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Renoir in VR: Comparing the Relaxation from Artworks Inside and Outside of Virtual Reality

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Abstract. Looking at artworks, experiencing nature, and being in virtual reality (VR) environments can relax people. We tested if the relaxation from viewing art and nature images with music for ten minutes while sitting in a recliner chair in a VR setup is different from experiencing the same content on a TV screen. Participants experienced this relaxation intervention after having finished a Montreal Imaging Stress Test. All tested conditions relaxed people but we found no significant differences between them from neither subjective nor objective measures in a between subjects study. However, trends in subjective and HRV measures pointed towards VR being more relaxing than TV.

1 Introduction

Stress is a serious health concern in modern society with physiological, cognitive, and behavioral consequences [18]. Hospitalized patients are particularly vulnerable and stress can result in extended recovery time for them post-surgery [17,30]. A number of activities such as meditation and breathing exercises can relax people. Other activities with potential relaxation benefits, which might also intrinsically motivate people to engage in them, include experiencing nature and artworks [22]. Immobile patients can rely on mediated experiences e.g. seeing nature through slide-shows on TV, which can be just as good at relaxing people as going into real nature [15]. Navigating in a VR nature scene has been shown to relax people more than viewing a slideshow in VR [31]. However, Anderson et al. [1] questioned the validity of the study due to the comparison of a large nature scene which people could walk around in and feel tactile feedback from movement to not moving around while looking at a slideshow of static abstract images. It was unclear whether it was the natural environment having a positive effect over the abstract images or whether increased immersion had a natural advantage for relaxing people.

We devised a study to test whether VR induces higher relaxation when depicting relaxing images than depicting those same images on a standard TV screen after exposure to an artificial stressor. The study further investigated whether potential advantages of VR are due to the removal of extraneous visual distractions. To that end we compared both physiological data (heart rate and its variability) and self-reports from twenty-one participants. Participants experiencing art in VR tended to find this more relaxing than participants watching the same footage on a TV screen according to subjective measures.

2 Background

Stress can come from many different sources and result in many different effects. People suffering from stress may show reactions in a physiological-, physical-, and/or a behavioural manner [3,19]. Many studies have examined the effects of stress on the body [18] including in clinical settings where stress has been associated with longer recovery time post-surgery [30]. Higher cortisol levels, which are associated with stress, negatively impact memory and cognition [23].

Several methods for relaxing exist such as people experiencing nature environments, both real and virtual, as well as art [1,15,22,24,27,30]. Kjellgren et al. [15] compared the relaxing effect of experiencing real nature in a forest for 30 minutes and a slide show of forest images displayed on a TV screen, and found that the two environments were equally good at reducing stress. Nielsen et al. [22] investigated the relaxing effect of art in hospitals by comparing a hospital room over two weeks, with the room being without any art in one week and filled with art the other week. The study found that art "*... promotes an experience of enhanced quality and satisfaction among patients.*" [22].

Other studies relied on virtual nature environments in VR to relax people [16,24,31]. VR technologies immerse users through visuals and sound like other types of media, such as television or films. But the key feature that distinguishes VR from other types of media is the sense of presence it induces [32]. As advanced TV screens, VR can create the illusion of visual depth by providing an image for each eye with a slight offset from each other. VR systems achieve this through a head mounted display (HMD) [25]. More importantly, VR can provide interaction in the form of translating head and/or body movements in the real world to movements in the virtual environment. This activates the human sense of proprioception, since the virtual environment behaves as if the user was using six Degrees of Freedom (DOF) of movement in a real environment [13].

Previous VR studies aiming at relaxing people have immersed them in different nature setups lasting from three [24] to 15 minutes [1]. This included watching a rendered jellyfish in an underwater environment [27], a rendered 3D park scene [24], looking at rural Ireland [1] and a remote beach [1] both in 360° videos and compared this to e.g. an empty class room in 360° videos [1]. All of these studies had their participants seated and could move their heads to look around the scene. Only the study by Riva et. al. allowed the participants to explore the VR environment by using a controller to move around [24]. The objective of the participants differed between the studies, ranged from simply visually exploring the environment [1] to do deep breathing exercises in pace with part of the environment [27]. Some studies employed comfortable chairs to further enhance the participants sense of presence [1,34] while others used swivel chairs to simplify looking around in the scene while sitting [24,32]. Most studies using technology to relax people were based in laboratories [1,15] or hospitals [22].

When evaluating stress or relaxation through interventions, studies relied on obtaining subjective and objective measures usually in comparison to a baseline. Subjective measures included the Perceived Stress Scale (PSS) [27], Positive and Negative Affect Schedule (PANAS) [1,24,27], and the Relaxation Rating scale (RRS) [27,34]. For the RRS, people rate their subjective relaxation on a Likert scale from 1 to 7, with 1 being *"Not Relaxed At All"* and 7 being *"Totally Relaxed"*. Common physiological measures of stress or relaxation have included breath rate [27], heart rate (HR) [6,8,31], heart rate variability (HRV) [1,27], cortisol [7], and electrodermal activity (EDA) [1,31].

In terms of Heart Rate Variability (HRV) and measuring relaxation, the measures used have depended on the duration of the experimental design [6]. Short-term experiments have lasted anywhere between two and 15 minutes [6,21], while long-term designs should last for at least 24 hours [6]. HRV measures concerning relaxation for short-term designs exist both in the time and frequency domain. Recommended short-term time-domain measures are the percentage of consecutive NN intervals that differ by more than 50 ms (pNN50) and the square root of the mean square differences of successive NN intervals (r-MSSD) [6]. Recommended short-term frequency-domain measures are HF power and LF/HF ratio [6,20]. For frequency domain measures to yield valid data that can be analysed alone, a minimum of four minutes of heart rate data is required [6]. An increase in all the mentioned HRV measures, except for LF/HF and LF, indicate a relaxation response which is an increase in vagal tone of the parasympathetic nervous system meaning the body is entering a rest-and-digest state. An increase in LF/HF and LF instead indicates a stress response [28]. However, there are disputes over the validity of the LF/HF ratio as a measure of cardiac sympathovagal balance, the relationship between sympathetic nervous activity (fight-or-flight), linked to LF, and the parasympathetic (rest-and-digest), linked to HF. Some argue against it as a reliable measure [2], while others argue for its continued use [6]

Methods of inducing stress both inside and outside VR environments have included: the Golden Stroop [10], mental arithmetic tests [1,31],the Montreal Imaging Stress Task (MIST) [4], and the Trier Social Stress Test (TSST) [7,12,14]. Deep breathing constitutes one approach to induce relaxation. Deep breathing causes respiratory sinus arrythmia (an increase in heart rate when inhaling and decreasing while exhaling) and in turn increases heart rate variability [26].

In summary, previous studies have found that using VR can help relax people in stressful situations [1,27]. But it remains unclear whether the immersion possible in VR relaxes people more than watching the same content on a standard TV screen.

3 Study

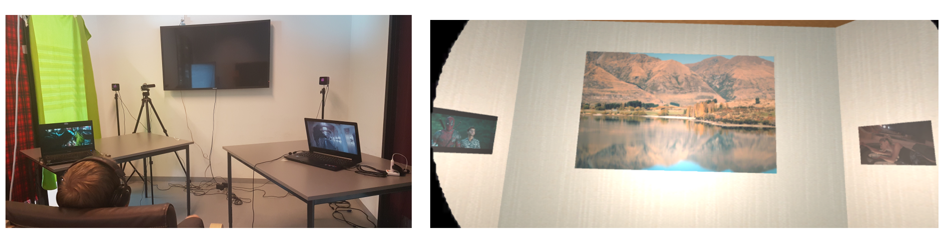
We developed three different relaxing interventions all of which showed a slideshow of images accompanied by music. The images included ten non-abstract artworks and ten nature photographs - each shown for 30 seconds.

During one intervention the slideshow was shown on a TV screen. On each side of the TV screen, we placed laptops as visual distractions. Each laptop played a list of videos consisting of either movie trailers or music videos. These laptop screens were positioned such that they were not the focus of the participant, but were still able to be seen. They were 90° apart, measured from the participant's head (see Figure 2).

The other two interventions used VR to deliver the slideshow - with and without visual distractors. Both limited the participants field of view to 90° by using a plane with a transparent hole overlaid on the camera (*c.f.* Figure 1b). One of the VR interventions replicated the visual distractions seen in the TV condition by placing one on each side of the big image (see Figure 1b). We used the same trailer and music videos as in the TV condition. The other VR intervention featured no such distractions.

Procedure: The experiments took place in a quiet and isolated room. To keep out any uncontrollable distractions, blankets blocked the windows as seen in Figure 1a. The participants sat in a soft, comfortable recliner chair for the entire duration of the experiment. For the VR condition a computer running the VR scene was used along with an HTC Vive HMD including lighthouses for tracking with 6-DOF.

After giving their consent, participants were fitted with a Polar H10 heart rate belt that captured the participants interbeat intervals, which were retrieved by Elite HRV [11] running on a smartphone. They were then seated in the chair. To obtain valid frequency domain HRV measures we recorded five minutes of baseline data before commencing with the experiment. See Figure 3 for the full



(a) The setup of TV and visual distractor laptop screens. Equipment used for VR and a camera can also be seen.

(b) The VR scene. In the condition without distractors the two screens next to the paiting were missing

Fig. 1. The experiment setup.

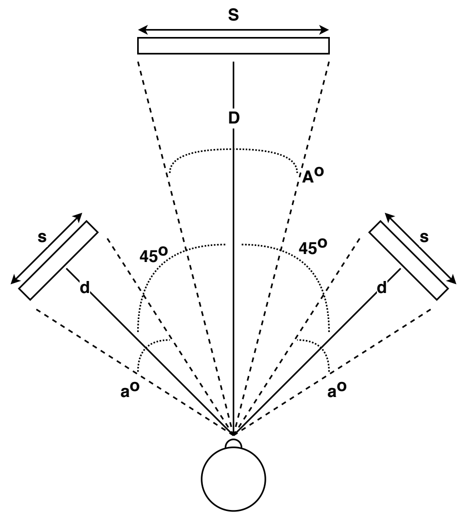


Fig. 2. The placement of main and distractor screens, both for VR and TV conditions

timeline of the experiment. After the baseline measurement the participants filled out an RRS to give their subjective relaxation.

As a stressor we decide on using the Montreal Imagning Stress Task, which can be seen in Figure 4. In this test, the participants had to answer arithmetic problems as fast as possible to achieve as high a score as possible. They were told that they were able to see how well they were doing compared to the average person. When doing well participants would get less time for each problem resulting in a below average score. All participants completed this test in VR. We instructed the participants on the controls, and the facilitator informed the participant how much time was remaining during the stressor. This happened every minute and when 30 and 10 seconds were remaining. When the five minutes had passed, the participant rated their relaxation again using an RRS.

The participants then experienced one of three relaxation interventions: TV with, VR with, or VR without visual distraction. All participants wore over-the-ear headphones for the music during the intervention, while participants

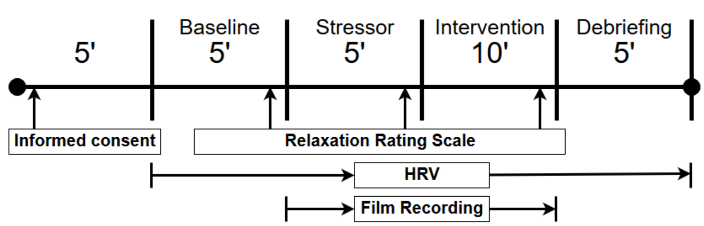


Fig. 3. *Timeline of the procedure*

experiencing the VR interventions also wore an HMD. After the intervention, the participants filled out a third and final RRS. At the end the facilitator explained the nature of the experiment and gave the participants the opportunity to relax. The participants could give comments or just have a little chat. After a few minutes the measurements were stopped and the sensors removed. The participants received sweets and juice as compensation for their time.

3.1 Participants

Twenty-one university students (two female) aged 19-26 years old (mean age: 22) participated in the study - seven in each condition. All participants were asked if they had any medical conditions such as psychiatric, chronic, or neurological conditions or if they used any blood regulating medicine such as beta-blockers, since that would have caused them to be excluded due to possible impacts on HRV measures [1,24]. No participants were excluded based on these grounds.

4 Data processing and analysis

We checked the inter-beat intervals (IBI) for missing and extraneous heartbeats. Using the RHRV toolkit [9], we computed average measures of heart rate, pNN50, r-MSSD, HF power, and LF/HF ratio for each participant by episode (baseline, stressor, and intervention). This relied on a window size for time-domain calculations of 300 seconds, with the RHRV default bin width of 7.8125 milliseconds. The frequency-domain Fourier transform used a window size of 100 seconds and a window shift of two seconds. For each condition, we inspected QQ-plots to check whether the aggregated physiological measures per condition of the participants were normally distributed.

We tested for significant differences between the interventions based on all obtained measures as absolute values as is (*absolute relaxation*) and as relative values computing the differences between the values during the stressor and relaxation episodes (*relative relaxation*). We tested for significant differences between the three condition, by running three pairwise tests with Bonferroni corrections ($0.05/3 = 0.017$).

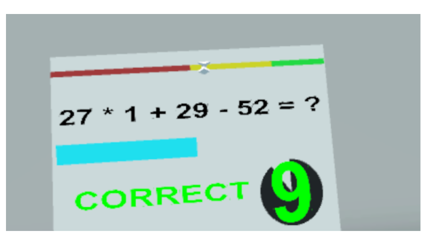
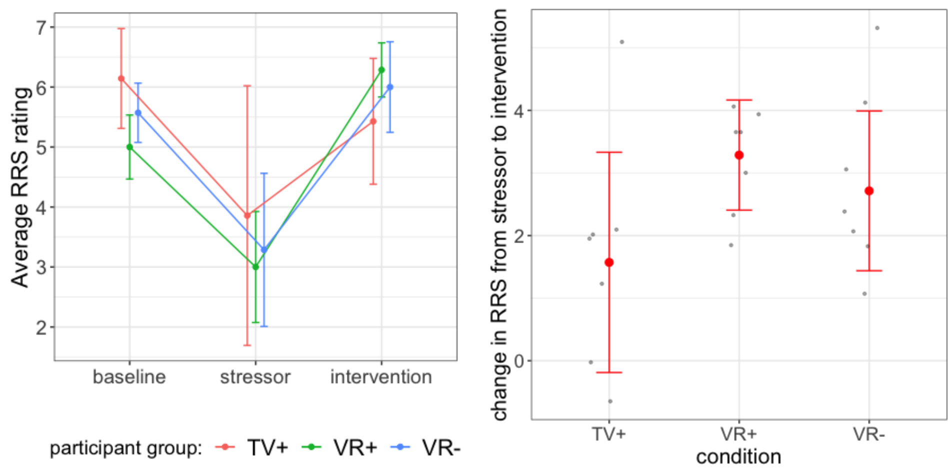


Fig. 4. *A cropped screenshot of the MIST stressor*



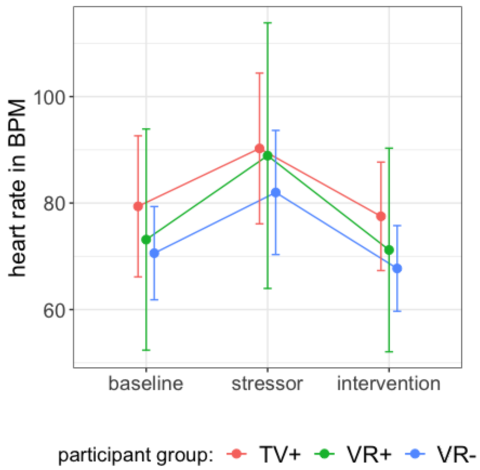
(a) during the episodes by participant group with 0.95 c.i. error bars (b) Change in RRS from the stressor to the intervention (relative relaxation)

Fig. 5. Subjective relaxation results (RRS)

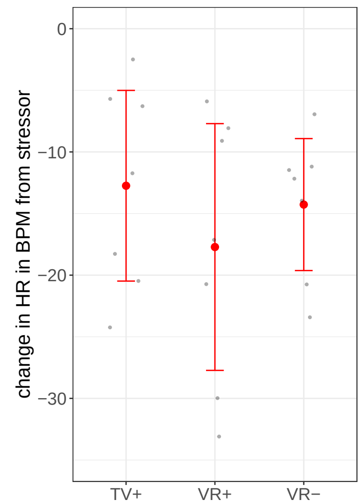
5 Results

Both VR interventions yielded a higher average relaxation rating than the TV intervention, both in terms of absolute and relative relaxation (see Figure 5). However, a Kruskal-Wallis rank sum test between the conditions found no significant differences between the conditions - neither in absolute ($F(2)=0.33$, $p=0.85$) nor relative relaxation ($F(2)= 4.61$,$p=0.1$). While the differences were not statistically different, the trend of the RRS averages in Figure 5b showed that the TV condition was less relaxing than the VR conditions. Remember that all participants experienced the same baseline and stressor - only the relaxation intervention differed.

Comparing the average HR of participants during the intervention with the average HR during the stressor revealed a reduction during the intervention, pointing towards a relaxing effect of all interventions (see Figure 6). According to t-tests the participants' heart rate was significantly lower during the intervention than the stressor when comparing the absolute values for all three conditions at the same time ($t(37)=-2.90$, $p=0.01$). Post-hoc t-tests found that the only condition for which the change in HR during the intervention compared to the baseline was significantly different from zero was for VR$-$ ($t(6)=-2.71$, $p=0.02$). But ANOVAs comparing these changes in HR during the intervention relative to the baseline ($F(2)=0.16$, $p=0.86$) and relative to the stressor ($F(2)=1.45$, $p=0.26$) episodes between the conditions found no significant differences between the conditions. So, the findings from the t-test and ANOVAs did not match.



(a) by participant group with 0.95 confidence interval error bars



(b) Change in HR from the stressor with confidence intervals (red)

Fig. 6. Heart rate results

Table 1. *All one-tailed p-values for the experiment, rounded to two decimals. P-values lower than 0.15 are marked with a star (*). The pairwise tests are:* $I = VR+ > TV+$, $II = VR- > TV+$, $III = VR- > VR+$.

	Absolute Relaxation			Relative Relaxation		
Condition	I	II	III	I	II	III
r-MSSD	0.13 *	0.95	0.98	0.40	0.27	0.36
LF/HF	0.064 *	0.064 *	0.355	0.519	0.684	0.742
HF	0.96	0.77	0.36	0.98	0.99	0.77

Since some participants had zero values in pNN50 indicating a floor effect, we relied on the r-MSSD, LF/HF, and HF measures for the HRV analysis. QQ-plots showed that none of the measures (r-MSSD, LF/HF, and HF) were normally distributed and Mann-Whitney U tests were used to compare the three relaxation interventions pairwise. Table 1 shows the p-values for these tests. There were no significant differences, neither in absolute nor in relative relaxation for any of the HRV measures. However, the pairwise tests comparing LF/HF measures during VR+ with TV+ and VR- with TV+ were close to the 0.05 threshold for p (see Table 1) indicating the tendency that both VR conditions were more relaxing than the TV condition.

6 Discussion

We found evidence from RRS and HR measures that all three interventions relaxed people in contrast to the stressor. We did not compare the interventions against the bodies natural relaxation by using a no-intervention control group and can therefore not say how much better the intervention is compared to not doing anything. However, this was not within the scope of our study. From studies by Anderson et al. [1] and de Kort et al. [16] showing that VR increased immersion, we hypothesized that experiencing art in VR would be more relaxing than on a TV. Surprisingly, we found no such significant differences between relaxation in VR and using a TV screen. But the trends from self-reports and heart rate changes both pointed in the expected direction of VR being more relaxing than the TV condition. Given the low number of participants (seven per condition) and the between subjects design this lack of significant result could be due to a lack of statistical power for the ANOVA tests. Close to significant differences in pairwise comparisons of HRV (see Table 1) added further evidence in this direction. However, these tendencies came mostly from the LF/HF ratio measure. Whether this represent a valid measure of sympathovagal balance remains a point of controversy.

We expected the distracting videos to leave the participants less relaxed from the art content, which did not turn out to be the case. For the experiment we used two video playlists of well-known movie trailers and music videos as visual distraction to determine if removing these via VR would have an influence on participants' relaxation. Human vision is better at spotting movement closer to the edges of the vision [29,33]. Therefore, we set the visual distractions close to the edge of the cone of vision rather than in the center. This resulted in 45° angles from the center of the slideshow to the center of the distractors. In VR, the FOV limiter prevented the participants from viewing the entirety of both distractor screens at the same time without moving their head. This limiting of the videos could make the videos less distracting in the VR condition as only parts of the video could be seen and therefore easier to ignore by participants, or potentially add to the distracting effect as being able to only see part of the video could be annoying. Although the differences between the conditions were not significant trends showed the participants who experienced these videos reported being more relaxed on the RRS on average than the participants who did not experience the distractors. This could be because these videos were familiar to the participants or that some participants found them relaxing.

Our study relied on an artificial stressor in a quiet environment, which might have resulted in participants being already very relaxed creating a ceiling effect, which did not allow for finding significant differences. Future studies, Using a real stressor, e.g. people who are genuinely stressed from worrying and situated in a stressful environment (such as a hospital) might be better suited at showing differences between the the modes of delivery of art content. For example, in the TV condition people would still be exposed to the extraneous activities going on in the hospital. Such a future study would at the same time yield results with higher ecological validity than ours. To improve sensitivity researchers could consider measuring stress through measures other than heart rate and its variability. Cortisol levels, while expensive and cumbersome to measure, have been shown to be modulated by stress [5]. An option to increase immersion and potentially relaxation from the artworks, which are only shown for a limited amount of time, would be relying on animations such as the Ken Burns effect.

7 Conclusions

Subjective RRS responses and HRV measures showed that exposure to nature and art images accompanied by music for ten minutes helped people relax after doing mentally demanding arithmetics. Trends in heart rate variability measures, such as heart rate, and subjective self-reporting did point towards VR being more relaxing. But we found no significant difference between these conditions - possibly due to a lack of statistical power. However, if indeed there were no difference between these media option it would be good news for practitioners using such interventions. It would be sufficient to present this kind of footage on TV screens, which scale better for multiple viewers and do not require additional equipment and setup such as HMDs.

References

1. Anderson, A.P., Mayer, M.D., Fellows, A.M., Cowan, D.R., Hegel, M.T., Buckey, J.C.: Relaxation with immersive natural scenes presented using virtual reality. Aerospace medicine and human performance **88**(6), 520–526 (2017)
2. Billman, G.E.: The LF/HF ratio does not accurately measure cardiac sympatho-vagal balance. Frontiers in Physiology **4** (Feb 2013). https://doi.org/10.3389/fphys.2013.00026
3. Cooper, C., Dewe, P., O'Driscoll, M.: What is Stress? In: Organizational Stress: A Review and Critique of Theory, Research, and Applications, pp. 1–26. SAGE Publications, Inc., Thousand Oaks (2001). https://doi.org/10.4135/9781452231235
4. Dedovic, K., Renwick, R., Mahani, N.K., Engert, V., Lupien, S.J., Pruessner, J.C.: The montreal imaging stress task: using functional imaging to investigate the effects of perceiving and processing psychosocial stress in the human brain. Journal of Psychiatry and Neuroscience **30**(5), 319 (2005)
5. Dickerson, S.S., Kemeny, M.E.: Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. **130**, 355–391 (2004). https://doi.org/10.1037/0033-2909.130.3.355
6. Electrophysiology, T.F.o.t.E.S.o.C.t.N.A.S.o.P.: Heart rate variability. Circulation **93**(5), 1043–1065 (1996). https://doi.org/10.1161/01.CIR.93.5.1043
7. Fich, L.B., Jönsson, P., Kirkegaard, P.H., Wallergård, M., Garde, A.H., Hansen, r.: Can architectural design alter the physiological reaction to psychosocial stress? A virtual TSST experiment. Physiology & Behavior **135**, 91–97 (Aug 2014). https://doi.org/10.1016/j.physbeh.2014.05.034
8. Friedlander, L., Lumley, M.A., Farchione, T., Doyal, G.: Testing the Alexithymia Hypothesis: Physiological and Subjective Responses During Relaxation and Stress. The Journal of Nervous and Mental Disease **185**(4) (1997)

9. García, C.A., Lado, M., Méndez, A., Otero, A., Rodríguez-Liñares, L., Vila, X.: The RHRV project, http://rhrv.r-forge.r-project.org/
10. Golden, C.: Stroop Color and Word Test. In: Encyclopedia of Measurement and Statistics, pp. 973–973. SAGE Publications, Inc., Thousand Oaks (2007). https://doi.org/10.4135/9781412952644
11. HRV, E.: About Elite HRV (2018), https://elitehrv.com/about
12. Høngaard, J.S., Thomsen, A.M., Christensen, P.M.H.: A Virtual Reality Implementation of the Trier Social Stress Test Using Head-Mounted Displays. Ph.D. thesis, Aablorg Universitet, Aalborg (2016)
13. Jonathan, S.: Defining Virtual Reality: Dimensions Determining Telepresence. Journal of Communication **42**(4), 73–93 (February 2006). https://doi.org/10.1111/j.1460-2466.1992.tb00812.x
14. Kirschbaum, C., Pirke, K.M., Hellhammer, D.H.: The 'trier social stress test'– a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology **28**(1-2), 76–81 (1993)
15. Kjellgren, A., Buhrkall, H.: A comparison of the restorative effect of a natural environment with that of a simulated natural environment. Journal of Environmental Psychology **30**(4), 464 – 472 (2010). https://doi.org/10.1016/j.jenvp.2010.01.011
16. de Kort, Y.A.W., Meijnders, A.L., Sponselee, A.A.G., IJsselsteijn, W.A.: What's wrong with virtual trees? Restoring from stress in a mediated environment. Journal of Environmental Psychology **26**(4), 309–320 (Dec 2006). https://doi.org/10.1016/j.jenvp.2006.09.001
17. Linden, W.: Stress Management: From Basic Science to Better Practice. SAGE (Oct 2004)
18. McCarthy, M.: Healthy design. The Lancet **364**(9432), 405–406 (Jul 2004). https://doi.org/10.1016/S0140-6736(04)16787-1
19. McEwen, B.S., Karatsoreos, I.N.: What Is Stress? In: Chouker, A. (ed.) Stress Challenges and Immunity in Space: From Mechanisms to Monitoring and Preventive Strategies, pp. 11–29. Springer Berlin Heidelberg, Berlin, Heidelberg (2012). https://doi.org/10.1007/978-3-642-22272-6_3
20. Mietus, J.E., Goldberger, A.L.: Heart Rate Variability Analysis with the HRV Toolkit, https://physionet.org/tutorials/hrv-toolkit/
21. Myers, G.A., Martin, G.J., Magid, N.M., Barnett, P.S., Schaad, J.W., Weiss, J.S., Lesch, M., Singer, D.H.: Power spectral analysis of heart rate varability in sudden cardiac death: Comparison to other methods. IEEE Transactions on biomedical engineering **213**(12), 1149–1156 (1986)
22. Nielsen, S.L., Fich, L.B., Roessler, K.K., Mullins, M.F.: How do patients actually experience and use art in hospitals? The significance of interaction: a user-oriented experimental case study. International Journal of Qualitative Studies on Health and Well-being **12**(1), 1267343 (Jan 2017). https://doi.org/10.1080/17482631.2016.1267343
23. Oei, N.Y.L., Everaerd, W.T.A.M., Elzinga, B.M., Well, S.v., Bermond, B.: Psychosocial stress impairs working memory at high loads: An association with cortisol levels and memory retrieval. Stress **9**(3), 133–141 (Jan 2006). https://doi.org/10.1080/10253890600965773
24. Riva, G., Mantovani, F., Capideville, C.S., Preziosa, A., Morganti, F., Villani, D., Gaggioli, A., Botella, C., Alcañiz, M.: Affective interactions using virtual reality: the link between presence and emotions. CyberPsychology & Behavior **10**(1), 45–56 (2007)

25. Schuemie, M.J., van der Straaten, P., Krijn, M., van der Mast, C.A.: Research on Presence in Virtual Reality: A Survey. CyberPsychology & Behavior **4**(2), 183–201 (April 2001). https://doi.org/10.1089/109493101300117884
26. Shields, R.W.: Heart rate variability with deep breathing as a clinical test of cardiovagal function **76 Suppl 2**, 37–40 (2009). https://doi.org/10.3949/ccjm.76.s2.08
27. Soyka, F., Leyrer, M., Smallwood, J., Ferguson, C., Riecke, B.E., Mohler, B.J.: Enhancing stress management techniques using virtual reality. In: Proceedings of the ACM Symposium on Applied Perception. pp. 85–88. ACM (2016)
28. Terathongkum, S., Pickler, R.H.: Relationships among heart rate variability, hypertension, and relaxation techniques. Journal of Vascular Nursing **22**(3), 78–82 (2004)
29. Thomsen, A.M., Christensen, P.M.H.: Measuring reaction time to peripheral information using spatial augmented reality (2015)
30. Ulrich, R.S., Zimring, C., Zhu, X., DuBose, J., Seo, H.B., Choi, Y.S., Quan, X., Joseph, A.: A Review of the Research Literature on Evidence-Based Healthcare Design. HERD: Health Environments Research & Design Journal **1**(3), 61–125 (Apr 2008). https://doi.org/10.1177/193758670800100306
31. Valtchanov, D., Barton, K.R., Ellard, C.: Restorative effects of virtual nature settings **13**, 503–512 (2010). https://doi.org/10.1089/cyber.2009.0308
32. Villani, D.: Presence and Relaxation: A Preliminary Controlled Study. PsychNology Journal **6**(1), 7–25 (2008)
33. Ware, C.: Information Visualization: Perception for Design. Elsevier Science & Technology (2004)
34. Yu, B., Hu, J., Funk, M., Feijs, L.: A Study on User Acceptance of Different Auditory Content for Relaxation. In: Proc. of the Audio Mostly 2016. pp. 69–76. AM '16, ACM, New York, NY, USA (2016). https://doi.org/10.1145/2986416.2986418