Use of Virtual Environments to Mitigate Negative Affective States

Maria Grazia Lamberti[1], Alianny Melina Perez[2], Ana Alice Alves Santos[3], Nicolò Dozio[3], Francesco Ferrise[3], Monica Bordegoni[3]

[1]Politecnico di Milano, School of Design, mariagrazia.lamberti@mail.polimi.it
[1]Politecnico di Milano, School of Design, aliannymelina.perez@mail.polimi.it
[1]Politecnico di Milano, School of Design, anaalice.alves@mail.polimi.it
[2]Politecnico di Milano, Department of Mechanical Engineering, nicolo.dozio@polimi.it
[2]Politecnico di Milano, Department of Mechanical Engineering, francesco.ferrise@polimi.it
[2]Politecnico di Milano, Department of Mechanical Engineering, monica.bordegoni@polimi.it

Corresponding author: Francesco Ferrise, francesco.ferrise@polimi.it

Abstract. Promoting well-being is a fundamental aspect of achieving good health, a principle strongly emphasized by the World Health Organization (WHO) Constitution. Subjective well-being, rooted in the hedonic approach, recognizes the significant influence of cognitive and affective factors on individuals' overall well-being. This framework emphasizes the crucial balance between positive and negative affects, encompassing a wide range of moods and emotional states. Attaining well-being requires cultivating positive affects while minimizing the impact of negative ones.One effective strategy for promoting well-being is through contact with outdoor environments and nature, which has consistently shown positive outcomes. Natural landscapes, particularly those that enhance individuals' mental well-being, such as open forests with vegetation, have been associated with transmitting positive emotions and contributing to overall well-being. However, in an interconnected world, direct access to natural environments may be limited for some individuals. In this paper, we developed two affective VR environments following an existing design methodology. The aim of these environments was to shift the emotional states of participants from a negative one to a more positive one. Through this approach, we contribute to the growing body of evidence supporting the efficacy of immersive technologies in promoting well-being by leveraging the principles of subjective well-being and the beneficial effects of contact with outdoor environments and nature.

Keywords: Affective Virtual Reality; Emotions; Well-Being; Positive Affect; Negative Affect
DOI: https://doi.org/10.14733/cadaps.2025.1115-1124

1 INTRODUCTION

Promoting well-being is a fundamental aspect of achieving good health, a principle strongly emphasized by the World Health Organization (WHO) Constitution [1]. Subjective well-being, rooted in the hedonic approach [19], recognizes the significant influence of cognitive and affective factors on individuals' overall well-being. This framework emphasizes the crucial balance between positive and negative affects, encompassing a wide range of moods and emotional states [12]. Positive affects involve pleasurable engagement, while negative affects encompass unpleasant mood states such as anger, disgust, guilt, fear, and nervousness. Attaining well-being requires cultivating positive affects while minimizing the impact of negative ones. Affective dimensions can be effectively described using the parameters of valence and arousal, which can be represented through the Circumplex Model of Russell [16]. In this model, the horizontal axis represents valence, so that positive affects are positioned on the right side, while negative affects are on the left. The vertical axis represents arousal, so that the two top quadrants are for high valence while the bottom quadrants are for low valence. This model provides a valuable framework for depicting emotions evaluated through self-report measures, such as the Self-Assessment Manikin [3] that employs three scales of evaluation: the valence dimension, ranging from a fawning figure to a smiling one, the arousal dimension, ranging from a completely relaxed figure to a very excited one, and the dominance dimension, where changes in the figure size render the level of control.

One effective strategy for promoting well-being is through contact with outdoor environments and nature, which has consistently shown positive outcomes. Natural landscapes, particularly those that enhance individuals' mental well-being, such as open forests with vegetation, have been associated with transmitting positive emotions and contributing to overall well-being [1, 2, 21]. However, in an interconnected world, some individuals may have limited access to natural environments. Therefore, an important methodological question is: how can individuals without access to natural environments be enabled to shift from a negative mood to a positive one while harnessing the potential of technology?

The growing interest in developing virtual environments that enhance positive affects [7] has prompted designers to explore this area further. Nevertheless, despite the recognized effectiveness of engaging with these environments [14], the reproduction of natural landscapes in virtual reality (VR) as a mood induction procedure has been conducted without standardized procedures, hindering comprehensive comparisons across different studies [6].

This research aims to enable individuals to shift from unpleasant to pleasant emotions through the immersive experience of two natural virtual environments (VEs). By utilizing existing design methodologies and applying them to our study, we also seek to solidify a proposed testing methodology that can be both replicated and be used in future experiments of this nature to test for other emotional affective states and diverse virtual environments. Based on the existing literature [11], we employed a design methodology to develop two affective VEs. We selected the specific region of Russell's diagram associated with the desired emotional state after experiencing a negative one. We chose positive emotions to achieve, such as relaxation for the first environment and happiness for the second.

In addition to the referenced methodology, we conducted a morphological study of existing environments that evoke positive emotions, such as awe [8]. We combined this study with a review of the literature on the environmental affordances of outdoor environments [13]. The aim is to identify key elements to be incorporated into each environment based on research findings regarding the characteristics of environments that stimulate positive affect [1]. We collected insights from this initial literature review to be considered during the design of each environment to achieve the desired objective. Following the established methodology, we selected features such as auditory stimuli [20, 4], specific natural and positive elements such as lake, mountains, trees, sunset, or waterfall [9, 5], and colors [18]. Utilizing these insights, the elements we selected for each environment also adhered to the Valence and Arousal parameters consistent with the goal of transitioning from a negative affective state to a positive one.

[1] https://www.who.int/about/accountability/governance/constitution

2 DESIGN AND TESTING OF THE AFFECTIVE VR ENVIRONMENTS

This section describes the development and testing of two affective VEs that aim to create positive emotional states in users by immersing them in virtual natural surroundings.

2.1 Design of the Affective VR environments

We developed both environments using Unity version 2021.3.f.29 and designed the experience to last 90 seconds (as the testing environments described in a previous work [11]). The two scenarios, were designed with purposely selected elements that would attempt to induce a positive shift in the participants' emotional response. The choice of the constitutive elements of the two developed environments, reported in Table 1, involved an iterative design process, where various items like colors, landscapes, and sounds validated in different databases [18, 4, 5, 9] are rated on a 9-point scale were inserted and tested until a first prototype version of the final environments was obtained. In particular, graphical elements were guided by those present in the International Affective Picture System (IAPS) [5], while acoustic elements were inspired by those validated in the International Affective Digitize Sounds (IADS) [4].

Initial prototypes were evaluated in short pilot test sessions that allowed us to assess any design changes we could implement when it came to the final prototype. The pilot test involved 10 users that were asked to provide valence and arousal rates after exploring one of the initial prototype environments. Since the objective of the test was to validate the general dynamics of the environments and obtain initial feedback useful for continuing the design phase of the final environments, this phase was carried out in non-immersive mode, using a desktop version of the scenarios that could be explored using the mouse to control the point of view and W, A, S, and D keys or the directional arrows to move. A training environment was created to familiarize users with the controls: it consisted of a walkable plane with shapes scattered around so that participants could walk around them, change directions, and climb as needed. The same controls were kept for exploring the prototype environments.

This pilot testing allowed us to collect insights to determine whether the initial prototypes for our environments could effectively induce the intended emotional responses, independent of the final proposed technology (VR), which inherently tends to influence users' emotions and moods. The iterative process allowed us to make design decisions like understanding the walking speeds that participants preferred, the direction they tend to walk in when they first enter an environment and upon exploring around for a bit, and whether or not they tended to stay or walk off the suggested path.

Environment 1: The main objective of environment 1 (Fig. 1a) was to induce a state of relaxation in the user through a natural environment. Participants found themselves on a pathway in the middle of a coniferous forest with tall trees and birds during the daytime. They were attracted by the sound of waves and could walk following the path to a landscape where a lake was visible. Among the chosen elements that could evoke positive emotions there were natural elements such as coniferous trees and a lake, which represented the main components of the scene. Consistent with these elements, the auditory stimuli selected were constituted by the sound of birds and the sea's gentle waves. We chose a color palette predominantly composed of blues and greens, associated with the emotions of being consoled/protected and comfortable/relaxed [18]. Regarding the navigation experience, the character's walking speed was designed to convey a sense of relaxed walking. The risk in this case would have been to have a walking pace that was too slow, which could have resulted in boredom and a feeling of hindrance.

Environment 2: Here, the main goal (see Fig. 1b) was to create an engaging and entertaining experience. Participants were able to freely explore a lush environment with the vivid colors of a tropical landscape with palm trees, a lake, mountains, and listen to the sounds of a steady stream with birds. The elements selected

Table 1: List of the main design elements with their valence and arousal rates used for the development of the two affective VR environments. Color items from [18] are rated on a 5-point scale, while IAPS [5] and IADS[4] are rated on a 9-point scale.

	Environment 1			**Environment 2**		
	Items	*Valence*	*Arousal*	*Items*	*Valence*	*Arousal*
Colors	Light green	3.35	2.22	Dark red	2.78	2.83
	Light yellow	3.50	3.37	Light red	3.67	2.70
	Dark green	3.15	2.67	Vivid yellow	4.24	3.63
	Deep green	3.76	2.61	Light yellow	3.50	2.37
	Brilliant green	3.52	2.57	Vivid green	3.87	2.83
	Light blue	4.15	2.94	Vivid blue	4.11	2.89
	Vivid blue	4.11	2.89	Deep violet	3.11	3.08
	Light red	3.67	2.70	Vivid violet	3.24	2.89
IAPS	Sea	8.03	5.46	Sunset	8.00	4.92
	Nature	7.06	3.83	Beach	8.22	5.71
IADS	Birds (3)	8.25	2.58	Birds (1)	7.83	3.50
	Sea Wave	6.33	4.92	Stream	6.73	4.73
				Music	6.25	7.50

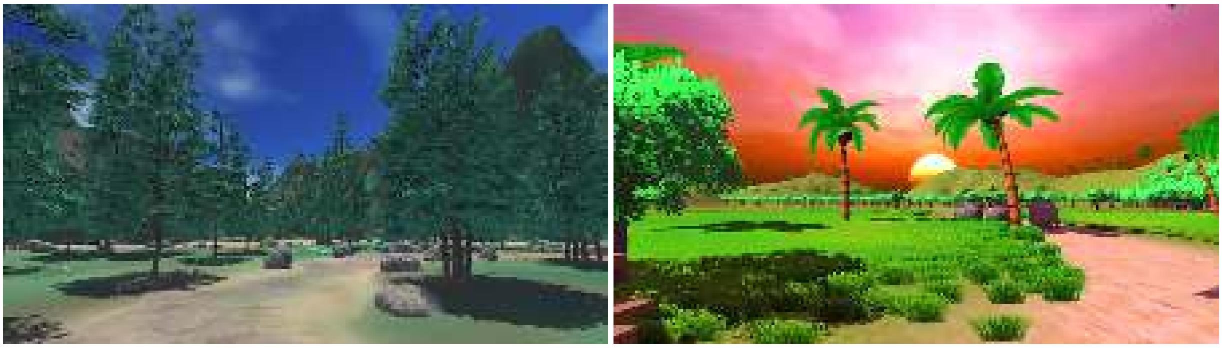
included a gentle breeze rustling through the grass, a lake, lush green grass, a bench, and trees. The scenario was set during sunset with a color palette for the sky comprised of vivid yet soft purples, oranges, and pinks, which are associated with awe, vigor, and creativity [18]. Here, the character's walking speed was slightly higher than the one implemented in the environment 1, as in this case the objective was to convey a sense of relaxed but also happy speed walking. We decided to elicit laughter and amusement as our predominant positive emotions to shift into. We integrated comical assets into the environment, including animated and whimsical elements like bouncing monkeys and dancing lizards. We also introduced a floating cat, which would perform a prolonged rotation in slow motion when users interacted with it. Other elements consisted of an oversized Chihuahua dog sporting a mustache, a large pink kitten, and an abstract creature that salsa-danced to the accompanying music. To enhance the overall experience, we chose the sound of birds singing in layered on top of a salsa/bossa nova track [15].

2.2 Testing

This section reports the testing on the effectiveness of the two virtual environments in promoting a shift from an induced negative emotional state to a more positive one.

2.2.1 Negative emotional state induction procedure (NESIP)

To test the actual effectiveness of the developed environments in shifting the perceived emotional state of the participants from an initial opposite state, the induction of a negative emotional state became a primary objective for this activity. We identified movie scenes as effective stimuli for eliciting negative emotional engagement [17].



(a) Environment 1 (b) Environment 2

Figure 1: The two environments developed to promote a shift towards positive emotional responses.

We selected two movie scenes to evoke similar emotional responses. The aim was to position participants in an emotional state characterized by a negative valence and positive arousal, corresponding to the upper-left quadrant of the Russell's Circumplex Model of affects. One of the emotional states in this quadrant is anger, therefore we chose to focus on anger eliciting scenes as we wanted to pursue a stronger emotional response. We sourced the chosen scenes from the FilmStim database dedicated to emotion eliciting films for researchers to ensure their ability to effectively induce a negative emotional state in participants [17]. We selected: "The Piano" (No.39, Code 49, Emotion: Anger) and "Sleepers" (No. 25, Code 35, Emotion: Anger), two movies known for their impactful emotional content.

2.2.2 Training environment

To ensure the validity of the test and facilitate the participants' interaction with the VR environment, we developed an immersive training scenario. The main objective of the trial application was to familiarize the users with the technology. Therefore, the interaction time with this application was not limited, allowing participants to explore without feeling pressured to learn quickly. This approach aimed to minimize biases and ensure that users understood how to move and interact with the VR ambient by the end of the training phase. The training environment featured a grayscale color palette, providing a visually simple setting. It consisted of 3D objects, including a simple maze to familiarize users with navigating a defined path. We also incorporated bridges and arches to simulate interactions with confined spaces and obstacles.

2.2.3 Participants

A total of 20 volunteers (10 females, 10 males) aged between 19 and 25 ($M = 22.7$; $SD = 1.78$) participated in the testing phase. All participants were recruited among the students of the Politecnico di Milano.

2.2.4 Measures

The self-report measure utilized in this study to collect rates on the perceived emotional state was the Self Assessment Manikin (SAM) [3]. The SAM questionnaire comprises three 9-point pictographic Likert scales that provide self-rates on the three dimensions of valence, arousal, and dominance. Since the dominance dimension was not considered during the design procedure used to develop the presented affective VR environments, only valence and arousal rates were collected during the current testing phase.

2.2.5 Procedure

The testing phase followed a between-subjects design where the developed affective VR environments constituted the two experimental conditions. Participants were split into two groups of 10 participants (5 males and 5 females).Before the start of the test the SAM baseline was collected and subsequently participants were asked to wear a Meta Quest 2 headset and proceeded to explore the training scenario. Navigation within the environments was performed using the right Quest Touch controller's thumbstick. When they felt confident with the mechanics used to explore the immersive environment, participants were asked to remove the headset and proceed with the negative emotional state induction procedure. The materials required for this stage were presented using a desktop computer connected to stereo speakers. At the end of the selected movie scene, SAM rates were collected once again before wearing the headset and exploring one of the two developed affective VR environments. Finally, once the exploration was completed, participants provided a final set of valence and arousal rates.

2.2.6 Results

Two normality tests (i.e., Kolmogorov Smirnov, Shapiro Wilk) were carried out on the data collected and the results showed an overall normal distribution. Firstly, an independent t-test was performed on the valence and arousal rates collected after the NESIP to verify that the two movie scenes selected did not evoke significantly different responses in the participants. The results did not highlight a significant difference between the two scenes for both the valence and arousal rates $t_{valence}(18)$ = -2.045; p $>$ 0.05; $t_{arousal}(18)$ = -1.363; p $>$ 0.05, and therefore no distinction concerning this variable was considered in the further analysis.

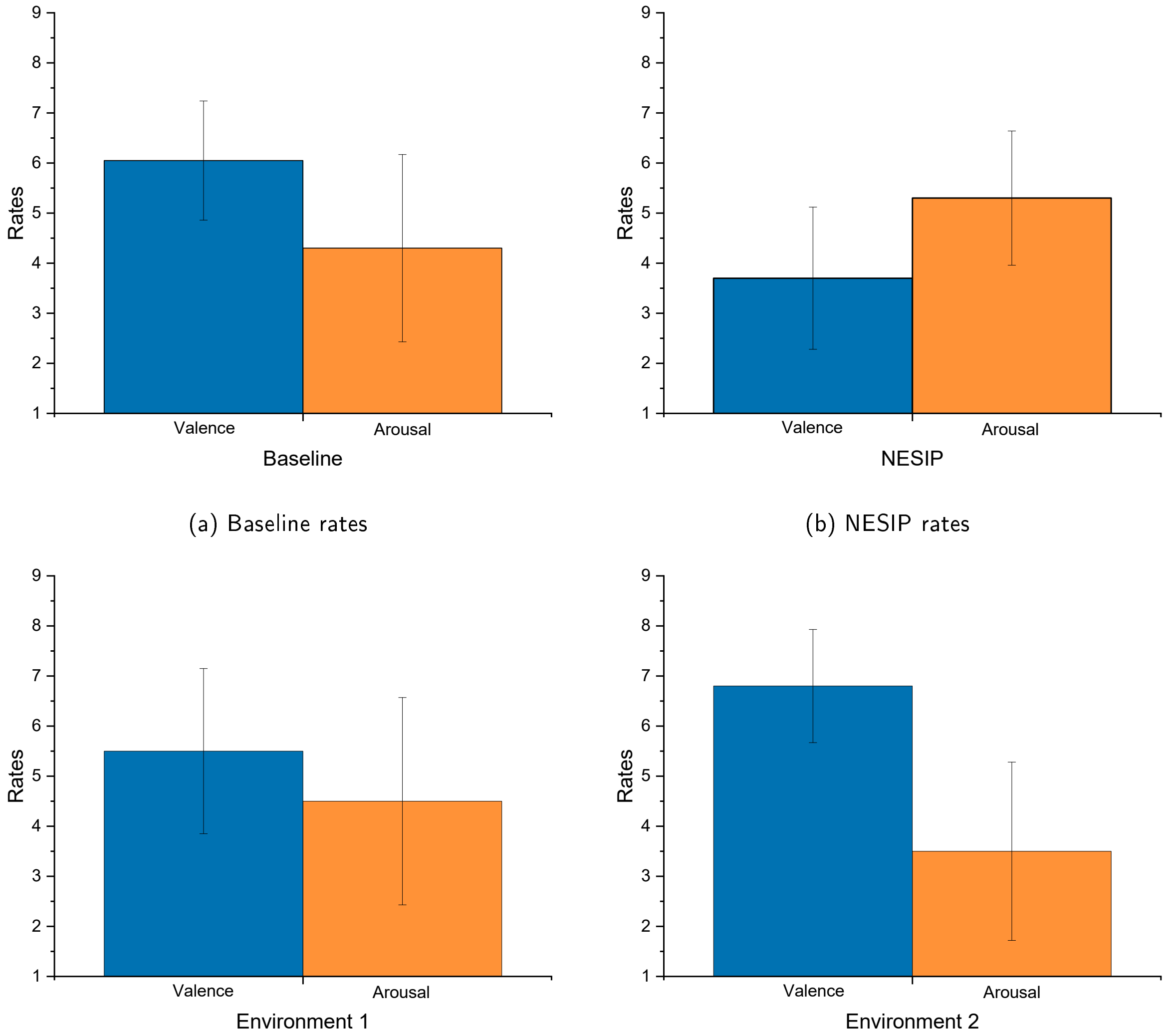
Data concerning the SAM rates have been analyzed applying a one-way repeated measures ANOVA with the three stages of valence and arousal rates as within-subjects measures and the two affective VR environments as the between-subjects-factor.

The results revealed a main effect on valence rates between the baseline, the NESIP, and the affective VR environments $F(1.48, 26.66) = 53.513$; $p < 0.001$; $\eta_p^2 = 0.748$. In particular, starting from an initial positive baseline ($M = 6.05$; $SE = 0.27$), valence rates significantly decreased after the NESIP ($M = 3.7$; $SE = 0.32$), to then return to significantly higher values ($M = 6.15$; $SE = 0.32$) after the exploration of the two positive affective VR environments. The analysis did not highlight the same effect for the arousal rates $F(1.44, 26) = 3.283$; $p > 0.05$; $\eta_p^2 = 0.154$, even if a subtle change was still visible between the baseline rates ($M = 4.3$; $SE = 0.43$), those acquired after the NESIP ($M = 5.3$; $SE = 0.3$), and the final ones collected after the VR environments exploration ($M = 4$; $SE = 0.43$).

Furthermore, the analysis suggested a significant interaction between the valence rates collected in the three experimental stages and the affective VR environment explored $F(1.48, 26.66) = 5.034$; $p < 0.05$; $\eta_p^2 = 0.219$. Still, no significant differences were identified by multiple comparisons between the rates concerning the two affective VR environments, as also confirmed by an additional independent t-test performed $t_{valence}(18)$ = -2.053; p $>$ 0.05; $t_{arousal}(18)$ = -1.159; p $>$ 0.05. Valence and arousal rates collected in the different stages of the testing phase are reported in Fig. 2.

3 DISCUSSION

The results of the experiment demonstrate the effectiveness of the design methodology used to develop two affective VR environments capable of shifting participants' emotional states from an initially induced negative state to a positive one (see Fig. 3). Despite the relatively simple scenarios employed in this study, the outcomes suggest the potential for impactful interventions that are both easy to recreate and modify to suit specific needs and goals. Interestingly, while the two scenarios failed to show a clear distinction between them in terms of response elicited, both were successful in achieving the primary objective of shifting emotions from negative valence to positive valence. This lack of differentiation could imply that the underlying mechanisms driving



(a) Baseline rates

(b) NESIP rates

(c) Environment 1 rates

(d) Environment 2 rates

Figure 2: Valence and Arousal rates obtained in all the different stages of the experiment.

emotional change in VR environments may not necessarily depend on the complexity or specific features of the scenario, but rather on broader factors such as immersion, engagement, and the current users' mood. These findings underscore the promising role of VR technology in enhancing well-being by providing accessible and customizable tools for emotional regulation and mood enhancement. The complexity of human emotions and its qualitative aspects pose challenges in accurately controlling and measuring subjective fluctuations. Further research is needed to capture all the nuances of such a complex phenomenon. Certainly, one of the major limitations of the work presented concerns the relatively small size of the sample of participants, which limits the reliability of the data collected, and the limited amount of environments developed. Future work will need to improve both of these aspects to further validate the effectiveness of VR as a fast and reliable tool for emotion induction, as well as potential long-term benefits and applications in various settings, including clinical therapy, education, and workplace interventions.

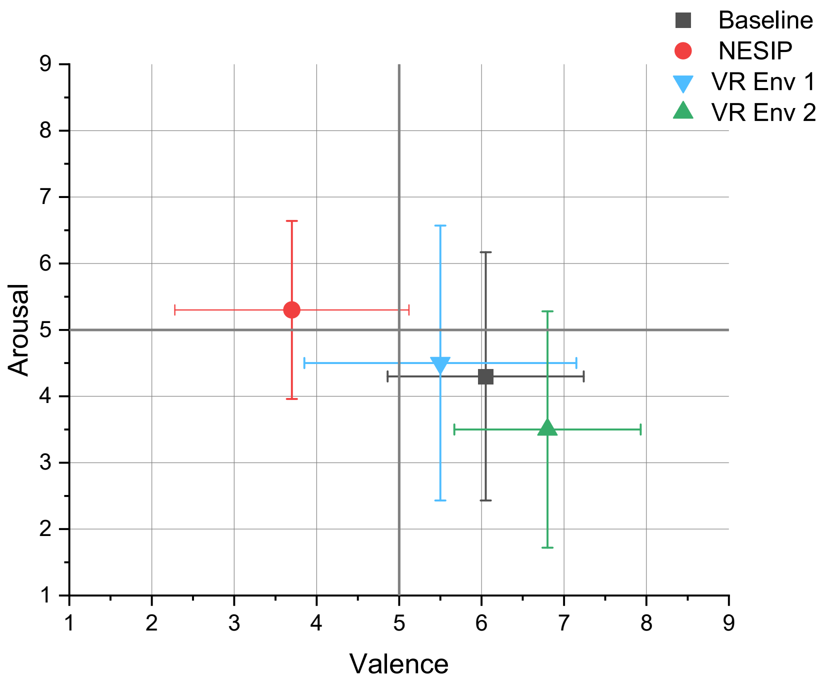


Figure 3: Distribution of the valence and arousal rates in the various stages of the experiment.

4 CONCLUSION

Virtual reality environments have proven to be a powerful tool for inducing emotional states [8, 11, 10]. The ability to induce emotions through VR holds significant potential across various applications, and its full extent may not have been fully explored yet. In this paper, we tried to investigate how to use natural scenarios to rebalance negative emotional states induced through validated movie clips [17]. Employing a methodology developed by the authors [11], we conducted an experiment to explore the effectiveness of this approach. While the experiment involved a limited number of participants, the results are promising, highlighting the capacity of virtual experiences to effectively induce a shift toward positive emotional states.

REFERENCES

[1] Abraham, A.; Sommerhalder, K.; Abel, T.: Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. International journal of public health, 55, 59–69, 2010. http://doi.org/10.1007/s00038-009-0069-z.

[2] Barragan-Jason, G.; Loreau, M.; de Mazancourt, C.; Singer, M.C.; Parmesan, C.: Psychological and physical connections with nature improve both human well-being and nature conservation: A systematic review of meta-analyses. Biological Conservation, 277, 109842, 2023. ISSN 0006-3207. http://doi.org/10.1016/j.biocon.2022.109842.

[3] Bradley, M.M.; Lang, P.J.: Measuring emotion: the self-assessment manikin and the semantic differential. Journal of behavior therapy and experimental psychiatry, 25(1), 49–59, 1994. http://doi.org/10.1016/0005-7916(94)90063-9.

[4] Bradley, M.M.; Lang, P.J.: International affective digitized sounds (2nd Edition; IADS-2): Affective ratings of sound and instruction manual. University of Florida, Gainesville, FL, 2007.

[5] Bradley, M.M.; Lang, P.J.: The International Affective Picture System (IAPS) in the study of emotion and attention. In J.A. Coan; J.J.B. Allen, eds., Handbook of Emotion Elicitation adn Assessment, 29–46. Oxford University Press, 2007. http://doi.org/10.1007/978-3-319-28099-8_42-1.

[6] Brambilla, E.; Petersen, E.; Stendal, K.; Sundling, V.; MacIntyre, T.E.; Calogiuri, G.: Effects of immersive virtual nature on nature connectedness: A systematic review protocol. Digital Health, 8, 20552076221120324, 2022. http://doi.org/10.1177/20552076221120324.

[7] Chan, S.H.M.; Qiu, L.; Esposito, G.; Mai, K.P.; Tam, K.P.; Cui, J.: Nature in virtual reality improves mood and reduces stress: evidence from young adults and senior citizens. Virtual reality, 27(4), 3285–3300, 2023. http://doi.org/10.1007/s10055-021-00604-4.

[8] Chirico, A.; Ferrise, F.; Cordella, L.; Gaggioli, A.: Designing awe in virtual reality: An experimental study. Frontiers in psychology, 8, 2351, 2018. http://doi.org/10.3389/fpsyg.2017.02351.

[9] Dan-Glauser, E.S.; Scherer, K.R.: The geneva affective picture database (gaped): a new 730-picture database focusing on valence and normative significance. Behavior research methods, 43, 468–477, 2011. http://doi.org/10.3758/s13428-011-0064-1.

[10] Dozio, N.; Marcolin, F.; Scurati, G.W.; Nonis, F.; Ulrich, L.; Vezzetti, E.; Ferrise, F.: Development of an affective database made of interactive virtual environments. Scientific Reports, 11(1), 24108, 2021. http://doi.org/10.1038/s41598-021-03380-y.

[11] Dozio, N.; Marcolin, F.; Scurati, G.W.; Ulrich, L.; Nonis, F.; Vezzetti, E.; Marsocci, G.; La Rosa, A.; Ferrise, F.: A design methodology for affective virtual reality. International Journal of Human-Computer Studies, 162, 102791, 2022. http://doi.org/10.1016/j.ijhcs.2022.102791.

[12] Galinha, I.C.C.; Pais-Ribeiro, J.L.: The structure and stability of subjective well-being: A structure equation modelling analysis. Applied Research in Quality of Life, 3, 293–314, 2008. http://doi.org/10.1007/s11482-009-9063-0.

[13] Hadavi, S.; Kaplan, R.; Hunter, M.C.R.: Environmental affordances: A practical approach for design of nearby outdoor settings in urban residential areas. Landscape and urban planning, 134, 19–32, 2015. http://doi.org/10.1016/j.landurbplan.2014.10.001.

[14] Liu, P.; Liu, J.; Fernandez, J.; Zou, Q.; Lin, M.: Positive affect and natural landscape in virtual reality: A systematic review comparing interventions, measures, and outcomes. Journal of Environmental Psychology, 102011, 2023. http://doi.org/10.1016/j.jenvp.2023.102011.

[15] Muzaproduction: Tropicana royalty free music. https://pixabay.com/music/bossa-nova-tropicana-96449/, 2022.

[16] Russell, J.A.: A circumplex model of affect. Journal of personality and social psychology, 39(6), 1161, 1980. http://doi.org/10.1037/h0077714.

[17] Schaefer, A.; Nils, F.; Sanchez, X.; Philippot, P.: Assessing the effectiveness of a large database of emotion-eliciting films: A new tool for emotion researchers. Cognition and emotion, 24(7), 1153–1172, 2010. http://doi.org/10.1080/02699930903274322.

[18] Suk, H.J.; Irtel, H.: Emotional response to color across media. Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation,

Colour Society of Australia, Centre Français de la Couleur, 35(1), 64–77, 2010. http://doi.org/10.1002/col.20554.

[19] Vanhoutte, B.: The multidimensional structure of subjective well-being in later life. Journal of population ageing, 7(1), 1–20, 2014. http://doi.org/10.1007/s12062-014-9092-9.

[20] Yang, W.; Makita, K.; Nakao, T.; Kanayama, N.; Machizawa, M.G.; Sasaoka, T.; Sugata, A.; Kobayashi, R.; Hiramoto, R.; Yamawaki, S.; et al.: Affective auditory stimulus database: An expanded version of the international affective digitized sounds (iads-e). Behavior Research Methods, 50, 1415–1429, 2018. http://doi.org/10.3758/s13428-018-1027-6.

[21] Yao, W.; Chen, F.; Wang, S.; Zhang, X.: Impact of exposure to natural and built environments on positive and negative affect: A systematic review and meta-analysis. Frontiers in Public Health, 9, 2021. ISSN 2296-2565. http://doi.org/10.3389/fpubh.2021.758457.