similar responses in first 30s. Asterisk show response phases when surprise differentiate from all 3 negative emotions.

al., [34-36] the cardiac defense response could be defined as the pattern of HR changes to intense stimuli consists of a sequence of phasic cardiac changes with four observable components within 60-80 sec after the onset of eliciting stimulus, and is mediated by both the sympathetic and parasympathetic branches of the ANS' [36]. The first two components are mediated predominantly by vagus inputs, whereas the last two reflect sympathetic-parasympathetic reciprocal interaction [18,34].

Relations between emotional states and cardiac responses should be considered with regard to the observations showing that autonomic, cortical, and somatic and other behavioral responses are not uniform, but rather are patterned [9,15,22]. Lacey (1967) argued that there are distinct forms of arousal, and presented evidence of dissociation of somatic and behavioral arousal, and uncorrelated changes of different ANS responses in different emotional states, furthermore even HR change in direction opposite to expectations inherent in view of arousal as energizing and protective sympathetic activity. Some other models of emotion emphasized involvement of both sympathetic (ergotropic) and parasympathetic (trophotropic) systems [9].

Of major significance to cardiovascular functioning are the observations of sensitivity of HR directionality. With respect to patterns of HR changes and changes in other ANS measures, Lacey (1967) showed that HR acceleration in "environmental rejection" situations in which the task of stimulation is aversive, or could be coupled with HR deceleration in "environmental intake" situations in which the task requires the taking in information [15,22]. Occurrence of long-lasting HR deceleration in surprise and fear in our study suggest that these emotions are more vulnerable to attentional modulation [12,36]. Surprise showed therefore prolonged perception process and delayed behavioral response.

Coles (1984) suggested that the various types of HR changes (i.e., tonic shifts in level, decelerative and accelerative phasic changes, and short latency variations in the duration of individual cardiac cycles) are manifestations of motor and perceptual preparatory responses and of fast and slower information-processing activities, which generally are under the control of vagus. Author [4] concluded that measures of cardiac activity can be useful as indirect measures of cognitive processing of emotional stimulus. Some authors [25-26] even consider parasympathetic control of HR as a primary autonomic mediator of affect, while other [7] limit the importance of vagal tone to positive emotions only. Parasympathetic inputs nevertheless are assumed to play leading role in mediation of dynamic HR changes, especially when immediate engagement of attention is required [25].

Obrist's (1981) expanded the reaches of cardiovascular physiology to behavioral and psychological domains describing the unique hemo- and cardiodynamic responses evoked by discrete emotional and stressful stimuli, but also addressed the biological mechanisms of varying circulatory adjustments to behavior. The concept of "over-perfussion" is central to Obrist's theory which proposed that cardiac output during sympathetically mediated increases in myocardial performance augment HR to levels that exceed real metabolic demand [24]. The role of sympathetic nervous system in mediating cardiac over-reactivity to emotional stress has been repeatedly shown in excessive HR and over-perfusion [24].

Therefore, data of the study supported an interpretation of the cardiac response to affective visual stimulation as a sequence of phasic heart rate changes (defense "cascade" by [8]) with both cognitive attentional and motivational (emotional) components. An interpretation of autonomic cardiac mechanisms suggested both parasympathetic and sympathetic mediation. Parasympathetic influences seemed to be more profound during the first 10 sec of exposure in most emotions. However negative chronotropy (and domination of parasympathetic inputs involved in attentional engagement) was more pronounced in surprise and fear emotions leading to dissociation of HR responses (20-30 sec) observed in surprise and positive emotions, as well in surprise and negative emotions (sadness, disgust, and anger), and also within some negative emotions (e.g., in fear-anger pair). This interpretation seems to be rational within context of most recent research [18, 35] on emotional and attentional modulation of cardiac defensive reflex and implications of contemporary theories of emotion, motivation and attention.

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