Open TSST VR: Trier Social Stress Test in Virtual Reality

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Abstract: Virtual Reality has been used in (clinical) psychology for decades now, but has seen a high rise in recent years with the increased availability of VR systems. One of the methods adopted to VR is the Trier Social Stress Test (TSST), which is designed to induce psychosocial stress. The currently leading TSST VR tool requires the bundle purchase of a license and an outdated hardware setup while suffering from the respective graphic limitations and requiring a professional to make slight changes to the experiment. We present a publicly accessible, open TSST VR tool with improved graphics, which is simple to change, allowing to effortlessly adapt the experimental parameter according to one's needs.

Keywords: Virtual Reality, Trier Social Stress Test, Stress

1 Introduction

Trying to meet a deadline, studying for that final exam, or just worrying about your financial situation until the next paycheck; everybody knows these stressful situations. But stress is not limited to negative tension, as hitting a jackpot for a gambler can be just as stressful as fighting an illness; any demand made upon the body creates stress [Sel76]. Psychological stress response may be measured with questionnaires. In addition, there are multiple methods to estimate physiological stress, with cortisol and catecholamines being the most prominent stress hormones. Salivary cortisol is a popular choice due to its non-invasive measurement in saliva, whereas catecholamines cannot be easily measured. Additionally, heart rate responses can be recorded as a stress indicator of the activity of the sympathetic nervous system. Understanding the effects of stress, how it works, and what events influence stress levels are the foundation of stress research. A multitude of standardized stress-inducing laboratory methods have been developed over the last decades, such as the *Trier Social Stress Test* (TSST) [KPH93], the *Socially-Evaluated Cold Pressor Test* (SECPT) [SHTW13] or the *Maastricht Acute Stress Test* (MAST) [SCQ+12].

The TSST is the first of these tests to reliably evoke endocrine and cardiovascular responses, therefore being a robust stress-inducing task and used widely in psychobiological stress research. The main components of the TSST are an anticipation phase (5 min) and

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a test phase (10 min), which consists of a free speech and a mental arithmetic task in front of an audience (judges). These two tasks cover the main factors for inducing stress: Social evaluative-threat and lack of control [DK04], which are robust to protocol variations [GJW17]. The participant is first instructed to prepare for a five-minute-long interview for a job of their choosing (anticipation phase) and may use pen and paper to do so. However, they are not allowed to make use of those during the mock job interview. The judges (audience) are trained to keep a neutral expression and to not comment unless the participant diverges too far from the task or finishes before the five minutes are over, in which case they have a list of prepared comments to keep the participant going. Immediately after the five minutes are over the mental arithmetic task begins, for which the participant is instructed to count backward from 1022 in steps of 13 and start over after making a mistake. A detailed description can be found at [2.2.1].

A number of different VR adaptations of the TSST have been made and preliminary studies conducted to validate those [KMM+07, KDT+08, JWO+10, WJO+11, ZBH+19]. Aside from being more cost-efficient (virtual agents replace the audience), a VR adaption of the TSST is even more standardized than its in vivo counterpart, as the design is identical for every test conducted down to the virtual audience. Altering the design is also more easily accomplished in a VR environment and may yield different results, as shown by Fich et al. [FJK+14] using an 'open door' variation (the room had multiple openings). As there is currently no free access to a VR TSST tool, most researches are using their own, independently designed tool, therefore negating the advantage of having identical tests across different faculties based on a well-validated system. To overcome these limitations, as our main contribution, we present a publicly available, adaptive VR version of the TSST, which additionally features a variety of changeable properties and allows for greater realism compared to current other options. Furthermore, it can be deployed and standard VR systems, which keeps the initial and maintenance costs low.

2 Related Work

A variety of methods and experiments for psychological research has shown to benefit from VR, with recent hardware capacities allowing for more widespread use than before. We will first elaborate on some of the more widely used applications of VR done in psychological research (see Section 2.1) and then discuss the most recent, validated TSST VR tool (see Section 2.2).

2.1 Psychological Tests in VR

Virtual Reality has known uses in psychological research for decades now, most prominently as therapy for phobia [PE08]. Powers has shown here, that treatment in VR is not only more cost-efficient (boarding a plane or ascending a skyscraper to treat fear of heights is expensive and/or takes a lot of time) but in some cases also more effective and negates the risk of re-

traumatizing the patient during the treatment, e.g., falling down a boulder a second time. Due to VR becoming more available in recent years, further applications are being found: Dechant et al. [DTW+08] researched a method to diagnose social anxiety disorder using VR; Gallup et al. [GVA19] find, that yawning is contagious even within a virtual environment, however being observed by virtual agents does not inhibit yawning, even though the mere presence of another real person in the same room suffices to limit yawning.

In the last decade, more complex experiments have found a hold in VR, the TSST being among them. Multiple versions of the TSST VR have been validated due to the different needs and lack of accessibility of previously created tools.

2.2 TSST VR

We will discuss the most recent adaption of the TSST in virtual reality [ZBH+19], which reported to invoke comparable subjective and physiological reactions to the in vivo TSST, using a refined TSST VR version based on the Steam Source engine; as other adaptions of the TSST VR have all reported milder response rates for salivary cortisol than their in vivo counterparts. The tool was developed by VTPlus GmbH (Würzburg, Germany) and uses the Oculus Rift DK2 as HMD together with external headphones. To use this tool one is required to purchase a full hardware setup (including HMD, Computer, Monitor, iPad, and a custom Desk) together with a software packet. The tool aims to imitate the in vivo counterpart as closely as possible, basing the virtual avatars' appearances on the in vivo judges. An iPad, directly connected to the computer on which the TSST VR runs, is used to control the VR application. Starting the session displays a room designed to look similar to their real surroundings, to hopefully further immersion by not being at a different place.

2.2.1 Phases

The TSST VR tool partitions the original TSST procedure, consisting of anticipation- and test phase, into six phases; each with a different amount of instructions available:

Phase 1 (Baseline) The participant is instructed via audio and subtitles to remain seated for the next few minutes (seven minutes), after which they are instructed to stand up and remain standing (three minutes); this is done so that baseline measurements can be taken (e.g. heart rate and cortisol). Every instruction is preceded by the experimenter pressing a <continue> button on the iPad and the subtitles appear on the screen as they would during a movie with no additional boxes for minimal occlusion.

Phase 2 (Preparation) The instructions for the mock job interview tasks are given (with subtitles and audio), the participant now having five minutes to prepare for the task.

Phase 3 (Entry, Judges) The door, located on the wall behind the participant, opens and the three judges enter the room to sit at a desk in front. From here on all instructions

are given without subtitles and spoken by the judge in the middle seat.

Phase 4 (Interview) After the participant is instructed to begin his speech, a judge turns on a camera (by pushing a button on the table). The experimenter can select comments or questions the judges should ask (e.g. instruct to continue if there is a long silence, or elaborate); with the list of comments/questions available being the same that the judges in the non-VR TSST are using.

Phase 5 (Arithmetic) Following the mock interview, the participant is asked to do some mental arithmetic (counting backward from 1022 in steps of 13); the only options available at this point are to prompt the participant to be faster or start over when they make a mistake.

Phase 6 (End) The judges inform the participant that the experiment is over and leave the room.

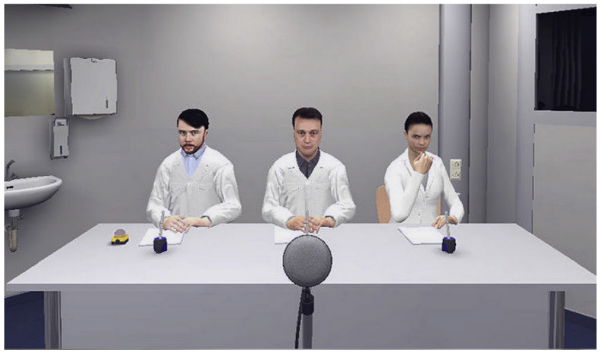
There are three primary motivations for creating a new TSST VR tool, even though validated tools exist. The first reason being availability, the preexisting tools are not free to use without purchasing the license. Secondly is adaptability, as the functionalities of the other tools are hard-coded, therefore any change a researcher would like to make to the TSST VR requires someone versed in the source engine (C++). Lastly would be graphics quality, with the current HMD's featuring full HD on both eyes and consumer hardware able to render without stuttering, the VR experience due to this point alone should be at a higher degree than previous versions of the TSST VR.

3 Open TSST VR

Different researchers may not be able to use an existing TSST VR version without significant changes, due to varying circumstances (e.g., studies done in different geographical regions may want to feature virtual agents of their most prominent ethnicity, instead of three caucasian agents and use a different language), requiring the purchase of an existing license and modifying the tool to suit their needs or to develop their own TSST VR.

Our main goals in developing a new TSST VR were first to provide a free tool for researches to use, secondly to keep it as adaptive as possible, allowing for changes to be made without the need for specialized personnel and lastly to make use of the leap in graphics and realism to virtual reality in recent years to allow for greater VR experience.

Open TSST VR is designed in Unity 2019.3.0f5, uses the Steam VR framework, and comes with a default procedure that is only slightly different from the previously described six phases of the refined TSST VR (e.g. exact wording of instructions and comments may differ). We will first describe the static differences and subsequently layout changeable options.



(a) TSST VR (VTPlus GmbH): The participants view of the judges from a seated position.

(b) Open TSST VR: View changed to the same perspective as (a) for better comparison.

Figure 1: Side-by-side comparison between the two TSST VR versions.

3.1 Room

Designed after a room used for the in vivo TSST, this room features as the only non-functional decoration a heater on the left wall. To provide light there are four tube lights on the ceiling and window slices of structured glass, coincidentally negating the need for a view outside, covering the upper half of the left wall. The microphone looks largely the same with only a slightly different model and additionally adjusts it's height based on the participant height, whereas the camera is mounted on a stand similar to the microphone and a completely different model. Both the camera and the microphone models are based on a free license, meaning one can purchase the models for free, but it is not allowed to distribute them; therefore their source files cannot be made publicly available by us. A comparison between the older TSST VR tool and our version can be seen in Figure 1; due to the limited resolution of the figures the difference in graphic quality is lost.

3.2 Agents

While the previous TSST VR version has modeled their judges based on their in vivo counterparts, we have chosen more arbitrary appearances for our models, which are not based on real people. In order to not be limited by ethnicity, up to three agents from a fixed pool of models can be chosen as judges for a session; importing new models without access to the project/source code is not supported due to the manual preprocessing of the models currently required, which may change in the future. The models were created using Adobe Fuse CC (Beta) [1] and rigged with facial blendshapes in Adobe Mixamo [2]. Both are free licenses and even though they can be purchased for free, it is not allowed to distribute models or animations they generate; therefore their source files cannot be made publicly available. Finally, some default animations were based on animations from Mixamo, adjusted to fit into our virtual environment.

[1] https://www.adobe.com/de/products/fuse.html
[2] https://www.mixamo.com/

3.3 Animations

Our animations are based on the same actions, while being less rigid than in older versions: eye contact is maintained while the agents are idle (not in a specific animation); the two outer agents occasionally write notes on a sheet of paper in front of them, whereas the middle judge will only look down as if to consult the sheet of paper without writing from time to time; to avoid the impression that the judges are staring, they will also glance at other locations below the HMD (to imitate looking at other body parts, e.g. hands) and occasionally blink. These happen automatically at random intervals, without the influence of the experimenter; the probability (and therefore frequency) can be changed in the configuration files (JSON, see below).

3.4 Procedure

The experiment procedure is saved as a JSON file and consists of a list of phases. Phases are JSON files as well, named after the entry in the list, therefore generating a new file and adding its name to the list of the procedure will create another phase for the experiment; likewise, removing a name from the list will similarly remove the phase. A Phase consists of a name, to be displayed on the client for the experimenter, a default duration, some properties of how the agents behave, and a list of actions. Actions are JSON Objects defining the events they should trigger (e.g. a judge should speak, turn the camera on or a menu with instructions should appear) and some details, such as the duration of displayed subtitles or the path to an audio file (for a judge to say). With default settings, the procedure is largely the same as the other TSST VR version, with small differences such as exact wording and how subtitles are displayed.

3.5 Lipsync

Being able to use custom audio files, which the judges speak aloud, would be comically at best with random mouth movements accompanying the sound. We use Oculus Lipsync [3] for real-time lip synchronization, which maps sounds to specific blendshapes using 15 visemes, providing realistic mimic without the need for predefined facial animations. The visemes were created in blender and require existing facial blendshapes (which Mixamo provides during the rigging process).

3.6 Openness

Since our models were created using Adobe Fuse CC (Beta) and thus require the appropriate license, we cannot provide their source files and by extension cannot publish the entire source of the project. Therefore we provide a compiled version with all models included, which can be adapted to specific needs by modifiying the configuration files, as long as there is no need

[3] https://developer.oculus.com/downloads/package/oculus-lipsync-unity/

to alter the models, animations or the environment. Additionally we provide the source code for the project, excluding the models that require licenses.

The source code (minus the models that require licenses) and the compiled project can be found at `https://github.com/EagleSixty6/OpenTSST-VR`.

4 Conclusion & Future Work

We presented a free TSST VR tool with a focus on being adaptable to different settings, that can be changed without expertise in programming. In comparison to older TSST VR tools, we provide higher graphic quality, smoother animations, and simple integration of other languages. Different agents can be chosen as judges, e.g., to adjust for ethnicity bias in different regions and their behavior can be fine-tuned. Additional features such as eye-tracking are in planning to allow researchers to explore more facets of stress. The Open TSST VR still needs to be evaluated, though one could assume that the greater realism provided by better graphics should further improve stress responses compared to other TSST VR tools. With the ability to effortlessly change the experimental parameters in our tool, aside from tweaking the TSST procedure to one's need, even completely different experiments could be devised.

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