Evoking Social Evaluative Threat Through Dancing in a Virtual Environment

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Abstract

Stress is a biopsychosocial construct that is assessed through self-reported distress and objective stress biomarkers such as heart rate and cortisol. Cortisol is the quintessential stress biomarker, showing reactivity to stimuli with elements of uncontrollability and social evaluative threat (SET). The Trier Social Stress Test (TSST) is the most commonly used instrument to induce biopsychosocial stress using a public speaking task with confederate judges. Prior studies have investigated an analogous task using Virtual Reality (VR) TSST. However, public speaking is difficult to translate to VR as the headset/headphones impair hearing and speech. We propose that a dance competition pitting participants against an opponent in front of an audience in a virtual environment contains (a) key stress elements of SET and uncontrollability and (b) physical movements of dancing are conducive to the virtual environment. We hypothesize that this virtual dance competition will elicit a stress response, as reflected by increased levels of cortisol and heart rate. Participants completed an initial non-stressful task involving throwing objects around a virtual room. During the stress condition, an in-game prompt instructed participants to learn and perform three dances. Participants faced a theater filled with a virtual audience to compete against a race and gender matched virtual avatar. Cortisol was assessed via 6 saliva samples collected before and after the control and VR-dance tasks, respectively. Cortisol Concentration (ug/dL) was measured using an enzyme-immuno-assay. Heart rate (bpm) was collected continuously using an ambulatory electrocardiograph (ECG) and were compiled in 30-second averages. Changes in cortisol and heart rate (HR) and respiratory sinus arrhythmia (RSA) as a function of time were analyzed using a repeated-measures ANOVA. Cortisol

reactivity (p = 0.104), RSA reactivity (p= 0.003), and HR Reactivity (p = 0.001). Our results suggest that our VR task elicited a response in both the HPA systems and Autonomic as shown by an increase in cortisol levels and heart rate, respectively.

Introduction

Stress is critical to the human condition in allowing us to adapt to a changing environment. Stress in an external environment is called a stressor (Shirtcliff, Peres, Dismukes, Lee, & Phan, 2014). Stress can be broadly classified in two ways: subjective stress and objective stress. Subjective stress is the evaluation of life events based on one's perception of stressfulness, which is done through self-evaluation surveys and questionnaires (Horowitz, Wilner, & Alvarez, 1979; Cohen, Kamarck, & Mermelstein, 1983; Qi, Gao, Guan, Liu, & Yang, 2016). However, subjective stress measures are not enough to fully capture one's stress response. Objective stress refers to events that are objectively stressful such as physical pain and other physiological responses as seen through biomarkers such as heart rate (HR), respiratory sinus arrhythmia (RSA), and cortisol (Cohen, Kamarck, & Mermelstein, 1983; Hamama-Raz, Solomon, Schacter, & Azizi, 2006; Fohr et al. 2015; Aybek, Apazoglou, Wegzyrk, & Mazzola, 2017). These three biomarkers describe facets of the human stress response system (SRS), the mechanism by which physiological changes occur within the context of a stressor.

The SRS is comprised of three interdependent systems: the sympathetic and parasympathetic branches of the autonomic nervous system (ANS), and the Hypothalamic Pituitary Adrenal (HPA) axis. The ANS and HPA axis are temporally distinct, with the ANS responding on a much quicker time scale. The ANS, otherwise known as the 'fight or flight' response, operates through the two branches (sympathetic and parasympathetic) that have a largely antagonistic relationship, responsible for excitation and relaxation, respectively. The final component, the Hypothalamic Pituitary Adrenal (HPA) axis controls the regulation of cortisol. In the context of a sufficiently intense stressor, the hypothalamus releases corticotropin-releasing hormone (CRH), which travels to the pituitary gland to stimulate the release of adrenocorticotropic hormone (ACTH). Then ACTH travels to the adrenal glands, in turn signaling the production and release of cortisol. Research examining the changes in cortisol levels in response to an acute stressor has been a well-established means for studying the physiological experience of stress (Shirtcliff, Peres, Dismukes, Lee, & Phan, 2014; Rohleder, Beulen, Chen, Wolf, & Kirschbaum, 2007; Boyce & Ellis, 2005).

The simplest biomarker of the SRS to measure is that of heart rate (HR), an index of the ANS, in which increases in bodily arousal is coupled with an increase in HR. However, as HR is regulated by both the sympathetic and parasympathetic branches of the ANS, it alone is an unreliable indicator of autonomic activity. To address this, respiratory sinus arrhythmia (RSA) is a cardiorespiratory phenomenon calculated from fluctuations in heart rate variability (HRV) as a consequence of the respiratory cycle (Bernston, Cacioppo, & Quigley, 1993). Low RSA is indicative of reduced parasympathetic influence on the body, impeding the ability to return to a restful state (Campbell, Wisco, Silvia, & Gay; 2019). These types of regulatory responses can be seen throughout the body, including the endocrine and cardiovascular responses as seen with elevated cortisol levels and heart rate (McEwen, 2006; van der Zwan, de Vente, Huizink, Bögels, & de Bruin, E. I., 2015; Shirtcliff, Peres, Dismukes, Lee, & Phan, 2014).

There is substantial difficulty in eliciting cortisol responses compared to other more immediate biomarkers. Cortisol follows a circadian rhythm that peaks in the morning, and declines to its lowest levels in the evening (Corbett & Simon, 2014). There are various facets of stress that elicit a cortisol response, with the main three being unpredictability, uncontrollability, and social evaluative threat (the fear of social judgment), being associated with increasing cortisol levels (Dickerson & Kemeny, 2004; Rohleder, Beulen, Chen, Wolf, & Kirschbaum, 2007; Corbett & Simon, 2015). For example, competitive dancing produces increases in cortisol, not because of physical exertion, but due to social evaluative threat (SET) (Rohleder, Beulen, Chen, Wolf, & Kirschbaum, 2007). After an acute stressor marked by unpredictability, uncontrollability, and SET, cortisol begins to rise and peaks 15 minutes after the event. Changes in cortisol levels can be seen in social situations with unpredictability, uncontrollability, and social evaluative threat (SET) (Shirtcliff, Peres, Dismukes, Lee, & Phan, 2014).

In recent years, these experiments have extended to the realm of virtual reality (VR) environments. In studying post-traumatic stress disorder (PTSD), VR exposure has been shown to Service Members from Iraq and Afghanistan "challenge their wartime fears and anxiety in a safe and interactive environment" (McLay et al. 2011). VR has also been shown to be effective in exploring different psychological conditions. One study suggests that VR could be used as a method in patients with first episode psychosis to expose them to controlled social environments (Veling, Brinkman, Dorrestijn, and van der Gaag, 2014). Another study has shown that VR can evoke a strong presence effect, despite low fidelity avatars, for people with a fear of public speaking (Slater, Pertaub, Barker, & Clark, 2006). VR has also shown utility in eliciting stress responses through stress-based tasks (Finseth, Barnett, Shirtcliff, Dorneigh, & Keren, 2018). While others have explored virtual stress tasks, competitive dancing in a virtual environment as a stress mechanism has never been studied. We sought to further evaluate the effectiveness of a stress task performed in a virtual environment to induce a stress response as measured by changes in cortisol secretion and heart rate. We designed an environment around competitive dancing including a theatre, dance teacher and audience. This study builds on previous work in the field that has shown a strong cortisol response to stress tasks that incorporate SET and uncontrollability (Shirtcliff, Peres, Dismukes, Lee, & Phan, 2014). Our environment is designed to make participants feel socially judged and powerless over the course of the stressor task. Furthermore, the physical act of dancing translates well into virtual reality. We hypothesize that competitive dancing in a virtual environment task will elicit a measurable cortisol response and heart rate reaction. This study is novel in that we are using VR as a tool to buffer SET from the researchers. This eliminates the need of hiring confederates to act socially ambiguous.

Methods

Participants:

Data was collected from 18 participants (8 male, 10 female), between the ages of 18 to 40 with no history of seizures, seizure disorder, or VR simulation sickness. All were attending a state university in the midwest for the summer. Participants were recruited through word of mouth from members of the research group.

Measures and Materials:

The virtual theater was implemented using the Unity3D game engine and the SteamVR plugin. The scripting for the virtual environment was done in the C# programming language. The audience members used models, textures and animations from Adobe’s Mixamo website.

The experiments were conducted on an HTC Vive headset and controller on a Windows computer. For measuring the participant's heart rate, an ambulatory electrocardiogram was used. The participants were asked to complete additional measures through an online form that asks how familiar they are with virtual reality. In addition, the participants were asked to keep a journal where they self-reported their stress levels and answered personal questions relevant to the study.

Procedure:

Participants attended the simulation at pre-arranged times in the afternoon and were provided written informed consent to agree to if they wanted to participate in the study. A same-sex researcher hooked up the participant to electrodes to measure heart rate via ECG and impedance cardiography. Participants were asked to give a saliva sample through passive drooling after the electrodes were placed. The participant then donned a virtual reality headset and completed the baseline task for 5 minutes. The baseline task involved throwing plates around a virtual room, chosen to acclimate to VR and allow us to record data in a similarly physical, but not stressful environment. After the control task, the participant gave another saliva sample. The participant then moved on to the VR stress task. Before the task began, the virtual competitor was assigned to match the race and gender of the participant (black, white, male, and female). We postulate that pitting participants against members of their own racial and gender in-group will remove social support (Heinrichs, Baumgartner, Kirschbaum, & Ehlert; 2003) and facilitate SET (Haslam, Jetten, O'Brien, & Jacobs; 2004). The participant cycled through 3 rounds of dance competition where they were taught a dance by a humanoid avatar for 45 seconds. Then instructed to wait and observe a virtual opponent, who did the same dance the participant had learned for 30 seconds. Finally, the participant was instructed to perform the dance themselves for 30 another seconds. In this competition, the crowd would cheer for the competitor, but remain silent for the participant to convey ambiguous judgment. The competitor was also not told how long any portion of the task would last; thus building suspense and making the task unpredictable. The researchers did not interact with the participant while the stress task was taking place. All instructions were given through onscreen prompts.

After the task, the participant was given another questionnaire to record their experience in the virtual environment. The participant then gave 4 more saliva samples after the stress task at 15-minute intervals to capture the rise and fall of their cortisol response. This was to account for the peak in cortisol levels which occurs 15-30 minutes after a stressor (Finseth, Barnett, Shirtcliff, Dorneich, & Keren; 2018).

Results

Changes in HR, RSA, and cortisol levels were analyzed via repeated-measures ANOVA. The initial analysis on cortisol by time found no significance ($p = .104$) between time and cortisol level; however, this result may be due to inadequate sample size, as the data does suggest that there was a measurable cortisol increase due to our task (Figure 1).

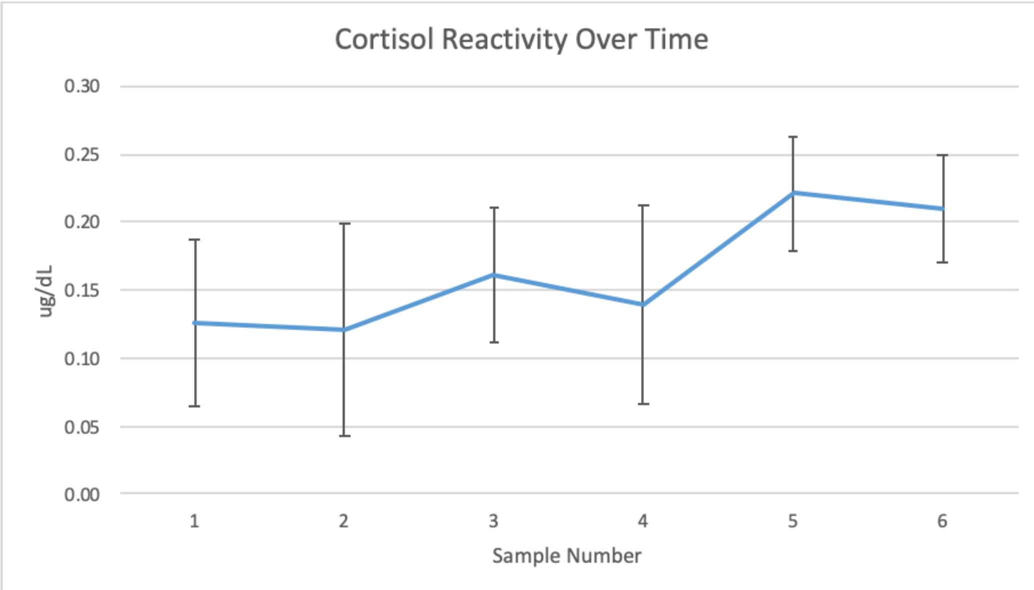

Figure 1. Cortisol levels over time

The HR by time analysis found significance for the dance task [$F(14, 224) = 2.718$, $p = .001$], but no significance for the control task ($p = .806$). These results support our hypothesis that the dance task elicited autonomic reactivity via increases in HR, whereas the control task did not (Figure 2).

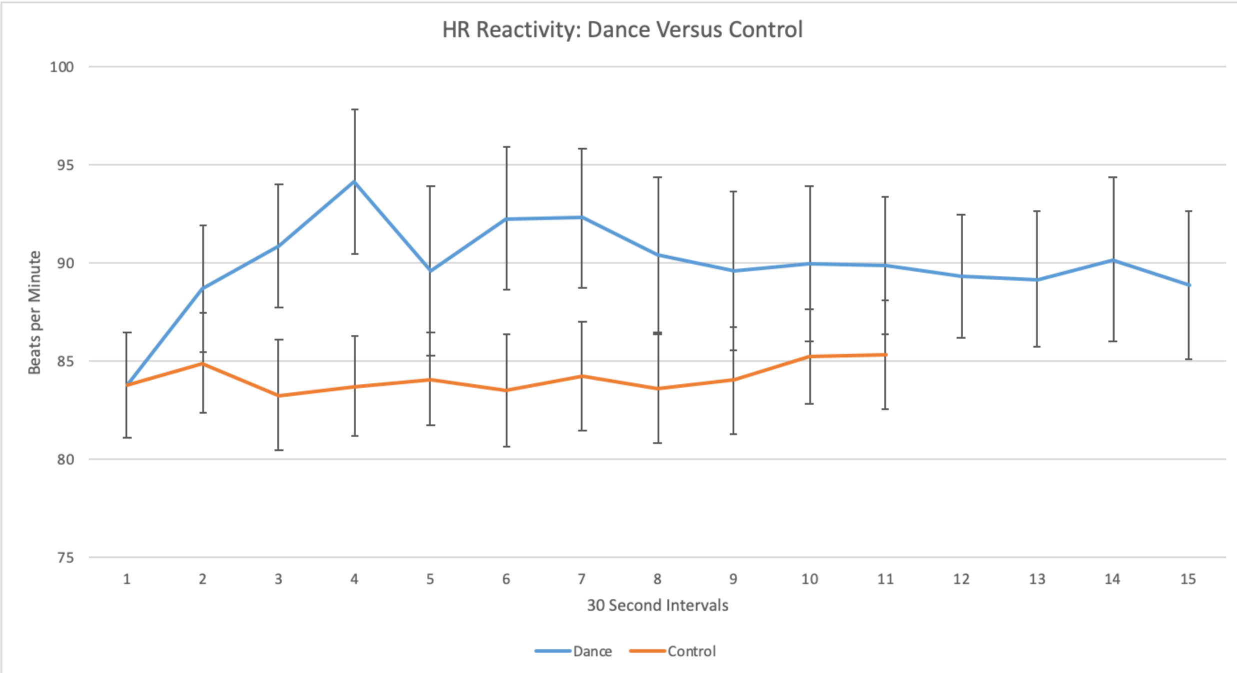

Figure 2. HR reactivity between control and dance task

The RSA by time analysis found significance for the dance task [$F(14, 224) = 2.474$, $p = .003$], but no significance for the control task ($p = .853$). These results support our hypothesis that the dance task elicited a withdrawal of the parasympathetic nervous system via a sharp decrease in RSA (Figure 3).

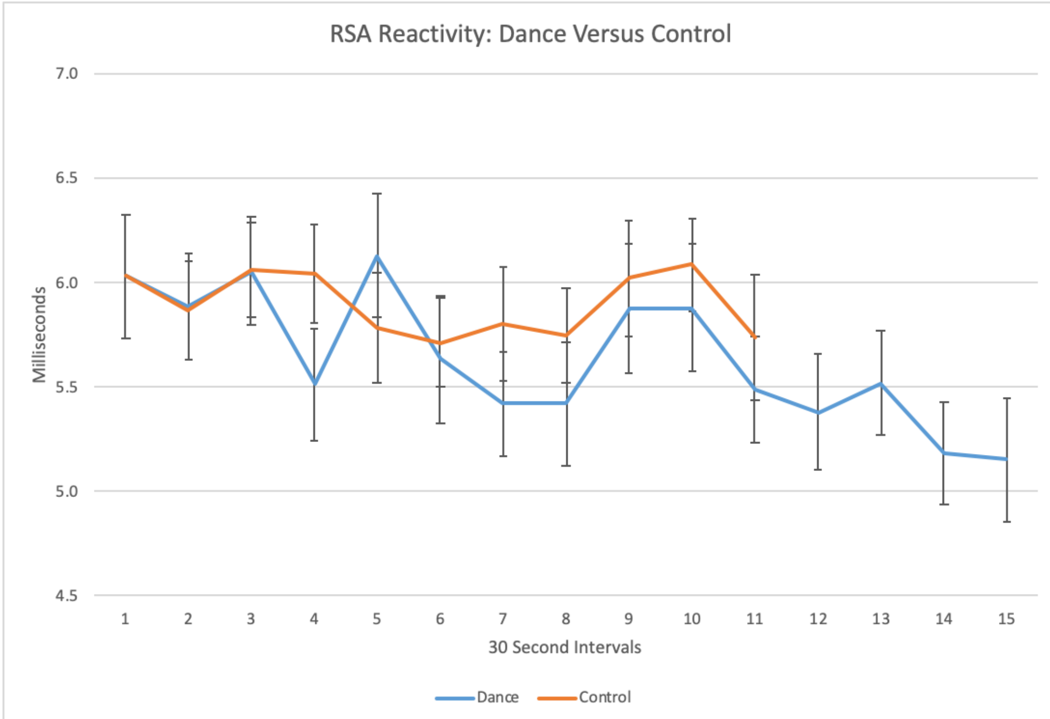

Figure 3. RSA reactivity between control and dance task

Discussion

The results of this study suggest that VR is a viable tool to reliably elicit a stress response. During the dance task, heart rate peaked early and gradually reduced over time, all the while remaining significantly above the control. This trend suggests that participants had an initial strong autonomic response, and then began to habituate to the dance competition. These findings are congruent with other existing literature, which indicates that social-evaluative threat can elicit a stress response within a virtual environment (Slater, Pertaub, Barker & Clark, 2006). When comparing RSA data between the control task and the stress task, the results suggest that there was significant parasympathetic withdrawal during the stress task, with RSA steadily decreasing over time. This data indicates our stress task inhibited the parasympathetic nervous system or effectively prevented relaxation. Although the results of the RM ANOVA weren't significant, cortisol data showed a steady increase over time, potentially indicating an HPA response.

Potential limitations of the task include small sample size, participants potentially having prior knowledge of the task, and limited selection of competitor avatars (only light-skinned or dark-skinned). Finally, as our task is similar to the TSST, we suspect one of the same shortcomings of the TSST befell our project: people confident in public performance being less likely to respond to the stress task (Slater, Pertaub, Barker, & Clark; 2006). It is likely that experienced dancers would have a weaker stress response.

Future work in this study could include creating alternative VR stress tasks that invoke a similar response; furthermore, improving the current stress task could increase our responder rate as well as decrease error within our data. Such improvements could include a wider array of race and gender options, as well as minimizing the stress of other tasks, such as electrode installation. Future work could also examine the differences in stress reactivity between gender and race in the context of our VR model. This would be building on previous literature that has shown reactivity differences between men and women (Liu, Ein, Peck, Huang, Pruessner, & Vickers; 2017) as well has between race (Townsend, Major, Gangi, & Mendes; 2011).

Conclusions

In summation, a virtual dance competition is an effective method for electing a stress response indicated by cortisol and heart rate fluctuations; However, our experiment was limited by the number of participants and by conflicting none task related stress. Despite these limitations, the data suggests that our model is able to trigger the two major structures associated with stress, the ANS and the HPA Axis. The ANS response correlates to changes in heart rate and RSA interval time. This RSA data suggests our task inhibits the parasympathetic nervous system.

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