The Immediate Impact of Immersive VR Natural Scene Mindfulness Intervention on the Perceived Stress of Corporate Employees

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Abstract. High work pressure is a common problem for employees in the workplace. A mindfulness-based intervention (MBIs) is often used to relieve stress. Virtual reality (VR) offers an innovative and immersive approach, which is used to achieve mindfulness experiences based on natural scenarios. This study employed a randomized controlled trial (RCT), comparing the immediate psychological and physiological effects of an audio-guided mindfulness intervention based on immersive VR natural scenes and a traditional closed-eye audio-guided mindfulness intervention on enterprise employees. The findings indicate that the VR condition yielded greater improvements in heart rate variability (HRV) and in the MDBF dimensions of alertness and calmness compared with the traditional condition. On the dimension of pleasure, however, there was no discernible difference between the two groups. Research shows that a VR natural scene mindfulness intervention can immediately and significantly improve HRV, alertness and calmness of enterprise employees. This provides a new and feasible solution for organizations to manage the mental and physical health of their employees.

1 Introduction

In the contemporary corporate scenario, employees often face high levels of stress, which significantly impacts their psychological states, performance outcomes, and turnover intentions [1]. One predominant form of such an intervention is mindfulness-based interventions (MBIs), which entails purposefully focusing on the ongoing experience with open and without evaluative judgment [2].

Traditional MBIs typically involve audio-guided mindfulness practices in a quiet and controlled environment. Technological advancements, such as virtual reality (VR), introduce a completely new way for psychological interventions [3]. Research have shown that exposure enhances mindfulness and reduce stress, thus positively affecting positive mental health outcomes [4,5]. However, accessibility to the actual natural settings might be limited by constraints of various kinds, which include but are not limited to time. VR technology provides an opportunity to overcome these limitations by allowing users to engage in highly

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immersive simulated natural environments. Immersive nature 360 videos have also been shown to have the benefits of mood improvements after brief exposures of about 6, 9, or 15 minutes [6,7].

Previous study has also illustrated that VR can effectively simulate the benefits of being in nature and can successfully reduce stress and improve cognitive performance [8]. Though, few studies have been done on measuring the immediate effect of immediate effects of immersive VR natural scene mindfulness interventions on both the perceived stress and state mindfulness in corporate employees. This study aims to use a randomized controlled experiment to investigate and compare the effects of a single session of immersive VR-based natural scene mindfulness intervention on psychological and physiological aspects against a traditional mindfulness intervention on corporate employees. The hypothesis is that, after the intervention, participants in the VR condition would demonstrate greater reductions in perceived stress and larger increases in heart rate variability (HRV) following the intervention.

2 Method

2.1 Research design

This study used a pre–post randomized controlled design (RCT) to test whether an immersive VR nature-scene mindfulness session produces immediate changes in perceived stress and HRV among corporate employees.

Independent variables: Time-interval and type of intervention (Immersive VR natural scene mindfulness intervention for experimental group. non-VR condition for control group).

Dependent variables: Immediate effects of the intervention (perceived stress and HRV)

A total of 79 corporate employees were recruited and allocated to either the VR condition or the control condition. Group assignment followed simple randomization with an independent researcher generated the allocation sequence using a lottery method. Participants will remain unaware of their group assignment throughout the experiment to avoid any bias related to expectations. All participants were assessed at two time points, immediately before and immediately after the intervention.

2.2 Participants

This study recruited employees aged 18-60 from a private enterprise operating in the sports industry in China. The sample were 25 male and 54 female. Participants were recruited from different departments in the organization, which ensured the diversity of the samples. In conclusion, valid HRV results were achieved for all 79 participants (experiment group: n=38, control group: n=32), while valid questionnaires achieved acceptable results from 70 participants in total. Based on the experiences that were collected, 4 participants noted that they had experience in VR, while 18 had experience in mindfulness.

2.3 Measurement tools

Perceived Stress: The Multidimensional Mood State Questionnaire (MDBF) Scale was used to measure the level of perceived stress both before and after the experiment. The questionnaire assesses three dimensions, including mood (good or bad), alertness (awake or tired), and calmness (calm or restless), which provide the implications for the participants' stress level changes before and during the experiment [9]. The final score will be recorded and analysed.

Heart Rate Variability (HRV): HRV was measured before and after the experiment by an Apple Watch to assess the physiological changes. Relaxation reactions are associated with increased parasympathetic nerve activity, which is indicated by elevated HRV [10].

Equipment and Virtual Scenarios: The VR-based mindfulness intervention employed the Apple Vision Pro headset as equipment. Participants in the experimental condition were provided with immersion in virtual nature scenes with beaches, specifically designed to promote relaxation and attentional focus during the mindfulness exercise.

Virtual scenarios: Beach and ocean scenes shown in Figure 1.

Mindfulness Experience: A brief questionnaire regarding prior mindfulness experiences was given to participants in order to create a foundation for managing the impact of mindfulness practice.

Fig. 1. VR natural scene (beach).

2.4 Procedure

To guarantee uniformity for both groups, the experimental process was broken up into multiple stages.

This study was conducted at the participating company. Upon arrival, participants were asked to sign an informed consent first, followed by completing a perceived stress questionnaire (MDBF scale) along with a background information questionnaire that collected demographic data (gender and mindfulness experiences), and assessed prior experience with VR and mindfulness practice. After completing the questionnaires, participants went through a 100 second baseline HRV measurement before the treatment.

Participants were assigned at random to either the experimental or control condition. The experimental group (n=40) participated in a 10-minute mindfulness intervention in which they were immersed in a virtual reality nature environment while listening to audio-guided instructions. Participants in the control condition (n=39) completed a 10-minute seated mindfulness intervention with their eyes closed and while listening to the same instructions. Participants in both conditions were asked to sit comfortably upright and not to move or make noise at any time during the intervention. A 10-minute intervention length was due to realistic limitations and the fact that previous research pointed out that even such short sessions of mindfulness, lasting about 10 minutes, had measurable effects on psychological and physiological outcomes [6,11].

After the intervention, participants' HRV was measured again, and perceived stress was reassessed using the same MDBF questionnaire. Moreover, a brief experiential review was conducted in order to assess subjective experiences of the participants.

2.5 Statistical analysis

The pre- and post-test scores and between-group differences were evaluated using mixed analysis of variance (ANOVA) to examine the hypotheses. To determine if the VR intervention group reported more significant drops in perceived stress and increases in HRV than the control group, the study in this instance concentrated on the intervention's immediate impact on these variables.

To further investigate the universality of the intervention effect and its potential influencing factors, subgroup analysis was conducted besides the overall analysis. The subgroups were established mainly according to the following two variables measured at baseline: (1) gender (male vs. female) and (2) mindfulness experience (the experienced group vs. the inexperienced group).

3 Results

3.1 Basic descriptive statistics

Baseline comparisons indicated no substantive differences between VR and control groups on the primary outcomes, including three dimensions of perceived stress measured by the MDBF scale (pleasure, alertness, and calmness) and HRV. In addition, The groups were also comparable in gender composition and prior mindfulness experience, due to successful randomization between groups prior to the intervention. Overall, baseline levels of perceived stress and HRV were consistent with those typically reported in working adult populations, suggesting moderate occupational stress.

Table 1. Descriptive Statistics of the Two Groups Before and After Tests (Mean ± standard Deviation).

Group	Time Point	Pleasure (M±SD)	Alertness (M±SD)	Calmness (M±SD)
VR Group	Pre-test (T0)	34.765 ± 7.4 15	18.000 ± 4.345	33.000 ± 5.115
	Post-test (T1)	36.294 ± 7.415	19.706 ± 4.345	35.500 ± 5.115
	Difference (T1-T0)	1.529 ± 4.011	1.706 ± 2.5438	2.500 ± 3.053
Control Group	Pre-test (T0)	34.647 ± 6.976	18.1547 ± 3.868	33.147 ± 5.012
	Post-test (T1)	34.765 ± 6.976	18.647 ± 3.868	34.735 ± 5.012
	Difference (T1-T0)	0.118 ± 4.892	0.500 ± 2.615	1.588 ± 3.115

3.2 The immediate effectiveness of VR natural-scene mindfulness intervention on HRV

To test whether HRV changed differently across conditions from pre- to post-intervention, mixed ANOVA analysis was applied, where Time (pre-test vs. post-test) was treated as a within-groups factor and Group (experimental vs. control) as a between-groups factor.

In the experimental group, it was discovered that the mean HRV change was positive (mean difference = 1.380, SD = 5.140, ranging from -7 to 11), meaning that it increased significantly as a result of the intervention. In contrast, the results of the control group revealed that the mean HRV change was negative (mean difference = −1.150, SD = 5.650, ranging from -11 to 9), indicating that it decreased as a result of the eyes-closed mindfulness intervention (Figure 2.). The average level of these two kinds of groups was almost identical before the experiment, ranking around 43.08 ms and 43.03 ms, respectively, showing that the experimental grouping was successful. Figure 3 further illustrates the disparity in the level of

HRV of two groups, the average change was positive in the VR group (Δ HRV = 1.375 ms) but negative in the control group (Δ HRV = −1.154 ms).

Mixed ANOVA results indicated neither the overall group difference ($F(1,77) = .345$, $p = .559$, $\eta p^2 = .004$) nor the overall time effect ($F(1,77) = .076$, $p = .783$, $\eta p^2 = .001$) reached significance, suggesting that both the intervention grouping and test time point alone cannot independently affect HRV levels. A significant Group × Time effect was observed ($F(1,77) = 6.218$, $p = .015$, $\eta p^2 = .075$), which indicates that the magnitude and direction of HRV change from pre- to post-test depended on the intervention type.

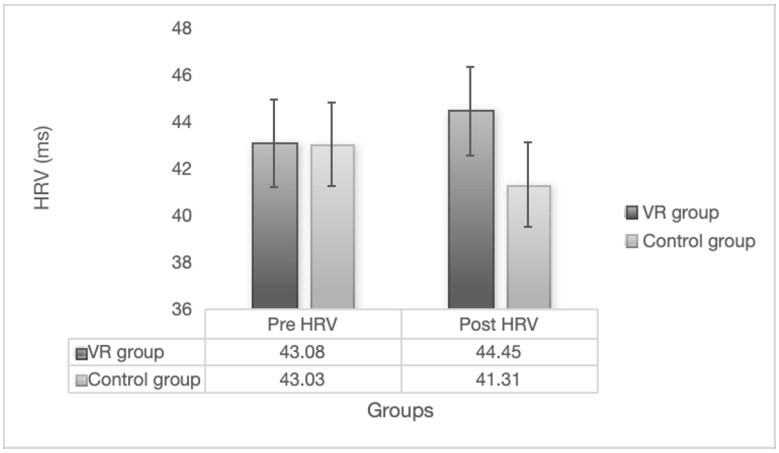

Fig. 2. The differences in HRV (mean) before and after the intervention.

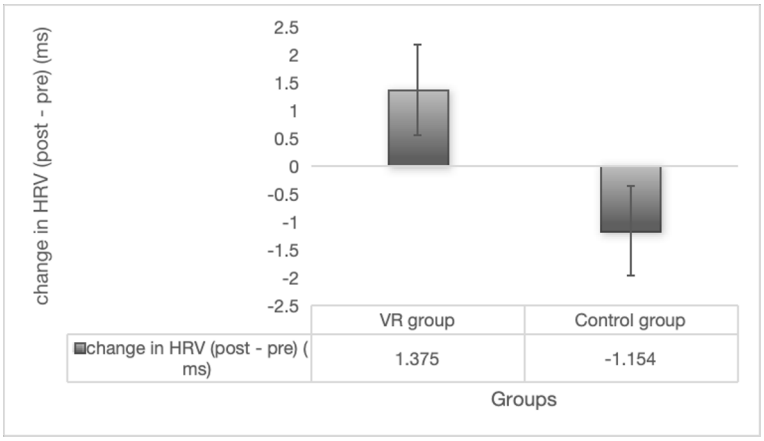

Fig. 3. The differences in HRV (mean) between VR (experiment) group and control group.

3.3 VR Intervention Showed Limited Effect on Pleasure

In terms of the dimension of pleasure, the descriptive statistics show (Table 1). As shown in Table 1, no significant changes in pleasure scores from pre-test to post-test were found in either group. Using a two-way repeated-measures ANOVA (Time × Group), a significant main effect of time was detected ($F(1,78) = 4.250$, $p = .043$, $\eta p^2 = .052$)., suggesting an overall increase in pleasure across participants. In contrast, the main effect of group, as well as the Time × Group interaction, was not statistically significant. (both $F < 3.0$, $p > .05$), indicating that the change pattern did not clearly differ between interventions. Analysis

revealed a statistically significant improvement from pre- to post-test within the VR group ($p = .032$, Cohen’ s $d = 0.210$). In the traditional group, the pre- to post-test change did not reach statistical significance ($p = .845$, Cohen's $d = .020$).

3.4 VR Intervention Significantly Enhanced Alertness

In the dimension of alertness, participants in the VR condition showed a larger post-test increase relative to baseline than did those in the control condition. Repeated measures ANOVA identified time as a significant main effect ($F(1,78) = 18.760$, $p < .001$, $\eta p^2 = .194$). The main effect of group did not reach statistical significance ($F < .100$, $p = .782$), but the interaction between time and group was significant ($F(1,78) = 5.420$, $p = .022$, $\eta p^2 = .065$), indicating different pre–post results across conditions.

3.5 Both Interventions Improved Calmness, with VR Showing a Stronger Effect

In the dimension of calmness, the post-test scores of both groups of subjects were significantly higher than those of the pre-test (Table 1). A repeated-measures ANOVA revealed a strong main effect of time ($F(1,78) = 32.540$, $p < .001$, $\eta p^2 = .294$), along with a significant Time × interaction with group ($F(1,78) = 4.120$, $p = .046$, $\eta p^2 = .050$). No statistically significant main effect was attributable to the group factor ($F < .100$, $p = .869$). The significant interaction was driven by a stronger pre-post gain in the the virtual reality condition ($p < .001$, $d = 0.490$) versus the traditional condition ($p = .003$, $d = 0.320$), leading to a trend-level group difference at post-test ($p = .058$).

4 Discussion

4.1 Overview of the main finding

4.1.1 Inconsistency of multidimensional effects

One of the main findings of this research is that the effect of the intervention was inconsistent across different dimensions of perceived stress and mood. While the score of alertness and calmness showed improvements in the VR group, pleasure did not significantly change in either condition, which points to the possibility that the reason for this result lies in different regulatory mechanisms of different psychological dimensions. Calmness (relaxation) and alertness (attention) are more closely associated with immediate physiological regulation and cognitive resource allocation, whereas pleasure (positive emotion) involves more complex reward systems and the accumulation of affective experiences. Short-term mindfulness interventions may more directly influence the former two.

In terms of practical value, it is determined that this discovery possesses significant value as a guide, whereby the VR nature scene intervention is relevant in situations where immediate relaxation of tension and enhancement of attention are necessary, but the VR nature scene intervention is limited in the enhancement of immediate positive emotion. In addition, the similarity in the results of the two intervention conditions with the dimension of pleasure provides additional indication that it may be necessary to incorporate additional intervention methods in order to attain the desired experience of enhanced positive emotion.

4.1.2 Congruence between physiological and psychological measures

The observed improvement in HRV measures in the VR group is consistent with the substantial improvement observed in measures of alertness and calmness. HRV is recognized as a measure of parasympathetic nervous system activity and autonomic adaptive flexibility. Whereas the within-group HRV changes for both the VR and control groups did not achieve statistical significance, the significant effect of time and group interaction confirmed that the more positive autonomic nervous system reaction for immersed VR mindfulness is a different effect from the more standard approaches to eyes-closed mindfulness. This is consistent with the suggestion that immersed mindfulness might produce a more positive downregulation of physiologic stress reactions and is consistent with the improvement in reported feelings of calmness.

4.1.3 Advantages compared to traditional methods

Compared with traditional mindfulness, the immersive VR intervention demonstrated clear advantages in immediate outcomes. Even if the control condition was measured, it reported non-significant, and in most cases, negative results, while the VR intervention demonstrated consistent improvements in psychosocial and physiological outcomes.

A possible reason might be that traditional mindfulness techniques depend heavily on human internal attention control ability and previous mindfulness skills; however, VR provides an attentional environment that reduces mental strains for focusing attention. This might be especially beneficial for corporate employees who are not sufficiently exposed to mindfulness techniques or may struggle to do so owing to high levels of work-related stress.

Furthermore, the results demonstrate the ineffectiveness of single intervention, using short and self-guided mindfulness techniques, in a work situation. In contrast, classical mindfulness techniques require a stronger internal control in attention and cognition from the individual. However, the inexperienced people could have different difficulties during the execution, for example, closing the eyes may increase exposure to internal thoughts, work-related concerns, mental exhaustion, especially if mindfulness intervention follows a series of demanding work tasks.

4.2 Possible mechanisms of VR outperformed traditional eyes-closed mindfulness

4.2.1 Attention capture and disengagement

VR may assist attention capture and minimize cognitive load via external focus, which is also the key to alleviating mind-wandering and undesirable ideas as practiced under traditional mindfulness. In VR, the visually engaging natural scene may reduce the effort required to sustain attention compared to eyes-closed mindfulness, which relies heavily on internal attentional control [12]. This external focus may be useful to people who lack the needed experience and to people under stress and unable to put aside work matters.

4.2.2 Restorative effects of natural scenes

Exposures to natural environments, though simulated, may promote psychological restoration and stress alleviation. Study suggests that natural scenes elicit rapid positive affective responses and reduce physiological arousal [13]. The VR images of the beach would have harnessed the inherent restorative qualities of natural environments, maximizing the

feelings of calmness. Empirical evidence confirm that VR nature exposure sessions can alleviate feelings of anxiety and relax moods, which align with the positive associations found with the HRV and calm improvements in the VR group [12].

4.2.3 Multisensory integration

The major point of difference between the conventional mindfulness and the VR-based mindfulness is that in the integration of visual, auditory, and spatial sensitivity experiences, which in turn, increases the sense of immersion. This boosts the sense of immersion, which further increases the emotional and physiological impact of the intervention [14]. It also considers the physiological effects of VR intervention, which is low because the environments provided are attractive and less distracting. This form of nature intervention is potentially effective in the promotion of relaxation and cognitive restoration compared to the effect of a single intervention [6]. Supporting the increased results of alertness and HRV changes observed in the VR intervention group.

4.2.4 Limitation and future directions

Certain limitations must be considered. For instance, the weight and size of the VR headset could affect how participants perceive comfort, posture, or muscle tension during the experience and possible responses in the cardiovascular system, such as HRV. To overcome this, the comfort must be considered a covariate for future research. In addition, the equipment used in this study is of a consumer-grade type, and hence the precision is limited for this device. Future research must validate the output against research-standard devices, such as ECG, along with this task scenario. Third, single-session effect does not establish whether VR mindfulness produces durable stress-regulation changes, whether benefits accumulate with repeated practice, or whether novelty effects fade. Thereby, to examine the cumulative benefits of repeated VR-based mindfulness therapies and assess the long-term sustainability of their stress-regulation effects, longitudinal studies are also required.

5 Conclusion

Workplace stress remains a persistent challenge for corporate employees, thus needing brief and accessible interventions that can be implemented within real organizational settings. Based on the evidence that mindfulness and nature exposure can support stress regulation, this study tested whether an immersive VR natural-scene mindfulness session could produce stronger immediate benefits than a traditional eyes-closed, audio-guided mindfulness. By using a randomized controlled pre–post design with corporate employees, participants completed a 10-minute audio-guided mindfulness intervention either in an immersive VR beach environment (Apple Vision Pro) or in a standard seated, eyes-closed condition, with outcomes assessed via the MDBF mood dimensions questionnaire and HRV measured by Apple Watch.

Overall, the findings partially supported the study hypotheses. Participants who engaged in the VR mindfulness intervention demonstrated significantly greater immediate improvements in alertness and calmness, as well as more favourable changes in HRV, compared to those who participated in the traditional mindfulness intervention. There were no discernible variations in the pleasure dimension of mood between the groups. As mentioned within the discussion, this follows from the advantages of VR, which can be particularly strengthened for employees who have limited mindfulness experience, including (1) focusing their attention and minimizing mind-wandering, (2) using the restrative value of

natural scenes, and (3) making the experience more engaging through multisensory integration. From a practical perspective, it can be most suited for short breaks aimed at calming and refocusing, which could be vital for stressed employees.

In conclusion, this study provides the evidence that which shows the practicality of the innovative tool of immersive natural scenery mindfulness interventions of VR systems being potentially available for organizations to support the wellness of their employees. Offering them with rapid enhancements in calmness, alertness, and physiological relaxation.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

1. American Psychological Association, 2023 Work in America Survey. (American Psychological Association, Washington, DC, 2023). https://www.apa.org/pubs/reports/work-in-america/2023-workplace-health-well-being
2. B. Benchimol-Elkaim, B. Khoury, A. Tsimicalis, Nature-based mindfulness programs using virtual reality to reduce pediatric perioperative anxiety: A narrative review. Front. Pediatr. **12**, 1334221 (2024). https://doi.org/10.3389/fped.2024.1334221
3. C. Failla, F. Marino, L. Bernardelli, A. Gaggioli, G. Doria, P. Chilà, R. Minutoli, R. Mangano, R. Torrisi, G. Tartarisco, R. Bruschetta, F. Arcuri, A. Cerasa, G. Pioggia, Mediating Mindfulness-Based Interventions with Virtual Reality in Non-Clinical Populations: The State-of-the-Art. Healthcare **10**, 1220 (2022). https://doi.org/10.3390/healthcare10071220
4. S. Marocco, V. Vitale, E. Grossi, F. Presaghi, A. Talamo, The potential of virtual natural environments: A critical analysis of a VR-based mindfulness approach. Front. Psychol. **16**, 1637669 (2025). https://doi.org/10.3389/fpsyg.2025.1637669
5. S.-L. Cheng, The Impact of Green Spaces on Physical and Mental Health: From Theory to Clinical Practice. Hu Li Za Zhi **72**, 26 (2025). https://doi.org/10.6224/JN.202504_72(2).05
6. M. H. E. M. Browning, K. J. Mimnaugh, C. J. Van Riper, H. K. Laurent, S. M. LaValle, Can Simulated Nature Support Mental Health? Comparing Short, Single-Doses of 360-Degree Nature Videos in Virtual Reality With the Outdoors. Front. Psychol. **10**, 2667 (2020). https://doi.org/10.3389/fpsyg.2019.02667
7. S. Ferreira, M. A. Rodrigues, C. Mateus, P. P. Rodrigues, N. B. Rocha, Interventions Based on Biofeedback Systems to Improve Workers' Psychological Well-Being, Mental Health, and Safety: Systematic Literature Review. J. Med. Internet Res. **27**, e70134 (2025). https://doi.org/10.2196/70134
8. R. Abu Hasan, S. Sulaiman, N. N. Ashykin, M. N. Abdullah, Y. Hafeez, S. S. A. Ali, Workplace Mental State Monitoring during VR-Based Training for Offshore Environment. Sensors **21**, 4885 (2021). https://doi.org/10.3390/s21144885
9. H. J. Girschick, Inkomplettes Kawasaki-Syndrom. Pädiatr. up2date **7**, 102-112 (2012). https://doi.org/10.1055/s-0032-1309996
10. F. Shaffer, J. P. Ginsberg, An Overview of Heart Rate Variability Metrics and Norms. Front. Public Health **5**, 258 (2017). https://doi.org/10.3389/fpubh.2017.00258

11. R. Palmer, C. Roos, N. Vafaie, H. Kober, The effect of ten versus twenty minutes of mindfulness meditation on state mindfulness and affect. Sci. Rep. **13**, 20646 (2023). https://doi.org/10.1038/s41598-023-46578-y
12. M. V. Navarro-Haro, Y. López-del-Hoyo, D. Campos, M. M. Linehan, H. G. Hoffman, A. García-Palacios, M. Modrego-Alarcón, L. Borao, J. García-Campayo, Meditation experts try Virtual Reality Mindfulness: A pilot study evaluation of the feasibility and acceptability of Virtual Reality to facilitate mindfulness practice in people attending a Mindfulness conference. PLOS ONE **12**, e0187777 (2017). https://doi.org/10.1371/journal.pone.0187777
13. S. Frost, L. Kannis-Dymand, V. Schaffer, P. Millear, A. Allen, H. Stallman, J. Mason, A. Wood, J. Atkinson-Nolte, Virtual immersion in nature and psychological well-being: A systematic literature review. J. Environ. Psychol. **80**, 101765 (2022). https://doi.org/10.1016/j.jenvp.2022.101765
14. S. H. M. Chan, L. Qiu, G. Esposito, K. P. Mai, K.-P. Tam, J. Cui, Nature in virtual reality improves mood and reduces stress: Evidence from young adults and senior citizens. Virtual Real. **27**, 3285 (2023). https://doi.org/10.1007/s10055-021-00604-4