Enhancing Stress Management Techniques Using Virtual Reality

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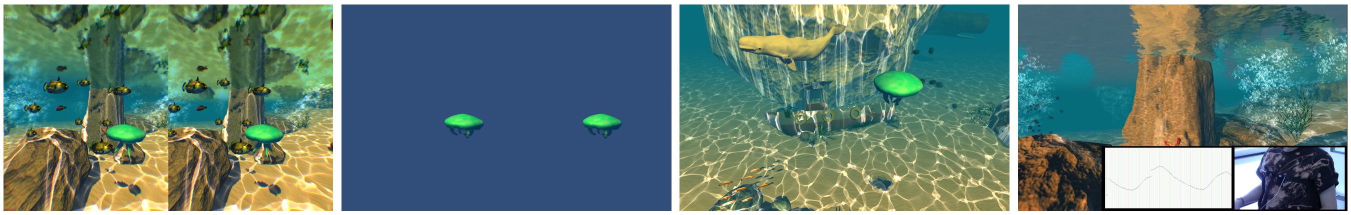

Figure 1: Far left*: screenshot of the underwater environment (UWE) with the rhythmically moving jelly fish that provides the guiding signal for the breathing.* Left*: Control condition in which users just saw the jelly fish on a dark blue background (JELLY).* Far right*: Underwater world setup where the participant wears an OculusDK1 head-mounted display and breathing monitor.*

Abstract

Chronic stress is one of the major problems in our current fast paced society. The body reacts to environmental stress with physiological changes (e.g. accelerated heart rate), increasing the activity of the sympathetic nervous system. Normally the parasympathetic nervous system should bring us back to a more balanced state after the stressful event is over. However, nowadays we are often under constant pressure, with a multitude of stressful events per day, which can result in us constantly being out of balance. This highlights the importance of effective stress management techniques that are readily accessible to a wide audience. In this paper we present an exploratory study investigating the potential use of immersive virtual reality for relaxation with the purpose of guiding further design decisions, especially about the visual content as well as the interactivity of virtual content. Specifically, we developed an underwater world for head-mounted display virtual reality. We performed an experiment to evaluate the effectiveness of the underwater world environment for relaxation, as well as to evaluate if the underwater world in combination with breathing techniques for relaxation was preferred to standard breathing techniques for stress management. The underwater world was rated as more fun and more likely to be used at home than a traditional breathing technique, while providing a similar degree of relaxation.

Keywords: virtual reality, relaxation, stress, breathing

Concepts: •**Human-centered computing** → **Virtual reality; Empirical studies in HCI;**

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Symposium on Applied Perception 2016 Short Paper, July 24-28, 2016, Anaheim, CA
ISBN: 978-1-4503-ABCD-E/16/07
DOI: http://doi.acm.org/10.1145/9999997.9999999

1 Introduction

Chronic stress is one of the major problems in our current fast paced society [Egger and Dixon 2014]. It is not uncommon to be constantly bombarded with information affording us to take actions and it can become increasingly difficult to calm our minds. The body reacts to environmental stress with physiological changes (e.g. accelerated heart rate), increasing the activity of the sympathetic nervous system [Lambert and Lambert 2011]. Once the stressful situation is over the parasympathetic branch of the autonomic nervous system takes control and brings the body back into a balanced state [Prinsloo et al. 2011]. This is a healthy and helpful mechanism as long as one manages to get out of the stressful situation and return into a balanced state. However, nowadays people are often constantly under pressure, perceiving many stressful events every day and therefore can be chronically out of balance. Hence, effective stress management techniques become of utmost importance and should be made readily available for everyone. Biofeedback training to increase heart rate variability (HRV) is a standard method used in stress management [Lehrer et al. 2007]. Paced breathing at approximately 6 breaths per minute leads to a coupling between breathing and heart rate (respiratory sinus arrhythmia, RSA), which stimulates the parasympathetic nervous system (PSNS) resulting in relaxation and improved cognitive performance [Prinsloo et al. 2011]. A measure of RSA is often used as an index for vagal tone, the activity of the vagus nerve. This nerve has a key component in controlling the PSNS and is furthermore also involved in emotion regulation [Prinsloo et al. 2011]. For example, self-induced positive emotions like appreciation can change the pattern of the heart rate resulting in changes in RSA and vagal tone[McCraty and Zayas 2014]. These mutual influences result in an upwards spiral in which vagal tone mediates positive emotions, which in turn lead to increases in vagal tone [Kok et al. 2013]. Therefore we utilize paced breathing methods in order to counter stress, to stimulate the PNS and to increase vagal tone. One common problem with paced breathing methods is that people get bored after some time, loose interest and do not follow the guiding signal with their breath anymore. We aim at tackling this problem and enhancing current stress management techniques by combining paced breathing methods with state of the art virtual reality (VR). Virtual environments provide a great way to quickly transport a user out of a stressful situation into a personalized experienced tailored to induce positive emotions and thoughts of well-being[Riva et al. 2007]. While being in the virtual world users can at the same time follow a visual guidance signal with their breath as well as explore fascinating virtual worlds which are fun and keep them engaged in the task. Using such technology might also help to get people engaged in the task in the first place. Doing a breathing exercise based on simply watching a bar moving up and down seems much less attractive than immersing yourself into a virtual world and following as in our project the rhythmic motions of an animal with your breath. This is a perfect example for a serious gaming task since it combines well-known stress management techniques with playful virtual environments.

2 Methods

Twenty-one participants (10 female) took part in the study. They were between 20 to 45 years old (M=29). The participants were paid and signed a informed consent prior to the experiment. Ethical approval was obtained from University of Tuebingen. After reading the instructions, participants put on a breathing sensor around their chest (gtec, piezo-electric crystal respiration effort sensor, g.RESPsensor) and a blood pulse sensor on their left index finger (Brain Products). Both sensors were connected to the BrainVision V-Amplifier which recorded the signals at 500 Hz. In order to establish a baseline for each participant we recorded physiological activity for 5 minutes while participants were watching a slideshow of nature scenes [Berman 2015]. Next they filled in the Perceived Stress Scale (PSS) questionnaire [Cohen et al. 1983] which assesses their general stress level over the last month. Before going into virtual reality, participants rated their current stress/relaxation level on a 7-point Likert-scale.

During the intervention (VR session) participants saw in front of them a jellyfish moving up and down in the 6 seconds paced breathing rhythm. Their task was to follow the rhythmic motion of the jelly fish with their breathing. Eleven participants saw an underwater environment (UWE condition, see Fig. 1 far left) [Soyka 2014] while the ten participants acted as a control group which only saw the jellyfish without any surrounding environment (JELLY, see Fig. 1, left). Participants were told that the aim of the experiment was to relax and to follow the jellyfish's rhythmic motions with their breathing. This visual guidance remained always within the users view. Both conditions were accompanied by the same underwater sounds. We told participants not to breathe too deep in order to avoid dizziness and hyperventilation. The VR intervention lasted 10 minutes for both groups and physiological activity was monitored during that time. After experiencing the virtual reality they immediately rated their stress level again, followed by additional questions about their perceived fun, task difficulty, time perception and relaxation value of the experience.

3 Results

3.1 Questionnaire Results

Questionnaire data were analyzed using the non-parametric 2 independent samples Mann-Whitney U test using SPSS. There were no differences in the cumulative perceived stress scores between the groups (see Figure 2). Overall participants were relatively relaxed already before VR exposure. Compared to the JELLY condition, participants in the UWE condition were more relaxed both before ($p = .038$) and after the VR exposure ($p = .041$). Paired-Samples t-tests (before/after) show improved relaxation levels after the VR exposure for both groups ($p < .001$). Both groups found the experiences equally relaxing (see Fig. 3 left), altohough the underwater world was rated as being significantly more fun and less boring ($p = .023$, see Fig. 3 right).

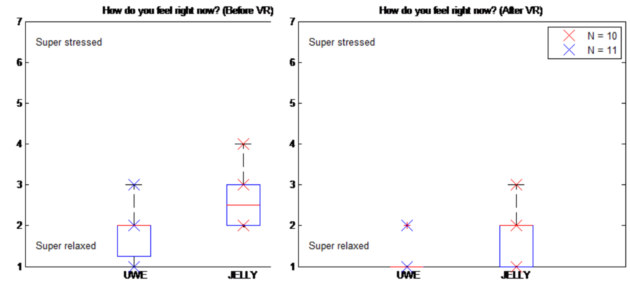

Figure 2: *Questionnaire data about perceived stress before (left) and after (right) the breathing experience. Horizontal bars indicate the median,boxes indicate quartiles, and stars depict individual data points.*

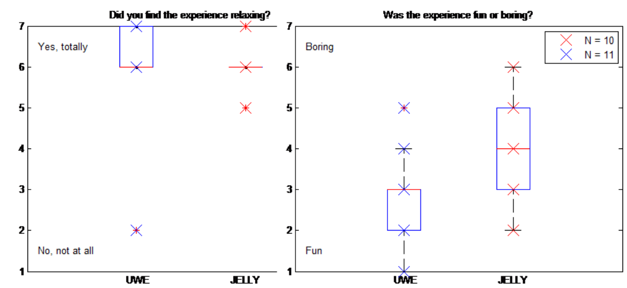

Figure 3: *Questionnaire ratings related to perceived relaxation and entertainment.*

On average, both groups rated the difficulty to follow the jellyfish motion with their breathing as relatively easy, although there was high variability (see Fig. 4, left). Finally, people in the UWE condition would use this tool at home for relaxation whereas people in the JELLY condition are reluctant ($p = .018$, see Figure 4, right).

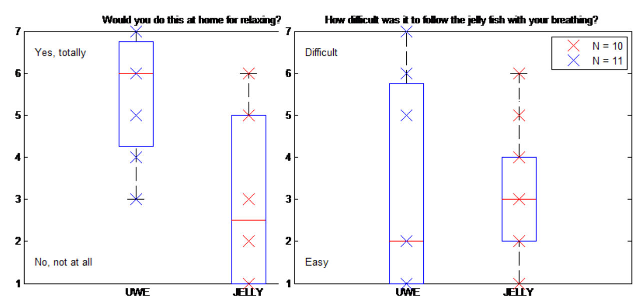

Figure 4: *Questionnaire ratings for ease of use and desired use at home for breathing relaxation.*

Time perception distribution was skewed towards longer times in the UWE condition even though it was the same average perceived time for both groups (See Figure 5).

3.2 Physiological Results

The photoplethysmogram data from the blood pulse sensor was converted into heart rate (HR) data using a custom written algorithm. For more information on how this can be realized, see for

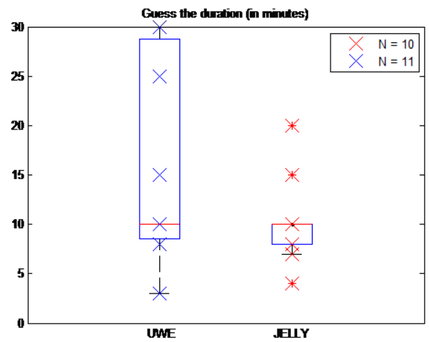

Figure 5: *Questionnaire data on perceived time perception for the different breathing experiences.*

example [Fu et al. 2008]. Therefore we ended up with HR and breathing data that could for example look like Figure 6 (left). In order to analyze the breathing data, we computed the power spectral density (PSD) to see how frequency components of the breathing signal were distributed. For the VR intervention we expected to see a clear peak at 0.1 Hz (period of 10 seconds which equates to 6 breaths per minute as in the jellyfish pacing). In Figure 6 (right) you can see the PSD during a typical baseline measurement.

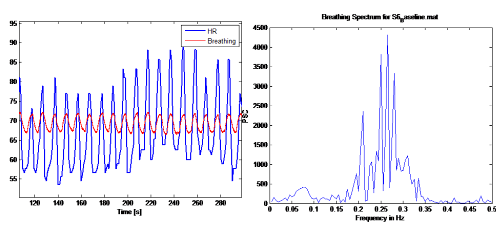

Figure 6: *Example of HR and breathing data (left), and a baseline example of power spectral density of breathing data (right).*

From the PSD, we extracted the position and height of the largest peak for each participant during the baseline and the intervention. The peak height measures how much of the signals power is concentrated in the peak. Next we looked at the HR data and index the heart rate variability (HRV) by measuring the standard deviation of the heart rate. Furthermore we computed the correlation between the HR and the breathing to assess the coupling between the two. In case of perfect coupling we would expect to find a correlation of 1, whereas during random breathing (as for example in the baseline condition) we would expect to find a correlation close to 0.

For the locations of the peaks of the breathings PSD we find the distributions seen in Figure 7 (Note: Due to technical issues during data acquisition, not all baseline data for each participant is available). Whereas for both interventions the breathing peak peaks were almost all at .1 Hz indicating that participants were able to breathe at 6 breaths per minute, breathing during the baseline condition (BASE) was more than twice as fast. The peak heights (see Figure 8) illustrate that the power of the signal is equally concentrated in the peaks during the intervention conditions.

The standard deviations of the HRs (see Figure 9) were higher during the interventions, indicating that participants did activate their parasympathetic nervous system more when engaging in the relaxed breathing in VR. Also the correlation between HR and breathing (see Figure 10) is higher during the interventions than during the baseline, showing that the two signals couple together.

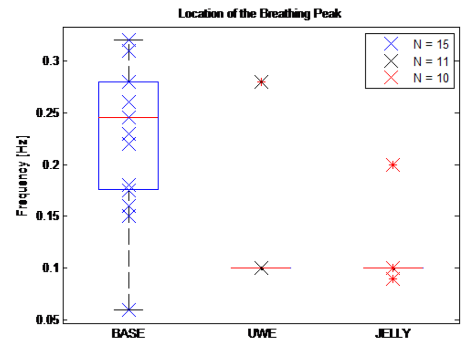

Figure 7: *Location of the breathing Peak, where 0.1 would indicate that participants are able to breathe at 6 breaths per minute. Breathing Peak was significantly different by condition* $(F(2, 35) = 17.75, p < 0.001)$.

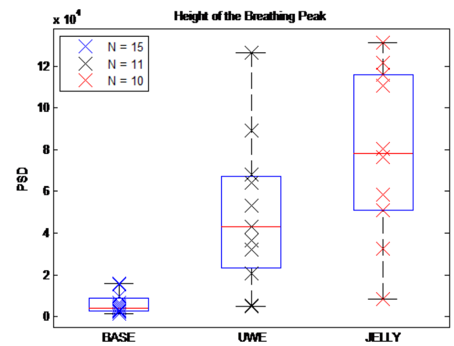

Figure 8: *Height of the breathing peak during the baseline and both breathing experiences. Height of the breathing peak was significantly different by condition* $(F(2, 35) = 18.69, p < 0.001)$.

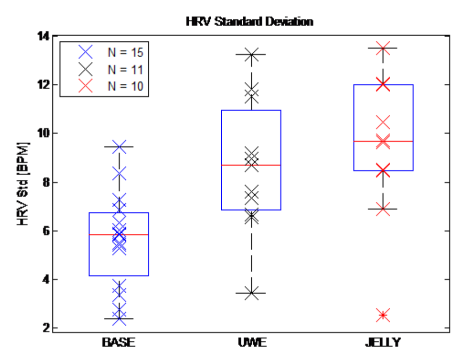

Figure 9: *The standard deviation of the heart rate. HRV was significantly different by condition* $(F(2, 35) = 7.64, p = 0.002)$.

We conducted a One-Way ANOVA with three levels of the factor condition (baseline, UWE and JELLY), for all four measures (breathing rate peak, breathing height, heart rate variability and the correlation between heart rate and breathing). We found a significant effect of condition on all four measures (F and p values can be found in each of the respective figures). Post-hoc tests with Bonferroni corrections reveal that for all measures there were differences between baseline and both intervention groups (all p's < 0.02). However, there were no differences between the UWE and JELLY condition (all p's $>= 0.4$). This indicates the intervention was working and that both interventions were equally effective on a physiological level.

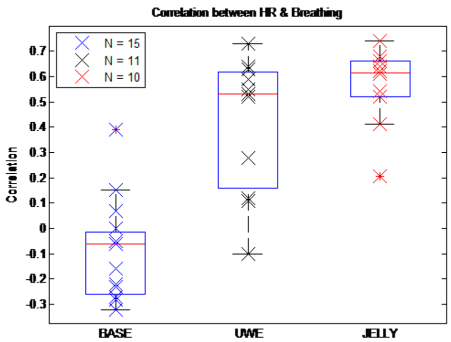

Figure 10: *Correlation between heart rate and breathing. The correlation between heart rate and breathing was significantly different by condition* $(F(2, 35) = 34.14, p < 0.001)$.

4 Summary and discussion

In this research we have taken first steps towards developing a VR application for stress management, specifically an underwater virtual world that can be used for paced breathing techniques. We have evaluated the effectiveness of the virtual world in an experiment where we sought user feedback about the experience as well as measured physiological responses when asked to perform a paced breathing technique. Our results are promising and suggest that virtual reality head-mounted displays might be useful to assist in stress management techniques. People were able to perform the paced breathing technique even when surrounded by a rich virtual world. They also reported a greater level of enjoyment for the virtual underwater world more as compared to an empty scene and they found the experience relaxing. In sum, questionnaire and physiological measures together suggest that the underwater world provides a potential improvement to current stress management techniques based on paced breathing, because it was as effective as traditional methods (here: the JELLY condition without the underwater environment) and at the same time more fun and more accepted as a tool for home training.

We are aware of several limitations in the current study. Most notably, as we were interesting in exploring the suitability of a novel virtual environment for supporting relaxation we did not include a control condition that used an established relaxation format in a non-VR setting. That is, we currently have no data on how much participants might have relaxed without any VR exposure, which is one of the things we plan on adding in follow-up studies. After incorporating the insights and feedback gained from the current study into an improved VR system future studies could investigate how this might support participants' ability to relax and de-stress, and compare it to other established techniques as well as a condition where users are simply asked to do their best to relax and de-stress without any technical/VR support.

In future virtual worlds aimed at facilitating relaxation, we will need to develop at least some subtle goals, tasks and/or feedback for the users if we want them to use this kind of relaxation technique as a regular part of their routine. Inspired by the playful interaction paradigm of research like the Sonic Cradle [Vidyarthi and Riecke 2014], in our future work we aim to add additional options for advanced users. We intend to adapt the interaction design tailored to the user such that the mere act of exploring and interacting with the virtual world and characters within will by itself help users to relax without the need for an explicit breathing technique. This added option for the user would enable user's to see if they can achieve paced breathing and the benefits thereof without the explicit feedback of a timed paced breathing in a more interactive world. This might have benefits for increased awareness of bodily states throughout the day and should be evaluated in further experiments.

5 Acknowledgments

The authors would like to thank Joachim Tesch.

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