



Original article

The effect of virtual reality forest and urban environments on physiological and psychological responses

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ABSTRACT

Previous studies used pictures or movies to investigate the impact of virtual nature environments on physiological and psychological health, providing inferior immersive experiences. The latest virtual reality (VR), launched in 2016, allows users to be fully immersed in simulated surroundings. However, the effects of the simulated environments created by the latest VR technology on health were not yet known. This study employed both cross-over and pretest-posttest design to examine the influence of forest and urban VR environments on restoration (N = 30). Both physiological and psychological responses were collected. The results show that participants' systolic blood pressure and heart rate decreased with time, regardless of environmental differences. About psychological responses, an increased level of fatigue and a decreased level of self-esteem were reported in simulated urban environments. In contrast, an increased level of vigor and a decreased level of negative emotions (i.e., confusion, fatigue, anger-hostility, tension, and depression) were observed in simulated forest environments. In sum, greater benefits were found when immersing in forest settings. The latest VR technology can serve as an alternative way to access nature environments for restoration.

1. Introduction

With the rapid development of urbanization, a large percent of population is living under stress, which is associated with poor health (Karjalainen et al., 2010). Previous studies have demonstrated the positive association between green exposure and individuals' health that highlights visiting natural environment as a cost-effective approach for restoration and public health (Hartig et al., 1991; Powell and Blair, 1994; Nielsen and Hansen, 2007; Hartig et al., 2014). Powell and Blair (1994) indicate that individuals' physiological health could be improved if living in an environment surrounded by more green space, mediated by higher motivation to exercise. Nielsen and Hansen (2007) conducted research in Denmark and concluded that individuals' physiological and psychological health were improved if their living environment was covered with more green space where people could visit for physical activities and stress release. Studies of nature surroundings and human health have found that forests have been found to have a great impact on health promotion and disease prevention (Li et al., 2008; Park et al., 2008; Park et al., 2009; Lee et al., 2009; Li, 2010; Tsunetsugu et al., 2010; Lee et al., 2011; Morita et al., 2011; Beil and Hanes, 2013; Tsunetsugu et al., 2013). In terms of physical health, visiting forests have been found to contribute to a decrease in

sympathetic activities and an increase in parasympathetic activities, indicating its function in reducing stress levels (Park et al., 2008; Park et al., 2009; Lee et al., 2011; Tsunetsugu et al., 2013). Additionally, a reduction of other physiological stress indicators (e.g., heart rate, blood pressure, and salivary cortisol level) were observed when visiting forests, confirming the impact of forests in restoration (Lee et al., 2009; Tsunetsugu et al., 2010; Beil and Hanes, 2013). Regarding psychological effects, previous studies found an association between positive emotions and forest visits. Individuals felt more relaxed, dynamic, and rested after visiting forests (Tsunetsugu et al., 2007; Lee et al., 2011; Mao et al., 2012; Tsunetsugu et al., 2013). In contrast, a decrease in levels of stress, fatigue, and irritation were reported after their visit to forests (Lee et al., 2011; Mao et al., 2012; Tsunetsugu et al., 2013). Other than improving physiological and psychological health, forests also play a role in disease prevention (Li et al., 2008; Li, 2010; Morita et al., 2011). Li (2010) indicates that taking a forest bath could enhance immune system by increasing nature killer cells (NK cells), and the activities of NK cells could last for more than a month after visiting forests. In sum, with the substantial evidences showing the effects of forest in improving public health, the benefits of visiting forests should be promoted. Two major theories were highlighted in nature and human health studies, Kaplan & Kaplan's Attention Restoration Theory

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(Kaplan and Kaplan, 1989) and Ulrich's Stress Recovery Theory (SRT, 1991). Based on the principle of ART (1989), natural environments are more restorative than urban environments because of their ability to catch involuntary attention (Berto, 2014). SRT is a psycho-evolutionary theory that considers non-threatening natural settings as restorative environments, leading to a more positive emotional state and a decreased level of physiological arousal (Ulrich et al., 1991). The difference between these two theories is that ART emphasizes cognition while SRT focuses on affective responses.

One motivation to develop virtual reality (VR) environments is to benefit those who are not able to go outside, by offering them virtual nature exposure (Berto, 2014). The virtual forest environments provide an opportunity to people who are unable to frequent a real forest and enjoy beneficial effects from forest landscapes. Virtual reality is an advanced technology combining a high degree of control with ecological validity that can simulate highly realistic environments, leveraging basic neuroscience research and therapeutic applications (Bohil et al., 2011). The content in VR can be produced by either computer-generated imagery (CGI) or a 360-degree panorama camera. The former features great interactivity; however, it requires specialized skills for 3D modeling, texturing and programming. In contrast, although the interactivity of 360-degree video is limited because it is pre-recorded, the sensory vividness of the physical environment has led to an increasing popularity in environmental simulations (Jacobs, 2004; Bishop and Rohrmann, 2003). Given the capability of VR in helping users immerse themselves in the created environment and interact with the simulated world in real time (Burdea and Coiffet, 2003; Stanovsky, 2004), VR has been applied in many fields for skill training or dealing with problems in the real world. For example, VR could be used in medical education to help surgeons hone their skills before real operations. Despite early virtual equipment being limited by numerous obstacles, such as cost, software skills, bulkiness of equipment and cybersickness (Bohil et al., 2011), the applications of VR on human health practices were never stopped. For example, in the late 1990s the virtual forest rehabilitation system and Bedside Wellness Systems were designed to simulate a virtual forest walk with sounds and smells to reduce patients' stress levels and to improve their quality of life (Ohsuga et al., 1998; Oyama et al., 1999). Additionally, along with therapists' assistance, VR could help patients overcome mental disorders such as anxiety disorder and posttraumatic stress disorder (PTSD) by teaching them techniques for dealing with triggering situations (Botella et al., 2015; Reger et al., 2016). Whether the simulated nature environments have a positive impact on individuals' health gives rise to other questions. A few studies investigating the association between simulated environments and health have been conducted. Annerstedt et al. (2013) examined 30 male participants' physiological recovery in a virtual reality forest. They found simulated nature environments with sounds of nature helped participants' recovery. In contrast, neither the control group nor participants immersed in the simulated nature environments without sounds showed significant improvement. Baños et al. (2013) studied the relationship between simulated nature environments and emotions among 19 cancer patients. They concluded patients had a decrease in negative emotions and an increase in positive emotions after watching a computer-generated forest environment. Another study conducted by Valtchanov et al. (2010) compared the difference in regards to restorative effects between a slide show and virtual reality nature settings. They concluded that participants who were immersed in VR nature settings had an increased positive affect and coinciding decrease in stress levels. As more studies were conducted whose results suggested the effectiveness of simulated nature environments on health improvement, there arose another question of whether or not a simulated nature environment has the same effect as an actual natural environment. Kjellgren and Buhrkall (2010) made a comparison between a natural environment and a simulated one in terms of restorative effect and found that both natural and simulated nature environments helped reduce stress. Nonetheless, the simulated nature setting did not increase

participants' states of consciousness and energy when compared to the natural environment. This may be because the effect of simulated settings is mediated by the level of immersion, diminishing its effect on health.

Although the impacts of virtual nature environments on individuals' physiological and psychological health have been studied (Oyama et al., 1999; Hoffman et al., 2000; Valtchanov et al., 2010; Annerstedt et al., 2013; Baños et al., 2013), most studies investigate the above-mentioned relationships by using pictures, 2D movies, or 3D movies on a flat screen to simulate environments, which provide inferior immersive experiences. A new generation of immersive VR system with Head-Mounted Display (HMD) has been launched that is able to support 360-degree videos and allows users to be fully immersed in the simulated surroundings, as well as provides experiences extremely close to those in the real world. The immersive VR environments incorporate highly sensitive head-and-body tracking systems to provide a first-person perspective. The virtual reality experience is vivid and real, enhancing a sense of "presence" that influences the emotional responses and levels of relaxation (Berto, 2014). Studies of VR pain analgesia for burn victims find that more highly immersive VR equipment could enhance the sense of presence in virtual environments, corresponding with greater levels of relief (Bohil et al., 2011). These arguments highlight that the greater immersive experiences the individuals perceived, the greater health improvements they obtained from simulated natural environments. In other words, the level of immersion plays an important role in studying benefits of virtual environments. Due to the short history of the latest immersive VR technology, only a few studies have examined the individual health benefits of virtual environments utilizing this technology. So, the effects of simulated environments created by the latest immersive VR technology on psychological and physiological responses are not yet known. Accordingly, this study is concerned with understanding individuals' perceived restorativeness on physiological and psychological responses, with a particular interest in virtual restorative environments. From both ART and SRT perspectives, it's not surprising that virtual reality natural environments have more restorative value than do urban settings. Additionally, there are two types of virtual environments, the virtual environments on videos and those on computer-generated environments (Valtchanov et al., 2010). Given the former type of simulated environments provides a better immersive experience with sensory vividness in a real world, this study aims to explore the effects of simulated environments on individuals' psychological and physiological responses by applying a cutting edge VR technology with 360-degree videos. The research tasks of this study are (1) to investigate the effects of simulated urban and forest environments on individuals' physiological responses and psychological effects by using a newer-generation HMD VR device than previous studies and (2) to compare the differences in the change of psychological responses and psychological effects between urban and forest environments.

2. Materials and methods

2.1. Participants

Participant recruitment was announced through Internet and social network websites (e.g. Facebook) in September 2016. Participants aged between 20 and 35 with sound wellbeing were eligible to attend this study. Those with a history of neuropsychiatric disorder, cardiovascular disease, or who were taking disqualifying medicine were excluded from the study. In total, 30 participants were retained for the experiment. Among them, 13 were male and 17 were female. The majority of them (93.3%) were aged between 20–29. The study was approved by IRB review at the authors' institution (NTU-REC No. 201607HS008).

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