REVIEW ARTICLE

Strategies for natural healing design based on restorative environment theory

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As a cross-cutting field that integrates environmental psychology and health design, nature healing facilitates physiological and psychological restoration *via* exposure to natural or simulated ecological elements and plays an irreplaceable role in dealing with mental health crises such as anxiety and depression that are prevalent in modern society. This research systematically sorted out the results of previous studies and summarized the research hot spots and turns in recent years including the conditions, characteristics and evaluation systems of restorative environments in the three links of natural healing system composition, space design and benefit optimization, as well as the essential relationship between the interaction of human and natural systems. The changes in spatial structure and sensory presentation brought about by technologies such as virtual reality and multimodality were analyzed in the light of experimental results and best practice from previous studies. This research systematically synthesized core design principles for natural healing, offering a theoretical framework to guide future innovations in restorative environment design. The results provided methodological innovation for interdisciplinary research in the theory of environmental psychology, multimodal technology, and interactive design aesthetics, while offered the high-stress society a solution that combined scientific efficiency and humanistic temperature.

Keywords: natural healing; restorative environment theory; interactive design; virtual reality technology.

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Introduction

In recent years, mental health has become a universal social issue across all countries. In-depth medical studies on psychological healing have demonstrated that a comfortable and well-designed natural environment can promote health both physiologically and psychologically. However, the development of natural healing design in China started late, facing challenges such as single space, single form, unclear intervention effect, and inability to meet psychological healing needs. Additionally, there is a lack of standardized construction criteria, leading to uneven design quality. A healing environment is defined as a setting that restores and renews the physical and mental resources that humans continuously expend. Based on empirical research, Ulrich *et al*. proposed that healing environments should satisfy the conditions of appropriate depth and complexity, a certain overall structure and a specific focus point, containing enough natural elements such as plants and water bodies, and no hazards present [1]. Kaplan *et al*. elaborated on the four characteristic elements of healing environments including sense of distance, richness, attractiveness and compatibility, attractiveness

and compatibility [2]. By understanding the conditions and characteristics that such environments should meet, more scientific, innovative, and effective approaches can be developed to natural healing design from the perspective of environmental psychology.

Composition of natural healing systems driven by restorative environment conditions

1. Ecological landscape: sufficient natural factors

Healing landscapes use landscape elements in healing spaces for treatment and rehabilitation. Natural healing landscapes focus more on the requirements of restorative environments for natural factors, emphasizing the mutual interaction between humans and the natural environment. By leveraging the beneficial elements within the ecological landscape and promoting two-way communication between people and their surroundings, the physical and mental states of users can be enhanced. Previous research demonstrated that, in a relatively comfortable natural landscape space, people could better regulate their stress and psychological state. Three types of natural landscapes that could improve positive emotions were proposed [3]. However, Wang *et al.* reported that there was no statistically significant correlation between landscape diversity and healing effects through controlled experiments [4]. Therefore, ecological landscape types should be tailored to different healing groups and functions rather than merely increasing diversity.

2. Interactive environments: complexity and depth

The process of constructing interactive environments in restorative settings consists of two main aspects. First, the complexity of restorative environments provides comprehensive sensory stimulation to facilitate physiological interactions [5]. For example, incorporating elements such as sunlight, water, and the scent of soil stimulate all senses, allowing individuals to relax physically and mentally, thereby reducing stress. Second, the depth of the restorative environment enables psychological interactions, which is achieved through the design of healing processes that integrate drama, creation, games, and other forms of interaction with timely feedback (Figure 1). These elements guide individuals to connect with the intangible aspects of nature, adding an abstract depth to the interactive environment. By altering the way healing spaces are enclosed and the degree of enclosure, these designs stimulate a desire for exploration and reshape the relationships between individuals and space, nature, and themselves. For example, Suzhou Middle School (Suzhou, Jiangsu, China) Daomeng Space combines natural elements with the concept of natural healing to upgrade the teaching building space, giving the six sub-spaces of elephant, bamboo, celery, forest, flower, and cloud their images and meanings, and using the language of nature in space and interactive design, achieving relaxation and decompression based on the soothing and healing effects that different natural environments and elements bring to people. The light yarn, flowing bamboo, fluttering leaves, and gentle “wind” not only alleviate psychological stress, but also bring new ideas. The Wind and Bamboo Secret Language module collects spiritual feedback and gathers warm interpretations, becoming a spiritual resting place for students and teachers.

3. Healing mechanism: safety of space

According to the requirements of the overall structure and center of the healing environment, the design of the healing system needs to plan the landscaping and interactive areas to form a soft landscape zone. Safety is a crucial condition for healing. All elements of the natural healing system such as plants, facilities, materials, and contents must be considered for safety, which ensures that individuals can relax their basic psychological defenses and feel a sense of spatial belonging. The Crown Sky Garden at Chicago Children’s Hospital (Chicago, IL, USA) exemplifies this approach. Housed in a glass greenhouse, it features a bamboo forest, recycled resin panels, natural stones, and reclaimed timber from the

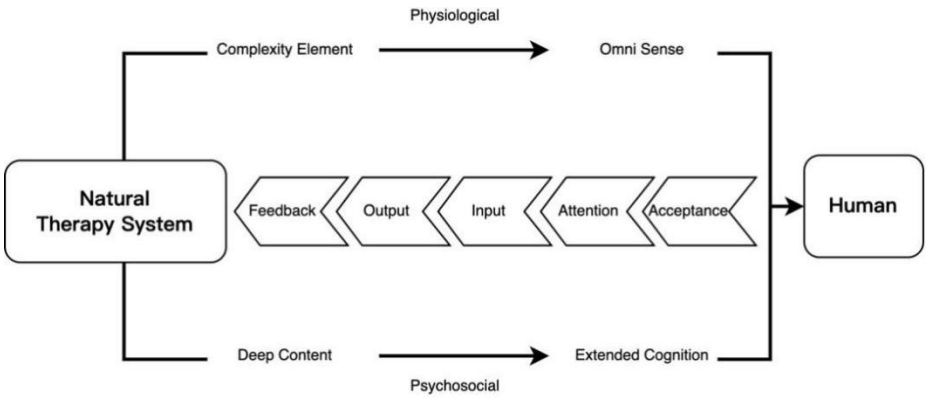

Figure 1. The process of building an interactive environment.

local area. A bamboo walkway connects the floor and skylight, naturally divided by streamlined fountains. This setup allows children to experience nature healing through direct contact with nature or by using interactive installations. Additionally, the space includes solitude areas to accommodate the needs of special-needs children, enhancing the effectiveness of rehabilitation.

The shaping of natural healing space guided by the characteristics of healing environments

1. Distance from daily life: creating a sense of distance

The remoteness of the healing environment primarily brings about healing through the detachment effect of distance, which can be divided into physical and psychological distance. In terms of physical distance, it is essential to avoid psychological trauma and persistent resistance by staying away from stressful physical conditions. Psychologically, natural healing spaces inherently provide a sense of distance. The architectural photography exhibition "Under the Sun" (MIA Design Studio, Ho Chi Minh, Vietnam) uses reflected light, sunlight, bamboo shadows, and breezes to highlight the contrast between reality and illusion. Real space becomes unreal through endless layers of reflections. When real space disappears, the past will resurface, bringing with it the realest feelings inside people, which creates a memory-laden background that feels like a paradise away from the world's hustle and bustle. Similarly, Jaemee Studio's Water Lily Meditation Space Project (Jersey City, New Jersey, USA) creates a sense of distance by separating visual and auditory senses, providing an environment for individuals to merge with nature and meditate quietly. Inspired by lily pads floating at a pond adjacent to the Eight Mile River, the Lily Project encourages visitors to have a colorful and playful interaction with the monumental nature.

2. Attractiveness of the environment: attraction and integration

The attractiveness of the healing environment lies in its ability to attract attention without subjective effort, which can be categorized into soft attraction and hard attraction [6]. Soft attraction involves subtle, moderate allure from natural elements, while hard attraction involves strong, fixed attention from man-made elements, offering quick engagement. By enhancing the aesthetics of space according to the healer's needs and increasing emotional interaction between the space and the individual, a healthy combination of soft and hard attraction can be achieved [7]. Studio Ossidiana (Rotterdam, Netherlands) designed the El Paseo Community Garden space with this approach. It integrates a half-garden, half "part kitchen, part game, part stage" structure, combining the natural scene's soft attraction with the

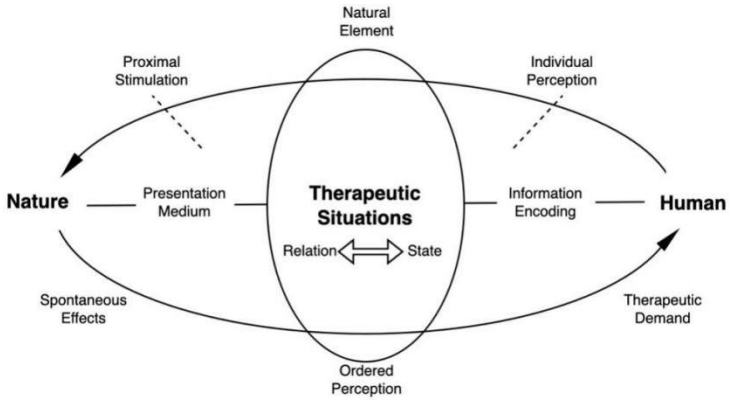

Figure 2. Lens model relationship between humans and nature in the healing system.

humanistic connotation's hard attraction to create a pleasurable and engaging community space.

3. Sensory richness: multi-dimensional experience

The richness of the restorative environment involves a multi-level combination of physiological manifestations and psychological effects. Natural phenomena like sunshine, flying butterflies, water ripples, and clouds bring positive associations, while natural textures enhance the sense of vitality. The sympathetic association effect of the five senses ensures that visual signals are transmitted to the sense of touch. SeekLab's interactive exhibition Wind Catchers exemplifies this with installations in the sky, river, and forest combined with a video documentary, which creates a non-urban natural experience through multi-sensory feedback, offering a multi-dimensional intimate contact with nature.

4. Compatibility of process: subject-object resonance

Compatibility, in the context of healing environment theory, refers to the relationship between the healing space and the individual, determining if the individual can be positively stabilized and developed. Marx's Practical anthropomorphic view of nature suggests a common language exists between the natural environment and individuals, termed resonance in physics. This resonance is reflected in the openness of nature, allowing a high degree of participation. The Brunswick's lens model can explain this relationship well, illustrating how natural spaces facilitate deeper interaction impulses between individuals and the environment (Figure 2).

Optimization of nature healing benefits under the restorative environment assessment system

Based on the fundamental framework of healing theories, empirical studies often employ various physiological and psychological measurement methods to comprehensively examine healing benefits. This research analyzed the optimization of healing benefits from the perspectives of virtual-real ratio, sense of symbiosis, and interactivity, based on the assessment system of restorative environment theory.

1. Virtual-real ratio and healing effects

The virtual-real ratio in restorative environments refers to the proportion of natural healing content that is presented virtually versus in reality. With the advancement of new media technologies, healing scenes and content are increasingly moving towards virtual and metaverse spaces. However, due to the immersive characteristics of real natural environments, virtualized natural healing spaces

still require more efficacy testing. By integrating existing empirical research results, the impact of virtual immersion on healing benefits in nature healing can be analyzed more clearly. In the 2D virtual nature scene, subjective ratings of recovery are significantly higher, while the effect on cognitive performance is not significant. In terms of emotional well-being, the three mood categories of nervousness, upset, and restlessness are significantly reduced but slightly less than that in the 360-degree virtual nature scene with the values of all indicators of physiological stress recovery decreasing to some extent. In the 360-degree virtual nature scene, subjective ratings of recovery are significantly higher and comparable to the real nature environment. The impact on attention-based cognitive abilities is not significant but is able to stimulate creative thinking significantly. For emotional well-being, the performance in alleviating negative emotions is comparable to that of the real nature environment, but it was not able to increase the positive emotions significantly. For recovery from physiological stress, the performance is significantly higher than that in the 2D virtual environment in the data on visual attention. In terms of physiological stress recovery, the visual attention data is significantly higher than that in the 2D virtual nature scene, but the difference in electrocardiogram (ECG) data was not significant. It is evident that there is no linear relationship between the immersion of virtual natural scenes and emotional restoration. Highly immersive natural landscape presentations increase cognitive load, and their emotional relaxation effects are not superior to those of static virtual natural scenes. Issues such as discomfort caused by head-mounted displays also significantly increase negative emotions and fatigue, indicating that current levels of virtual technology cannot fully replace real natural healing landscapes.

2. Sense of symbiosis and healing sensory experience

The sense of symbiosis in restorative environments refers to the match and unity between the information provided by natural healing and the various human senses. The body, as the foundation of action and part of the environment, has a crucial interactive relationship with the media in natural healing. Multisensory combined stimulation can better evoke emotional and affective responses [8, 9]. Current multimodal emotion recognition technologies based on facial expressions, eye movements, speech, and gestures have shown broad application prospects in psychology. Integrating these technologies with multimodal feedback in natural healing systems will make the process more human-centered, achieving healing effects through more matched, precise, and efficient methods by enabling holistic interaction between physiological and psychological states and the natural healing system.

3. Sense of participation and healing psychology

The sense of participation in restorative environments refers to the interactive methods and degree of experience of the healer within the natural healing system, which can be evaluated from dimensions such as immersion, presence, and perceived realism. New media art can use computers to create real-time generated ecological landscapes and interactive environments, facilitating self-exploration through multiple communication channels [10]. New media technologies allow healers to independently choose their perspective and alter spatial parameters, significantly enhancing their sense of participation in the surrounding environment. When individuals immerse themselves in highly participatory natural healing, they can achieve subjective comfort and harmonious healing experiences through self-created healing scenes, thereby gaining a sense of self-realization, achievement, and happiness.

Interaction paths in natural healing under the restorative environment theory

The interactive design of natural healing involves analyzing the fundamental relationship between nature and humans on a human-centered basis.

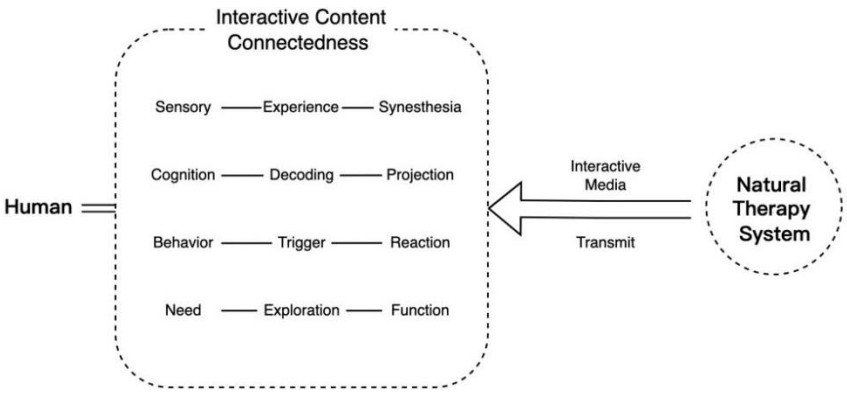

Figure 3. Interaction path relationship diagram between natural healing system and individual.

Participants achieve a multi-sensory integrated experience through interaction with specific restorative objects and media content (Figure 3).

1. Content connection: tangible expressions in natural healing

Restorative natural healing systems present interactive healing information through various technical media and creative expressions, aiding individuals in transforming the natural healing world into projections of their inner psychological conflicts and emotional connections. The emotions, attitudes, and coping mechanisms reflected in the healing process represent the healer's personal psychological state and cognitive responses. The psychological construction and interaction contents in natural healing primarily go through three stages. The first stage involves decoding and internalizing healing information. Supported by restorative natural environments, individuals express their physical and mental states using natural elements as a base, gradually concretizing emotional exploration, internal perception, and psychological imagination. This stage links specific elements or scenarios in natural healing content with the subconscious, transforming personal thoughts, feelings, and experiences into conscious understanding through non-verbal coding [11]. The second stage involves interpreting and reconstructing healing information. Using perceptible natural imagery, individuals conduct deeper self-inspection, transforming natural healing information into internal experiential expressions and using empathy to resolve surface psychological conflicts. The third stage involves comprehending and integrating healing information, merging the constructed conscious world of natural healing with the individual's unconscious psychology. This process fundamentally teaches individuals how to manage and resolve their internal conflicts, transitioning from self-repair to the acceptance and recognition of external healing functions, ultimately achieving self-expression and transcendence.

2. Media transmission: embodied practice in natural healing

Emotions are an evaluation of an individual's state, causing corresponding bodily reactions. The body itself is part of the complete construction of interactive works [12]. McLuhan's concept of the medium is the extension of man suggests that the "information" transmitted by media is not limited to content but includes the receiver's reactions and feedback [13]. Interactive media, therefore, are not merely physical devices or tools but vital communication bridges between the healer's body and the external world, coupling closely with their body, mind, and context. When the body's intermediary nature is awakened, the perception system and the interactive media of natural healing together construct the message transmission path. The digital age has brought diverse healing forms and new emotional issues.

The present digital scene is no longer a customized space under special conditions but an objectively existing living environment. Thus, digital media interaction becomes an essential element in natural healing. With the expanded application of digital technology, natural healing media now transcend physical spaces and virtual screens using new devices and technologies to bridge time and space, making comprehensive sensory system interaction between humans and nature possible. There are several broad types of current healing interactive systems.

(1) Interactive devices

Using technologies such as interactive projection, motion capture technology, algorithmic generation, digital twins, *etc*. For example, Embodied nature, produced by Mischer'traxler studio (Vienna, Austria) in 2022, presents more than 100 global species all in the same scale. When visitors approach this work, they see their own silhouettes in the diversity of nature, evoking the self-knowledge that individual human beings are part of nature.

(2) Immersive space

Tree, developed by MIT Media Lab (Massachusetts Institute of Technology, Cambridge, MA, USA) in 2017, uses virtual reality (VR) headset, wearable sensing devices, virtual reality technology, *etc*. to create a fully immersive narrative space that allows visitors to experience the entire process of growing from a seed to a tree, and precisely controls physical effects through a vibration suit driven by localized sensors in addition to audio-visual, presenting a haptic experience that includes vibration, heat, and wind in order to feel the disturbances of forest fires as well as the landing of birds on the branches of a tree.

(3) Interactive theatre feast

Fei Jun's EAT ART - MR Emotional Cuisine in 2023 used technologies including multimodal fusion and mixed reality and opened the experience of the healer beyond aesthetic expectations in a self-feedback guided way. The heart rate of the participants was measured, and the emotion type was identified. A robotic arm and augmented reality (AR) smart glasses were used to combine the virtual visual presentation of emotions and provide the audience with food that matched the emotions, forming a personalized emotional healing experience that mobilized the senses such as vision, hearing, and taste.

(4) Interactive products

By using wearable devices, ultra-wideband technology, *etc*. Marily Papanastasatou, a multidisciplinary designer from Greece, produced sensory souvenirs in 2022, which explored spatial environments based on natural sounds and smells, used ultra-wideband technology to analyze different stimuli based on distance and location, recognized different stimuli, and recorded them for later review and sharing.

(5) Artificial intelligence (AI) interactive generation

The National Grand Theatre of China (NGTC) (Beijing, China) presented Fei Jun's Emotional Theatre in 2023, which detected and presented the audience's emotions through AI and emotional computing technologies, and generated a unique and healing audio-visual theatre experience that was tailored to the unique emotions of each audience member with a data collection module, graphic generator software, and a touch control device to provide the experience to the audience. The data collection module, graphic generation software and touch control device created a positive psychological effect from emotion recognition, transformation, to acceptance.

Conclusion

This research focused on creating restorative natural environments and interactive scenes that integrated social functions and met individual needs based on the characteristics of restorative environment theory. By shaping restorative natural environment spaces and interactive

scenarios and combining relevant experimental validation results, the impact of natural elements, immersion, and participation on promoting physical and mental health within natural healing systems were identified. From the overall system structure, spatial characteristics, healing benefits optimization to individual interaction path integration, the strategies for creating more mature and reasonable restorative natural healing designs were proposed, which represented a fusion of psychological intervention and environmental studies, as well as a scientific practice direction in digital interaction design. Moreover, in designing natural healing systems, besides enhancing aesthetics, diversity, and immersive experiences, controlling the interaction of various elements to better suit complex psychological needs should also be a key focus for research and practice.

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