Stress interface inducer, a way to generate stress in laboratory conditions

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Introduction

Behavioral studies carried out in the laboratory are often confronted by the issue of generating stimuli for cognitive states. This study proposes a framework for stimulating stress in the laboratory in order to collect data under controlled conditions.

Stress research may be divided into two main categories (acute vs. chronic) related to the temporality of the stressor [1]. Acute stressors are the ones which are presented for a duration of some minutes while chronic stressors are presented for weeks [2] Our paper concerns the elicitation of acute stress under laboratory conditions. In order to justify the different choices made for the conception of the stress interface inducer (SII), a short literature review concerning the theories and the methodologies used in stress researches is initially provided. Then, the development of SII and the relevant protocol are described. Finally, the results of one experiment are presented.

1. Stress: literature review

The versatility of the term stress is so wide that some authors like Stoke and Kite [3] argued about its usefulness as a scientific term. Tepas et al. [4] pointed out for instance that the term stress is often associated with a variety of constructs like: adaptation, anxiety, arousal, burnout, coping, exertion, exhaustion, exposure, fatigue, difficulty, mental load, repetitiveness, strain, stressor, and tension. The vagueness of the term stress is a consequence of its adoption in a variety of research domains that range from organizational studies to psychiatry. Not surprisingly, even at a theoretical level, no agreement can be found concerning the phenomenon of stress. In search of simplicity the different theories are often grouped into 3 main categories: the response-based models, the stimulus-based models and the interactional models. Response-based models see stress as a cluster of psychological and physiological responses in reply to a challenging situation. This approach focuses on the consequences of the stress and is represented by authors like Selye [5] who introduced the notion of General Adaptation Syndrome to describe the three stages of the body resistance to prolonged stress. Stimulus-based models, on the other hand, focus on the events that cause a stress response. In particular, they analyze the characteristics that a stimulus must possess in order to provoke stress. Three of these main characteristics are overload, conflict and uncontrollability. Stimulus-based researchers like Ivancevich and Matteson [6] have studied the influence of limited time and high performance standard on work overload. The transactional models see stress as a unbalance between environmental demands and individual resources. According to this view, stress responses are created when a threat is perceived and the individual is unable to cope with it. Probably the most influential model of the transactional approach is the one proposed by Lazarus [7]. This model is characterized by two stages of appraisal. In the primary appraisal, the subject evaluates if the situation represents an actual threat (i.e. is “relevant to” and is “conflictive with” the individual’s goals). In the secondary appraisal, the individual evaluates the resources available to face the threat and decide the coping strategies.

2. Stress Measurements

In order to identify the theoretical framework and the way to elicit stress in our participants, we focused on the subjective and objective measurements of stress. Concerning the subjective measurements of stress, we decided to adopt two standard questionnaires used in stress studies (see Method - *Subjective measurement)*. Regarding the objective measurements, a significant numbers of articles investigating the links between stress and physiological responses have demonstrated that provocation of punctual stress causes physiological responses in individuals. Such responses may be modifications and variability of heart rate, modifications breathing rate, blood pressure and galvanic skin activity [8]. For example, Shi *et al.* [9] shows a strong correlation between

stress levels and electrodermal activity (EDA). Pickering *et al.* [8] shows that blood pressure increases at the same time as stress. Healey *et al.* [10] shows a correlation between breathing rate and stress levels. Sierra De Santos *et al.* [11] shows the relevance of measuring stress by measurements of electrodermal and heart activity (95% recognition rate). Lastly, Partala *et al.* [12] demonstrates that there is a link between pupil activity (dilation and constriction) and stress.

Method

1. *Material*

The variety of theoretical frameworks that investigate stress is reflected in the amount of paradigms adopted to elicit the feeling of stress in a laboratory. A multitude of stressful tasks has been proposed ranging from simple tracking tasks [13] to more complex methods like the Montreal Imaging Stress Task [14] or software like GASICA [2]. Some of these tasks tend to produce stress exploiting social reaction. A typical example of such task is the "Trier Social Stress Test" [15] in which participants are asked to perform a short speech in front of an audience. Other experimental paradigms rely on the unbalance between task and resources to cause stress. The most common paradigms which are used to obtain such unbalances are based on the presence of a secondary interfering task [16] or on temporal constraints. This last was the option chosen to provoke a stress response in our participants. Our experimental design, in fact, is based on the procedure proposed by Campbell [17] to investigate the effect of time on simple mathematical operations. Thereby, we created stressful situations where individuals had to carry out additions under time pressure. 3 conditions were created:

- *Condition 1 - Time to response is large*: participants had to answer following a beep sound occurring 2650ms after the calculation was presented.

- *Condition 2 - Time to response decreases across trial*: participants had to answer before a beep sound. This beep occurred 2650ms after the calculation was presented for the first trial and was reduced to 900ms for the last trial. At each trial, time before the beep sound decreased by 50ms.

- *Condition 3 - Time to response is short*: participants had to answer before a beep sound and the beep occurred 900ms after the calculation was presented.

For each experimental condition, there were 36 trials (3 conditions: 108 trials per participant). Each trial consisted of a simple mathematical sum, such as "2+7" or "5+8". Lastly, to expose the stressful situation to participants, we developed a software program with the following characteristics: display user instructions, displays randomly additions with several response times (i.e. level of time pressure), makes a beep at each trial after a delay fixed by preset conditions (i.e. level of time pressure) and saves performance data (success/error and response times) for each trial.

2. *Physiological measurement*

The following physiological indexes were measured: cardiac, respiratory and electrodermal responses, and eye-tracking data. Biopac Bionomadix MP150 was used to measure physiological responses. SMI glasses 2 60Hz were used to record eye tracking data.

We used the following indexes to test the effect of conditions on physiological data: electrodermal activities (EDA), heart rate activities (ECG RR / ECG R Wave) and respiration activities (Respiratory Rate). For each index, we computed the mean by condition.

3. *Subjective measurement*

After each condition (i.e. 36 trials), participants filled out two standardized scales to evaluate the effect of induced stress on subjective feeling: The first questionnaire is the Short Stress State Questionnaire (SSSQ) [18] that evaluates 3 aspects of the feeling of stress (Engagement, Distress and Worry). The SSSQ is actually a

simplified version of the original Dundee Stress State Questionnaire [19]. The second questionnaire is the Raw-TLX (RTLX), a simplified version of the NASA Task Load Index [20] that has proved to perform comparably to the original version [21]. The RTLX assesses the perceived workload of a task as a simple (unweighted) sum of 6 dimensions (mental demand, physical demand, temporal demand, performance, effort, and frustration). The choice of these 2 questionnaires allows us to assess different aspects of the feeling of stress in our participants.

4. Participants

24 participants took part in the study and received in exchange a coupon for €15. All participants signed up with informed consent before beginning the experimental procedure and were informed about the goals of the study, procedures, cautions and ethical issues for the participation in the study.

5. Procedure

The following procedure was used during the experiment (see figure 1): before starting calculation, a baseline for physiological measurement is recorded. After, participants start calculation and pass all the 3 conditions (within-subject design). Between each condition, a break is observed to reduce stress levels. To avoid order effect, the presentation of condition is counterbalanced and the presentation of the calculations is randomized.

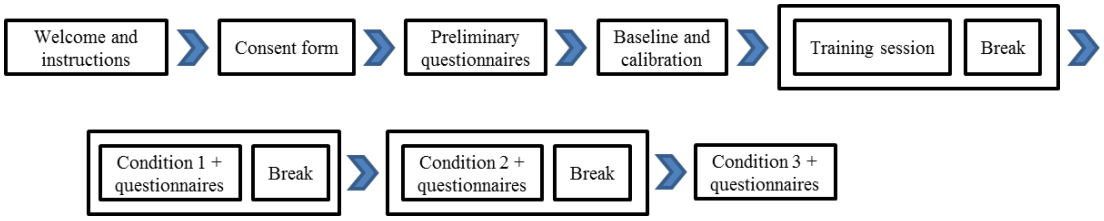

Figure 1. Experimental procedure

Results

We tested the influence of the experimental conditions (i.e. condition 1: long response time, condition 2: response time reducing over time and condition 3: short response time) on subjective and physiological data. Since all conditions were presented to each participant (within-subject design), we used a statistical method that takes into account non-independence to analyze data: a mixed model (also called random effect model) [22]. Mixed models are used because they offer more flexibility and robustness in modeling than repeated ANOVA [23]. Technically, to take into account individual variability and correlation between data, flexibility on intercept is added by including a random parameter (u_{0j}) in the regression equation (see equation 1). Thereby, variability between participants (e.g. personal sensibility to mental exigence) is integrated into the modeling. Since the condition variable (treated with dummy variables) in our experiment is categorical (i.e. the 3 experimental conditions), this equation (see equation 1) is used in our analyses for each dependent variable (DV). In equation 1, Y corresponds to the DV. Subscript j corresponds to the participant and subscript i to an observation nested in a participant. Coefficient β_0 correspond to the intercept (i.e. corresponding to condition 1) and u_{0j} to the coefficient applied to β_0 for each subject. β_1 and β_2 correspond to coefficients activated for conditions 2 and 3 (since the modalities of variable condition are treated as dummy variables). $\boldsymbol{\varepsilon}_{ij}$ corresponding to the term error for observations and participants.

Equation 1

$$Y_{ij} = (\beta_0 + u_{0j}) + \beta_1 Condition2 + \beta_2 Condition3 + \varepsilon_{ij}$$

Figure 2 gives an illustration of used mixed model. We plotted the prediction of a regression including a random intercept.

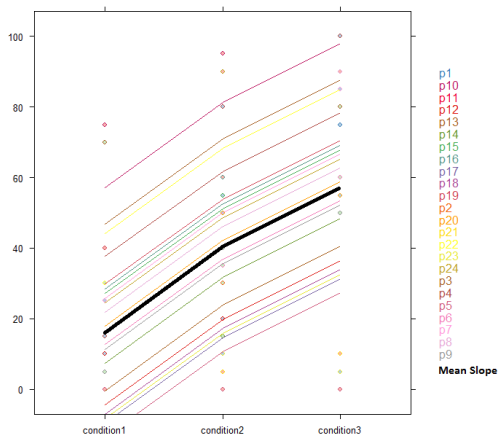

Figure 2. Plot of used mixed model. Bold line indicates the mean effect and colored lines indicate predictions for each participant.

For assessing the effect of a variable in the mixed model, comparison of models is used [24]. Technically, we computed a first model including only random effect (to take into account correlation between data acquired from the same individual). After, we computed a second model including the variable condition. We compared their deviances: these results are presented in Table 2 and Table 4. Lastly, we computed multiple comparisons between conditions.

1. *Subjective measurement*

Table 1 presents descriptive statistics for subjective measurement. Comparisons of models showed significant differences (see table 2) for all dimensions of RTLX. More precisely, comparison between conditions indicated significant difference between condition 1 (i.e. long response time) and condition 2 (i.e. response time decreasing over time) but also between condition 1 and condition 3 (i.e. short response time) for all RTLX dimensions. For SSSQ, only distress is evaluated as significantly different between conditions.

Table 1. Descriptive statistics (Mean and Standard Deviation) for subjective measurement

Scale	**Variable**	**Condition 1**		**Condition 2**		**Condition 3**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
RTLX	Mental demand	16.46	19.86	40.62	29.09	57.29	36.77
	Physical demand	13.54	17.16	30.21	29.06	38.54	32.01
	Temporal demand	22.50	26.91	66.67	19.21	78.12	19.10
	Effort	18.75	23.69	55.00	26.25	68.96	24.14
	Performance	21.25	19.80	50.62	23.83	66.46	23.01
	Frustration	19.38	15.90	39.17	21.35	60.42	22.89
SSSQ	Engagement	30.12	5.79	30.17	4.84	29.38	4.75
	Worry	13.04	4.64	12.17	4.39	13.79	5.35
	Distress	10.00	1.67	13.71	4.33	16.29	6.48

Table 2. Comparison of models between conditions

Scale	**Variable**	**Chi-square**	**p-value**	**Condition 1 - Condition 2**	**Condition 1- Condition 3**	**Condition 2- Condition 3**
RTLX	Mental demand	χ^2 (2) = 35.73	<.001	z = 4.24***	z = 7.17***	z = 2.93**
	Physical demand	χ^2 (2) = 19.81	<.001	z = 3.26**	z = 4.89**	z = 1.63 NS
	Temporal demand	χ^2 (2) = 52.75	<.001	z = 8.44***	z = 10.63***	z =2.19 NS
	Effort	χ^2 (2) = 55.56	<.001	z = 7.81***	z = 10.82***	z = 3.01**

	Performance	χ^2 (2) = 46.59	<.001	z = 5.79***	z = 8.91***	z = 3.12**
	Frustration	χ^2 (2) = 54.55	<.001	z = 4.76***	z = 9.87***	z = 5.11***
SSSQ	Engagement	χ^2 (2) = .92	.34	z = .05 NS	z = -.95 NS	z = -1.00 NS
	Worry	χ^2 (2) = .72	.40	z = -1.00 NS	z = .86 NS	z = 1.85 NS
	Distress	χ^2 (2) = 30.03	<.001	z = 3.75***	z = 6.35***	z = 2.61**

*Signifiant codes: ***: p<.001; **: p<.0.01; *: p<.0.05; NS : Non-Signifiant*

2. Physiological measurement

Table 3 presents descriptive statistics for physiological measurement. Comparison of models showed significant differences (see table 4) for EDA and Respiratory Rate. More precisely, significant differences appear between condition 1 and 2 but also between condition 1 and 3 for EDA and Respiratory rate. Currently, the valuable eye-tracking data is not presented in this document, but it will presented in a future paper.

Table 3. Descriptive statistics for subjective measurement

Variable	Condition 1		Condition 2		Condition 3	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
EDA	.47	.03	.49	.04	.49	.04
ECG RR	.35	.26	.32	.28	.34	.27
Respiratory Rate	.34	.24	.26	.22	.24	.18
ECG R Wave	.32	.24	.31	.26	.33	.26

Table 4. Comparison of model between conditions

Variable	Chi-square	p-value	Condition 1-Condition 2	Condition 1-Condition 3	Condition 2-Condition 3
EDA	χ^2 (2) = 7.70	<.001	z = .02 *	z = .01 *	z = -.31 NS
ECG RR	χ^2 (2) = 1.21	.54	z = -1.08 NS	z = -.41 NS	z = .66 NS
Respiratory Rate	χ^2 (2) = 19.60	<.001	z = -3.63 ***	z = -4.56 ***	z = -.93 NS
ECG RWave	χ^2 (2) = .75	.69	z = -.63 NS	z = .18 NS	z = .81 NS

Conclusion

Capacities of SSI to generate stress have been confirmed by subjective and objective measurements. Results show significant differences between low stress conditions and high stress conditions, for all dimensions of RTLX, and for the distress dimension on SSSQ. Differences were also found between the stress conditions on physiological data (ECG RR and Respiratory Rate).

Futures works will focus on data extraction and treatment of physiological data recorded for this study, with the objective to develop a recognition system of stress based on machine learning. Indeed, this SSI offers the possibility to measure physiological data during stressful situation. Moreover, the capacities of SSI make it possible to modify the method of stimulating stress by imposing time constraints or cognitive tasks. The results presented were obtained by imposing time constraints; the next step will be to induce stress by imposing cognitive tasks on the individuals with the aim of exploring eventual specific physiological patterns. Another use of this application could be as a tool for stress sensor benchmarking.

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