RESTING CARDIAC VAGAL CONTROL PREDICTS SPEED OF RECOVERY DURING A MENTAL STRESSOR

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Abstract

Cardiac vagal control is a physiological index of parasympathetic nervous system influence on the heart. The present study examined whether greater vagal control at rest would predict more flexible cardiac responses during stress. Respiratory Sinus Arrhythmia (RSA), an index of cardiac vagal control, and heart period (HP) were assessed during 5-min baseline and 5-min serial paced mental arithmetic task (stress). Data (N=102) collected during each 5-min period were divided into ten 30-sec chunks. RSA and mean HP were derived for each chunk. Across all subjects, both measures dropped significantly at the beginning of the stress state and started recovering to baseline level during the stress state, although individual differences in speed and extent of recovery were substantial. Speed of recovery was defined by the regression slope across 10 chunks during the stress task, both for RSA and for HP, with greater positive slopes indexing stronger recovery. Consistent with the hypothesis that better cardiac vagal control can predict more flexible cardiac reactivity in response to stressor, higher baseline RSA was associated with faster recovery speed for both RSA and HP during stress, after accounting for the initial value (defined by regression intercept) at the beginning of the stress state. Compared to participants with better recovery (residualized regression slope>0), participants with poorer recovery (residualized regression slope<0) exhibited lower baseline cardiac vagal control and more restricted changes of both cardiac vagal control and heart period during the stress.

Introduction

Cardiac vagal control is a construct that describes the parasympathetic nervous system influence on the heart. According to the Polyvagal Theory proposed by Porges (Porges, 1995), in mammals, vagal efferent activity exerts an inhibitory effect on cardiac activity during unchallenged situations, but it can rapidly withdraw in response to environmental challenges such as exercise, stress, or mental demand, resulting in a boost of cardiac output to meet the increased metabolic need. It has long been noticed that higher cardiac vagal control level is associated with better health outcomes (Donchin, Constantini, Szold, Byrne, & Porges, 1992), greater attention control (Richards, 1987), and better self-regulation (Porges, 1992). Consistent with previous research findings, the present study examined whether greater vagal control at rest would predict more flexible cardiac responses during stress. In this study, respiratory Sinus Arrhythmia (RSA) was used as a measure of cardiac vagal control. Participants' RSA and heart period (HP) were collected both before and during a serial paced mental arithmetic task, i.e. a mental stressor. We predicted that: (1) Both RSA and HP will drop at the beginning of the stress due to increased metabolic needs and will gradually return to the resting level at later stage; (2) The speed of recovery will differ across participants with higher resting RSA predicting faster recovery; and (3) Participants with poorer recovery should exhibit lower resting RSA and more restricted cardiac response compared with their counterparts with better recovery.

Method

Subjects

- A total of 116 participants participated in the study, for which they received credits toward a course in introductory psychology.
- Participants who were currently taking cardio-vascular medications or those with a history of cardiac disease were excluded from the study. Fourteen were excluded from analyses due to electrocardiogram (ECG) recording difficulties, leaving a final sample of 102 participants (49 men and 53 women).

Procedure

- After signing a consent form, participants were prepared for psychophysiological recording. Three Ag-AgCl electrodes were attached to each participant in a Lead-II formation (see Papillo and Shapiro, 1990)[1] wherein one electrode is affixed to the right forearm, a second to the back of the left leg below the calf muscle, and a third (ground) to the left forearm. Impedances were reduced to less than 20Kohms on all electrodes for each participant. ECG signals were amplified 1000 times with a bandpass of .05 to 100 Hz, and then digitized at 500 Hz[2].
- Participants were then asked to sit quietly for a period of 5 min so that the experimenter could collect "some baseline readings." The signal data collected during this period yielded baseline RSA. Participants were then asked to perform serial paced mental arithmetic (counting backward in varying intervals, starting with a four-digit number) for approximately 5 minutes to induce attention-focusing activity.

Data Reduction

- EKG data: Raw digitized ECG signals were analyzed off-line. Signals were first filtered with a digital band-pass filter (−92 dB per octave, 3–50 Hz). The first derivative of the filtered waveform was then obtained, which facilitated identification of the R-spike. An inter beat interval (IBI) series was generated to a file using a peak detection algorithm, after which the series was screened by hand and corrected for artifacts.
- Baseline RSA: Heart period variability in the high frequency band (.12–.4 Hz) was extracted using CMetX software (Allen Chambers, & Towers, 2007). CMet converts the IBI series to a time-series sampled at 10 Hz, filters the series using a 241-point optimal finite impulse response filter with half-amplitude frequencies of .12 and .40 Hz, and then takes the natural log of the variance of the filtered waveform as the estimate of RSA.
- Chunk RSA and chunk HP: The 5-minute IBI series collected during baseline and the stress were equally divided into ten 30-second chunks. Mean heart periods were calculated for each of the chunks and were used as "chunk HP." To calculate RSA for each chunk, the IBI series of each chunk was first converted to a time-series sampled at 10 Hz using CMetX. The new IBI time series were tapered using a Hamming window and then were submitted to FFT. We then took the natural log of the high frequency power (.12 – .4 Hz) and used it as estimate of chunk RSA
- Speed of recovery was defined by the regression slope across 10 chunks during the stress task, calculated separately for RSA and for HP, with greater positive slopes indexing stronger recovery.

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1 The first six of these 98 subjects were run using a Lead I formation (one electrode on each forearm with a ground on the left wrist), but the Lead II was then used as it produced a more consistent R-spike.

2 Five subjects were inadvertently digitized at 200 Hz.

Results

RSA and HP decreased significantly at the beginning of the stress.

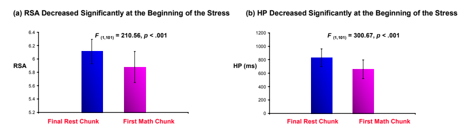

Figure 1. Compared to the last chunk at rest, both RSA and HP dropped significantly at the beginning (the first chunk) of the stress state (i.e. the arithmetic task). RSA: Respiratory Sinus Arrhythmia, HP: Heart Period. Error bars depict plus or minus 1 standard deviation.

Both RSA and HP started recovering towards baseline levels during the stress.

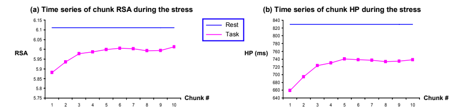

Figure 2. RSA and HP started recovering towards baseline level at later stage of the stress. The blue line represents RSA level of the last chunk during rest. The pink line indicates RSA of each chunk during the stress. RSA: Respiratory Sinus Arrhythmia, HP: Heart Period.

Greater vagal control at rest predicted faster recovery during the stress after controlling for the initial value.

$$\text{RSA regression slope} = B_0 + B_1 \times \text{RSA regression intercept} + B_2 \times \text{Resting RSA}$$

$$\text{HP regression slope} = B_0 + B_1 \times \text{HP regression intercept} + B_2 \times \text{Resting RSA}$$

Table 1. Results of Regression Analyses.

DV	*IV*	*B*	*SE*	*t*	*p*
RSA Slope	Intercept	-0.04	0.01	-6.82	<.001
	RSA	0.003	0.001	2.33	0.02
HP Slope	Intercept	-0.02	0.005	-5.22	<.001
	RSA	1.23	0.55	2.23	0.03

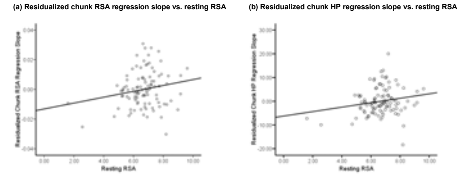

Figure 3. After accounting for the initial value (regression intercept), greater resting RSA predicted faster recovery (regression slope) for both RSA and HP during the stress. Residualized regression slopes were obtained by partialling out the influence of regression intercepts. RSA: Respiratory Sinus Arrhythmia, HP: Heart Period. Cook's distance did not exceed .163 for any subject on either metric, thus justifying retaining all subjects.

Results (cont.)

Poorer recovery was associated with lower resting cardiac vagal control and more restricted changes of cardiac reactivity during the stress.

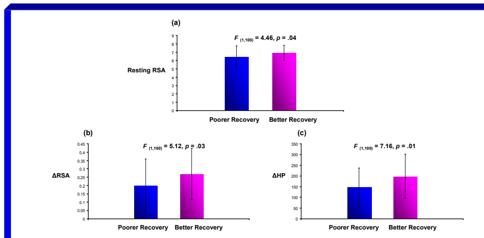

Figure 4. Compared to participants with better recovery (residualized RSA regression slope >0; N = 47), participants with poorer recovery (residualized RSA regression slope <= 0; N = 55) exhibited lower RSA (a) at rest and more restricted RSA (b) and HP (c) reactivity during stress. RSA: Respiratory Sinus Arrhythmia, HP: Heart Period. Residualized regression slopes were obtained by partialling out the influence of regression intercepts. For both RSA and HP, Δ = final chunk at rest – first during task. Error bars depict plus or minus 1 standard deviation.

Discussion

- As expected, both RSA and HP dropped at the beginning of the mental stress, which reflects increased cardiac mobilization during the mental arithmetic task.
- Both measures started recover to the baseline level even during the task. That the recovery occurred during the task may reflect participants' familiarization with the mental arithmetic procedure, decreased difficulty and increased automaticity over time, and their gradually decreased anxiety level compared to what they might feel at the beginning of the task.
- As predicted, the speed of cardiac recovery differed across participants and was predicted by individuals' baseline RSA level. Specifically, higher resting cardiac vagal control predicts faster recovery during the stress. Moreover, participants with poorer recovery in this study exhibited lower RSA at rest and more restricted changes of both RSA and HP at the beginning of the task. The results of the present study further support the notion that higher cardiac vagal control may facilitate more flexible responses during stress, which in turn may lead to long-term health benefits.

References

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