Psychological Research of Early Career Scientists
2025, Vol. 1, No. 1

not peer reviewed
ORIGINAL RESEARCH ARTICLE

PRECS
Psychological Research of Early Career Scientists

The influence of one's immersion ability on physiological and psychological relaxation in a virtual natural relaxation video

Louisa Richter[1], Raphaela J. Gaertner[2], & Jens C. Pruessner[2,3]

[1]Department of Psychology, University of Vienna, Germany
[2]Department of Psychology, Division of Neuropsychology, University of Konstanz, , Germany
[3]Centre for the Advanced Study of Collective Behaviour, University of Konstanz, Germany

In recent years there has been an increasing interest in the effects of relaxation. Experiencing nature, even in virtual reality (VR), has been shown to decrease stress and improve well-being. But research into the exact mechanisms of how relaxation has its positive effects is scarce. This project aims to answer the question if an individual's ability to immerse in sensory environments has an influence on their ability to relax. Immersion ability was collected by the immersion tendency questionnaire, developed by Witmer and Singer (1994). For this study 60 participants took part in a relaxation intervention. Throughout the exposure, heart rate variability (HRV) was measured, and subjective re-laxation was recorded. 57 datasets were included in the results. The VR only inflicted an increase in relaxation in subjective relaxation. The HRV markers "High Frequency" (HF) and "root mean square of successive differences" (RMSSD) values did not show in-creased parasympathetic activity in reaction to the relaxation task. Repeated measure ANCOVA did not find an influence of an individual's immersion ability on their ability to relax, neither subjective nor objective. As the markers of physiological relaxation did not increase, the results are inconclusive. Problematic factors in this study could be that the VR environment was not immersive or long enough. Additional limitations are discussed.

Keywords: Relaxation, immersion ability, VR nature environment, heart rate variability, subjective relaxation

In recent years there has been a growing interest in research about relaxation and stress with 50% of papers about "physiological relaxation" being published in the last ten years (https://www.webofscience.com/wos/woscc/basic-search, 06.07.2023). This can be due to multiple factors, including the increase of stress an individual is facing in our society (e.g., Gillespie et al., 2001) and an increase in mental disorders (e.g., Bor et al., 2014). These have been found to have a negative impact on our physical and psychological health (Lucassen et al, 2014), which also includes high costs for our health system (Ramaciotti & Perriard, 2000). As it is not always possible to reduce the source of our stress, it has become increasingly important to find ways to relax and decrease the body's stress response. This can be partly achieved by mindfulness training and other relaxation interventions, as they seem to be a protective factor against anxiety, working memory effects and negative mood (e.g., Abenavoli et al., 2013; Banks et al., 2015).

Many techniques have been studied to achieve relaxation, with virtual reality (VR) and other immersive technologies emerging as a popular area of research (reviewed by Riches et al., 2012). While there has been a large amount of research on the effectiveness of different relaxation techniques, there has been a neglect of exploring potential interindividual personality traits that may exist. This thesis aims to explore the influence that an individual's immersion ability has on their ability to relax in a virtual natural en-vironment. By investigating this, we hope to contribute to the understanding of how im-mersive technology can be used to promote relaxation and reduce stress.

This work originated from the Master thesis of Louisa Richter. This study was sponsored by University of Konstanz research funds to Jens C. Pruessner. The authors declare no conflict of interest.
Formatting based on a template by Brenton M. Wiernik (https://osf.io/t4eqp/; DOI 10.17605/OSF.IO/HSV6A).
Correspondence concerning this paper should be addressed to Jens C. Pruessner (jens.pruessner@uni-konstanz.de).

Full Datasets and R-scripts available on request.

Relaxation interventions have been found to influence our body and mind in different ways. It can improve mood and reduce depression and anxiety in older adults (Klainin-Yobas et al., 2015). Additionally, relaxation interventions have been found to decrease overall stress (Kaspereen, 2012).

With the increased research on relaxation, there has been a focus on identifying effective and feasible techniques for individuals. One of these techniques is breathing exercises. They have been shown to not only reduce perceived stress and improve mood, but also to positively influence physiological parameters of stress, such as cortisol and heart rate variability (HRV) (Perciavalle et al., 2017). Slow breathing exercises have been found to increase the low frequency parameter of HRV, due to an increased vagal (parasympathetic) activity (Kromenacker et al., 2018). Additionally, Van Diest et al. (2014) found that the optimal breathing pattern involves a shorter inhalation time than exhalation time.

Another technique that has shown to be promising for inducing relaxation and reducing stress is spending time in nature. In a review, Farrow and Washbourn (2019) re-ported that forest bathing, or in Japanese "shinrinyoku", is associated with increased HRV, activation of the parasympathetic nervous system and reduced anxiety. These findings suggest that spending time in nature may be an effective method for inducing relaxation.

Given that not everyone has access to natural environments, it is important to explore alternative ways to experience the positive effects of nature. Previous studies have demonstrated that VR can be used to simulate natural environments and induce relaxation. Even if a virtual approach includes a reduction in sensory inputs (no touch, smell, taste), it has been found to reduce stress objectively and subjectively in measures of HRV, cortisol and anxiety (Annerstedt et al., 2013; Anderson et al., 2017; Lsizio et al. 2018; Riches et al., 2021). Therefore, VR may provide an accessible and feasible way for individuals to experience the restorative effects of nature. These findings highlight the potential benefits of nature simulation in VR as a practical tool to increase relaxation and reduce stress.

HRV is a physiological measure that can be used to assess the activity of the parasympathetic nervous system. This allows to conclude on the state of relaxation an individual is facing. It is calculated by measuring the time intervals between two consecutive heartbeats (RR-Intervals), and a subsequent analysis (Terathongkum and Pickler, 2004). This analysis will calculate the variability of the intervals in terms of frequency or time. These different measurements have been associated with sympathetic and parasympathetic activation. For the HRV measurements in this thesis, higher values in RMSSD and HF are indicators for higher parasympathetic activity, which is associated with relaxation. Lower values in these have been found to be associated with an increased rate of morbidity and mortality (Thayer and Lane, 2007; Thayer et al., 2010). However, it is important to control variables such as breathing, as breathing exercises have been shown to increase chaotic behavior of HRV (Tavares et al., 2017). Despite this limitation, HRV is a suitable measurement to assess the physiological relaxation of participants.

Humans can express their level of short-term relaxation subjectively (Steghaus et al., 2022). Via questionnaires it is possible to express the subjective level of relaxation by introspection about physical states. It has to be noted though, that some studies have shown for physiological stress measurements to precede the psychological assessment (e.g., Hansson et al., 2008). These results suggest that individuals first experience a physiological stress reaction, and only later are able to give subjective feedback to their stress experience. A combination of physiological and psychological measurements can provide a more comprehensive understanding of an individual's relaxation levels.

The definition of immersion has been a topic of discussion for nearly 30 years. In particular, the differentiation to the concept of presence has led to many debates. Nilsson et al. (2016) issued a comprehensive review of the literature, building on the work of Murray (after Nilsson, 1997), who compares immersion to the feeling of being immersed in water. Immersion is therefore seen as a subjective feeling. Nilsson et al. (2016) continued defining four categories of definitions: immersion as a property of a technical system (Slater et al., 2003), as a perceptual response of feeling enveloped (e.g., Witmer and Singer, 1998; Arsenault, 2005), as a responsive to narratives or as a response to challenges. Although Slater et al. (1999; 2003) do take a stand with a more rarely used definition, they still manage to highlight the problem as too much non-productive research being done by just discussing these topics (Slater et al., 2009).

Based on this, we defined and treated immersion as a perceptual reaction of feeling engaged by one or more external stimuli (Witmer and Singer, 1998). These stimuli can be triggered by complex VR environments, but also by single stimuli, such as books ("the book problem", Biocca, 2003). Furthermore, we continued differentiating between immersion tendency (also described as immersion ability) as an individual's predisposition to feel immersed, and immersion potential as the degree to which a system can inflict immersion (Agrawal et al., 2020; Witmer and Singer, 1994). It has been found that the sense of presence experienced in relaxation treatments influences the relaxation, including a reduction in anxiety and physiological and psychological relaxation (Villani et al., 2007). Knaust et al. (2022), on the other hand, could show, that more immersive interventions with a nature Video (PC vs Head-mounted display) achieved a higher relaxation, but only in subjective measurements, not physiological. The individual immersion ability has been shown to influence the feeling of presence, and therefore the effectiveness of the intervention (Johns et al., 2000). It was also found that an individual's immersion ability may only have an influence on their feeling of presence in highly immersive environments. While the data collection includes a breathing task and a virtual nature experience as relaxation interventions, our focus was solely on the VR environment (Johns et al., 2000).

In this paper we wanted to analyze the influence of one`s individual immersion ability on their ability to relax. While subjects stated their immersion tendency, they also stated the immersion of the relaxation task they experienced. They further reported the subjective relaxation they felt before and after the task. Additionally, HRV as physical measure was included. As a manipulation check we tested, if the participants showed physiological and psychological relaxation in reaction to the virtual intervention. We hypothesized that the VR nature environment would be perceived as more immersive than the breathing task, indicated by a higher score in the Immersion experience questionnaire after the tasks. We also assumed that participants with higher Immersion Tendency scores would show, in reaction to the relaxation intervention, a higher objective relaxation (measured by HRV) in the VR environment than participants with lower scores. We further assumed that participants with higher Immersion Tendency scores would show, in reaction to the relaxation intervention, a higher subjective relaxation (measured by questionnaire) in the VR environment than participants with lower scores. Next, we hypothesized that participants with higher Immersion Tendency scores would report greater immersion in the VR environment than participants with lower scores, indicating that immersion ability would enhance the experience of immersion in relaxation. Finally, we postulated that changes in HRV during relaxation tasks would be positively correlated with subjective ratings of relaxation in the VR condition, indicating that changes in HRV would reflect the subjective experience of relaxation.

Methods and Material

Data collection

The Data for this project were collected in the context of a larger project of the Neuropsychology group at the Department of Psychology at the Univer-sity of Konstanz. Ethic approval was granted by the ethic commission of the University of Konstanz. The experiment was carried out in accordance with the ethical standards of the Declaration of Helsinki. All participants provided written informed consent.

Participants

Data from 60 participants were collected during the period from March 2023 until May 2023. They were recruited by an university online tool to recruit participants. All participants were students at the university and received by choice 20€ or study credits for their classes. All participants were fluent in German. To take part in the study they had to have an BMI between 18.5 and 29.9 (Zahorska-Markiewicz et al., 1993) and were not allowed to participate if they had diabetes (Benichou et al., 2018), epilepsy (Lotufo et al., 2012), or a heart disorder (Cygankiewicz & Zareba, 2013) as these factors might affect HRV. Participants were also instructed to not consume caffeine (Koenig et al., 2013), alcohol (Ralevski et al., 2019) or nicotine (Piha, 1994) for four hours before the study was conducted and to not engage in intense sports twelve hours before. The experiment consisted of two testing appointments. 60 Participants showed up for the first appointment, but one failed to show up for the second. Of the 59 participants left, two had to be excluded because of technical difficulties with the physiological recordings, which was only noticed at the time of data analysis. Thus, 57 subjects were included for this project. Participants had a mean age of 22.04 Years (*SD* = 3.11) with 41 (71.93%) being female.

Procedure

Participants signed up for two appointments with 5-9 days in between to avoid carry-over effects. Both appointments followed the same procedure (*Figure 1*). In the first session, participants started by reading and signing the consent form. Following that, they were asked to put on a Polar H10 sensor and chest belt for recording of their heart rate. A ten-minute baseline recording followed during which participants could read an unarousing newspaper or engage in mandala

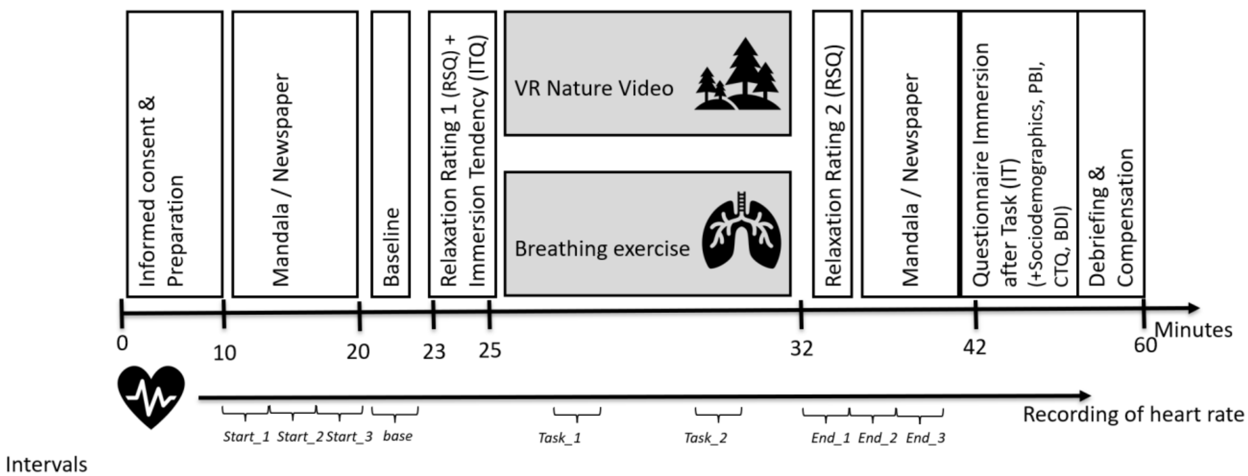

Figure 1. Visualization of the procedure during the appointments. Including the timestamps for the heart rate variability (start_1 to end_3). Figure kindly made available by Raphaela Gärtner.

drawing. Following that, participants were instructed to watch a grey rectangle on an iPad in front of them for three minutes, serving as a baseline condition. Afterwards subjects filled out questionnaires about their current state of relaxation and, only in the first appointment, about their individual immersion ability. Next, the actual relaxation task started.

The order of tasks was counter-balanced by throwing a coin. One task consisted of a breathing task, the other was a nature environment in VR. Both took 7 minutes to complete. After the task participants again filled out the questionnaire about relaxation. Following the task, subjects sat calm for 10 more minutes, drawing mandala or reading newspaper. After this time was over, they had to fill out the last questionnaires which took around 10 more minutes. This involved questionnaires about their experience with VR, the immersion they felt during the task and their sociodemographic data. In the context of the larger project, Parental Bonding Instrument (PBI), Beck's depression Inventory (BDI), Childhood Trauma Questionnaire (CTQ), Social Interaction Anxiety Scale (SIAS) and Social Phobia Scale (SPS) were also collected (results will be reported elsewhere). The whole session took around one hour each.

Relaxation tasks

Breathing task. One relaxation intervention was a breathing task instructed by the app "Awesome Breathing: Pacer Timer" (Awesome LABS LLC) downloaded for free from the App Store. This app showed a circle that will grow and shrink with participants breathing in while the circle is growing, and breathing out while the circle is shrinking. The times set were 4 seconds to breath in and 6 to breath out, as it was shown that a longer exhalation than inhalation time has a more relaxing and stress reducing effect (van Diest et al., 2014). The whole task was 7 minutes long and stopped automatically.

VR nature environment. The other task was a nature environment in VR. The video was taken by members of the Neuropsychology group. The environment showed a mountain region with a little house, trees, and a water stream. This was accompanied by nature sounds of the water, birds, and wind. The video was taken with a 360° camera (*Figure 2*). For showing the stimuli the Oculus Quest 2 (Meta seated in Menlo Park, California) was used (*Figure 2*).

Figure 2. Nature environment in the virtual reality (VR) and VR setup.

Measurements

Heart rate variability. Heart rate variability (HRV) was derived from heart rate recordings measured with the chest belt H10 by Polar Electro Oy ("Polar", Kempele, Finland). Data were stored with the app “Heart Rate Variability Logger” (Altini, 2013) available in the App store. To im-prove the conductance the participants were instructed to moisten the belt as written in the instruction manual. Multiple analyses were conducted with these data. This included time domain and frequency domain analyses. For this thesis we focused on the values of HF-HRV and RMSSD, to include a time domain and a frequency domain analysis. RMSSD has been shown to be less influenced by breathing and should therefore be included due to the breathing task (Penttilä et al., 2001).

Questionnaires. For this study, three Questionnaires were used.

The RSQ is a 10-item questionnaire about the state of relaxation the participants experience at the moment (Steghaus and Poth, 2022). The Questionnaires asks about muscle relaxation, sleepiness, cardiovascular activity, and general relaxation. The Items were developed in German and could therefore be used without translating. The Questions were answered with a 1-5 Likert scale, 4 of the items had to be reversed for analysis. The answers were then summed up and used for the statis-tical analysis as one score.

The ITQ is a questionnaire originally developed by Witmer and Singer (1994). It has 29 Items, but we used a shortened version by Robillard (2013) with 18 Items. This shortened version was approved with an internal consistency of Cronbach’s Alpha of .78. The Questionnaire was translated with a two-person system where both translated the questions to German and then differences were discussed and agreed on. The questions were answered with a 1-7 Likert scale. Answers were summed up and used for the statistical analysis as one score. Questions were e.g., about how easily they become involved in movies or how easily they forget their real-world environment while seeing a movie or playing a game.

The IEQ is a questionnaire developed to measure one’s immersion in a game. Rigby et al. (2019) adjusted this Questionnaire to fit in with measuring the immersion of video media. We adjusted these questions to fit on immersion in tasks in general and again translated them to German with a two-person system. The questionnaire consists of 24 items that can be categorized in four categories: Captivation, real-world dissociation, comprehension, and transportation. Due to a mistake in the application of the questionnaires, we only included the questions about the real-world dissociation which asks in three items how much the participant was aware of their real-world surroundings. This subscale was internal consistent with Cronbach’s Alpha = .824. Answers were given with a 1-7 Likert scale with all the items needing to be re-versed. Scores were summed up and used for the statistical analysis as one score.

Study Design

The study was designed to be an experimental study, but our Hypothesis are correlational. A randomization occurred in the order of the relaxation task. Data were collected by three experimenters; participants were randomly assigned to them.

Statistics Analysis

HRV. The analysis of the HRV was done with the software ‘R’ (R Core Team, 2023) and the user interface R-Studio (Posit Team, 2023) in multiple steps. The scripts for HRV data analysis were provided by the department of neuropsychology, Konstanz.

The first script was used to preprocess and clean the data. This included fixing for outliers that could e.g., appear due to short loss of signal or external stimuli (e.g., noise in background) that increased the HR shortly. Additionally, it was used to check for missing data and to fix duplicates.

The second script was used to calculate multiple times intervals. The time intervals were each three minutes long due to the baseline being three minutes long. Therefore 9 time intervals where calculated. Three for the first ten minutes of calming down, one for the baseline, two for the relaxation task and again three for the ten minutes after (*Figure 1*).

For each of the time intervals five values were calculated. Only two were used for this analysis. As time domain analysis the root mean square of successive differences (RMSSD) was calculated. Time domain analysis calculates differences based on the different amount of time between two RR intervals. As a frequency domain analysis, the high frequency (HF) was calculated. This measures the amount of signal energy within component bands (Shaffer and Ginsberg, 2017). Both measurements can be interpreted with a higher HRV being a sign for a higher parasympathetic activity.

Before statistical analysis began, we removed outliers that were more than three standard deviations away from the mean and replaced them with the value of three standard deviations.

For the statistical analysis the packages "car" (Fox & Weisberg, 2019), "tidyverse" (Wickham et al., 2019), "readxl" (Wickham, 2023), "knitr" (Xie, 2023), "psych" (Revelle, 2023), "ez" (Lawrence, 2016), "BSDA" (Arnholt & Evans, 2021), "ggstatsplot" (Patil, 2021) and "lsr" (Navaro, 2015) were used.

Manipulation Check. To analyze if the VR nature environment triggered relaxation, a one-factor repeated measure ANOVA was conducted with Time as the changing factor. Prior to this a Shapiro-Wilk test and Leven's test were conducted to check for requirements of ANOVA. This was done individually for RMSSD and HF. This was followed up with a Tukey post-hoc testing. Additionally, an one-way ANOVA was conducted to check for subjective relaxation with the RSQ.

Hypothesis 1. To check if the VR environment is perceived as more immersive than the breathing task, a t-test for dependent samples was conducted with the scores of the IEQ.

Hypothesis 2. To analyze if participants with higher ITQ scores show a higher relaxation in the VR environment a repeated measure ANCOVA was conducted with Time being the changing factor and the Immersion Tendency score as the covariate. This was done for RMSSD and HF. Results were tested with Tukey post-hoc test.

Hypothesis 3. To compare if participants with a higher ITQ score experience more subjective re-laxation a repeated measure ANCOVA was conducted. Again, with Time as the changing factor and Scores of the ITQ as the covariate.

Hypothesis 4. To check if participants with a higher ITQ score also give the VR environment a higher score in the IEQ, a Pearson's product-moment correlation was conducted.

Hypothesis 5. To analyze if the subjective and objective changes in relaxation correlate with each other, the area under the curve was calculated. This was done for the comparison between HF and RSQ and between RMSSD and RSQ. The results were correlated.

Results

Manipulation Check

To conduct an ANOVA, requirements need to be fulfilled. This includes the Shapiro-Wilk test to control if the data are normally distributed. For the datasets of HF (HF: W = 0.83, p < .001; RMSSD: W = 0.94, p < .001) and RMSSD this was not fulfilled. Additionally, the Levene's test to control for homogeneity in variances was conducted. The requirements were again not fulfilled for HF (F = 3.30, p = .001) and RMSSD (F = 3.37, p < .001). The results should therefore be interpreted carefully as there is a higher probability of accepting a wrong alternative hypothesis (Johnson, 2016). Regarding the RSQ data the homogeneity of variances was not fulfilled, but the data were normally dis-tributed (Levene: F < 0.001, p < .001; Shapiro-Wilk: W = 0.99, p = .306).

The ANOVA was conducted for the nature video data. For HF all 9 time intervals were included. Mean, standard deviation and standard error for each time point can be found in the appendix (*Table A1*). The analysis showed a significant difference

($F(8, 448) = 12.46$, $p < .001$), a visualization of the temporal development can be found in the appendix (*Figure A1*). Post-hoc analysis revealed significant differences between base with start_1, start_2 and start_3 (with base having higher HF values) and between end_2 and end_3 with base (with base having higher HF values), *p*-values can be found in the appendix (*Table A2*).

For RMSSD the data also included 9 time intervals. Mean, standard deviation and standard error for each time point can be found in the appendix (*Table A3*). The ANOVA showed significant differences for the VR condition ($F(8, 448) = 9.64$, $p < .001$)), a visualization of the temporal development can be found in the appendix (*Figure A2*), but the following post-hoc analysis showed no significant differences with adjusted p. P-values can be found in the appendix (*Table A4*). Participants did not experience higher parasympathetic activity in reaction to the VR intervention.

RSQ data showed a significant difference between before and after the intervention ($F(1,112) = 16.35$, $p < .001$) with the scores being higher after the task (Before: $M = 35.09$, $SD = 3.97$, $SE = 0.53$; After: $M = 38.21$, $SD = 4.28$, $SE = 0.57$) (*Figure A3*).

The manipulation check revealed that the intervention only worked partially. While subjective relaxation showed an increase, physiological relaxation as indicated by HRV is highest in the baseline with a constant drop down afterwards in HF and no significant differences in RMSSD.

Hypothesis 1

To analyze, if participants experienced the VR environment as more immersive than the breathing task, a t-test for dependent samples was conducted. The IEQ scores for the VR ($M = 12.14$, $SD = 3.81$, $SE = 0.50$, range = 18) and for the breathing task ($M = 8.68$, $SD = 3.32$, $SE = 0.44$, range = 13) were compared as can be seen in the appendix (*Figure A4*). The conditions differentiated significantly with a $t(56) = -5.94$ and $p < .001$, the VR received higher scores in the IEQ than the breathing task. Cohen's *d* was calculated to be 0.79 which is close to a strong effect. The first hypothesis could thus be supported.

Hypothesis 2

ITQ scores ranged from 50 to 99 ($M = 75.75$, $SD = 12.19$). For Hypothesis 2 an ANCOVA was conducted for HF and RMSSD. The ANCOVA for HF showed a significant effect of Time ($F(8, 503) = 3.75$, $p < .001$) as seen in the manipulation check, but did not show significant results for the ITQ score as a covariate ($F(1, 503) = 0.46$, $p = .497$).

The ANCOVA for RMSSD showed no significant effect of Time ($F(8, 503) = 1.33$, $p = .22$), as seen in the manipulation check, and no significant effect of ITQ score as a covariate ($F(1, 503) = 0.46$, $p = .479$). The second hypothesis could thus not be supported.

Hypothesis 3

To analyze the influence of the covariate ITQ score on the subjective relaxation an ANCOVA was conducted. This ANCOVA showed significant differences over time ($F(1, 111) = 16.20$, $p < .001$) as seen in the manipulation check, but not for the covariate ITQ score ($F(1, 111) = 0.01$, $p = .922$). The third hypothesis thus had to be rejected as well.

Hypothesis 4

Pearson's product-moment correlation showed no significant correlation ($r(55) = .037$, $p = .783$) between ITQ and IEQ, as can be seen in the appendix (*Figure A5*). The fourth hypothesis was thus not supported.

Hypothesis 5

For the fifth Hypothesis the increase of the Area under the curve was calculated for every participant for RMSSD, HF and RSQ. This is a value for calculating the changes in the measurements over time. RSQ was correlated individually with RMSSD and HF AUCg values. Results for the comparison of HF and RSQ showed no significant correlation ($r = .07$, $t = 0.51$, $p = .611$). The correlation between RSQ and RMSSD also showed no significance ($r = .12$, $t = 0.87$, $p = .389$). The fifth hypothesis was therefore not supported.

Discussion

Evaluation of results

The primary aim of this thesis was to investigate and assess how an individual's ability to immerse in sensory stimuli affects their ability to relax in a highly immersive environment. To achieve this, this project included both subjective and objective measurements, in addition to individual immersion ability. The results indicated that, contrary to the hypotheses, an individual's immersion ability had no impact on their ability to relax in a virtual environment.

Manipulation Check. The manipulation check was conducted to confirm whether the relaxation task induced relaxation in the participants. The results for this were diverse.

For high frequency (HF) the participants experienced the highest values, and therefore the highest parasympathetic activity, during the baseline timestamp. These findings suggest that participants experienced the highest relaxation when closely watching the grey square on the iPad screen. Surprisingly, the relaxation task itself did not reveal any increased values. This was interesting as it was contradictive to what we expected. As heart rate variability (HRV) is affected by breathing, it could be possible that the calmness of looking at a screen is an influencing factor. Additionally, the lack of movement in the baseline measurement compared to the VR environment may have changed the physical parameters of HRV.

Regarding the root mean square of successive differences (RMSSD) analysis, the results did not show any significant differences between any time intervals. This contradicted our expectations of observing higher values in reaction to the intervention task.

Interestingly there has also not been an increase in the baseline measurement. Participants seemed to not have any RMSSD reaction to the intervention.

The combined results of the HRV markers suggested that the intervention to increase relaxation was not successful. All other results should therefore be interpreted with care.

The results for the subjective relaxation indicate significant differences between before and after the task. Participants felt more relaxed after being in the virtual reality (VR) than before. The results therefore seemed to contradict each other, as HF showed the highest relaxation at the baseline, while the relaxation state questionnaire (RSQ) showed the lower score at that time. There are three possible explanations for this phenomenon.

First of all, it could have been due to the physical relaxation preceding the subjective one (Hansson et al., 2008). This would mean that the subjective relaxation that we measured after the task could have been due to a longer reaction time on the baseline task. This would mean that our relaxation task was not successful.

Alternatively, it could have been due to no connection between subjective and objective measurements. This would suggest that the responsible systems for the psychological and physiological relaxation are independent from each other. This would be supported by the results of hypothesis 5 which showed no correlation between the two.

The third possibility could be that the higher immersive task would have a bigger influence on the subjective measurements than on the objective ones. This was indicated before by Knaust et al. (2022) in a study about different ways to present immersive natural environments. Participants would therefore report subjective relaxation while their physio-logical parameters do not show any.

The first Hypothesis was to check, if the VR environment was actually perceived as more immersive than the breathing task. This hypothesis was fulfilled, participants experienced the VR as more immersive. To be more precise, they felt more distanced from the real-world in the VR vs. the breathing task. This was not surprising, as VR is in general seen as an immersive medium, while a guided breathing task does have reduced sensory input. Additionally, it may have been that the participants gave biased answers due to knowing that VR is supposed to be more immersive. It may be interesting to analyze this with more questionnaires, especially about how captivating the task was for them.

The second hypothesis was about the influence of an individual's immersion ability on their relaxation. The ANCOVA did not find any influence of their immersion ability scores on the physiological relaxation. Neither with HF nor with RMSSD parameters. This was contradictive to our hypothesis.

The results must be interpreted carefully though, as the manipulation check did not show any significant relaxation with the VR intervention. The participants did not experience any physical relaxation with the intervention and therefore the immersion ability can also not explain any variance. This lack of influence could be because the participant may not have had enough differences in their immersion ability scores. A sample with more diversity in age and economical status would be interesting for this, as they may have more variance.

Additionally, it could have been because the VR was not immersive enough, possibly due to the limitation in sensory modalities stimulated by the VR. A virtual natural environment does not include olfactory, tactile or taste stimuli, while a real natural environment can do that.

The third hypothesis showed that one's immersion ability did not have an influence on their subjective relaxation. This could again have been due to the interindividual differences not being big enough or to lack of immersion in the VR. Compared to the second hypothesis, the manipulation check did work for the subjective relaxation. This seemed even more contradictive to literature, because previous findings showed higher immersion only influenced subjective relaxation (Knaust et al., 2022).

The nature of the task could have had an effect on the participants ability to relax and may have also influenced the immersion ability. Participants did have different levels of experience with VR, with some wearing VR glasses for the first time and others using them regularly. This could have influenced their reaction to the VR nature environment and overwrite the effect that their immersion ability could have. People that wore glasses for the first time could have been more nervous or excited and therefore experience less relaxation.

Additionally, the immersion tendency score (ITQ) was mainly measured by questions about books and games. It is possible that participants experience this differently in a VR environment and questions about their immersion experience in VR could be interesting.

The fourth hypothesis analyzed the correlation between participants individual's immersion ability and the immersion scores they gave the VR. There was no correlation between these two scores. Their individual ability to immerse did not enhance the immersion they felt. This could also explain, why the immersion ability did not have an influence on the relaxation. If participants did not experience the task as more immersive, there can-not be an effect of immersion ability on the relaxation. An interesting approach would be to ask not only about the real-world dissociation but also how present they felt during the task.

The fifth hypothesis was about analyzing the correlation between the subjective and objective relaxation. Interestingly, there was no correlation between these two. It was shown before, that in stress research the physical reaction may precede the psychological one (Hansson et al., 2008). But as we saw, there was no physical relaxation due to the intervention, but only due to the baseline task for HF. Therefore, this is not a possible explanation. Instead, it could have been due to the differences in relaxation in subjective and objective measurements, as subjective and physiological relaxation do not necessarily relate to each other (Burns et al., 1999).

There have been studies about the influence of one's immersion ability on their feeling of presence, and on the influence of more immersive tasks on the relaxation. This thesis was, to our knowledge, the first one to study the direct correlation of an individual's immersion ability on their ability to relax in an immersive intervention.

There were multiple limitations that have to be acknowledged in this thesis. First the study design may have been problematic. The relaxation task took around 7 minutes to complete, and it was therefore possible that the time intervals spend in the VR was not long enough to actually trigger relaxation. A longer setup could have been of advantage.

Additionally, HRV data are very sensitive to changes in the environment, including external stimuli that are hard to avoid, even in a laboratory environment. For example, noise outside of the room could influence the HRV, even if we tried to preprocess the data for that. There were big interindividual differences in HRV, which can be seen by the high variance in the HRV markers. Other physiological measurements (e.g., heart rate, blood pressure, cortisol, salivary-α-Amylase) could have been of interest for this.

The participants we recruited were from an academic setting with mainly women being in the sample. This may have been an influencing factor as it was not a representative sample. The participants may not have been the same regarding immersion ability or reactivity to relaxation interventions such as the general population. The relatively young sample may have also posed a problem as they have a higher technical affinity than older samples (Göbl et al., 2022). A broader sample could be an interesting follow-up study.

Another problem that has to be addressed is the immersion of the VR. As the intervention did not involve any real task for the participants to capture their attention and distract them from the real-world surroundings, it is possible that the VR was not immersive enough to trigger relaxation. As Johns et al. (2000) showed before, it is possible that the immersion ability only has an influence on the feeling of presence in high-immersive environments. Therefore, it would be interesting in the future to do research with more and different immersive relaxation tasks. This could for example be done by giving the participants a task or an interactive element in the VR.

A problem that appeared in the analysis was the high relaxing influence of the baseline. Participants showed the highest physical relaxation within this part of the experiment. This baseline asked the participants to watch the screen closely, without moving and while staying focused on the cross in the middle of the square. It is questionable, why this triggered parasympathetic activity, but the VR environment didn't. It may be that staring at a screen can indeed be seen as a calming task. It could make sense to instead take a baseline measurement from the first ten minutes of relaxation, as they have a more realistic base. Jennings et al. (1992)

analyzed the concept of "vanilla tasks" as a baseline measurement task instead of one without task. But even the mandala drawing in this part could be seen as a relaxing task (Kovacs-Donaghy, 2013). It may be interesting to study the influence of immersion ability in relaxation tasks in a more realistic setting.

But why did the VR environment not trigger physiological relaxation? This may have been due to the VR being a novel experience for many. It could have been an exciting experience to see an extremely realistic video surrounding them and may have distracted them from the actual relaxing effect. Also, even if previous research has shown it, it may be possible that the reduction of sensory stimuli from nature experience to VR nature experience also reduce the relaxing effect of it. Additionally, Anderson et al. (2017) could show that an individual's scene preference had a significant effect on their experience. It would be interesting to give participants the opportunity to choose between different environments.

The aim of this thesis was to analyze the influence of one's immersion ability on their ability to relax in a high immersive environment. As the relaxation task did not trigger physiological relaxation, it is not surprising that the immersion ability did not have a statistical influence on the relaxation. Additionally, though, it also did not have an influence on subjective relaxation. With the manipulation check failing it is still an important part of future research to investigate immersive relaxation interventions. A special focus here should be interventions that are feasible for everyone. VR is still a relatively new field of research, and studies wield different results on the use of immersive interventions. Even if this thesis did not find any significance for the immersion ability it cannot be ruled out as an influencing factor. Again, research is very inconclusive in their results about defining terms like "immersion" and "presence".

Relaxation is a field of research that will, without any doubt, get even more important in the next years. It therefore seems of importance, to not only search for possible interventions to achieve relaxation, but to also analyze interindividual differences in the experience of these interventions. It may then be possible to find ways to relax for people in an individual way. Future research is encouraged to focus on immersive relaxation techniques and interindividual difference in our way of experiencing these. With this it may be possible to give us as a society and as individuals the best ways possible to deal with the increase of stress in our environment and in us.

References

Abenavoli, R. M., Jennings, P. A., Greenberg, M. T., Harris, A. R., & Katz, D. A. (2013). The protective effects of mindfulness against burnout among educators. *Psychology of Education Review*, *37*(2), 57-69.

Agrawal, S., Simon, A., Bech, S., Bærentsen, K., & Forchhammer, S. (2020). Defining Immersion: Literature Review and Implications for Research on Audiovisual Experiences. *Journal of the Audio Engineering Society*, *68*(6), 404–417. https://doi.org/10.17743/jaes.2020.0039

Anderson, A. P., Mayer, M. D., Fellows, A. M., Cowan, D. R., Hegel, M. T., & Buckey, J. C. (2017). Relaxation with Immersive Natural Scenes Presented Using Virtual Reality. *Aerospace Medicine and Human Performance*, *88*(6), 520–526. https://doi.org/10.3357/AMHP.4747.2017

Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, Å. M., & Währborg, P. (2013). Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. *Physiology & Behavior*, *118*, 240–250. https://doi.org/10.1016/j.physbeh.2013.05.023

Arnholt, A., Evans, B. (2021). _BSDA: Basic Statistics and Data Analysis_. R package version 1.2.1, <https://CRAN.R-project.org/package=BSDA>.

Arsenault, D. (2005). Dark waters: Spotlight on immersion. In *GAMEON-NA International Conference* (pp. 50-52). Eurosis.

Awesome Labs LLC (n.d.). *Awesome Breathing: Pacer Timer* (Version 47.1) [Mobile app]. App Store. https://apps.apple.com/de/app/awesome-breathing-pacer-timer/id1453087953

Banks, J. B., Welhaf, M. S., & Srour, A. (2015). The protective effects of brief mindfulness meditation training. *Consciousness and cognition*, *33*, 277-285.

Benichou, T., Pereira, B., Mermillod, M., Tauveron, I., Pfabigan, D., Maqdasy, S., & Dutheil, F. (2018). Heart rate variability in type 2 diabetes mellitus: A systematic review and meta–analysis. *PloS one*, *13*(4), e0195166.

Biocca, F. (2003, May). Can we resolve the book, the physical reality, and the dream state problems? From the two-pole to a three-pole model of shifts in presence. In *EU Future and Emerging Technologies, Presence Initiative Meeting* (Vol. 12, pp. 13-69).

Bor, W., Dean, A. J., Najman, J., & Hayatbakhsh, R. (2014). Are child and adolescent mental health problems increasing in the 21st century? A systematic review. *Australian & New Zealand journal of psychiatry*, *48*(7), 606-616.

Burns, J., Labbé, E., Williams, K., & McCall, J. (1999). Perceived and physiological indicators of relaxation: as different as Mozart and Alice in chains. *Applied psychophysiology and biofeedback*, *24*, 197-202.

Cygankiewicz, I., & Zareba, W. (2013). Heart rate variability. *Handbook of clinical neurology*, *117*, 379-393.

Farrow, M. R., & Washburn, K. (2019). A Review of Field Experiments on the Effect of Forest Bathing on Anxiety and Heart Rate Variability. *Global Advances in Health and Medicine*, *8*, 216495611984865. https://doi.org/10.1177/2164956119848654

Fox, J., Weisberg, S. (2019). _An R Companion to Applied Regression_, Third edition. Sage, Thousand Oaks CA. <https://socialsciences.mcmaster.ca/jfox/Books/Companion/>.

Gillespie, N. A., Walsh, M. H. W. A., Winefield, A. H., Dua, J., & Stough, C. (2001). Occupational stress in universities: Staff perceptions of the causes, consequences and moderators of stress. *Work & stress*, *15*(1), 53-72.

Göbl, L., Weis, A., Hoffmann, M., Wiezorreck, L., Wensing, M., Szecsenyi, J., & Litke, N. (2022). An exploratory cross-sectional study on technical affinity and smartphone use among practice staff and patients: development of an app for multimorbid patients in general practice. *Zeitschrift fur Evidenz, Fortbildung und Qualitat im Gesundheitswesen*.

Hansson, A. S., Vingård, E., Arnetz, B. B., & Anderzén, I. (2008). Organizational change, health, and sick leave among health care employees: A longitudinal study measuring stress markers, individual, and work site factors. *Work & Stress*, *22*(1), 69-80.

Jennings, J. R., Kamarck, T., Stewart, C., Eddy, M., & Johnson, P. (1992). Alternate cardiovascular baseline assessment techniques: Vanilla or resting baseline. *Psychophysiology*, *29*(6), 742-750.

Johns, C., Nuñez, D., Daya, M., Sellars, D., Casanueva, J., & Blake, E. (2000). The Interaction Between Individuals' Immersive Tendencies and the Sensation of Presence in a Virtual Environment. In J. Mulder & R. van Liere (Eds.), *Virtual Environments 2000* (pp. 65–74). Springer Vienna. https://doi.org/10.1007/978-3-7091-6785-4_8

Johnson, T. R. (2016). Violation of the homogeneity of regression slopes assumption in ANCOVA for two-group pre-post designs: Tutorial on a modified Johnson-Neyman procedure. *The Quantitative Methods for Psychology*, *12*(3), 253-263.

Kaspereen, D. (2012). Relaxation intervention for stress reduction among teachers and staff. *International Journal of Stress Management*, *19*(3), 238.

Klainin-Yobas, P., Oo, W. N., Suzanne Yew, P. Y., & Lau, Y. (2015). Effects of relaxation interventions on depression and anxiety among older adults: a systematic review. *Aging & mental health*, *19*(12), 1043-1055.

Knaust, T., Felnhofer, A., Kothgassner, O. D., Höllmer, H., Gorzka, R.-J., & Schulz, H. (2022). Exposure to virtual nature: The impact of different immersion levels on skin conductance level, heart rate, and perceived relaxation. *Virtual Reality*, *26*(3), 925–938. https://doi.org/10.1007/s10055-021-00595-2

Koenig, J., Jarczok, M. N., Kuhn, W., Morsch, K., Schäfer, A., Hillecke, T. K., & Thayer, J. F. (2013). Impact of Caffeine on Heart Rate Variability: A Systematic Review. *Journal of Caffeine Research*, *3*(1), 22–37. https://doi.org/10.1089/jcr.2013.0009

Kovacs-Donaghy, I. (2013). *The mandala offers relaxation to hospital staff: A convergent triangulation mixed methods study* (Doctoral dissertation, Walden University).

Kromenacker, B. W., Sanova, A. A., Marcus, F. I., Allen, J. J. B., & Lane, R. D. (2018). Vagal Mediation of Low-Frequency Heart Rate Variability During Slow Yogic Breathing. *Psychosomatic Medicine*, *80*(6), 581–587. https://doi.org/10.1097/PSY.0000000000000603

Lawrence, MA. (2016). _ez: Easy Analysis and Visualization of Factorial Experiments_. R package version 4.4-0, <https://CRAN.R-project.org/package=ez>.

Liszio, S., Graf, L., & Masuch, M. (2018). The relaxing effect of virtual nature: immersive technology provides relief in acute stress situations. *Annu. Rev. Cyberther. Telemed*, *16*, 87-93.

Lotufo, P. A., Valiengo, L., Bensenor, I. M., & Brunoni, A. R. (2012). A systematic review and meta-analysis of heart rate variability in epilepsy and antiepileptic drugs. *Epilepsia*, *53*(2), 272-282.

Lucassen, P. J., Pruessner, J., Sousa, N., Almeida, O. F., Van Dam, A. M., Rajkowska, G., & Czéh, B. (2014). Neuropathology of stress. *Acta neuropathologica*, *127*, 109-135.

Altini, M. (2013). *Heart Rate Variability Logger* (Version 5.1.0) [Mobile app]. App Store. https://apps.apple.com/de/app/heart-rate-variability-logger/id683984776

Meta Quest 2 (Menlo Park, California)

Navarro, D. J. (2015) Learning statistics with R: A tutorial for psychology students and other beginners. (Version 0.6) University of New South Wales. Sydney, Australia

Nilsson, N. C., Nordahl, R., & Serafin, S. (2016). Immersion Revisited: A review of existing definitions of immersion and their relation to different theories of presence. *Human Technology*, *12*(2), 108–134. https://doi.org/10.17011/ht/urn.201611174652

Patil, I. (2021). Visualizations with statistical details: The 'ggstatsplot' approach. Journal of Open Source Software, 6(61), 3167, doi:10.21105/joss.03167

Penttilä, J., Helminen, A., Jartti, T., Kuusela, T., Huikuri, H. V., Tulppo, M. P., Coffeng, R., & Scheinin, H. (2001). Time domain, geometrical and frequency domain analysis of cardiac vagal outflow: Effects of various respiratory patterns: Assessment of cardiac vagal outflow. *Clinical Physiology*, *21*(3), 365–376. https://doi.org/10.1046/j.1365-2281.2001.00337.x

Perciavalle, V., Blandini, M., Fecarotta, P., Buscemi, A., Di Corrado, D., Bertolo, L., Fichera, F., & Coco, M. (2017). The role of deep breathing on stress. *Neurological Sciences*, *38*(3), 451–458. https://doi.org/10.1007/s10072-016-2790-8

Piha, S. J. (1994). Cardiovascular autonomic reflexes in heavy smokers. *Journal of the Autonomic Nervous System*, *48*(1), 73–77. https://doi.org/10.1016/0165-1838(94)90161-9

Polar H10 Heart Rate Sensor (Polar Electro Oy, 90440 Kempele, Finland)

Posit team (2023). RStudio: Integrated Development Environment for R.
Posit Software, PBC, Boston, MA. URL http://www.posit.co/.

R Core Team (2023). _R: A Language and Environment for Statistical
Computing_. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

Ralevski, E., Petrakis, I., & Altemus, M. (2019). Heart rate variability in alcohol use: A review. *Pharmacology Biochemistry and Behavior*, *176*, 83–92. https://doi.org/10.1016/j.pbb.2018.12.003

Ramaciotti, D., & Perriard, J. (2000). Die Kosten von Stress in der Schweiz. *Pressemitteilung vom*, *12*, 2000.

Revelle, W. (2023). _psych: Procedures for Psychological, Psychometric, and Personality Research_. Northwestern University, Evanston, Illinois. R package version 2.3.3, <https://CRAN.R-project.org/package=psych>.

Riches, S., Azevedo, L., Bird, L., Pisani, S., & Valmaggia, L. (2021). Virtual reality relaxation for the general population: a systematic review. *Social psychiatry and psychiatric epidemiology*, *56*, 1707-1727.

Rigby, J. M., Brumby, D. P., Gould, S. J., & Cox, A. L. (2019, June). Development of a metaionnaire to measure immersion in video media: The Film IEQ. In *Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video* (pp. 35-46).

Robillard, G. (2004). *IMMERSIVE TENDENCIES QUESTIONNAIRE*.

Shaffer, F., & Ginsberg, J. P. (2017). An Overview of Heart Rate Variability Metrics and Norms. *Frontiers in Public Health*, *5*, 258. https://doi.org/10.3389/fpubh.2017.00258

Slater, M. (1999). Measuring Presence: A Response to the Witmer and Singer Presence Questionnaire. *Presence: Teleoperators and Virtual Environments*, *8*(5), 560–565. https://doi.org/10.1162/105474699566477

Slater, M. (2003). A note on presence terminology. *Presence connect*, *3*(3), 1-5.

Slater, M., Lotto, B., Arnold, M. M., & Sanchez-Vives, M. V. (2009). How we experience immersive virtual environments: The concept of presence and its measurement. *Anuario de Psicología*, *40*.

Steghaus, S., & Poth, C. H. (2022). Assessing momentary relaxation using the Relaxation State Questionnaire (RSQ). *Scientific Reports*, *12*(1), 16341. https://doi.org/10.1038/s41598-022-20524-w

Tavares, B. S., de Paula Vidigal, G., Garner, D. M., Raimundo, R. D., de Abreu, L. C., & Valenti, V. E. (2017). Effects of guided breath exercise on complex behaviour of heart rate dynamics. *Clinical Physiology and Functional Imaging*, *37*(6), 622–629. https://doi.org/10.1111/cpf.12347

Terathongkum, S., & Pickler, R. H. (2004). Relationships among heart rate variability, hypertension, and relaxation techniques. *Journal of Vascular Nursing*, *22*(3), 78–82. https://doi.org/10.1016/j.jvn.2004.06.003

Thayer, J. F., & Lane, R. D. (2007). The role of vagal function in the risk for cardiovascular disease and mortality. *Biological psychology*, *74*(2), 224-242.

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, *36*(2), 747–756. https://doi.org/10.1016/j.neubiorev.2011.11.009

Thayer, J. F., Yamamoto, S. S., & Brosschot, J. F. (2010). The relationship of autonomic imbalance, heart rate variability and cardiovascular disease risk factors. *International journal of cardiology*, *141*(2), 122-131.

Van Diest, I., Verstappen, K., Aubert, A. E., Widjaja, D., Vansteenwegen, D., & Vlemincx, E. (2014). Inhalation/Exhalation Ratio Modulates the Effect of Slow Breathing on Heart Rate Variability and Relaxation. *Applied Psychophysiology and Biofeedback*, *39*(3–4), 171–180. https://doi.org/10.1007/s10484-014-9253-x

Villani, D., Riva, F., & Riva, G. (2007). New technologies for relaxation: The role of presence. *International Journal of Stress Management*, *14*(3), 260–274. https://doi.org/10.1037/1072-5245.14.3.260

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, LD., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, TL., Miller, E., Bache, SM., Müller, K., Ooms, J., Robinson, D., Seidel, DP., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K., Yutani, H. (2019). "Welcome to the tidyverse." _Journal of Open Source Software_, *4*(43), 1686. doi:10.21105/joss.01686 <https://doi.org/10.21105/joss.01686>.

Wickham, H., Bryan, J. (2023). _readxl: Read Excel Files_. R package version 1.4.2, <https://CRAN.R-project.org/package=readxl>.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, *7*(3), 225-240.

Witmer, B. G., & Singer, M. J. Measuring Presence in Virtual Environments.(1994). *US Army Research Institute for the Behavioral and Social Sciences, Orlando, Fl*.

Xie, Y. (2023). _knitr: A General-Purpose Package for Dynamic Report Generation in R_. R package version 1.43, <https://yihui.org/knitr/>.

Zahorska-Markiewicz, B., Kuagowska, E., Kucio, C., & Klin, M. (1993). Heart rate variability in obesity. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity*, *17*(1), 21-23.

Appendix

Table A1

Mean, standard deviation and standard error for high frequency data in all time intervals

Interval	Start_1	Start_2	Start_3	Base	Task_1	Task_2	End_1	End_2	End_3
M	297.76	245.33	259.61	508.26	384.64	344.7	371	320.36	315.02
SD	283.47	244.87	256.78	515.69	353.35	327.53	266.6	250.66	258.28
SE	35.8	30.88	31.13	63.42	43.93	41.3	34.72	32.23	33.43

Table A2

p-value for high frequency post-Hoc analysis in between Time intervals

Interval	Start_2	Start_3	Base	Task_1	Task_2	End_1	End_2	End_3
Start_1	.991	.999	.009*	.852	.996	.917	.999	.999
Start_2		.999	.000**	.269	.716	.362	.914	.940
Start_3			.001*	.392	.836	.501	.967	.98
Base				.457	.115	.352	.039*	.029*
Task_1					.999	1.000	.977	.963
Task_2						.999	.999	.999
End_1							.992	.986
End_2								1.000

significant values are noted with * = <.05 and ** = <.001.

Table A3

Mean, standard deviation and standard error for root mean square of successive differences data in all time intervals

Interval	Start_1	Start_2	Start_3	Base	Task_1	Task_2	End_1	End_2	End_3
M	38.34	34.34	35.46	42.19	41.73	38.91	43.09	41.28	40.58
SD	22.11	20.27	20.44	21.81	19.12	18.86	19.82	21.3	21.84
SE	2.92	2.6	2.53	2.89	2.53	2.5	2.57	2.7	2.88

Table A4

p-value for root mean square of successive difference post-Hoc analysis in between Time intervals

Interval	Start_2	Start_3	Base	Task_1	Task_2	End_1	End_2	End_3
Start_1	.974	.995	.984	.993	1.000	.953	.999	.999
Start_2		.999	.463	.547	.943	.333	.678	.754
Start_3			.638	.719	.985	.497	.828	.883
Base				1.000	.995	.999	.999	.999
Task_1					.998	.999	1.000	.999
Task_2						.979	.999	.999
End_1							.999	.999
End_2								1.000

significant values are noted with * = <.05 and ** = <.001.

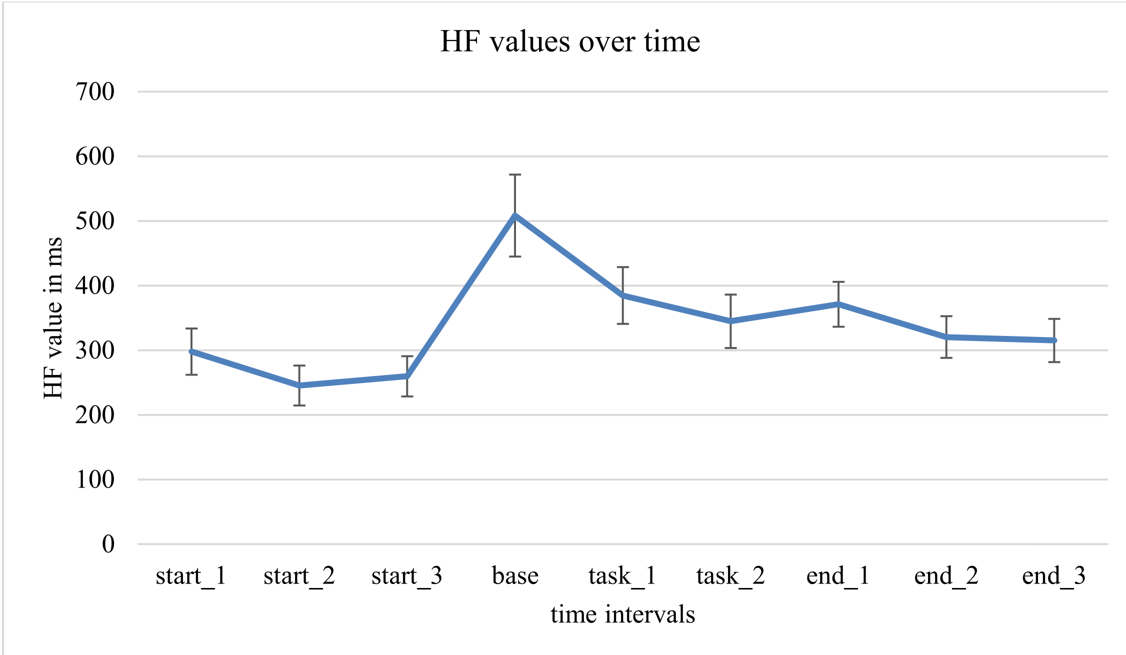

Figure A1. Visualization of changes in high frequency values. The graph shows changes over all 9 time intervals with base being the baseline measurement and task_1 and task_2 being the relaxation intervention. The error bar represents the standard error.

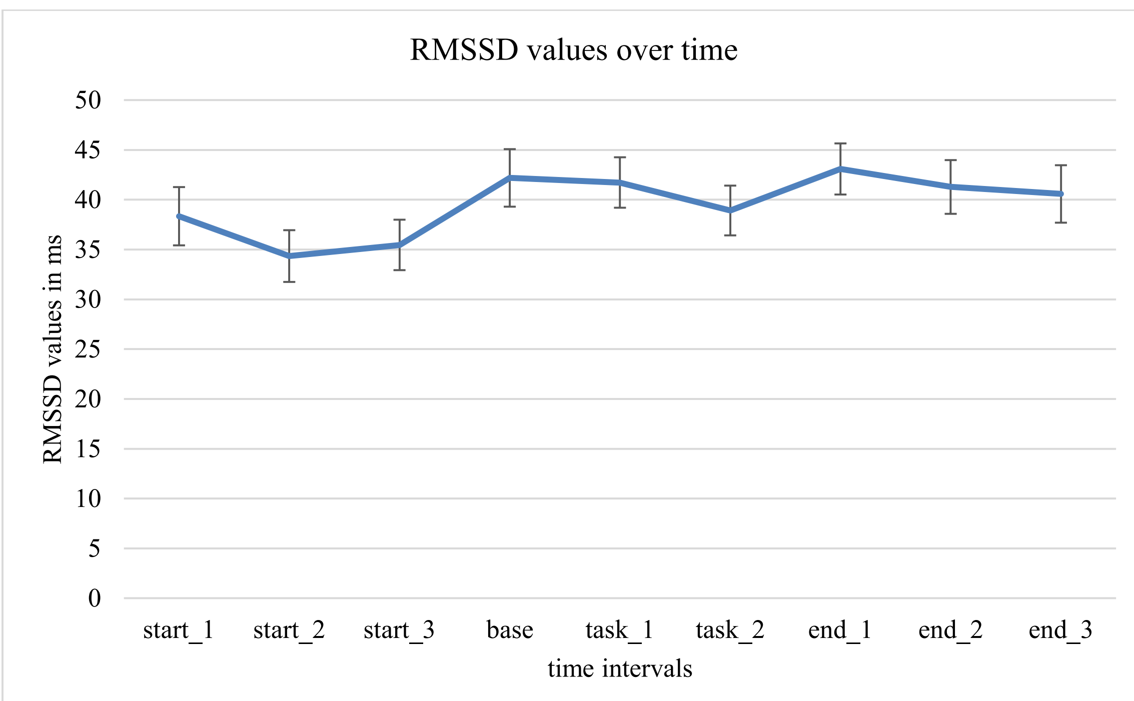

Figure A2. Visualization of changes in root mean square of successive differences values. The graph shows changes over all 9 time intervals with base being the baseline measurement and task_1 and task_2 being the relaxation intervention. The error bar represents the standard error.

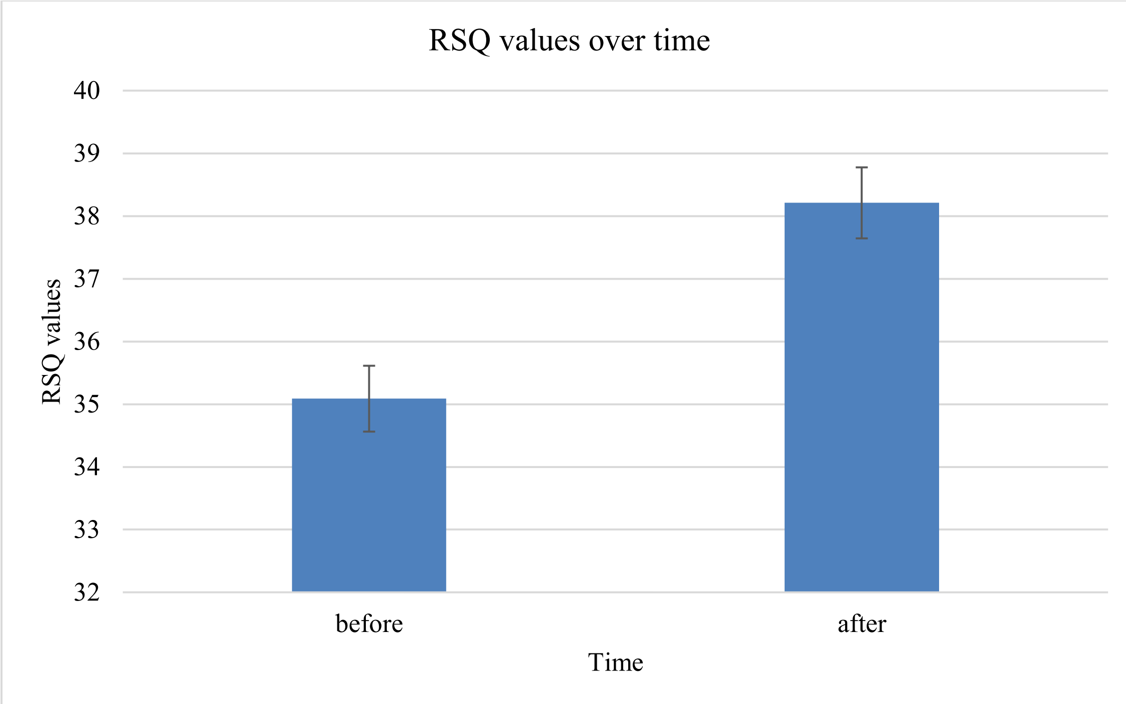

Figure A3. Scores in the relaxation state questionnaire before and after the relaxation intervention. Error bars represent the standard error.

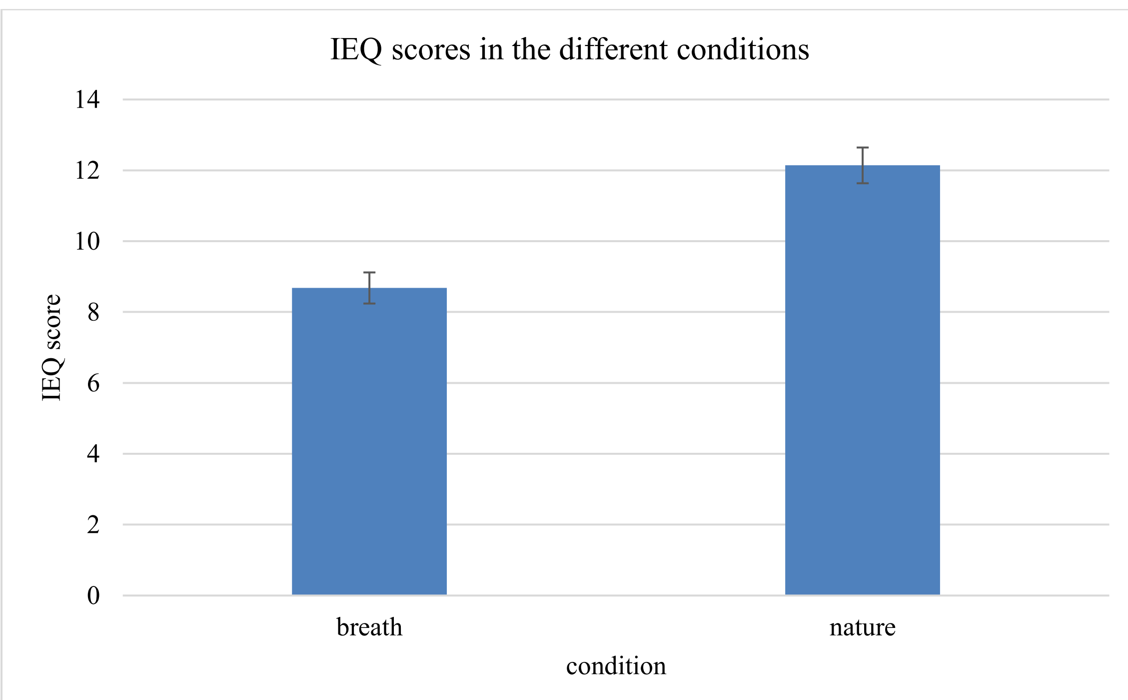

Figure A4. Comparison of immersive experience questionnaire scores in breathing task and virtual reality nature environment with the error bars representing the standard error.

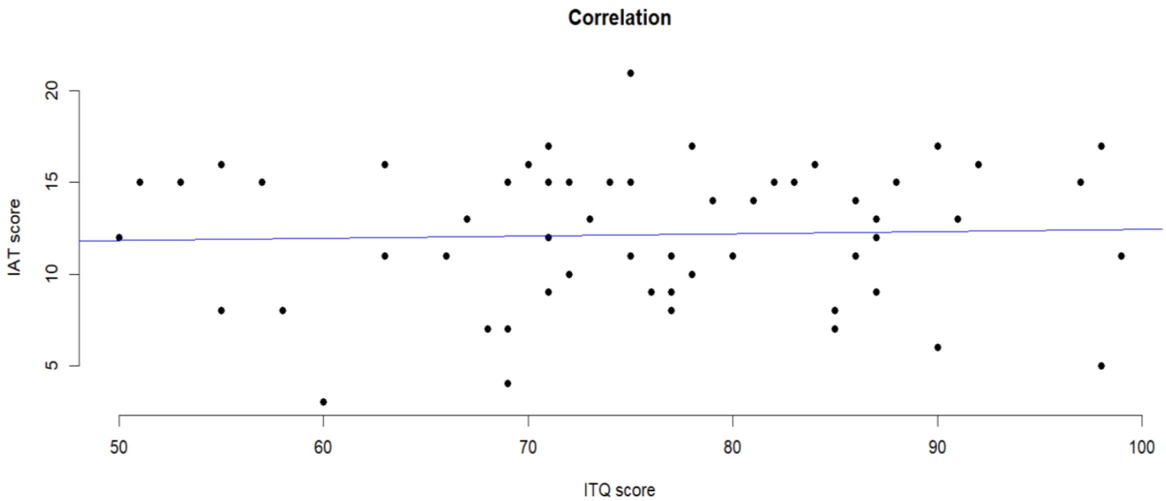

Figure A5. Correlation between immersion tendency questionnaire and immersion experience questionnaire.