

Controlled Game-Based Stress Manipulation

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Introduction

The goal of the research project presented in this paper is two-fold. First, we want to conduct fundamental research into the manipulation of stress using digital games, to which end we will construct an experimental set-up utilizing an adaptive digital game as a stressor. Second, we want to utilize this set-up to gain insight into the effects of different levels of stress on the fronto-striatal circuits of the brain (FSC). This insight is expected to contribute to the development of novel treatments of stress-related symptoms associated with disorders of the FSC¹. Currently the project is in the first phase in which we pursue the first goal; fundamental research into stress manipulation. This is done by constructing and evaluating an experimental set-up allowing controlled manipulation of stress presented to human individuals by means of an adaptive digital game. To this end we first reviewed which biosignals and corresponding measurements met the requirements to be usable in our set-up. Next we conducted a meta-analysis analyzing which digital game and study methodology characteristics are related to the stressor function of a digital game. Finally, based on the data from both the review and meta-analysis, we are currently constructing a feedback model that automatically regulates the level of stress presented in the set-up, depending on a particular desired level. This is achieved by utilizing the continuous measurement of the player's stress related biosignals, comparing these signals with the desired level of stress and real-time adaptation of the digital game characteristics. In this paper, we will briefly discuss some of the underlying assumptions in the project, the main components of the experimental set-up that will be constructed and the current status of the project.

Stress and Gaming

In order to capture the diverse stressor characteristics a digital game can present and because the physiological stress response is the most prominent response in our set-up, we use a broad and physiologically-based definition. In our research stress is considered as any stimulus, internal or external, that presents a (perceived) challenge to the homeostasis of a biological system and the stress response, either physiological, psychological and/or behavioural, aimed at restoration or maintenance of the homeostasis (cf. Newport and Nemeroff (2002), [4]). The stimulus presenting the challenge to the homeostasis will be referred to as the stressor and the response to this challenge as the stress response. Moreover, we refer to variables influencing the relation between the stressor and stress response, such as age or gender, as intervening variables. In general, stressors can range from physical stimulation, such as a cold pressor task where participants place their hands in an ice water container, to psychological stressors, such as the performance of a public speech [3,5]. Physiological stress responses pertain to biosignals, such as cortisol levels, heart rate variability and electrodermal activity; psychological stress responses include alterations in affect and cognition, such as aggression and hostility.

Games have consistently been proven capable of eliciting both physiological and psychological stress responses (for example, see [1] and [2]). As we aim at real-time manipulations of the stressor, a digital game is a very suited stressor since it allows for real-time adaptations of the stressor parameters (without the participant directly noticing), which is harder in other stressor modes such as video, images or speaking tasks. Furthermore it is very flexible: we can present different stressor types such as aversiveness and social-evaluative threat through one construct, broadening our range of possible manipulations. Key elements in digital games are players, (inter)action, environment, goals and rules. An advantage of digital games is that many, or even all, of the key elements can be taken over by computer technology. A computer may simulate (parts of) the game environment,

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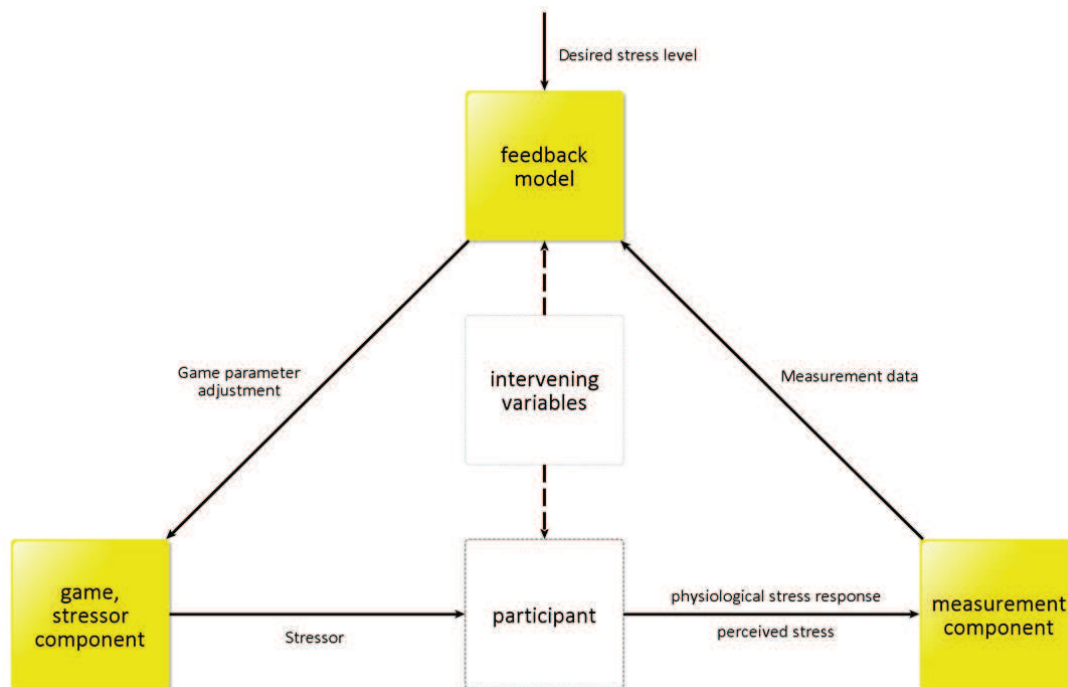


Figure 1. Overview of the set-up.

the interaction or even one or more players. Just like conventional games, digital games may offer various types of challenge that simulate the performance of particular activities, ranging from physical and mental activities (e.g. hitting another player, taking business decisions) to inactivity, such as meditation and relaxation for a particular period of time. In our project, we assume that only a particular set of game characteristics present a challenge for the homeostasis of the player and, therefore, function as a physiological or psychological stressor that causes a particular stress response.

Set-up

As depicted in Figure , the set-up we are constructing consists of three components. The first component, the digital game, represents the stressor and is presented by the lower left square. The second component, depicted by the lower right square, is the measurement component, which consists of a set of measurement devices continuously measuring diverse biosignals for detection of the stress responses and the perceived stress indicated by the participant². The third component, that is the top square, depicts the feedback model. The model takes the current stress state of the participant in the form of the values of different biosignals and perceived stress, together with the desired level of stress, and adjusts the game characteristics based on this information. For example, when the measured values of the biosignals and perceived stress indicate that the participant is more stressed than the desired stress level, the game characteristics are adjusted in such a way that relieves the intensity of the stressor, hereby relieving the stress response in the participant. Throughout this process of manipulating the stress state of the participant we consistently safeguard the coherence between the stressor and stress response by using models of the underlying stress systems and by controlling for the relevant intervening variables for the specific stressor-stress response relations (i.e. variables influencing this relation, such as gender, psychological, age or psychological factors such as neuroticism), based on these underlying models.

² Perceived stress is included in the measurements to further investigate the relations between physiological stress responses and perceived stress. Since perceived stress is only one of the many signals being used as input, the unwanted phenomenon where participants infer the effects the reported perceived stress has on the game parameters are very slim.

The benefits from this set-up are manifold:

- By allowing continuous control and manipulation of the stressor in a real-time feedback loop different types of stress research can benefit from this set-up. Examples include research into prolonged stress exposure in which case the stressor can be adjusted to present a constant stressor over time, or memory and cognition research where data can be gathered in an extremely controlled environment.
- The set-up may be useful for stress therapy containing exposure to stressful stimuli, for example, such as used in certain Post Traumatic Stress Disorder (PTSD) therapies, since the presentation of stressors can now be manipulated and controlled to a far greater extent than was previously possible.
- The set-up elaborates on existing Brain-Computer-Interfaces (BCI's), since the set-up already contains the essential components of a BCI, it can be easily adapted to be incorporated in existing BCI's, giving essential information regarding the current stress state of the user.
- Gaming industry can utilize the set-up to for sensing of stress responses and automatic adjustment of game parameters to maximize the user experience, immersion and flow of the player.

Status of the project

We have first focused on the measurement component by determining the requirements on the biosignals and the corresponding measurements that need to be met in order for these signals to be usable in our set-up. These requirements are the following. First, the biosignals must respond to the stressor consistently over repeated trials, both quantitatively and temporally. Second, the measurement technique and the corresponding biosignal have to show low response latency, meaning that a change in stressor intensity should be reflected in a biosignal without too much time delay. Third, in order to have continuous insight into the stress state of the participant, the measurement should be applied continuously or at least as frequent as necessary for real-time adaptation by the feedback model. Fourth, the measurement should not induce an additional stress response or disturb the experiment. The fifth requirement is not a requirement on the set-up per se, but is needed because in the second phase of the research we will utilize this set-up to gain insight into the effect of different levels of stressor intensity on the fronto-striatal circuit of the brain (FSC) by using the set-up in combination with fMRI. Therefore, the fifth requirement is that the measurement must be applicable inside fMRI. From this set of requirements it follows, for instance, that measuring cortisol levels falls outside the range of measurable stress responses, because the signal often responds inconsistently and shows large time delays of about 20-40 minutes to a particular stressor. Stress response measures which will be used in our research are, for instance, heart rate and heart rate variability, blood pressure, electrodermal activity and electroencephalographic measures. Secondly we have looked at the stressor component to determine the relevant digital game characteristics for eliciting stress responses. To this end, we have conducted a meta-analysis on 59 studies utilizing a digital game stressor and measuring stress responses. The initial analyses show that several specific digital game characteristics such as the level of aversiveness, the level of realism and diverse methodological characteristics such as the data reduction method and baseline measurement type were found to be significant moderators of stress responses such as heart rate and blood pressure.

Currently we are finishing the meta-analysis and constructing the feedback model based on the results found in the analysis. For this feedback model we use the multiple linear regression model constructed in the meta-analysis, hereby utilizing the gathered data of a large body of studies to infer the relations between game characteristics and stress responses. It will be the first time that the adaptations in an adaptive stressor game will be based on such a detailed and extensive meta-analysis on game characteristics, as such an analysis has not been done before. This method provides added value, since it allows to create a more effective stressor and allows for the modelling of very specific relations between game characteristics and physiological stress responses. For example, the impact of the level of aversiveness in the digital game on heart rate is independently modelled of the impact of this characteristic on the other responses such as electrodermal activity.

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