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Heart rate variability in psychosocial stress: Comparison between laboratory and real-life setting

Jakub Rajcani, Petra Solarikova, Daniela Turonova, Igor Brezina

Department of Psychology, Faculty of Arts, Comenius University, Bratislava, Slovakia

Correspondence to: Jakub Rajčáni, Department of Psychology, Faculty of Arts, Comenius University, Gondova Street Nr. 2, SK-814 99 Bratislava, Slovakia, E-MAIL: jakub.rajcani@uniba.sk

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Abstract

INTRODUCTION: Heart rate variability (HRV) is one of the important physiological biomarkers which can be used in the context of stress and also as an indicator of cardiovascular health. In this study we aim to investigate autonomic dysregulations of stress reaction previously described in both highly anxious and allergic individuals. Similarities between these two groups were reported on level of subjective perception of stress and neuroendocrine stress reaction. In autonomic nervous system, some studies documented sympathetic hyperactivity in allergy, others found enhanced vagal activation and HRV. Results in highly anxious group document mostly decrease in HRV when compared to low anxiety controls. We assume, that Heart rate and HRV can be used as tools to investigate both sympathetic and vagal induced changes in stress reaction. To assess psychophysiological changes in stress reaction both in laboratory and "real-life" we used both settings and compare the findings in this study.

METHOD: 27 subjects (aged 18–26) divided into three groups: allergy, high trait anxiety and controls participated in this study. In laboratory setting psychosocial stress test (PSST) based on simulated public speech was used. Naturalistic setting consisted of repeated measurements of ECG and assessment of subjectively experienced stress during stressful and relaxing days, which were individually chosen by each subject in relation to current events in their lives. ECG data were obtained using portable device FAROS 90°. Subjective stress measures used in both settings were methods STAI and PSS as well as simple 10-point scales of stress.

FINDINGS: In comparison between laboratory and "real-life" setting in the same sample, we found the same trends in HR, HRV measures, as well as subjective stress measures. Stress reaction in both studies resulted in increased HR and decreased HRV, however, the effect sizes in laboratory study were stronger. In both allergy and highly anxious people we found higher RMSSD and HF-HRV during stress and not during relax. These finding although not statistically significant can be interpreted in relation to autonomic dysregulation and enhanced vagal activation previously described in allergy. High anxiety group however exhibited very similar pattern to allergy group. Similarities between groups can be seen in the context of prior findings of blunted cortisol stress reaction in both groups reported by neuroendocrine studies. Anxiety and allergy group also exhibited higher values of subjectively perceived stress, when compared to controls.

Introduction

Stress is a state resulting from uncontrollable overloading demands of the environment that elicits both psychological and physiological changes. In current psychophysiological research of stress, laboratory setting is dominant form of research design. Laboratory tests like TSST (Kirschbaum *et al* 1993) have the advantage of high control over stressful stimuli and elicit a significant stress response as measured by salivary cortisol or sympathetic nervous system reactions (Kudielka *et al* 2004). In a follow up to laboratory studies, we propose monitoring of psychophysiological factors of stress in natural conditions, using repeated measurements in stressful and relaxing days during everyday life. Used design is based on existing naturalistic studies of cortisol in stress (Van Eck *et al* 1996, Scholtz *et al* 2006).

This paper aims to describe and compare findings from laboratory and naturalistic design of stress protocol in the same sample of subjects, using heart rate (HR) and heart rate variability (HRV) as psychophysiological indices of stress and vagal influence on stress reaction. Factor of subjective experience of stress is addressed using state anxiety (STAI) (Mullner *et al* 1980) in laboratory setting and perceived stress scale (PSS) (Cohen *et al* 1983) for monitoring in real life conditions.

In research of stress we currently focus on investigation of stress reactions in allergic and highly anxious people. Studies in research of allergy point to importance of stress in etiopathogenesis of allergic reactions (Suaréz *et al* 2012). People with allergies tend to exhibit psychological traits of high anxiety, depresivity, emotional lability and problems in coping with stress (Hashizune & Takigawa 2006). Yamamoto *et al* (2009) also point to increased subjective experience of stress in people with allergies and higher comorbidity of anxiety disorders. People with allergies also exhibit similar trend of blunted cortisol reactivity to stress (Buske-Kirschbaum *et al* 2002, 2010) as was found in healthy high trait anxiety individuals (Jezova *et al* 2004).

However, findings in research of autonomic nervous system (ANS) reactions of allergic and highly anxious people in stress show mixed results. While some studies documented sympathetic hyperactivity via markers of salivary alpha amylase (Buske-Kirschbaum *et al* 2002) or increased heart rate (HR) (Tran *et al* 2010). Other studies documented lowered autonomic activation in stress. Seiffert *et al* (2005) observed lowered HR increase during mental stress in adolescents with atopic dermatitis compared to healthy controls. Similarly, HRV studies of allergy shown increases in overall HRV and parameters attributed to vagal activity (Yokusoglu *et al* 2007, Boettger *et al* 2009).

On the other hand, people with high trait anxiety tend to exhibit increased HR and diminished HRV (Brosschot *et al* 2007, Miu *et al* 2009) which is in line with HRV evidence in anxiety disorders (Chalmers *et al* 2014). Other studies however found no significant difference in HR or HRV attributed to trait anxiety (Dishman *et al* 2000).

Our study aims to further elucidate the relationship between anxiety and allergy by separately assessing these factors in stressful situations in both laboratory and real life setting. We will compare changes in HR, HRV and subjective perception of stress in both settings across groups of allergic a healthy highly anxious people.

Study I

Methods

27 subjects (17 women, 10 men) aged (18–26) all pregradual university students took part in laboratory study. Subjects were assigned to one of three research groups. Allergy group was defined by allergy diagnosed by allergologist (atopic dermatitis, allergic rhinitis or allergic asthma) and occurrence of allergy symptoms for 2 years (n=8 subjects). Within the group 4 people had allergic rhinitis, 3 had both allergic rhinitis and atopic dermatitis and 1 person had atopic dermatitis. At the time of laboratory experiment none of them shown acute allergic symptoms and have not taken corticosteroid medication for at least a month nor antihistaminic medication for at least a week.

Trait anxiety was assessed using slovak version of STAI-T (Mullner *et al* 1980). Because we wanted to compare people with very high anxiety to those with very low trait anxiety (similarly to Jezova *et al* 2004), only subjects scoring over 49 in STAI-T with no history of allergic symptoms were assigned to high trait anxiety group (n=11). Control group consisted of people with no history of allergic symptoms and low trait anxiety under 39 (n=8). All of the participants were otherwise (besides allergy in allergy group) healthy and took no other medication which could influence the results.

Laboratory setting used was psychosocial stress test (PSST) (Jezova *et al* 2004) based on a simulated public speech. After 5 min. adaptation for physiological measurement (phase 1) subject was given 10 minutes to prepare a public speech on a given topic (phase 2). Given topics reflected current socially conflicting or emotionally disturbing issues (Duncko *et al* 2006). Preparation was followed by stress inducing speech task. Subjects delivered their speech in front of commission of three people, who behaved in not-supporting manner, and were asked various questions regarding general knowledge and mental arithmetic for 15 minutes (phase 3 & 4). During the test participants were also told they were being filmed by cameras and they were seeing themselves on screen. Stress test was followed by 30 minute periods of relax – being seated alone in laboratory with instruction to calm themselves (phase 5 & 6).

During the entire test ECG was measured by portable ECG device FAROS 90°. HR and HRV were analyzed from 5 minute measurements taken from each research phase. HRV analyses were done in software Lab Chart 8.0 using time-domain analysis, and also spectral analysis based on FFT algorithm. HRV analysis was carried out based on HRV methodological standards (Task Force 1996,Berntson *et al* 1997), used HRV indices were: SDNN and RMSSD from time-domain analysis and spectral indices of LF, HF and LF/HF.

Subjective experience was addressed by assessing state anxiety (STAI) prior to revealing the stressful task and immediately after the speech. In addition, participants were asked about their subjective feeling of stress on a 10-point scale at the end of the experiment. All statistical analyses were done in IBM SPSS software.

Results

For statistical assessment of within subject effect of PSST protocol and between subject effect of research group on HRV we used repeated measures model. We observed significant within subject changes in HR and HRV between phases of PSST. In HR: F=78.61; p=0.00; η^2=0.77. Mean rise of HR during public speech compared to adaptation period was by 27.14 bpm. In HRV we observed strong decreases during public speech task SDNN (F=12.28; p=0.00; η^2=0.34; largest mean difference: –24.18), RMSSD (F=20.45; p=0.00; η^2=0.46), from spectral analyses HF-HRV (F=12.33; p=0.00; η^2=0.34) and LF/HF (F=7.34; p=0.00; η^2=0.23).

Effects of research group (allergy and anxiety) were not significant in HR nor any of HRV indices. However, we observed smaller reduction of vagal indices during public speech in both allergy and anxiety, in particular in RMSSD and HF-HRV.

As with interaction between both factors of PSST phase and research group none were significant. Strongest interaction was observed in SDNN (F=1.59; p=0.15; η^2=0.12).

Differences in subjectively experienced anxiety were as follows: STAI-A before public speech and STAI-B after speech difference was significant independently of research group (F=17.19; p=0.00; η^2=0.40). However, both allergy and high anxiety group exhibited significantly higher state anxiety in both STAI-A and STAI-B (F=3.38; p=0.05; η^2=0.21). Allergy group shown highest subjectively perceived stress on a 10-point scale: (median=9), followed by anxiety group (median=7). Both significantly differed from controls (median=5) (Kruskal-Wallis: p=0.02).

Study II

Methods

The same sample of 27 participants took part in "real life" design study. Due to missing data and movement artifacts 5 participants were excluded. Research sample is similarly divided into allergy group (n=6), high anxiety group (n=10) and control group (n=6) Used ECG data and subjective assessments of stress were collected between 1/2015 and 12/2015 in several repeated measurements during everyday life. This study focuses on differences between subjectively selected stressful day and subjectively selected relax day. Subjects chose dates of these days based on evaluation of their real life stressors. Most of those were connected to work demands and overload.

In each given day, participants recorded their ECG using FAROS 90° device for 20 minutes in the morning (6:30–8:30), afternoon (14:00) and evening (20:00). Times of ECG measurements corresponded to the collection of salivary samples for cortisol analysis, which will be analyzed in different paper. Subjects were seated during measurement and at the same time they carried out psychological self-assessment using certified slovak translation of Perceived stress scale (Cohen *et al* 1983). HRV indices were analyzed from recordings using Lab Chart 8.0 by the same criteria as in laboratory study. HRV from 5 min ECG windows (morning, afternoon and evening) were averaged. All statistical analyses were done in IBM SPSS software.

Results

In "real-life" design study we used repeated measures model to compare HR and HRV during stressful and relax days across research groups. In HR we found difference between stressful and relax day (F=5.54; p=0.03; η^2=0.23) with mean HR rise by 4.38 bpm during stressful day. In HRV, although not statistically significant, there were within subject differences between research days: SDNN (F=3.60; p=0.07; η^2=0.16), RMSSD (F=3.82; p=0.07; η^2=0.17), HF-HRV (F=2.75; p=0.11; η^2=0.13). In LF/HF interaction between research group and research day was stronger than both these factors independently (F=1.45; p=0.26; η^2=0.13).

Besides these differences we found no statistically significant differences between research groups (allergy, anxiety, control). However, we observed similar trends in allergy and anxiety group in vagal parameters of HRV (HF-HRV, RMSSD). While allergy and high anxiety subjects shown almost no difference between stressful and relax days, control group had severely diminished RMSSD and HF-HRV during stressful day (see Figure 2).

In subjectively perceived stress measured by scale PSS (Cohen *et al* 1983) we found differences between stressful and relax days (F=9.53; p=0.01; η^2=0.32). Although we did not observe statistically significant differences due to research group (F=1.57; p=0.23; η^2=0.14), PSS score was higher in both allergy and high anxiety groups when compared to control group.

Discussion

Results is laboratory study show strong effect of increased HR and decreased HRV during public speech, which returns to base values during habituation phase. These results are in line with the bulk of the research data (Kudielka *et al* 2004, Ježová *et al* 2004; Reinhardt *et al* 2012) showing strong physiological response in

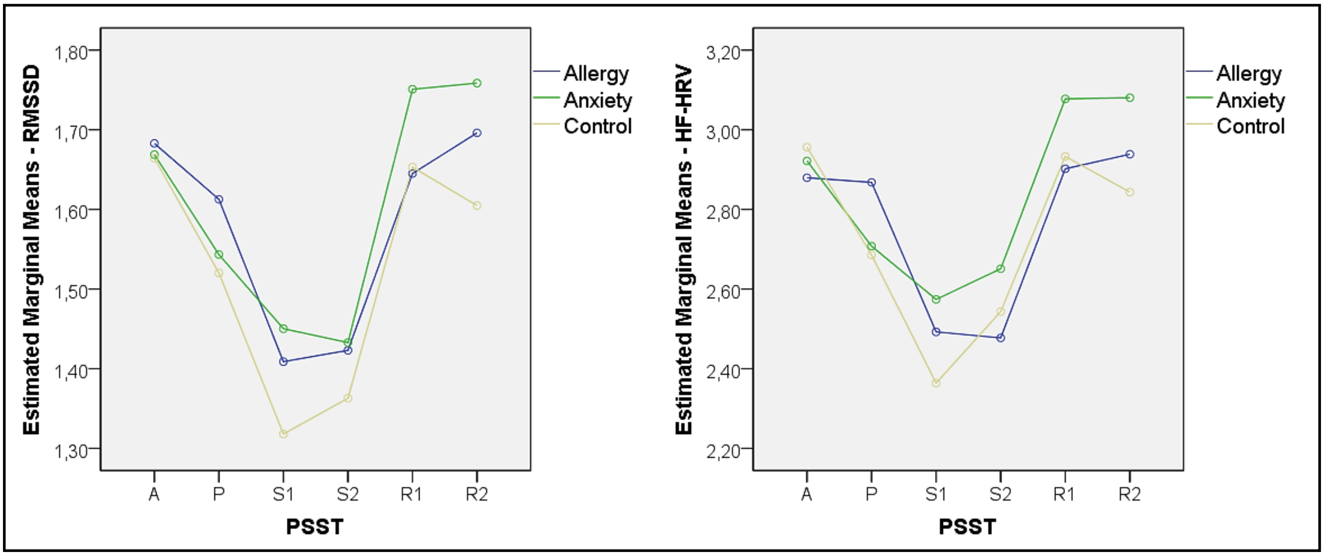

Fig. 1. HRV changes between PSST phases, comparison of allergy, anxiety and control group. (phases: A-adaptation, P-preparation, S1&S2-public speech, R1&R2-relaxation.

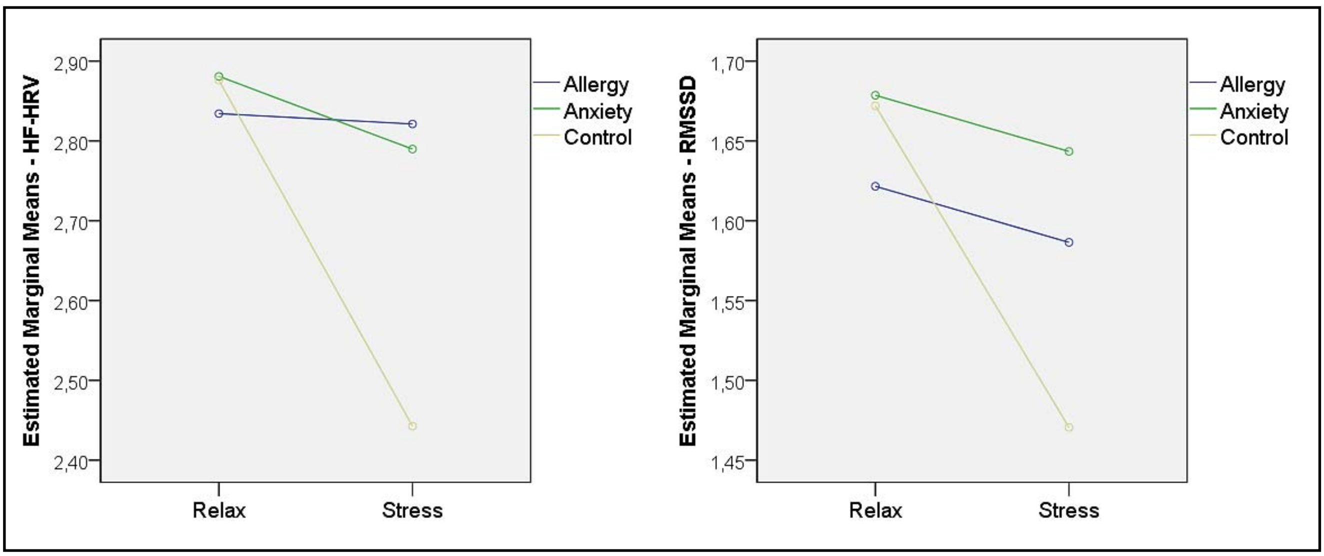

Fig. 2. Differences in vagal indices of HRV between stressful and relax day in allergy, anxiety and control group.

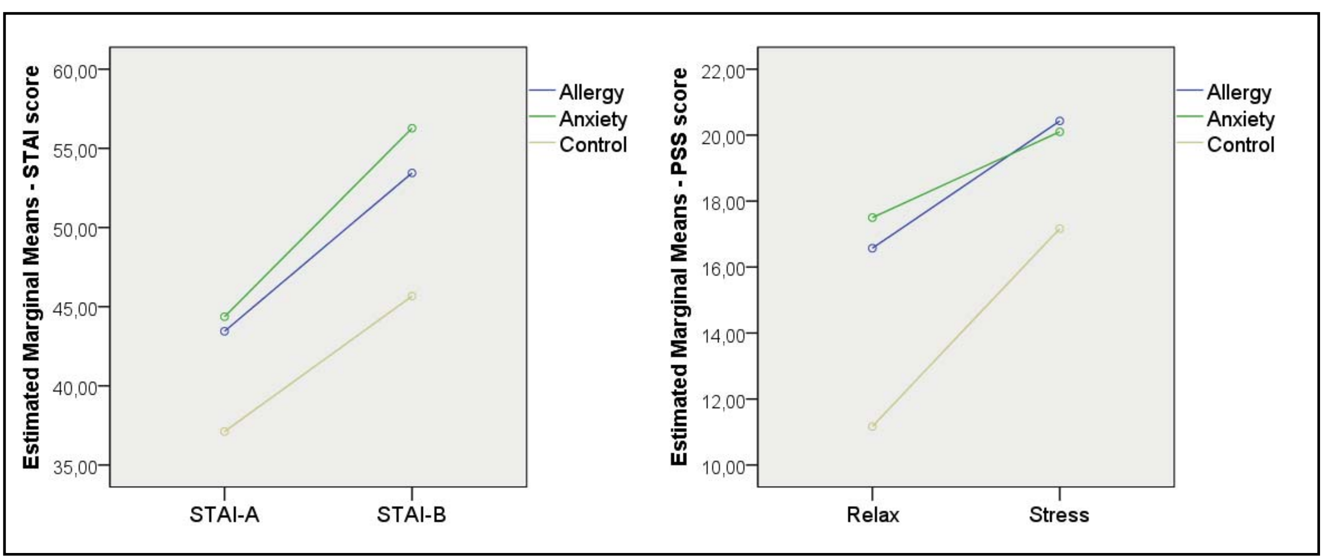

Fig. 3. Subjective measures of stress. Left: Comparison between STAI-A and STAI-B across groups (laboratory study). Right: Differences in PSS score (naturalistic study) between stressful and relax day across groups.

laboratory simulated social stress. The impact of stressful protocol is so strong, that large extent of variance in monitored variables can be ascribed to this factor. It may be due to this strong within subject factor, that smaller between subject differences were insignificant. However, we observed some differences between research groups, particularly in smaller reduction in HRV indices of vagal activity (mainly spectral HF-HRV and RMSSD) in acute stress (S1 & S2 phase). This may indicate to phenomenon of enhanced parasympathetic or lowered sympathetic activity previously described in allergy (Yokusoglu *et al* 2007, Boettger *et al* 2009). In our data, high trait anxiety subjects shown similar effect to the allergy group which again points to similarities between physiological stress reaction in the two research groups.

When assessing subjective experience of stress, all groups shown similar trend of increase of state anxiety immediately after the public speech (S2 phase). However, overall state anxiety was much higher in both allergy and high trait anxiety subjects. Both groups shown very similar values while control group show score about 10 points lower. Similarly, simple 10-point scale of perceived stress show even larger effect, with allergy group reporting strongest feeling of stress (median 9), followed by high trait anxiety group (median 7) and controls exhibiting lowest subjective perception of stress (median 5).

Study II shows the same sample of people responding to real life stressors. While in laboratory study, stress was artificially induced, here we observed the extent of stress reactions to various every day stressors. Naturalistic study serves as a follow up to laboratory study and although it is not as methodologically sound, it enables us to understand subtler stress reactions in day to day life.

Similarly, to laboratory study we also found increased HR and decreased HRV during stressful time when compared to relax. The effect is not so strong in naturalistic study; however, it shows similar trend to laboratory study. Again similarly to laboratory study, no statistically significant differences between research groups were found. However, we observed small or missing reduction of RMSSD and HF-HRV, associated predominantly with vagal activation, during stressful days. On the other hand, control group shows larger reduction in RMSSD and HF-HRV when in stress. Levels of RMSSD and HF-HRV were the same in all groups during relax. This finding corresponds to similar findings found in laboratory study, and other studies of ANS reactions in allergic or highly anxious people.

Evidence in subjective perception of stress also corresponds in both laboratory and real life study. Differences between stressful and relax days represent a difference of roughly 4–6 points of PSS score. Again we observed similar trend as in state anxiety, that allergy and high anxiety groups exhibit very similar score in both stressful and relax days. Control group scored about 7 points lower than allergy and high-anxiety group, and its mean score in stressful days is about similar to relax day score in allergy and anxiety.

Conlusions

This study demonstrates comparable effects in laboratory and real-life study of stress. We found weaker but analogical findings in stressful days during everyday life to laboratory stress protocol. Among reported observations were also smaller or missing reductions of HRV indices associated predominantly with vagal tone (RMSSD, HF-HRV) in highly trait anxious and allergy subjects during stress. Both these groups exhibited similar effect when compared to control group. Allergy and high trait anxiety group were also similar in self-assessment of experienced stress and anxiety in both laboratory and real-life setting. However, due to small number of subjects in this study we need to assess current findings in further research.

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