Relaxation with Immersive Natural Scenes Presented Using Virtual Reality

Allison P. Anderson; Michael D. Mayer; Abigail M. Fellows; Devin R. Cowan; Mark T. Hegel; Jay C. Buckey

INTRODUCTION: Virtual reality (VR) can provide exposure to nature for those living in isolated confined environments. We evaluated VR-presented natural settings for reducing stress and improving mood.

METHODS: There were 18 participants (9 men, 9 women), ages 32 ± 12 yr, who viewed three 15-min 360° scenes (an indoor control, rural Ireland, and remote beaches). Subjects were mentally stressed with arithmetic before scenes. Electrodermal activity (EDA) and heart rate variability measured psycho-physiological arousal. The Positive and Negative Affect Schedule and the 15-question Modified Reality Judgment and Presence Questionnaire (MRJPQ) measured mood and scene quality.

RESULTS: Reductions in EDA from baseline were greater at the end of the natural scenes compared to the control scene (−0.59, −0.52, and 0.32 μS, respectively). The natural scenes reduced negative affect from baseline ($\Delta = 1.2$ and $\Delta = 1.1$ points), but the control scene did not ($\Delta = 0.4$ points). MRJPQ scores for the control scene were lower than both natural scenes (4.9, 6.7, and 6.5 points, respectively). Within the two natural scenes, the preferred scene reduced negative affect ($\Delta = 2.4$ points) more than the second choice scene ($\Delta = 1.8$ points) and scored higher on the MRJPQ (6.8 vs. 6.4 points).

DISCUSSION: Natural scene VR provided relaxation both objectively and subjectively, and scene preference had a significant effect on mood and perception of scene quality. VR may enable relaxation for people living in isolated confined environments, particularly when matched to personal preferences.

KEYWORDS: virtual reality, attention restoration theory, isolated confined environments.

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Virtual reality (VR) technologies are growing rapidly, with many new applications in the areas of psychology and healthcare.[19] One potential application for VR is providing exposure to natural settings.[1,23] Attention Restoration Theory (ART) suggests that exposure to nature can reduce stress, improve mood, and restore work productivity.[6,17,25] Many of the tasks performed in our daily lives require directed attention, where focusing on the task requires effort and depletes mental resources.[24] These resources can be restored by exposure to environments that provide psychological distance from routine mental concerns (i.e., a sense of "being away") combined with effortless, interest-driven attention ("fascination"), supported by an environment of substantial scope ("extent").[14] Each of these three mechanisms leading to mental restoration (being away, fascination, and extent) are found in natural settings.

Not everyone can access nature easily. People living and working in isolated and confined environments (ICE), such as those found in the Arctic, Antarctic,[20] on submarines,[7] or in space,[15] cannot freely seek out natural settings. Furthermore, environmental stressors in ICEs are exacerbated by limited access to loved ones, high workload demands, or inability to have time away from coworkers.[9] For these populations, replicating the restorative effects of nature may be achievable using immersive VR. New VR technology has made it possible to provide a high degree of scene immersion and presence, which may allow those in ICEs to feel they have escaped their surroundings.

Simulated nature has been shown to provide some of the benefits seen with actual nature.[22] In these studies, however, the

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control scene is often an urban setting,[4,22,23] making it difficult to determine whether the natural scenes are relaxing subjects, or whether the urban scenes were preventing relaxation. Valtchanov et al.,[23] for example, evaluated natural scene VR for achieving the benefits associated with ART. The control scenes, however, were static urban images, while the natural scene was a computer-generated forest participants could explore. The natural scenes showed benefit, but separating the effects of rendering modality (photographed or computer generated) and immersion (static images or a dynamic world) from the environment (urban or natural) was not possible.[23]

Also, it is not known to what degree individual scene preferences influence the effectiveness of ART. Kaplan suggests the environment and the person's desired intent in the environment, or "compatibility," must match for it to be restorative.[17] People in general subjectively prefer natural settings to urban or built settings, perhaps because they find it mentally restorative subconsciously.[24] Similarly, scenes with water are rated more highly than scenes without water.[27] Some have tried to objectively quantify the link between scene content and preference through fractal dimensionality. Some have shown that there is a range of dimensionality most preferred in scenes.[13] Within these bounds, though, there is still a great degree of personal preference that may influence the effectiveness of VR for a given individual. Understanding the degree to which individual preference influences restoration is important for developing content specifically for ICEs. In these settings, VR material may be deployed at the beginning of a mission without the opportunity for updating content and it must be acceptable to the people on the mission.

We evaluated presenting immersive natural settings using VR technology to reduce stress and improve mood. We compared the responses to natural settings with responses to a neutral indoor control scene using a consistent display modality (filmed, 360° views). Two natural settings, each containing elements of water but in different settings, were used to evaluate the influence of scene preference on relaxation. We hypothesized the natural scenes would be more effective in reducing stress and improving mood than the control scene. We also hypothesized that individual preferences would affect which natural scene subjects would find most restorative.

METHODS

Subjects

The Dartmouth College Committee for the Protection of Human Subjects approved the protocol and all subjects consented to participate in the study. Participating in the study were 18 participants (9 men, 9 women) with an average age of 32 ± 12 yr. Subjects had no reported psychiatric or chronic medical conditions, and all subjects had no or minimal prior experience using VR.

Materials

Three 15-min 360°, high-definition scenes (two natural settings, one indoor control) were evaluated using a head mounted display (HMD) (Oculus Rift DK2, Oculus VR, Menlo Park, CA). The control scene was comprised of empty indoor classrooms. There were no people, plants, or animals present in the control scene. The first natural scene was filmed at various locations over Ireland (Ireland VR from http://www.feeltherelaxation.com). It consisted of large expansive natural vistas with views of water. It also occasionally included animals such as sheep and birds, as well as evidence of human presence such as houses and roads. The second natural scene was filmed at various beach locations on the Australian coast (Dream Beach VR, also from http://www.feeltherelaxation.com) and was accompanied by ocean sounds and soothing music. This film included expansive natural vistas, but did not include animals or any element of human presence. In addition to the visual presentation on the HMD, this scene was viewed in a physically immersive environment. A beach lounge chair and heat lamp was placed in the direction from which sunlight was visually presented in the film.

Procedure

Fig. 1 shows a graphical representation of the study protocol. All studies were carried out in a quiet laboratory space at Dartmouth Hitchcock Medical Center. Subjects filled out a Value of VR Questionnaire (VVR) to assess how valuable subjects perceived VR prior to exposure. Before the start of the experiment, subjects viewed an 8-min rendered scene to ensure the headset was comfortable and their vision was clear. Before viewing each experimental VR scene, subjects were given a mentally stressing arithmetic test. The test was 2 min long and the test operator increased the subject stress level by watching the subject, recording performance, and calling out time markers, such as "10 seconds remaining." Electrodermal activity (EDA) and electrocardiogram (EKG) were collected to measure psychophysiological arousal and heart rate variability (HRV) (Biopac MP150 with EDA100C and ECG100C modules, Goleta, CA). Subjects wore two leads on the index and middle finger to measure EDA, and two leads on the upper right clavicle and lower left chest to measure EKG. These objective measures of stress were measured continuously. For analysis, the data were binned into the following 2-min long intervals: resting baseline prior to beginning the experiment, during the stress test, and at the beginning, middle, and end of the 15-min VR session. The Positive and Negative Affect Schedule (PANAS) questionnaire was given at the beginning of the experiment, between the stress test and VR, and after VR. The 15-question Modified Reality Judgment and Presence Questionnaire (MRJPQ) was given after

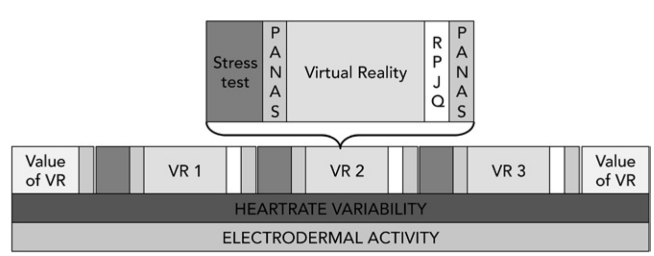

Fig. 1. Graphical representation of the experimental protocol.

VR. Then the same process (mental arithmetic, PANAS, VR scene presentation, PANAS, MRJPQ) was repeated for the two other scenes. The order of scene presentation (Control, Ireland, and Dream Beach) was randomized and counterbalanced by sex. At the end of the study, subjects were asked to fill out the VVR again to assess how valuable subjects found their experience with VR. Qualitative comments on scene content were also noted and a ranking of scene preference from favorite to least favorite was collected.

EDA and HRV were analyzed over the 2-min increments within the continuous data set described previously. Data analysis was done using the same software package with which the data were collected (AcqKnowledge 4.4.0, Biopac). EDA values for each subject were averaged over the 2-min time period. Every individual has a unique EDA baseline, or skin conductance level. Therefore, all EDA data were analyzed as a change from the seated, pre-experiment baseline. In this way, EDA data were a measure of the skin conductance response, or the amplitude of change, from the baseline.[11]

The HRV data were cleaned before analysis. For each subject, a single EKG waveform was selected as an "ideal" waveform. All other EKG waves were compared to this waveform. The ideal waveform was correlated to all other EKG waveforms and the original data were transformed into an RR-tachogram. The tachogram is used to find errant values in the data, when interval points deviated substantially from the trend ($\pm$ 0.4 s). These regions were identified and cleaned. An average of 0.4 corrections were made per subject. After the data were cleaned the power spectral density was calculated for all time periods. The low frequency (LF) spectrum ranged from 0.04 to 0.15 Hz and the high frequency (HF) spectrum ranged from 0.15 to 0.4 Hz. The ratio of LF/HF was also calculated because it represents sympathetic-vagal balance.[21]

The PANAS is a measure of the extent subjects' experience 20 emotions right now on a 5-point scale ranging from "very slightly" to "very much." Half of the presented emotion words concern positive affect (interested, alert, attentive, excited, enthusiastic, inspired, proud, determined, strong, active); the other half negative affect (distressed, upset, guilty, ashamed, hostile, irritable, nervous, jittery, scared, afraid).[10,26] The rated value for each emotion is summed to create a score for positive affect (PA) and negative affect (NA). PA and NA are measures independent of one another. Internal consistency is high, ranging from $\alpha = 0.86$ to 0.90 for PA and $\alpha = 0.84$ to 0.87 for NA. Test-retest reliability is also strong.[10]

The MRJPQ measures the quality of the VR experience by the extent the person feels they were "present" (e.g., To what extent did you feel you were physically in the virtual world?), experienced the situation as "real" (e.g., To what extent was what you saw in the virtual world similar to reality?), and felt an emotional impact [e.g., To what extent did the virtual world make you feel emotions (anxiety, sadness, happiness, etc.)?].[2,28] It was modified from a larger 77-item questionnaire created by Baños et al.[2] The 15 items were selected from the larger subset and were rated on a 0 (not at all) to 10 (absolutely) scale. The MRJPQ was validated on 194 subjects and showed a Cronbach's alpha of 0.88, with interitem correlations between 0.057 and 0.64, and an average of 0.33 (data in preparation for publication).

The VVR is a 6-item questionnaire designed to evaluate the value subjects find, or anticipate to find, in VR. For example, subjects agree or disagree with statements such as "I would recommend the Virtual Reality system to a friend to use", and "I enjoyed using the Virtual Reality system." It is rated on a 7-point Likert scale ranging from 1 (Strongly Agree) to 7 (Strongly Disagree).

Statistical Analysis

Data were divided first by scene and evaluated, then by preference rankings. EDA, HRV, PANAS, and MRPJQ data were evaluated for normality with the Shapiro-Wilk test. When normality was achieved, data were analyzed with a 2-factor repeated measures ANOVA (RMANOVA) on time and scene. If the data were not normal, then a nonparametric Friedman test was applied if there was more than two levels, and a Wilcoxon signed rank test if there were only two levels. The reliability of the MRPJQ was assessed with the Cronbach's alpha and interitem correlations. Cronbach's alpha above 0.7[18] and mean interitem correlations between 0.15 and 0.5 were acceptable in this study.[8] The VVR was analyzed with paired *t*-tests to assess if subjects changed their opinions before and after exposure to VR.

RESULTS

EDA data were normally distributed and analyzed with a 2-factor RMANOVA, shown in **Fig. 2**. The test showed a significant effect of time [$F(3,51) = 44, P = 0+$] and scene [$F(2,34) = 3.7, P = 0.03$]. The control scene was statistically different from Dream Beach ($P = 0.002$). Subjects exhibited a decrease in EDA for all three VR scenes from the beginning, middle, to the end. Over the course of the control scene, however, subjects only returned from their induced stress level to baseline. In contrast, the Ireland and Dream Beach scenes produced a marked decrease in EDA below baseline levels, with Dream

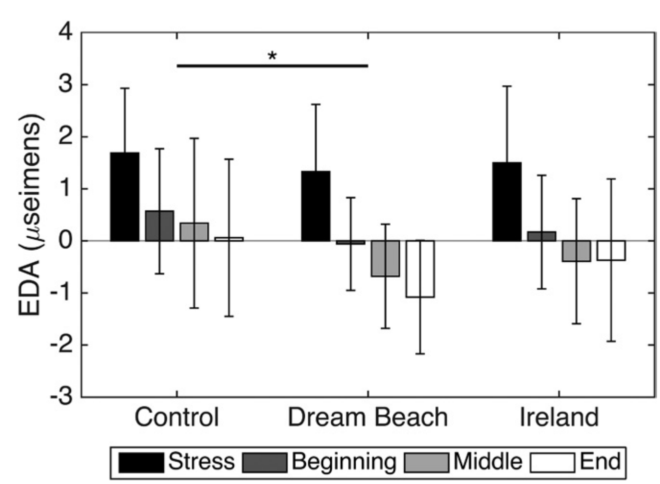

Fig. 2. EDA across subjects, shown as mean and standard deviation. *Indicates a significant difference between scenes.

Beach being significantly below baseline ($P = 0.001$). The control scene generally exhibited greater fluctuation of EDA, while the Ireland and Dream Beach scenes generally exhibited an exponential, smooth decrease in EDA over time. None of the EDA measurements taken during the stress tests were significantly different from one another [$F(2,34) = 0.47$, $P = 0.63$].

HRV data were not normally distributed for any variable, shown in **Table I**. The HF, LF, and ratio of LF/HF were analyzed with nonparametric tests. The HRV power spectral density was analyzed for changes with time. LF showed a significant difference with time for Control [$\chi^2(3) = 9$, $P = 0.029$] and Ireland [$\chi^2(3) = 7.8$, $P = 0.05$], but Dream Beach did not change with time [$\chi^2(3) = 0.1$, $P = 0.99$]. For both Control and Ireland, the value during the stress test was lower than values in the beginning of VR, but no other time points were different. HF changed with time for Control [$\chi^2(3) = 13.2$, $P = 0.004$], Dream Beach [$\chi^2(3) = 21.6$, $P = 0+$], and Ireland [$\chi^2(3) = 18.5$, $P = 0+$]. For each scene, the stress test was significantly different from the remaining time points during VR. The ratio of LF/HF changed with time for Control [$\chi^2(3) = 11.1$, $P = 0.01$] and Dream Beach [$\chi^2(3) = 13.8$, $P = 0.003$]. The Beginning time point for Control was different from the Middle and End time points. The Stress time point for Dream Beach was different from all other time points. Ireland was not significantly different with time [$\chi^2(3) = 5.6$, $P = 0.13$].

The LF, HF, and LF/HF end points for each scene were compared to the baseline to determine if subjects recovered over the course of VR from the stressed condition to pre-experiment values. There was no significant difference for LF [$\chi^2(3) = 6.2$, $P = 0.10$], but there was for HF [$\chi^2(3) = 7.8$, $P = 0.05$]. There was also a significant difference for LF/HF [$\chi^2(3) = 9.6$, $P = 0.02$]. For both HF and LF/HF, the end point for Dream Beach was less than the baseline, but Control was also lower than baseline for LF/HF. The HF, LF, and LF/HF measurements taken during the stress test were not significantly different from each other.

The PANAS was analyzed for change in mood. PA scores were normally distributed, so a RMANOVA was used. PA showed a significant main effect of time [$F(1,16) = 4.56$, $P = 0.05$], but not scene [$F(2,32) = 0.97$, $P = 0.39$]. The difference in PA and NA before and after VR exposure is shown in **Fig. 3**. With time, the control scene showed a significant decrease in PA ($P = 0.004$), while Ireland and Dream Beach did not ($P = 0.12$ and $P = 0.21$, respectively). The NA scores were not normally distributed. Like PA, there was no significant effect of the scene on NA results [$\chi^2(2) = 4.0$, $P = 0.13$ for post-VR values]. Again, there was an effect of time with a significant decrease after viewing Ireland ($Z = 2.8$, $P = 0.005$) and Dream Beach ($Z = 2.1$, $P = 0.03$), but not Control ($Z = 1.8$, $P = 0.07$). The PA and NA values were not different [$F(3,51) = 0.2$, $P = 0.8$ and $\chi^2(2) = 1.3$, $P = 0.5$, respectively] when measured after any stress test/before VR for any scene.

The MRJPQ results are shown in **Fig. 4**. The Cronbach's alpha of the MRJPQ was greater than 0.9 and mean interitem correlation was between 0.39–0.42 for all scenes, satisfying the reliability criteria. The data were normally distributed. A 1-factor RMANOVA showed a significant main effect of scene [$F(2,34) = 10$, $P = 0.0004$], with the control significantly less than others ($P < 0.014$). The Ireland and Dream Beach scenarios scored nearly equivalently.

One subject did not take the VVR after the experiment, so his or her data were excluded ($N = 17$). Likert scores for two questions on the survey were significantly different before and after the experiment. Subjects agreed more with the statements, "Overall people would benefit from using the VR system" ($P = 0.03$) and "VR systems can improve people's ability to relax" ($P = 0.015$) after the experiment. These were the questions subjects initially disagreed with the most.

Preference for scene was also assessed. Subjects were nearly evenly divided in preference for the natural scenes, with eight preferring Dream Beach and ten preferring the Ireland scene. Neither of the objective physiological measures, EDA and HRV, showed results differing from those when evaluated by scene. The EDA did not show changes by preference [$F(1,17) = 2.1$, $P = 0.17$] and the end points were not different from one another ($P = 0.14$). The HRV values at the end of the VR scene were not different between the first and second choices (LF $Z = 0.2$, $P = 0.83$; HF $Z = 0.19$, $P = 0.85$; LF/HF $Z = 0.45$, $P = 0.65$).

Subjective measurements, however, did change when data were grouped by preference. For the PANAS, shown in Fig. 3, the NA showed the most profound differences beyond what was seen when analyzed by scene. There was a significant main effect by scene preference [$\chi^2(2) = 16.5$, $P = 0+$]. The first choice scene was significantly lower than baseline NA ($P = 0.003$), and lower than the second choice scene

Table I. Heart Rate Variability Data Presented in Mean (SD).

	BASELINE	STRESS	BEGINNING	MIDDLE	END
		CONTROL*			
LF (ms^2)	180 (230)	140 (250)	160 (150)	140 (190)	130 (180)
HF (ms^2)	100 (110)	60 (40)‡	100 (80)	120 (100)	100 (80)
LF/HF	2.28 (1.87)†	2.53 (3.17)	2.00 (1.86)	1.45 (1.5)	1.38 (1.28)
		DREAM BEACH**			
LF (ms^2)		120 (110)	110 (70)	90 (60)	110 (70)
HF (ms^2)		70 (40)‡	130 (90)	140 (70)	130 (90)
LF/HF		1.87 (1.13)‡	1.00 (0.63)	0.86 (0.42)	0.92 (0.36)
		IRELAND***			
LF (ms^2)		150 (180)	200 (190)	150 (180)	130 (110)
HF (ms^2)		70 (50)‡	120 (10)	110 (80)	110 (120)
LF/HF		2.39 (2.22)	2.27 (1.83)	1.8 (1.5)	1.88 (1.75)

Low frequency (LF) is associated with sympathetic and parasympathetic activity, high frequency (HF) with parasympathetic activity. Decreased LF/HF ratio indicates decreased cardiac sympathetic nervous system activity, or relaxation.

* Indicates significance across scene time points ($P < 0.05$) for all parameters.

** Indicates significance across scene time points ($P < 0.05$) for HF and LF/HF.

*** Indicates significance across scene time points ($P < 0.05$) for LF and HF.

† Indicates the value was significantly different from Control and Dream Beach end points. ‡Indicates the value was significantly different from all other time points in the scene.

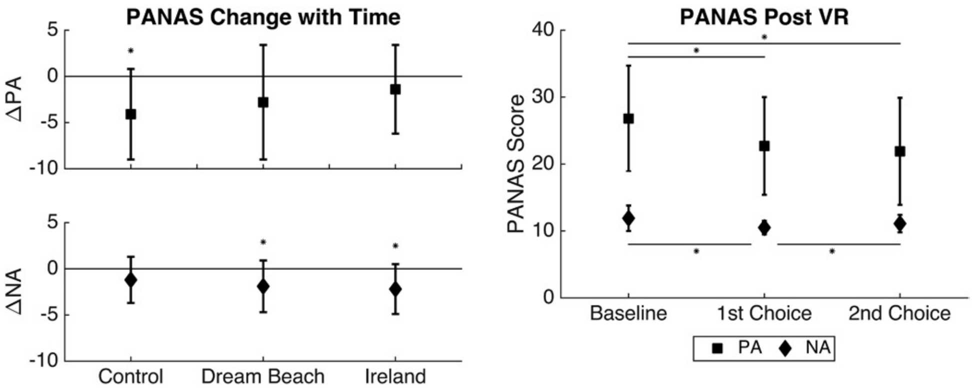

Fig. 3. PANAS scores across subject, shown as mean and standard deviation. The figure on the left shows the change with time by scene. The figure on the right shows raw PANAS values after viewing VR and at baseline by natural scene preference. *Indicates significant differences.

($P = 0.04$). PA decreased from baseline after viewing both the first and second scene choices [$F(2,32) = 17$, $P = 0+$], but there was no difference between the two natural scenes ($P = 0.30$). Scores for the MRPJQ, shown in Fig. 4, were higher for the first choice scene than the second choice scene ($P = 0.03$).

DISCUSSION

These results indicate that VR-presented natural scenes showed improved relaxation over the VR control scene, as hypothesized. These results are consistent with the findings of other researchers in attention restoration theory[5,14,23] and simulated nature studies.[1] We used a neutral, indoor scene that is not likely to induce stress, unlike urban controls used in other studies where the objective was to assess the preference for natural over urban settings.[4,14] Additionally, we included both subjective and objective measures of stress, relaxation, and mood.

In this study, the pre-VR math test produced consistent, elevated stress levels, as shown by EDA, HRV, and the PANAS, which showed consistent changes each time the subject performed the math test. From the stressed state, both natural scenes showed improved relaxation compared to the indoor control scene.

EDA decreased exponentially with time for all scenes. Natural scenes, however, produced greater decreases than the control scene. The EDA values at the end of the control scene indicated subjects returned to baseline. The Ireland and Dream Beach values, however, showed a marked decrease below baseline at the end of VR exposure. EDA is a measure of skin conductance corresponding to state of arousal, or stress. It is indicative of sympathetic response without a parasympathetic component.[11] Therefore, EDA levels increase as stress is induced and subsequently decrease when the stressful stimulus is removed. These results indicate subjects were more relaxed after the natural scenes than they were prior to the experiment and after viewing the control.

The subjective measures also indicated differences when viewing scenes. PA decreased after viewing the control scene, but not for the two natural scenes. NA also decreased after viewing the two natural scenes, but was not changed after the control scene. The PANAS is a frequently used measure for general affective states.[26] The pre-VR PANAS was taken after the stress test. Therefore, the control scene was the only scene to further decrease PA and did not improve NA from a stressed condition. Similarly, the MRPJQ scores were significantly lower for the Control scene compared to the two natural scenes. Higher scores indicate elements of the scene felt real and immersive, and elicited an emotional response.

HRV also generally indicated relaxation with time for the LF, HF, and LF/HF ratio, but did not show clear differences across scenes. The components of the power spectral density of HRV are indicative of changes in the autonomic nervous system. The LF is associated with sympathetic activity and may include parasympathetic activity in its components.[21] The HF is associated with parasympathetic activity. Since the LF component may include both sympathetic and parasympathetic activation, a decreased LF/HF ratio indicates decreased cardiac sympathetic nervous system activity, or relaxation. These data show that HF decreased initially with stress then increased as subjects relaxed with VR. The LF/HF ratio was elevated during the stress test and decreased with time during VR. Although the data were consistent

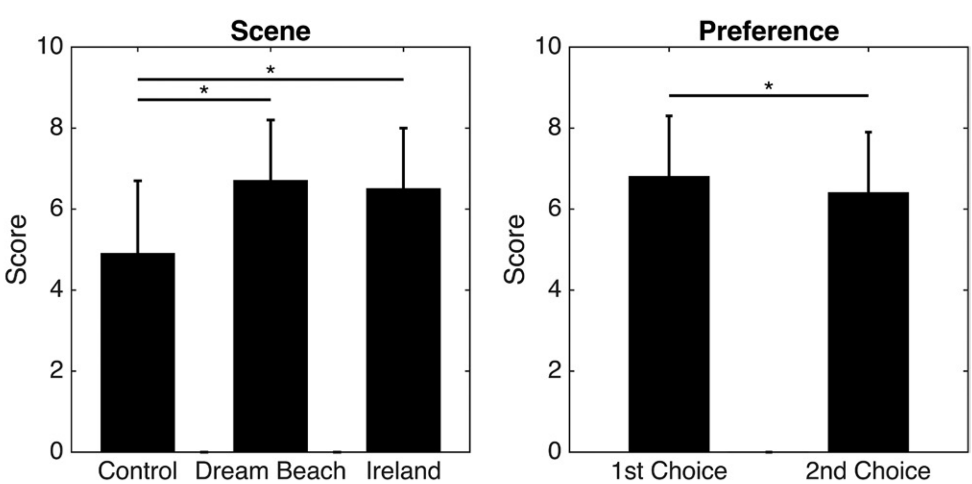

Fig. 4. Scores for the MRPJQ are shown by both scene and preference for the natural scene. Data are shown as mean and standard deviation. *Indicates a significant difference.

with anticipated changes during stressing and relaxing stimuli, statistical differences between scenes were not consistent for each measurement of the power spectral density.

The evaluation of subject preferences for the natural scenes showed no difference in objective physiological measures, but did show differences in subjective measures of mood. The scenes each contained elements important to ART such as water, green spaces, and expansive vistas.[17] Their content (bucolic countryside in Ireland and a secluded beach in Dream Beach), however, were sufficiently different such that any given individual may prefer one over the other, thereby influencing the restoration achieved with natural scene VR. By objective measures, the impact of preference was not detectable. By subjective measures, however, scene preference mattered. NA was influenced by scene preference, decreasing from pre-experiment baseline for the favorite scene, but not for the second favorite scene. The MRPJQ was higher for the first choice than the second choice, even though there was no difference between Dream Beach and Ireland when analyzed by scene rather than preference.

Although the objective measures of EDA and HRV showed similar trends in the control scenes to those seen in natural scene VR, subjective impressions capture the difference between positive relaxation vs. boredom. Subjects reported feeling relaxed during Dream Beach. Subjects also reported enjoying the Ireland scene and were engaged in the environment since the scenes were the most dynamic. By contrast, many subjects reported being bored, frustrated, or nervous in the control scene.

Overall, subjects found the VR experience to be positive, which was reflected in their change in attitude toward VR. The VVR showed that subjects' opinion of VR improved after the study. They enjoyed VR and found it relaxing. Subjects indicated that VR is a valuable tool and an experience they would like to repeat.

VR has many advantages for use in ICEs because it offers stress reduction and relaxation in an autonomous and confidential way, while also providing an immersive, engaging experience.[16] Confidentiality can be provided since only the user sees what is on the screen, even if they are using the program in a common area among coworkers. Although the objective measures did not show a significant difference in HRV and EDA responses between natural scenes, the measures on subjective preference suggest that a large variety of content needs to be made available in isolation and confinement in order to achieve compatibility with a large number of people.

Users of VR in ICE may have unique needs, which may be overlooked by traditional VR research. For example, urban scenes have not had restorative effects in average populations.[4,22,23] For people in ICEs, however, these kinds of environments may present a sense of normalcy and an escape from their current setting. Our participants noted several times how the animals present in the Ireland scene added to their enjoyment, a sentiment that may be further enhanced when an individual has not seen an animal in months while in an ICE. Outside of ICEs, individuals have the opportunity to change their environment, which can be restorative, even if it is not explicitly a natural environment. The interior of many ICE habitats, such as the interior of a spacecraft or submarine, is limited in extent and variety, which can be monotonous over time. In simulated Mars missions, a lack of motivation and decrease in cognitive performance due to lack of sensory stimulation has been seen.[3] Adding variety to the environments people in ICEs encounter through VR may combat these negative effects, and is an active area of current research.

Implementation was not evaluated in this study, but ICE participants would likely use VR by voluntarily seeking it out for pleasure and relaxation. Since they are usually constrained by lack of personal time, it is feasible for VR to be used as a countermeasure and could be a prescribed activity by flight surgeons or other healthcare professionals.[12] Additionally, it is not known whether HMDs, such as the Oculus Rift used in this study, offer advantages over content delivered with high-resolution screens. High-resolution screens provide a detailed, realistic image, but HMDs provide a sense of visual synchrony by occupying the subject's field of view and altering presented visual content with head movement. The individualized nature of the VR delivery may also offer a degree of escape from the user's environment that may be attractive to an individual in an ICE. Nevertheless, providing scenes on a virtual window that an entire crew can experience at times throughout the day is a relatively easy countermeasure to implement. If the restorative effects of the virtual window are equivalent to the HMD delivered content, ease of implementation may be important for operational planning.

Subjects were seated in all scenes, but they were supine and allowed to elevate their legs on the lounge chair for Dream Beach. This may have influenced HRV data by increasing parasympathetic activity, leading to higher HF values and lower LF/HF ratios for the Dream Beach condition. Also, due to the variability of the HRV measures, this study may not have had the power to detect small changes. The HRV results regarding relaxation with time for all scenes, however, corroborate the EDA results. We also did not control for the use of musical overlay and length of each location within a scene. Music can influence the results by enhancing the visual stimulus, providing relaxation independent of the visual stimulus, or even by reducing distraction from background noise. Regardless of the acoustic environment accompanying the scene, it is important to ensure the test environment is free of background noise. This is particularly important for VR in field use, for example, in isolated confined environments. These factors may influence the nature of relaxation achieved and should be pursued in future studies. PA does not increase from the stressed state after VR for the natural scenes as might be expected. This likely indicates the level of stimulation does not increase (which would increase the scores for feeling interested, alert, attentive, excited, enthusiastic, inspired, proud, determined, strong, or active), rather than being an indication of a negative reaction to the film. This study included 18 subjects and therefore may not be generalizable to the rest of the population. Future work includes dissecting scene content by theme with subjects in an ICE to determine the influence scene content has on subject VR relaxation and preferences.

These results indicate that natural scenes delivered via VR provide relaxation and restoration both objectively and subjectively after a stressful experience. Although the effect of preference for VR scene content is not apparent when looking at objective measures, scene content preference had a significant effect on subjective responses to the scenes. VR could improve life in ICEs by providing a sense of being away and an escape from daily operational pressures and stressors. For people in these kinds of environments (such as astronauts, submariners, and others), VR may be a way to improve mental health outcomes. From this lab-based validation of VR for relaxation and restoration, we are currently evaluating its effectiveness for subjects in ICEs in the Arctic and in long duration space simulations. Future areas of work may also include characterizing the content of natural scenes based on more objective measures, such as fractal dimensionality.

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