Using wearable technology for psychophysiological experiments.

Gender roles and cognitive appraisal impact cardiac response to socio-evaluative stress.

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***Abstract*— In this paper, we present a psychophysiological study, which uses a wearable device for the continuous collection of heart rate (HR) measures in 66 participants (53% women). We examine the impact of gender roles and cognitive appraisal on HR and HR adaptation during laboratory induced stress. We show that average values hide patterns of adaptation and advocate the use of measurements with a high granularity (e.g., at the level of the second). Using such measurements, we show that femininity, masculinity (gender roles) and threat and challenge appraisals moderate HR adaptation to stress.**

Quantified self; Connected devices; Gender roles; Cognitive appraisal; Stress

I. Introduction

A. Wearable technology in research

Advances in the miniaturization of sensors and computers allow their ubiquitous use in many areas of daily life. In particular, the use of wearable technology for clinical applications is on the rise [1]. It is now possible to unobtrusively use such technology to monitor and enhance the life of individuals [2]. Further, individuals are more and more encouraged to monitor health indicators themselves with the aim of reducing the frequency of clinical assessments and thereby slowing the increase of health care costs [3].

Some initiatives have popularized the use of wearable connected technology in studies interested in continuous measurements of HR adaptation (BPM). For instance, Jovanov and colleagues [4] have designed complex equipment composed of sensors connected to a server through a PDA for the uninterrupted collection of HR variation data allowing assessing stress during training. Yet, the recourse to such technology in heath psychology research is virtually inexistent.

In this paper, we present a HR adaptation study that relies on the Mio Alpha, a Bluetooth HR monitoring strapless device, for data collection. The device is commercially available for the general public. The Mio alpha uses a photoplethysmographic pulse rate sensor [5] for measuring HR and RR intervals continuously and unobtrusively. This study is part of a larger project aiming for a better understanding of gender differences in physiological patterns in the face of stressors. Our study is among the first in the field of health psychology to use connected wearable technology for the uninterrupted measurement of HR.

Below, we first briefly review the literature on gender differences in reactions to stressful situations – the focus of the study, before presenting our research questions and results. We finally conclude on the use of wearable technology for psychophysiological research.

B. Sex differences in physiological aspects of stress response

Stress leads to the activation of different regulatory systems of the body: the hypothalamus–pituitary–adrenal (HPA) axis and the sympatho–adrenal–medullary (SAM) axis, maintaining homeostasis, and provokes changes in immunological and cardiovascular parameters. Yet, the physiological response to stress is impacted by sex. Sex-based differences could be notably observed in cardiovascular responses [6]. An overview of recent studies [7] underlines that sex differences in unstressed condition are subtle, but after a psychological stressor they become pronounced.

The cardiovascular system is extremely responsive to various psychological and behavioral states [8]. Psychological research results show that laboratory stressors also significantly increase HR [9]. As it has been pointed out, gender difference exists in stress-related HR changes: women have higher HR at rest and larger increase during challenge [6].

Stressors that involve social-evaluative threat are the most powerful way to induce stress in the laboratory [10]. The Trier Social Stress Test (TSST) entails a social-evaluative context with uncontrollable outcomes. It is one of the most efficient standardized tools to evoke stress response in laboratory settings [11]. Usually, females experience greater HR increase when confronted with the TSST [12].

C. Sex differences in subjective aspects of stress response

Response to stress appears to be sex-specific, but the difference in stress reactivity between genders could be partially explained by subjective aspects, such as the appraisal process, consisting of primary appraisal, secondary appraisal (coping) and reappraisal [13]. Several studies conclude that sex difference in appraising situation as stressful is pronounced, women subjectively experiencing more stress than men [14].

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However, physiological differences between the sexes are diminishing [15].

On the survey side, interview and questionnaire-based studies have shown that women generally consider psychologically stressful situations as more threatful than men do, most probably because of their differentiated socialization [13]. Yet, these differences are lower now than in the past [16]. Research results on gender and coping are mixed. Males have been found to adopt more problem-focused and detachment coping whereas females use more emotional-focused and avoidance coping [17, 18].

D. Gender traits and stress response

One of the explanations for the inconsistency in differences between the sexes is the changing gender roles [16,19]. Studies have shown that gender roles – the extent to which individuals behave in traditionally masculine or feminine ways – impacts how stressful situations are appraised: women and men who are more masculine, i.e., agentic, appraise stressful situations more as challenges and less as threats than less masculine individuals. Further, masculine individuals feel they have more control on their lives, which in turn explains their less threatful reactions to stressful situations [20].

E. Research questions

Most psychophysiological studies interested in gender roles and cardiovascular stress responses make predictions only on average values. For instance, Schmid & Schmid Mast [21] tested the impact of high power (typically masculine) on the average stress response during the TSST compared to average baseline. Yet, average values can hide precious information about the way individuals differ in their reactions to stressors.

No study has investigated the relative contribution of gender traits and cognitive appraisal on temporal patterns of HR adaptation within a stressful task. Thus, the unique role of gender roles and cognitive appraisal in the initiation of arousal, and in recovery, remains unknown.

Here, we examine the impact of gender roles and cognitive appraisal on HR and HR patterns of adaptation in the laboratory.

II. Method

A. Participants

Participants were recruited at different faculties of Neuchâtel University (Switzerland) through distribution of flyers, announcement and direct contact. The study was presented as the study on verbal communication and cognitive aptitudes. Participants were rewarded with 10 Swiss francs and were offered to participate in a lottery with a valuable prize. The total sample consisted of 66 (53% women). Their mean age was 24 years (SD=5.4 years). All the participants gave written informed consent.

B. Study Protocol

Upon arrival, participants received a short description of the procedure, signed a consent form and were equipped with the Mio Alpha watch for continuous wireless transmission of HRs. A Samsung Tab 4 tablet recorded HR measures throughout the experiment. After that, participants were confronted with a modified version of the Trier Social Stress (TSST; The detailed procedure is presented below). Participants then filled in a questionnaire during the Recovery phase.

Participants were given 10 minutes to rest in order to obtain baseline HR measures (Rest phase). Participants were then told they would be requested to deliver a 5-minute speech (Verbal task) and to perform a 5-minute arithmetic task (Cognitive task). The participants performed the two tasks (the Verbal task always first) after a 7 minutes Anticipation phase, in front of the experimenter, who behaved in evaluative way: The experimenter remained neutral and did not respond emotionally, avoided eye contact and maintained a neutral attitude. During the tasks, participants' performance was videotaped. They were told that their recorded performance would be later assessed by a jury. This made the situation even more stressful.

C. Questionnaire measures

Among other measures, participants filled in the femininity and masculinity scales [22]. The femininity scale contains items such as *affectionate, understanding,* and *tender*. The masculinity scale contains items such as *dominant, strong personality*, and *willing to take a stand*. Participants also filled in the stress appraisal measure for both tasks separately [23]. Here we use the threat (e.g., *I feel anxious about the task*) and challenge appraisal (e.g., *I am excited about the outcome of the task*) measures. All scales had a good reliability (all alphas > .71).

D. Groups of high and low scoring participants

For the visualization of differentiated patterns of arousal (see sub-section B below), we created groups with participants scoring extremely low and extremely high on each dimension, separately. For each dimension the low scoring group was composed of participants with a score lower than the average of all participants on the considered dimension, minus the standard deviation. Reversely, the average plus the standard deviation was used as a threshold for composing the group of participants with a high score. The number of participants by group is as follows: Low Femininity: 10 participants, High Femininity: 12; Low Masculinity: 10, High Masculinity: 10; Low Threat Appraisal: 14, High Threat appraisal: 9; Low Challenge appraisal: 13, High Challenge appraisal: 11.

III. Results

A. Manipulation check

The TSST elicited the expected changes in the HR of the participants. As displayed on Table 1 below, participants had a higher HR in the Anticipation phase, the Verbal task phase and the Cognitive task phase, compared with the Rest phase (intercept). They had a lower HR in the Recovery phase compared with the Rest phase.

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TABLE 1

MIXED-EFFECTS ANALYSIS OF DIFFERENCES BETWEEN THE TSST PHASES (DV: HR AVERAGED WITHIN PHASE) WITH UPPER AND LOWER BOUNDS (95% C.I.)

	B	Lower Bound	Upper Bound
Intercept	90.924*	75.361	106.487
Sex	0.188	-6.223	6.598
Age	-0.278	-0.873	0.317
Anticipation	3.824*	1.599	6.051
Verbal task	9.071*	6.856	11.287
Cognitive task	7.034*	4.819	9.250
Recovery	-2.984*	-5.209	-0.756

*: $p < .05$

B. *Patterns of arousal at at the minute level (within phase)*

Figure 1 below presents the patterns of HR adaptation during the TSST. Rest, Anticipation and Recovery phases are cropped to 5 minutes for this plot. Most interestingly, there is an average increase of 16 beats per minute at the onset of the Verbal task, compared to the Rest phase. HR then decreases sharply and reaches the average of the anticipation phase by minute 5.

We briefly mention that gender roles and cognitive appraisal are non-significant predictors of HR at the minute and phase levels. For space reasons, we do not present the results of these analyses.

IMPACT OF GENDER ROLES AND COGNITIVE APPRAISAL ON HR DURING THE FIRST MINUTE OF THE VERBAL TASK

Here, we examine the impact of gender roles and cognitive appraisal on the heart adaptation pattern of the verbal task, during its first minute, i.e., when the participants start the task. The average pattern for the Verbal task is shown on figure 2 (left panel). HR increases sharply between the first and 30th second, then stabilizes and begins to decline by second by the 40th second.

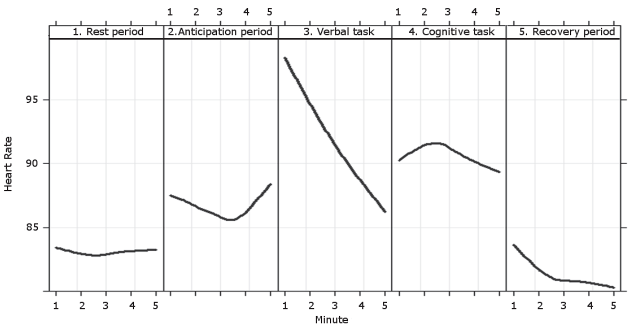

Figure 1. Global patterns of HR adaptation during the TSST.

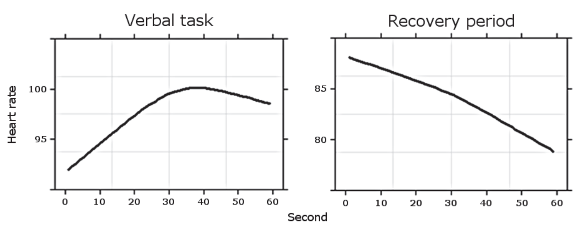

Figure 2. Local pattern of HR adaptation, by second during the Verbal Task and Recovery phase (first minute)

In the analysis in Table 2 (under Verbal task) we regressed HR during the first minute of the verbal task on gender roles (Femininity and Masculinity) and cognitive appraisal (Threat and Challenge appraisals). We also included time (Second) as a predictor as well as its interaction with all mentioned variables. The analyses are controlled for Gender and Age. Note that part of variance at the level of the participants was 82% in the null model (ICC1 = .817).

TABLE 2

MIXED-EFFECTS ANALYSIS OF PATTERNS OF AROUSAL IN THE VERBAL TASK AND THE RECOVERY PHASE OF THE TSST WITH UPPER AND LOWER BOUNDS (95% C.I.)

	Verbal task			Recovery Period		
	B	Lower Bound	Upper Bound	B	Lower Bound	Upper Bound
Intercept	86.670*	37.577	135.764	63.443*	26.740	100.14
Sex	-5.080	-14.269	4.110	1.435	-5.559	8.429
Age	-0.649	-1.450	0.152	-0.040	-0.635	0.556
Masculinity	-3.810	-11.432	3.812	1.175	-4.588	6.938
Femininity	6.655	-1.935	15.245	5.523	-0.900	11.946
Challenge	4.788*	0.425	9.150	1.725	-1.606	5.057
Threat	-2.138	-6.885	2.609	-2.503	-6.269	1.262
Second	2.417*	1.884	2.950	0.919*	0.447	1.392
Second Sq.	-0.038*	-0.046	-0.029	-0.019*	-0.027	-0.012
Mas.xSec	0.019	-0.079	0.118	-0.120*	-0.208	-0.032
Fem.xSec	-0.319*	-0.430	-0.209	-0.100*	-0.198	-0.002
Chal.xSec	-0.244*	-0.299	-0.188	-0.055*	-0.107	-0.004
Thr.xSec	0.066*	0.008	0.125	0.019	-0.035	0.073
Mas.xSecSq	0.000	-0.001	0.002	0.002*	0.001	0.004
Fem.xSecSq	0.005*	0.003	0.006	0.001	0.000	0.003
Chal.xSecSq	0.004*	0.003	0.004	0.001	0.000	0.001
Thr.xSecSq	-0.001	-0.002	0.000	0.000	0.000	0.001

*: $p < .05$

Higher challenge appraisal of the Verbal task resulted in higher HR during the task, which is consistent with [24]. We also found significant linear (variable Second) and quadratic trends (variable Second squared) in HR adaptation as a function of time during the verbal task.

Significant interactions between time and most predictors show that the linear temporal adaptation of HR during the first minute of the Verbal task is conditionnally dependant upon gender roles and cognitive appraisal. Significant interaction between Second squared and Femininity as well as challenge shows that the quadratic effect of time on HR is also conditionally dependent upon these predictors.

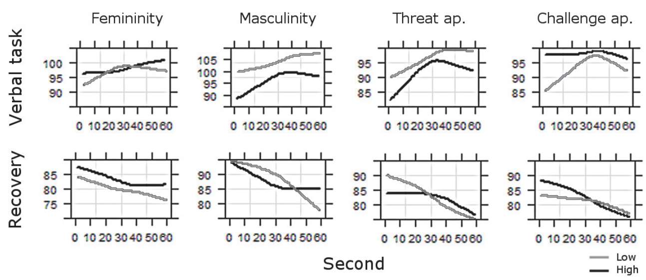

Figure 3. Impact of gender roles and cognitive appraisal on local pattern of HR adaptation during the Verbal Task and the Recovery phase (first minute)

The impact of gender roles and cognitive appraisal on HR adaptation during the first minute of the Verbal task is further displayed in Figure 3 (top panel) and can be compared to the average values over the whole sample (Figure 2).

Impact of gender roles and cognitive appraisal on HR during the first minute of the Recovery phase

The average pattern of HR adaptation during the first minute of the Recovery phase is displayed in Figure 2 (right panel). During this time, HR decreases approximately by 10 BPM. How do gender roles and cognitive appraisal impact this decrease? Results of an analysis similar to the one described in C. are presented in Table 2 (ICC1 = 0.759). We found no main effects except the linear and quadratic effects of time. Femininity, masculinity and challenge appraisal moderated the linear decrease of HR during the first minute of the Recovery phase. The quadratic effect of time is further conditionally dependent on masculinity. Figure 3 (bottom panel) displays these differentiated patterns of HR adaptation.

IV. Conclusion

We examined whether HR and HR adaptation were affected by gender roles and cognitive appraisal. Challenge appraisal increased HR in our mixed-model analyses with seconds as analysis units. Gender roles and cognitive appraisal impacted patterns of adaptation (second-by-second) during and after stressful tasks. There were no main effects of these at the task and minute levels. This speaks in favor of a higher granularity of measures HR studies in health psychology, where baseline and task average values are used in most research.

Continuous measures of HR previously came at a high cost. Wearable products such as the Mio Alpha watch coupled with a Bluetooth SMART compatible smartphone or tablet render the access to such measure inexpensive. Further, these devices afford making use of the measures in almost every setting, allowing to increase the ecological validity of studies in the psychophysiology of stress.

Further studies relating gender traits to physiological measures in the face of stressors are necessary in order to better understand the causes of the higher morbidity that is robustly observed in women compared to men [25].

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