Title:
Mitigating Negative Affective States Through Virtual Environments

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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 [17], 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 [10]. 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 [14].

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 [2]. The growing interest in developing virtual environments that enhance positive affects [5] has prompted designers to explore this area further. Nevertheless, despite the recognized effectiveness of engaging with these environments [12], 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 [4].

This study aims to investigate the potential of Virtual Reality (VR) in facilitating the transition from negative to positive mood states through immersion in natural VEs. Understanding the influence of VR on mood states is crucial for developing effective interventions to enhance well-being. Based on the existing literature [9], we employed a design methodology to develop two affective VEs. We selected the

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specific region of Russell's diagram associated with the desired positive state after experiencing a negative one. We chose to achieve positive emotions, 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 [6]. We combined this study with a review of the literature on the environmental affordances of outdoor environments [11]. 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 [2]. 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 [18], specific natural and positive elements such as lake, mountains, trees, sunset, or waterfall [7], and colors [16]. 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 more positive one.

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.

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 our previous work [9]).

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 day. 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 [16]. 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, and mountains, meet some funny animals, and listen to the sounds of a steady stream with birds and music in the background. The elements selected included a gentle breeze rustling through the grass, a lake, lush green grass, a bench, and trees. To elicit laughter and amusement, we integrated comical assets into the environment. These include 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, resulting in a comedic effect. 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 the background layered on top of a salsa/bossa nova track [13]. The scenario was set during sunset. Therefore, the color palette for the sky comprised vivid yet soft purples, oranges, and pinks, which are associated with awe, vigor, and creativity [16]. Here, the character's walking speed was slightly

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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.

(a) Environment 1

(b) Environment 2

Fig. 1: The two environments developed to elicit positive emotional responses.

Testing:

This section reports the testing of the two environments. In particular, through testing, we want to prove that the designed experiences, although very simple, are able to bring a subject from a negative emotional state, here artificially induced, to a positive one.

Negative emotional state induction procedure (NESIP):

To test the actual effectiveness of the developed environments in moving the 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 emotional engagement [15]. 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. 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 [15]. 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.

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.

Participants:

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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.

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.

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.

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.

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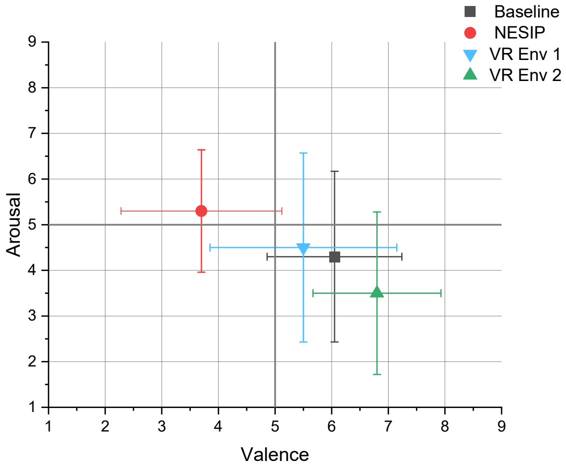

Fig. 2: Distribution of the valence and arousal rates in the various stages of the experiment.

Conclusions:

Virtual reality environments have proven to be a powerful tool for inducing emotional states [6, 9, 8]. 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 [15]. Employing a methodology developed by the authors [9], 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 evoke positive emotional states.

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