Investigating the Efficacy of Virtual Experiences on Stress Reduction

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***Abstract*— This paper explores the combination of Attention Restoration Theory and immersive virtual technology as a novel therapy for short-term stress reduction in the workplace. The goal of this work is to understand how various immersive technologies impact the effect of both nature and urban environments on acute stress. In order to assess this, study participants were guided through "micro-vacations," or a series of virtual nature or urban images, after being induced with stress. The micro-vacations were presented via three different virtual immersive technologies: a virtual reality (VR) experience using a headset in a booth, a GeoDome experience, or a 2D experience which acted as a control. Biometric, subjective mood and comfort data were gathered from the participants throughout the study in order to measure the changes in stress and mood before, during, and after the micro-vacation experiences. We hypothesize that the nature environments are more relaxing than the urban environments, and that both the VR booth and GeoDome will reduce stress levels in participants to a greater degree than the 2D images.**

Keywords—Attention Restoration Theory, GeoDome, micro-vacation, stress, virtual reality

Introduction

Due to rising costs of medical and pharmaceutical treatments, employers are seeking innovative ways to manage healthcare expenses for employees and their dependents. Studies show that 42% of employees report feeling stressed at work and are linked to 15-30% greater healthcare costs [1]. However, a much smaller portion of employees (~22%), report being able to cope with stress very well [2]. Many people in the workplace struggle to manage their stress on a regular basis, thus impeding productivity and overall workplace satisfaction. Given the high prevalence of stress, many employees may require some intervention to help reduce stress and increase productivity. Traditional treatments for stress and anxiety include medications, therapy, or self-care techniques such as meditation [3]. However, these treatments may be expensive and time consuming, and are not quick outlets for everyday stressors found in the workplace, such as running meetings and presentations. Readily accessible digital technologies, such as VR technology or an immersive GeoDome, are better suited for improving mental health in a workplace setting where the GeoDome is a 180 degree view domed screen on which the images and videos are projected onto. Providing scalable alternatives for accessible stress management can mitigate the rising cost of healthcare for both employers and employees.

Literature Review

Attention Restoration Theory (ART) posits that nature can have a restorative effect on the ability to concentrate, thus reducing stress and anxiety and promoting productivity [4,5]. Previous evidence of biometric data support that VR environments can be successful in reducing anxiety [6]. Other related literature has found that simulating nature using VR has had a positive effect on psychological and physiological responses, seeing improvements with fatigue, confusion, tension, and blood pressure [7,8,9]. Therefore, such studies support the use of VR as a way to improve psychological health. In addition, prior work has also been conducted on Virtual Reality Exposure Therapy (VRET) which has demonstrated promise in treating a variety of psychological disorders such as anxiety, phobias, post-traumatic stress disorder (PTSD), depression, bipolar disorder and more [10,11]. However, there is little literature exploring the degree of restorativeness using different immersive technologies such as a GeoDome and its effect on psychological and physiological responses.

The main goal of this study is to understand if immersive virtual technology can assist individuals in relieving short-term stress. The design of our experiment allows us to compare the effect of different immersive technologies and between different types of immersive environments. We hypothesized that the virtual nature environments are more relaxing than the urban environments, and that both the VR booth and GeoDome will reduce stress levels in participants to a greater degree than the same setting portrayed in 2D images.

Methodology

Our experiment consists of three separate conditions with two independent participant groups that utilize the same methodology (see Fig. 1). The first participant pool consisted of older adults aged 65-75 years old, while the other consisted of a younger participant group recruited from the student population. Participants were recruited from the Jefferson Area Board for Aging and the University of Virginia using fliers and randomly assigned to a control, GeoDome condition or VR condition. The control condition was a lab setting where the participants viewed a flat laptop screen displaying the stimuli in 2D; the Elumenati GeoDome (See Fig. 2) condition consisted of a 180-degree view domed screen on which the visual stimuli was projected while participants sat down without having to wear a headset; the VR condition was a private booth, provided by EvenHealth, in which the participants sat inside and used an

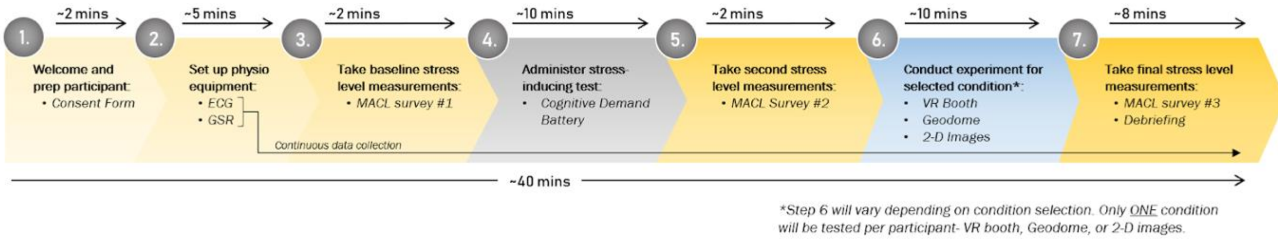

Fig. 1. Experimental Design Methodology

Oculus Go VR headset which displayed the experimental stimuli as a 360-degree immersive experience. Within these three conditions, the participants were randomly assigned to either a natural or urban visual experience. The nature images were validated by various student cohorts who ranked a series of images (n=20) based on their positive characteristics. Five of these images were chosen for use in this study.

Fig. 2. Elumenati GeoDome viewing condition

After obtaining participant consent, biometric Shimmer sensors that captured physiological stress were put on the participants and remained on for the duration of the experiment [12,13]. Physiological stress was captured through two biometric markers: Galvanic Skin Response (GSR) and Heart Rate Variability (HRV). GSR is a measure of emotional arousal, and can be used to indicate stress and anxiety levels. Higher GSR values correspond with higher levels of stress and anxiety. HRV measures the variation in time between consecutive heartbeats and can also be an indicator of stress [14]. Lower HRV indicates higher stress levels. GSR sensors were attached over three fingers of each participant, and ECG leads for collecting HRV data were placed on the participants' chest. The participants then self-reported initial mood data through the short version of the UWIST Mood Adjective Check List (MACL) at several stages throughout the study (See Fig. 1). The MACL measures three categories, each receiving a different score: acute stress, arousal, and hedonic tone [14]. While the stress scale measures feelings of subjective tension, the arousal scale measures feelings of subjective energy. Lastly, the hedonic tone scale measures overall pleasantness of mood, and is associated with feelings of somatic comfort and wellbeing.

The Cognitive Demand Battery (presented using PyschoPy) is a mild stressor that consisted of 3 tasks performed in quick succession and was repeated over 10 minutes. To complete the tasks, participants sat at a desk and utilized a laptop. The 3 tasks the participants completed include two sequential subtracting tasks of serial 3's and 7's from a random number, and a Rapid Visual Information Processing (RVIP) test in which participants view a number stream where new numbers appear individually at a rate of 1/600ms and are asked to identify targets – three odd or three even numbers appearing consecutively at a rate of 4 per 30 seconds.

Participants were then exposed to either urban or visual imagery for 10 minutes (5 images, each presented for 2 minutes) in their respective experimental condition (control, VR, or GeoDome). A comfort scale was administered to assess how participants felt physically during the experiment through five short questions. Each question was answered on a five-point Likert scale from 'Not at all' (1) to 'Very much so' (5). The questions were introduced with the framing, "With regards to the visual experience you just undertook, please indicate your response to the following questions," and the questions were as follows:

TABLE I. COMFORT SCALE QUESTIONS

Question
1) How completely were all your senses engaged?
2) How much did you feel that you were in the places you saw?
3) How much did the visual aspects of the environments involve you?
4) How physically comfortable did you feel in this environment?
5) Did you feel any discomfort (e.g. dizziness?)

At the end of the study, the participants were provided with a paper list of mental health resources available to the UVA and Charlottesville communities as a precaution should they feel that they have stress and anxiety symptoms that may require professional help after the study.

PRELIMINARY RESULTS

Due to restrictions inflicted by the COVID-19 pandemic, this work was unable to be completed. However, we present preliminary results on a limited sample of older adults exploring Geodome and 2D conditions.

I. Demographics

Thirteen participants, aged between 65 and 70 years old (mean age = 67.08, standard deviation = 1.88), took part in this study in March 2020. Of these thirteen participants, 38% were male and 62% were female. Seven participants took part in the GeoDome condition and six took part in the 2D condition. Due to the small sample size, many statistical results were found insignificant as we lose degrees of freedom when investigating deeper within the different independent variables. However, the analysis and preliminary results set up the framework for further analysis and motivation for future work when a bigger sample size is being used.

II. Subjective Data Results

In order to analyze the subjective data, three separate analyses were conducted.

Impact of the Stressor

Paired t-tests were performed on the MACL scores before and after the stressor in each of the three mood categories: acute stress, hedonic tone, and arousal. While both the stress and hedonic tone categories showed statistically significant differences (hedonic tone; t (12) = 3.861, p = .002, stress; t (12) = 3.467, p = .005), there was no significant difference in arousal outcomes (t (12) = .451, p = .66). The mean responses can be seen in Fig. 3 below:

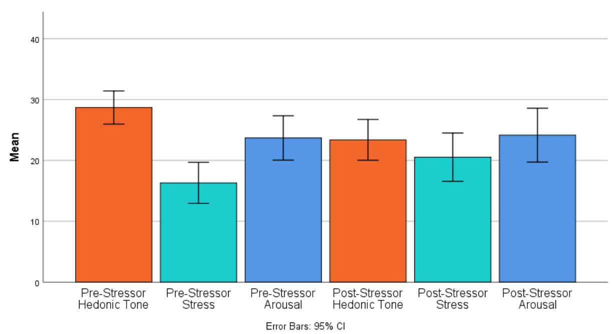

Fig. 3. Mean values of each MACL outcome measure between pre- and post-stressor assessment.

Fig. 3 displays a reduction in hedonic tone levels post-stressor (orange bars) and an increase in stress levels post-stressor (green bars) categories. However, as reflected with the t-test results, there is no significant difference in the arousal (dark blue bars) outcomes pre- and post-stressor.

Mood Adjective Checklist

The second analysis for subjective data explores the effect of both the viewing condition (2D, GeoDome) and the environment (urban, nature) on participant mood. A one-way ANOVA was run on the change scores (calculated as the difference in scores immediately pre- and post- the virtual immersion) for each of the three MACL mood categories. However, none of the models showed statistical significance (hedonic tone; F (3,7) = .704, p = .579, stress; F (3,7) = .754, p = .554, arousal; F (3,7) = .068, p = .975.) Fig. 4 displays the mean change scores per MACL outcome and condition.

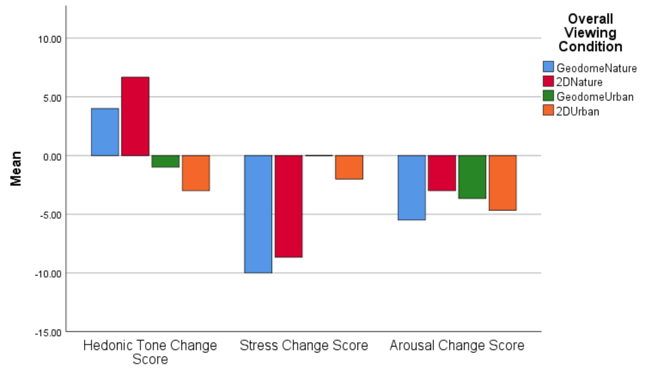

Fig. 4. Mean change scores of MACL outcomes per overall viewing condition.

Positive values in Fig. 4 indicate that scores were greater in the post-stimuli assessment than in the pre-stimuli assessment. Conversely, negative values indicate that scores were greater in the pre-stimuli assessment than the post-stimuli assessment. Fig. 4 therefore shows increases in hedonic tone for both nature conditions and decreases in hedonic tone in both urban conditions, with the 2D condition showing the largest negative change in hedonic tone. Within the stress category, stress decreases in three of the four viewing combinations, with the decrease most prominent in the nature conditions. Arousal scores decrease in all conditions. However, all models were not significant due to the small sample size.

Comfort Scale

Lastly, in order to analyze subjective comfort, multiple one-way ANOVAs were run to explore the effect of the overall four viewing combinations on any of the five comfort scale questions. Table II below reflects these results, with no statistically significant effect found overall between conditions.

TABLE II. ANOVA TABLE FOR COMFORT SCALE QUESTIONS

Question	**F**	**Degrees of Freedom**	**P**
1) How completely were all your senses engaged?	.436	3, 9	.732
2) How much did you feel that you were in the places you saw?	.512	3, 9	.684
3) How much did the visual aspects of the environments involve you?	.275	3, 9	.842
4) How physically comfortable did you feel in this environment?	2.404	3, 9	.135
5) Did you feel any discomfort (e.g. dizziness?)	1.424	3, 9	.299

Table II shows that there were no statistically significant effects. However, questions #2, #4, and #5 regarding feeling in place, comfort, and discomfort all showed high F values (>.5) for the sample size. Fig. 5 below displays mean responses to each question by overall viewing combination, with responses appearing in the same order as the questions above.

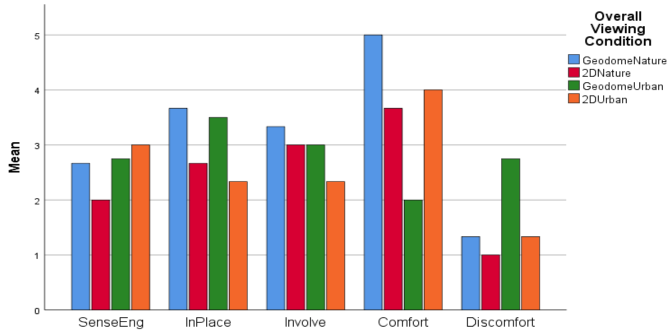

Fig. 5. Mean comfort scale responses by overall viewing combination

Fig. 5 shows little discernible change in the senses and involvement questions ("SenseEng" and "Involve"), but show interesting outcomes on the feeling in place and comfort questions ("InPlace," "Comfort," and "Discomfort"). Firstly, the feeling in place questions show higher responses in the GeoDome conditions when compared with the 2D output. Secondly, there appears to be little difference in comfort and discomfort levels when comparing nature and urban stimuli in the 2D condition. However, people report feeling higher levels of comfort when watching the nature stimuli in the GeoDome and conversely the lowest levels of comfort when viewing the urban stimuli in the GeoDome. The discomfort question shows a sharp rise in discomfort in the GeoDome Urban condition when compared to the other viewing combinations.

III. Biometric Data Results

Two separate analyses were conducted — one for the galvanic skin response (GSR) and one for the heart rate variability (HRV). ANOVAs were performed for both of these measures to check for statistically significant differences.

In order to analyze both the GSR and HRV data, three independent variables were examined: Condition, Environment, and Stage of the experiment. Condition had two levels: 2D experience, GeoDome experience. Environment had two levels: nature images, urban images. Stage had three levels: baseline measurements, cognitive demand battery (CDB) or the stressor, and virtual experience.

Galvanic Skin Response

One 3-way ANOVA and three 2-way ANOVAs were performed for GSR. These tested the main interaction which included all factors (Condition, Environment, Stage), each sub-interaction (Condition & Environment, Condition & Stage, Group & Stage), and the main effects.

These analyses yielded a significant difference for all of the independent variables, and all of the interactions. This was indicated by the results of both the ANOVA of the main interaction with all the variables, as well as the ANOVAs of the sub-interactions, so the latter were omitted from the presentation of results (See Table III).

TABLE III. RESULTS OF THE STATISTICAL TESTS OF THE EXPERIMENTAL EFFECTS ON GSR LEVELS

Variable(s) of Interest	F	p-value
Condition	8833.28	<0.001
Environment	79310.42	<0.001
Stage	2790.49	<0.001
Cond:Env	66792.30	<0.001
Cond:Stage	2035.59	<0.001
Env:Stage	47.47	<0.001
Cond:Env:Stage	907.12	<0.001

When looking at the type of immersive experience, GSR was lower during the GeoDome experience (Mean = 6.80, SD = 7.76) than during the 2D experience (Mean = 7.37, SD = 7.11) (See Fig. 6). GSR was also lower for the nature images (Mean = 6.42, SD = 7.39) than for the urban images (Mean = 7.55, SD = 7.59) (See Fig. 7). Lastly, when looking at different stages of the study, GSR was lowest during the baseline measurements stage (Mean = 6.93, SD = 7.59) and highest during the stressor (Mean = 7.34, SD = 7.29), with the virtual experience stage falling in between (Mean = 7.02, SD = 7.52) (See Fig. 8).

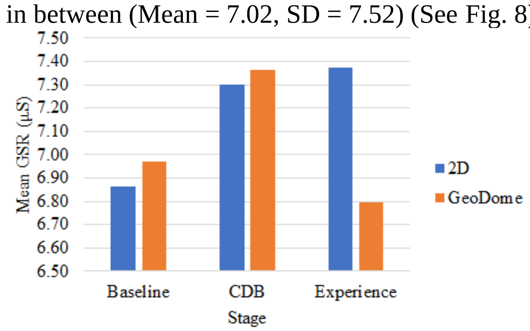

Fig. 6. Means for GSR as a function of Condition and Stage

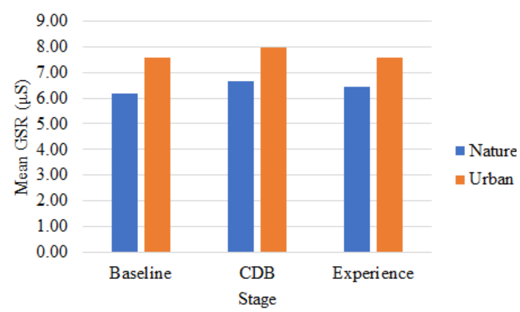

Fig. 7. Means for GSR as a function of Environment and Stage

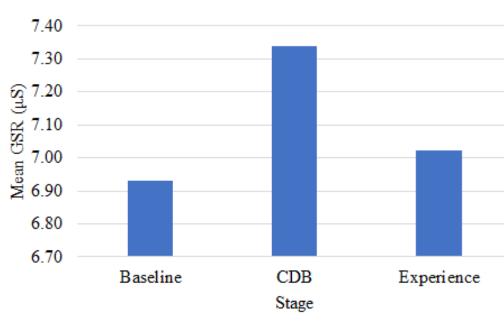

Fig. 8. Means for GSR as a function of Stage

Additionally, the GSR was lower for the 2D Nature experience (Mean = 6.26, SD = 6.98) than for the GeoDome Nature experience (Mean = 6.58, SD = 7.77); and it was higher for the 2D Urban experience (Mean = 9.03, SD = 6.98) than the GeoDome Urban experience (Mean = 6.93, SD = 7.75) (See Fig. 9).

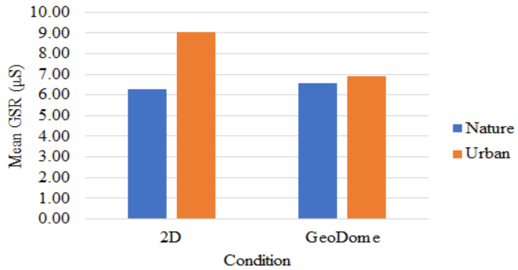

Fig. 9. Means for GSR during the virtual experience as a function of Condition and Environment

Heart Rate Variability

The measure used in this paper for HRV is the root mean of squared sequential differences (RMSSD) referring to the sequential R peak differences measured in milliseconds. Higher RMSSD values correspond to high heart rate variability and low levels of stress.

A paired t-test examined the differences within each subject and found that there was no significant difference at the 0.05 or 0.10 level of significance between the Baseline stage and the CDB stage (t-stat = 0.51, p-value = 0.621). There was a statistically significant (at 0.10 level) decline detected between the CDB stage and the Experience stage (t-stat = 2.05, p-value = 0.065).

TABLE IV. STATISTICS FOR PAIRED DIFFERENCES IN RMSSD WITHIN EACH SUBJECT

Diff.	**Mean(msec)**	**SD**	**95%CI**
Baseline-CDB	49.4	336.2	(-164.2, 263.0)
CDB-Exp	87.9	148.3	(-6.4, 182.1)

A factorial ANOVA was performed to examine the effect of the independent variables and interactions: Condition & Stage, Condition & Environment, Stage & Environment, and Condition & Stage & Environment. A summary of the ANOVA results is presented below (See Table V).

TABLE V. RESULTS OF THE STATISTICAL TESTS OF THE EXPERIMENTAL EFFECTS ON HRV LEVELS

Variable(s) of Interest	**F**	**p-value**
Condition	0.21	0.648
Environment	0.51	0.484
Stage	1.88	0.174
Stage:Env	3.13	0.062
Stage:Cond	1.23	0.310
Env:Cond	0.27	0.608
Env:Cond:Stage	0.42	0.663

The ANOVA did not yield any significant results at the 0.05 significance level. The interaction between the Stage and the Environment was significant at the 0.10 level. The experiment indicated that on average the lowest levels of HRV occurred in the Experience stage of the experiment (Mean = 94.3, SD = 31.9). The highest levels of HRV occurred before the CDB in the Baseline section of the experiment (mean = 231.6, SD = 268.7, See Fig. 10).

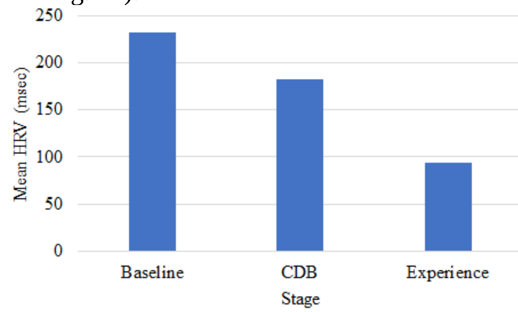

Fig. 10. Means for HRV as a function of Stage.

Conclusions & Future Work

Despite the limited sample size, we generally found a positive effect with hedonic tone and a stress reducing effect when participants viewed nature stimuli. This was again supported by the GSR data reporting a lower average reading for the nature condition than the urban condition. The GeoDome also had a more immersive effect than 2D with higher ratings in response to feeling "in the space."

When looking at the subjective data, the results reflect three main findings. Firstly, we found the stressor reliably increased levels of stress in participants and decreased positive mood, suggesting it was an appropriate stressor to use in this context. Secondly, nature images presented in either 2D or the GeoDome appear to increase hedonic tone and decrease the amount of induced stress. This is consistent with previous research which found viewing virtual wild nature had positive effects [8,16,17]. The results of the studies were all quite similar to the positive effects seen in hedonic tone that occurred in the nature condition. However, with the small sample size, these effects were not statistically significant. Finally, while again not having statistical significance, the use of a GeoDome appears to make participants feel more 'in the space' than the 2D stimulus delivery. The GeoDome appears to influence subjective comfort with participants experiencing nature in the dome reporting to feel more comfortable than all other groups and least comfortable when experiencing urban images in the dome.

For the biometric data, the GSR results support the team's hypotheses. Nature environments are more relaxing (lower average skin conductance) than urban, and the GeoDome experience is more restorative than the 2D experience. Furthermore, participants in the GeoDome were more relaxed at both the baseline and virtual experience stages than during the stressor test with lower average skin conductance, whereas participants in the 2D condition had a slightly higher average GSR level after the virtual immersion. Although the GeoDome participants reported having a lower average GSR level at baseline than after the virtual experience, the data suggests that the GeoDome had a more restorative effect than its 2D counterpart. The increase in average GSR levels during the stressor affirm the subjective stressor results. These results were consistent with similar studies using GSR or other biometric markers such as cortisol as the metric for stress [18,19].

The HRV data were generally inconclusive about the effectiveness of the stressor, 2D vs. VR, and Nature vs. Urban. The data seemed to contradict the hypothesis that the Experience stage of the experiment would result in higher heart rate variability. The interaction term between Stage and Environment, which was significant at the 0.10 level, was due to a much higher baseline among the nature group. However, even after filtering the signals the data remained noisy and there seemed to be outliers in terms of RMSSD being very high for certain participants. The Baseline measurement in particular was highly variable (SD = 871) which may have influenced the analysis. Going forward the baseline measurement should have been standardized in time in order to let the signal stabilize and allow for a more consistent RMSSD value to be obtained. Because the sample size was so small, a factorial ANOVA of this type lost many degrees of freedom which resulted in insignificant results.

Due to COVID-19, these are only preliminary findings since the experiment was cut short during the pandemic. Limitations in this project include lack of sufficient number of participants due to concerns about social distancing and lack of age heterogeneity within the participant pool. Future works in this research area would include expanding the participant pool to include students and people of working age, in addition to expanding the number of participants in this study. A document has been created that details the process and every step of the study for future projects.

The results in this study suggest nature stimuli had a restorative effect on stress. The data also reports that participants viewing nature in the GeoDome exhibited the most restorative properties after a stressor was applied to the participant, which is evident by both subjective data and biometric data in terms of self-reported stress and GSR. Therefore, there is potential for immersive virtual technology applications for stress management and relaxation.

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