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Can architectural design alter the physiological reaction to psychosocial stress? A virtual TSST experiment

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HIGHLIGHTS

- Stress reactions were induced with virtual reality TSST.
- Openness versus enclosure of the virtual space influenced the level of cortisol.
- Design of architectural space might influence stress response.

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ABSTRACT

Is has long been established, that views to natural scenes can a have a dampening effect on physiological stress responses. However, as people in Europe, Canada and North America today spent 50–85% of their time indoors, attention might also be paid to how the artificial man-made indoor environment influences these mechanisms. The question that this study attempts to start addressing is therefore whether certain design, characteristics of indoor spaces can make a difference to the physiological stress response as well. Using a virtual version of the Trier Social Stress Test, in which the space is computer generated and properties of the space therefore can be systematically varied, we measured saliva cortisol and heart rate variability in participants in a closed room versus a room with openings. As shown by a significant linear contrast interaction between groups and TSST conditions, participants in the closed room responded with more pronounced cortisol reactivity to stress induction, and continued to show higher levels throughout recovery, compared to participants in the open room. No differences were found regarding any part of the autonomic nervous system.

1. Introduction

It has long been established that views to natural scenes can have a positive restorative effect on the human physiology compared to urban scenes. A prominent example could be the paper by Roger Ulrich published in Science in 1984, demonstrating that views to nature influence recovery from surgery [1]. Very early on in its development, this line of research has targeted the issue of stress and demonstrated that the view to nature compared to urban scenes exercises a pronounced influence on the human stress systems [2]. Today, science keeps expanding our insight into the underlying mechanisms of the complex matter [3] which seems to gain in importance as stress is, increasingly, recognized as a major health problem within western societies, yearly affecting approx. 41 million people within the EU [4]. However, the fact that

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people in Europe, Canada, and North America today spend 50–85% of their time indoors [5,6], attention might also be paid to the artificial man-made indoor environment itself. Therefore, the question that this study attempts to start addressing is whether certain design characteristics of the artificial in-door environment can make a difference concerning how the stress systems are affected physiologically. We took the classical fight-or-flight behavior as a point of departure, as it, since the days of Walter B. Cannon, has been considered the most basic adaptive behavior to stress [7]. The modern conception still is that the purpose of the activation of the stress effector systems, the sympatho-adrenomedullary (SAM) system, and the hypothalamic–pituitary–adrenal (HPA) axis, is to prepare the organism to such behavior. This is done through the release of stored energy resources, the increase of blood pressure, heart rate and respiration, and the suppression of energy consuming processes that are not temporarily needed such as feeding and digestion, sexual behavior, and the specific immune system [8,9]. The appraisal of whether a threatening situation that demands the preparation of a flight-or-fight behavior is thought to be carried out by a complex interplay between a number of limbic structures within the brain, including the amygdala (AMG), the hippocampus (HC), and the prefrontal cortex (PFC) [10–12]. The actual coping strategy chosen is mediated by the periaqueductal gray (PAG) which can launch different coping strategies depending on whether the stressor is escapable or inescapable, or if it is of physiological or psychological nature [13]. Thus, it might seem reasonable, at this point, to hypothesize that the stress response will be modulated depending on whether escape is possible or not and that spatial features in the environment, therefore, might influence the magnitude of a stress reaction depending on this factor. Thus, it might seem reasonable to assume that the stress response to a stressful event that takes place in an indoor space might be influenced by whether the space offers potential escape routes. Therefore as a first attempt to address the problem we, in this study, induced stress in two different settings; a) in a closed room potentially not allowing escape, and b) in a room with three large openings, potentially allowing for escape.

We used a virtual reality version of the Trier Social Stress Test (VR-TSST), [16]. The traditional Trier Social Stress Test (TSST) is, perhaps, the most widely used standard protocol for inducing psychosocial stress in laboratory settings [14,15]. The participants have to perform a series of stressful tasks in front of a committee that, traditionally, consists of trained actors. In the VR-TSST both the committee and the space in which the tests was performed, were computer generated using a CAVE™ system, and had been shown to induce stress reactions comparable to that of the traditional TSST [16]. The use of the virtual version of the TSST allowed for a systematic variation of the space in which the test took place. Whether the space possessed openings that, potentially, allowed for escape or no openings at all could be isolated as the only variation between the spaces. Furthermore, the fact that the scene viewed through the openings was also computer generated made it possible to design a completely empty landscape containing no objects that, in themselves, could have provoked an approach or avoidance behavior, e.g. natural vs. urban elements, as the aim was to study the effect of the design of the space itself, and not the influence of the view from the openings in the space.

Because the aim was to study whether the architectural design of indoor spaces might be able to influence stress, the hypothesis that psychologically stressed participants in the closed room would respond with more pronounced reaction by the sympathetic nervous system (SNS) and HPA reactivity than participants that were tested in the open room was tested. As a stressor the VR-TSST was used, and as proxies of the parasympathetic nervous system (PNS), and SNS activity high frequency heart rate variability (HF-HRV) and T-wave amplitude (TWA) were calculated respectively [17–19]. Activity of the HPA-axis was measured by its end product cortisol in saliva samples, in which it can be detected with an approximately 10 min delay compared to free plasma cortisol [20,21].

2. Methods

2.1. The VR-TSST

The spatial context in which the VR-TSST was performed consisted of a combined preparation/recovery room and a test-room where the committee was placed. The TSST was composed of three psychosocial stressors which had to be conducted in front of the committee in the test-room, namely anticipatory stress in the form of an incomplete instruction by the committee about one of the tasks, a public speech task, and a mental arithmetic task [14]. Preparation of the speech and a recovery phase after the tasks took place in the preparation/recovery room. One test room was without openings all together while the open room, which should offer a potential for escape, had three large openings through which the floor of the room stretched to the horizon (see Fig. 1). Franz et al. [22] mention a possible bias in a virtual reality experiment due to objects seen through openings. To avoid this, the test-room was designed in such a way that the space outside the open room was completely empty containing no objects or landscape characteristics whatsoever. The sky of the outside landscape was neutral gray. However, a hint of clouds was added to make the 3D perspective adjustment effect work and, thereby, ensure that the openings could not be experienced as mere wall decoration. The computer-generated experience of the space, as well as the committee, was created by a system of projectors that project on to the walls and the floor [16,23]. The 3D effect was obtained by passive stereoscopy and a head tracking system. The head tracking system allows real time perspective adjustments inside the virtual environment which is important to obtain a realistic sense of space [25]. The design of the virtual test setting was kept as close to the study by Jönsson and colleagues [16] as possible to avoid

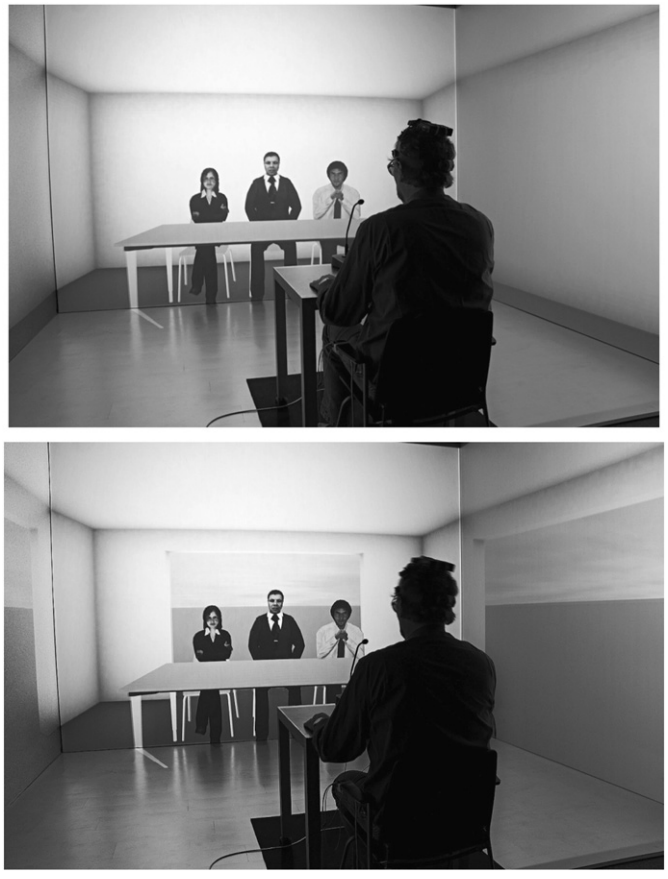

Fig. 1. A participant in front of the committee in the closed and the open room. Due to the stereoscopic projection the participant will experience a clear 3D environment.