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Respiratory sinus arrhythmia as a function of state anxiety in healthy individuals

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Abstract

Respiratory sinus arrhythmia (RSA) was examined in relation to state and trait anxiety in healthy individuals. Time-frequency analyses of HR-power spectrum in the high frequency region (0.12–0.40 Hz), related to RSA, were examined in 43 women and 39 men. Based on median split, the participants were divided into high and low state and trait anxiety groups. The main result showed that high state anxious individuals had higher RSA-magnitude (HF-power) than low state anxious individuals. The higher RSA-magnitude in the former group was interpreted as reflecting increased attention or vigilance together with motor and behavioural inhibition. No significant effects of trait anxiety or gender were found.

Keywords: HPV; Parasympathetic; RSA; State anxiety; Trait anxiety; Behavioral inhibition; Attention

1. Introduction

Most research concerning respiratory sinus arrhythmia (RSA) and anxiety has been conducted in order to study autonomic deviances in people suffering from various anxiety disorders (e.g., Lyonfields et al., 1995; Thayer et al., 1996). In order to understand the autonomic involvement in anxiety, it is important to study RSA in healthy normal individuals as well. The results of the few studies that have been conducted regarding RSA and subjective ratings of trait anxiety in non-clinical samples are rather mixed (Davis et al., 2002; Fuller, 1992; Knyazev et al., 2002). The relationship between RSA and subjective ratings of state anxiety seems not to have been examined at all. The main purpose of this paper was to examine RSA, as measured by spectrogram analysis of heart period variability, in relation to state anxiety in healthy individuals, but also to further examine the impact of trait anxiety on RSA.

1.1. RSA and heart period variability

Respiratory sinus arrhythmia (RSA) refers to the variation in heart rate (HR) caused by respiration (for reviews see Berntson et al., 1997, 1993; Task Force, 1996). During inspiration HR increases, during expiration HR decreases. The magnitude of RSA oscillation (at around 0.25 Hz) varies as a function of parasympathetic (vagal) control of the heart (Akselrod et al., 1985, 1981; Pomeranz et al., 1985), and quantification of RSA has thus been suggested to index cardiac vagal tone (Porges, 1992; Porges et al., 1982). Power spectrum analysis of heart period variability (HPV) provides a tool to examine autonomic cardiac control (Berntson et al., 1997; Task Force, 1996). Within the HPV power spectrum, three different frequency components have been distinguished that reflect different neurally mediated oscillations. The high frequency component (HF), at around 0.25 Hz, is related to RSA. HF oscillation is suggested to be mediated primarily by parasympathetic vagal activity (Akselrod et al., 1985, 1981; Pomeranz et al., 1985). The low frequency component (LF) at around 0.1 Hz mirrors the baroreceptor loop controlling blood pressure. The interpretation of the LF component is more controversial and has been proposed to predominately reflect sympathetic activity (Malliani et al., 1991), as well as a mixture of sympathetic and vagal influences (Akselrod

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et al., 1985, 1981). The very low frequency component (VLF), at around 0.03 Hz, has been related to the renin–angiotensin system and to thermoregulatory mechanisms (Hyndman et al., 1971; Kitney, 1975), although its origins and mechanisms remain unclear (Berntson et al., 1997). Hence, the HF component related to RSA is regarded as the most reliable of the frequency components (Berntson et al., 1997; Eckberg, 1997) and is the only one considered in this paper.

1.2. Anxiety and fear

Emotions are action dispositions reflecting central activation and readiness for action (Lang, 1995; Tomkins, 1995). Anxiety and fear function as action motivators in response to dangerous or threatening stimuli (Bolles and Fanselow, 1980; Oatley and Johnson-Laird, 1987; Rosen and Schulkin, 1998; Öhman, 1993). The behavioural and autonomic outcomes, however, have been suggested to depend on the specific situation.

The difference between fear and anxiety in non-human mammals has been conceptualised to depend on whether a threat is actually or potentially present (Blanchard and Blanchard, 1988). Fear-related behaviour (fight/flight) occurs when a predator is immediately present, whereas anxiety-related behaviour (risk assessment) occurs when a predator possibly is present (when for example only the smell of a predator is experienced). The risk assessment in response to a possible or poorly discriminable threat involves behavioural or motor inhibition and vigilant scanning of the environment, which is proposed to be the central component of an anxiety pattern (Blanchard and Blanchard, 1988).

Gray and McNaughton (2000) adopt the view that anxiety is related to potential threat, and that fear is related to actual threat, although they emphasize the constructs of passive avoidance (entering the threatening situation) respective active avoidance (withdrawal from the threatening situation). They suggest the existence of three independent neural systems: the behavioural inhibition system (BIS) which is activated when a threat is potential, the fight/flight/freezing system which is activated when a threat is actual and the behavioural activation system (BAS) which is activated by reward stimuli. BIS, involving the septohippocampal system and amygdala, is taken to be central to anxiety. Hyperactivity in these structures is seen as causal of pathological anxiety. The suggested role of BIS is to act as a comparator of inputs. In the case of a mismatch between an expected and an actual event, or approach-avoidance conflict, it will produce an output, such as in the case of punishment, reward omission, novel stimuli and innate fear stimuli. Activation of this system interrupts ongoing motor programs and increases attention to the perceptual world, and is suggested to be closely connected to the orienting response (Gray and McNaughton, 2000) and to HR deceleration (Fowles, 1982).

1.3. Cardiovascular responses to potential and actual threat

An experimental setting may be compared to a "potential threat" situation. The presentation of an aversive stimulus is presumably more likely to be perceived as a potential threat than an actual threat (Gray and McNaughton, 2000; Lang et al., 1997). When a stimulus is perceived as potentially dangerous or harmful, state anxiety is evoked, which may vary over time as a function of the degree of stress that impinges on the individual (Spielberger, 1966). Hence, considered as a potential threat, a fear-relevant picture would temporarily activate BIS, behaviourally indicated by an anxious and attentive state, and autonomically indicated by HR deceleration.

The heart rate pattern in response to pictorial stimuli in general is three-phasic: an initial deceleration, then acceleration, followed by a second deceleration (Cook and Turpin, 1997; Gatchel and Lang, 1973). The initial deceleration is indicative of an orienting response (OR) (Graham, 1992), that is vagally mediated (Cook and Turpin, 1997) and is considered to reflect attention or sensory intake (Lacey and Lacey, 1974) or reduced motor activity during attentive behaviour (Obrist, 1981). In response to fear-relevant pictures (and to aversive pictures generally) HR-deceleration is accentuated, or even sustained as long as the picture is shown (Hare, 1973; Jönsson and Sonnby-Borgström, 2003; Lacey and Lacey, 1974; Lang et al., 1993; Simons et al., 1999), indicating that more attention is given to threatening or aversive information (Cook and Turpin, 1997). Also indicative of increased parasympathetic or vagal cardiac control, RSA has been reported to increase in response to fear-relevant (Jönsson and Hansson, submitted for publication; Jönsson and Sonnby-Borgström, 2003) and aversive (Wittling et al., 1998) pictorial stimuli. However, HR does not invariably decelerate to aversive pictures. More indicative of a defensive response, individuals suffering from phobia respond with HR acceleration to pictures containing the feared object (Fredrikson, 1981; Hare, 1973). Similar results have been reported in response to emotional words. Patients suffering from generalized anxiety disorder (GAD) show HR acceleration to threatening words, whereas controls show HR deceleration (Thayer et al., 2000). Moreover, the GAD patients developed a conditioned anticipatory bradycardia to the threat words, and showed impaired habituation of cardiac orienting to neutral words. This suggests that the threatening object is perceived as actual rather than potential, resulting in response mobilization and flight reaction rather than behavioral inhibition and risk assessment.

1.4. State anxiety and RSA

State anxiety is defined as a transitory emotional reaction, occurring when a potential threat is perceived (Spielberger, 1966). It leads to coping responses, and behavioural and biological reactions (Endler, 1997). Considered as potential threats, fear-relevant pictures temporarily evoke state anxiety. Fear-relevant stimuli also result in sustained bradycardia and increased RSA. This points to a possible relationship between state anxiety and RSA. Some support of this suggestion comes from a study by Heponiemi et al. (2004). During the performance of an aversive task including punishment signals to activate BIS, RSA-magnitude was higher than during the performance of appetitive tasks (mental arithmetic and speech tasks both including potential monetary reward). However, the aversive task was also considered to require sensory intake which might