Therapeutic Effects of Interactive Experiences in Virtual Gardens: Physiological Approach Using Electroencephalograms

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Abstract: The utilization of landscape spaces in virtual reality therapy involves using virtual reality content for therapeutic purposes. However, the current virtual nature used for therapy generally provides only passive experiences to the users, similar to what they experience when watching a landscape-themed video. This study aims to verify that therapeutic effects of virtual gardens would be higher with interactions. The results of the study confirmed that interactive virtual gardens had a significant effect on brain wave response of the experimental group. Through this study as a prototype, the role of landscape architects can expand to the design and making of interactive therapeutic landscape utilizing the potential of virtual reality.

Keywords: Virtual reality therapy, virtual nature, therapeutic garden, brainwave analysis

1 Introduction

The positive effects of gardens on the physical, psychological, and emotional recovery, and stability of individuals have been reported in many earlier studies (ULRICH 1984, LARGO-WIGHT 2011, ULRICH et al. 1991). Clinical results confirmed that gardens can serve as useful medical facilities for treating patients; thus, the value and necessity of gardens have increaseed. However, people with physical disabilities have limited access to outdoor spaces. This led to the utilization of landscape spaces in virtual reality therapy (VRT), which involves using virtual reality (VR) content for therapeutic purposes.

VR is defined as a technology that enables users to experience situations that cannot be experienced in reality and to interact in real time between the virtual and real worlds by expanding their sense and perception through the fusion of both the worlds (WOO et al. 2016). VR is a digital fictional world with environments, situations, or technologies that may or may not be similar to reality, created using computer programs or engines (LEE 2004). Based on preceding studies, VR has the following features; immersion, interactivity, and extent (ROSEMBLOM 1997, RIVA 2006), A key advantage of VR content is that it enables users to experience a virtual space in an immersive environment without limitations in terms of access and time. This capability offers a new way of experiencing space for handicapped individuals with physical constraints or safety problems that make it difficult for them to access outdoor spaces. VR technology can improve the quality of life for handicapped individuals (MCCOMAS et al. 1998, PAK & MCLAUGHLIN 2018).

Further research and tests are being conducted on VRT. In most cases, the content used for VRT comprises virtual nature (Figure 1). Virtual nature is a type of VR environment created with the goal of reproducing natural scenery. The positive therapeutic effects of virtual nature on the mental and physical health of patients have been reported by many researchers (REYNOLDS et al. 2018, MOYLE 2018, TANJA-DIJKSTRA et al. 2018).

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However, the current virtual nature used for therapy generally provides only passive experiences to the users, similar to what they experience when watching a landscape-themed video. The users watch the virtual scenery through a head-mounted device (HMD) in relaxing positions and follow automatically configured routes designed by the developer or the programmer. In many cases, sounds of nature are played with instrumental background music for better therapeutic effects (MATILDA et al. 2013). The landscape spaces used in VRT are merely virtual simulations of real landscapes rather than virtual landscapes designed for therapeutic purposes. Furthermore, in most cases, these virtual landscapes are made by computer programmers or game designers, rather than by landscape designers. In terms of real space, previous studies have reported that the effects of therapeutic gardens are realized through physical movements and interactions with the environment (LEE et al. 2015). The absence of such interactions limits the therapeutic effects in VRT. Therefore, this research focused on experiments regarding the applicability and therapeutic effects of a virtual garden with interactive experiences; the potential roles and contribution of landscape architects toward designing landscapes for VRT were analyzed.

In the present study, we hypothesized that the therapeutic effects of virtual gardens would be higher with interactions. The primary aim of the study was to assess the therapeutic effects of virtual gardens with and without interactive experiences.

Fig. 1:
Screenshot of the stimulus " natural landscape video".
Nature treks (2019), https://www.viveport.com/apps/c68e084c-cb3a-47fd-867e-07b170b5aa8d/Nature_Treks_VR/.

2 Experiments

The purpose of this study was to verify the therapeutic effects of virtual gardens based on the presence of interactive experiences. In particular, we intended to compare the interactive experiences of a virtual garden with passive experiences for therapeutic effects. In the experiment, the therapeutic effects of two virtual garden experiences are compared: a video of a garden shown on a monitor and an interactive experience of a virtual garden using a HMD.

2.1 Testing Site and Procedure

The experimental site was a rooftop garden in the university campus; a virtual garden was modeled based on this real space using Unreal Engine 4 (UE4). The main movement line and three designated points were set up in the real and virtual gardens on the same routes (Figure 2). The experiment was conducted on 30 subjects with acquired physical disabilities. The subjects included 24 men and 6 women with an average age of 33, ranging between 30 and 81 years. Prior to the experiment, each subject was provided with a written statement explaining the purpose and the process of the research.

Subjects were divided into two groups; one group watched the video of the garden for a passive experience while wearing EEG headset. The other group used an HMD and a controller to simulate an interactive experience in the virtual garden (Figure 4). For evaluating the therapeutic effects of the real garden, the videos captured from the movement lines and three designated points were played on the monitor (Figure 2.a). For evaluating the therapeutic effects of the VR garden, subjects wore HMDs and were guided to the three designated points by the researcher. At each point, subjects were informed to spend 1 min interacting with the virtual garden elements through a controller. All subjects were interviewed after these two distinctive garden experiences for comparison.

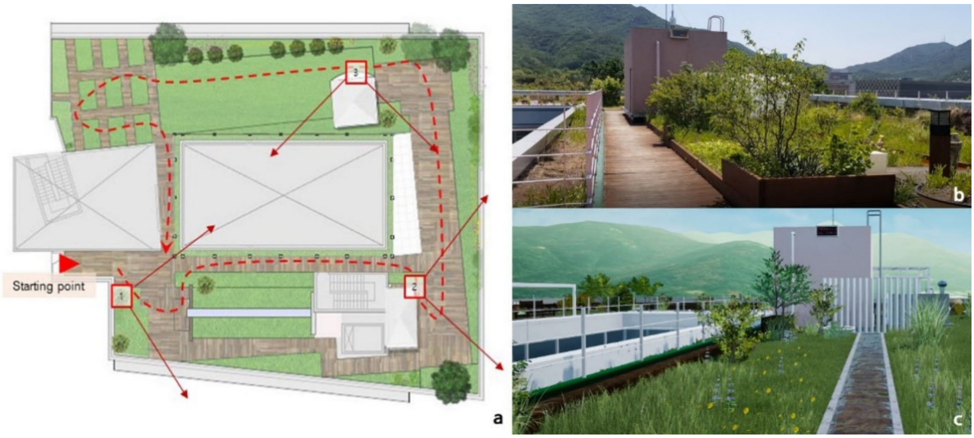

Fig. 2: Testing sites (a. three designated points and movement lines, b. actual garden video, and c. virtual garden)

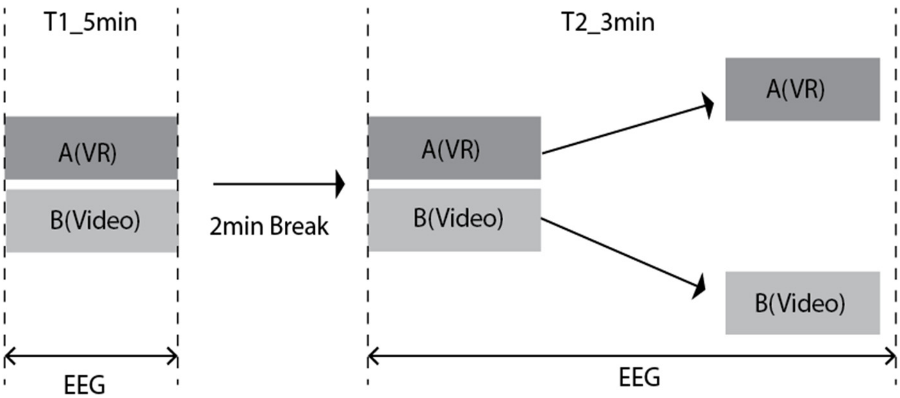

Fig. 3: Experiment procedure: Participants were recruited to either the VR experience group (A) or a Video Group (B)

Fig. 4: Participants undergoing electroencephalogram (EEG) monitoring (a.Video garden experience, b. VR interactive garden experience)

2.2 Brainwave Analysis Using EEG

Electroencephalogram (EEG) monitoring was performed to evaluate the therapeutic effects. EEG monitoring is a noninvasive physiological monitoring method that records brainwaves from electrodes attached to the human scalp and is often used as a quantitative and scientific method to verify therapeutic effects of treatments. In particular, brainwave analysis is performed when studying the physiological changes in the nervous and hormonal systems that cause specific emotions (KIM 2014, OLBRICH et al. 2011).

The standard 10-20 system is an internationally recognized system that specifies the electrode positions on the scalp in experiments involving brainwave analysis. Each position has a number identifying the lobes and hemispherical positions. Different parts of the brain are represented as follows using alphabets: F (prefrontal lobe), T (side lobe), C (center), P (head lobe), and O (larynx). Z means an electrode placed on the centerline. Electrodes were attached to the frontal lobe (AF3, AF4, F7, F3, F4, and F8) according to the international electrode placement method (Figure 5). EEG frequencies of relative alpha (8 – 13 Hz) and relative beta (13 – 30 Hz) waves were obtained.

1) Alpha waves: Alpha waves have a frequency band of 8 – 13 Hz and are brain waves that occur during rest. These waves usually appear when individuals are in a relaxed state and their amplitudes increase in relaxed state. For normal people, an increase in alpha waves at the front of the head means a state of meditation, peace, and calm; moreover, an increase in alpha waves at the prefrontal part is also observed in pathological conditions such as depression, attention deficit, and hyperactivity (KIM et al. 2017).
2) Beta waves: These waves have a frequency band of 13 – 30 Hz and occur when individuals are in a state of awakening, tension, and stress. These waves are observed in the temporal lobe when the eyes are closed during awakening and in the frontal lobe when the eyes are opened. If beta waves continue to appear when individuals try to solve problems, they will cause tension and anxiety. Further, beta waves are divided into three categories (low beta, medium beta, and high beta waves) depending on their frequency. Low beta waves (13 – 15 Hz) appear during passive brain activity, involving stress-free

situations and when performing simple activities. Middle beta waves (15 – 20 Hz) appear in situations involving logical thinking and problem solving. Appearance of high beta waves (20 – 30 Hz) means that there are very few alpha waves. The higher the speed of thought, the higher the frequency and amplitude of the beta waves; when these beta waves exist for a long time, they cause tension, anxiety, and panic.

Fig. 5: International electronic placement method 10-20

Before the test, the examiner measuring the brainwaves conducted sufficient prior studies and preliminary tests. As brainwaves are sensitive to light and sound, the testing environment was set up to minimize interference from the external environment. To help the subjects focus, the experiments were conducted in a noise-free laboratory with covered windows, preventing external light from entering. Subjects wearing the HMD and EEG electrodes were guided to sit on a chair with a backrest during the experiments.

Minimal body and head movements were recommended during the study to ensure reliability of the measurements. Subjects were instructed to close their eyes and hold a stable state for 3 min during the brainwave measurements to minimize disturbances caused by eye movements. Moreover, subjects were restricted in terms of movement or speech during the experiments. Data analyses were performed using only those measurements obtained between 60 and 120 s, excluding the first and last 60 s of the measurements that may have had environmental effects.

The relative powers of alpha and beta waves, in terms of psychological stability, were measured. The differences between the values of the relative alpha, relative beta, and alpha/beta ratios before and after each experience were statistically analyzed to observe changes in the brainwaves According to several previous studies, an increase in the level of relative alpha waves indicates elevated comfort in a psychologically stable state (KIM et al. 2017). EmotivPRO was used to obtain and analyze the brainwaves. The raw data were exported as files with comma-separated values that were subsequently analyzed using MATLAB ver.2016b (Math Works, USA) and EEGLAB plug-in functions.

3 Results

1) Changes in brainwaves after garden video experience: Changes in the relative alpha waves, which are emitted in stable, relaxed, and resting states, were analyzed. The proportion of relative alpha waves increased from 0.725 to 2.042, indicating a 64.5 % increase after watching the video of a natural garden. Paired T-test results indicated statistical significance. Moreover, the alpha/beta ratios (RAHB) before and after watching the video were obtained to assess the psychological comfort state that again showed a significant difference as indicated by the paired T-test results.

2) Changes in brainwaves after virtual garden experience: Relative alpha waves were emitted in stable, relaxed, and resting states. Their proportion increased by 78.1 %, from 0.5812 to 2.661 after the virtual garden experience. Paired T-test results revealed statistically significant differences in the values before and after the virtual garden experience. The RAHB values before and after the virtual garden experience were significantly different, as indicated by the paired T-test results.
3) Brainwave change comparison: The relative power of the alpha and beta waves, related to psychological stability, was analyzed. Differences between the relative alpha, relative beta, and alpha/beta ratio values before and after the experiences were also statistically analyzed to observe changes in the brainwaves. The proportion of alpha waves was 17 % higher in the virtual garden group than in the video experience group. This elevated level of relative alpha waves when the subjects were in a stable or relaxed state indicates a psychologically comfortable state, confirming the therapeutic effects of the VR garden experience.

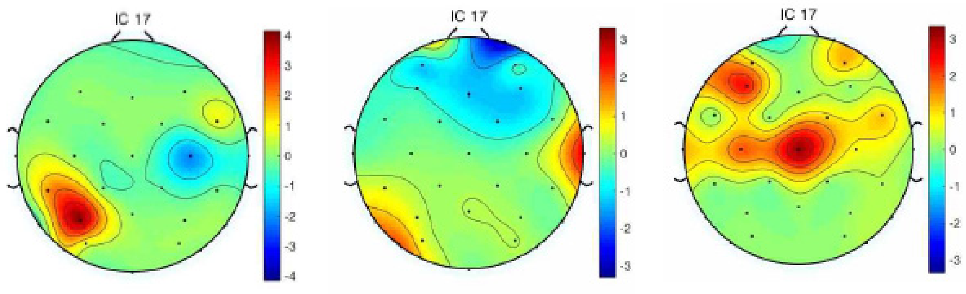

Fig. 6: EEG topography (a. normal state, b. garden video experience, and c. virtual garden experience)

Results obtained by analyzing and combining the brainwaves showed that the virtual garden experience had a significant effect on the brainwave responses of the subjects. By comparing relative alpha waves before and after the garden video and virtual garden experiences, we found that both experiences were associated with an increased generation of relative alpha waves, indicating the stable psychological state of the subjects resulting from the garden video and virtual garden experience. In particular, the levels of alpha/beta waves associated with stress increased significantly after the virtual garden experience. In their interview about what they found most memorable after the VR garden experience, the subjects indicated that the sense of reality and immersion in the virtual garden experience were the most memorable aspects (80%) during the entire experiment.

4 Discussion and Conclusion

The significance of this study is that the effects of interactive experiences in virtual landscapes on human emotions were tested and verified through quantitative methods involving brainwave analysis. In particular, a variety of interactions in VR gardens tailored to specific treatment and rehabilitation purposes can be developed for individuals with physical disabilities.

One limitation of the study is that the interactive experience in the virtual garden is simple and monotonous, and the brainwave analysis is performed at a very basic level. Nevertheless, this study verified the positive therapeutic effects of a virtual garden through quantitative data analyses involving brainwaves associated with various human emotions.

This is a prototype study highlighting the potential applications of landscapes in the field of VR therapy by evaluating the therapeutic effects of a virtual garden. Subsequent research pioneering the design of purpose-oriented virtual landscapes should be performed. Moreover, technical collaborations in the fields of specialized treatments and VR must be established to further investigate the potential therapeutic effects of virtual landscapes on disabled individuals who are unable to benefit access actual gardens in their daily lives.

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