



# Emotion Impact of VR Painting at Different Levels of Cognitive Demand

## Experimenting with VR Painting on Mood Improvement at Different Levels of Cognitive Demand

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**Abstract.** This study focuses on identifying the emotional impact of virtual reality (VR) painting as an art healing method. For an empirical study to analyze the emotional influence of VR painting, we conducted an experiment for empirical research based on different levels of cognitive demand. In this study, the mandala pattern was given a three-dimensional presentation in VR space to determine whether its psychological healing effect can be extended to the three-dimensional virtual space. In terms of results, the mood of the mandala group improved significantly.

**Keywords:** VR painting, emotion, cognitive demand, design

## 1 Introduction

Art has its origins in the human need to express the heart and communicate emotions. From the earliest cave paintings to contemporary art that is global, culturally diverse, socially engaged and technologically relevant, all embody humanity's exploration of the things around us and of life in the universe [1]. Throughout history, people have explored and developed the healing function of art. Art healing spans the two fields of art and psychology, integrating art activities with psychotherapy and bringing the unique benefits of art into the process of psychotherapy.

Different from verbal communication in conventional psychotherapy, art therapy is about immersing oneself in artistic creation through various media in a non-traditional linguistic way using a unique artistic language [2]. Under the guidance of a therapist, participants actively engage in the process of creating art, using the five senses, perception, cognition, exploration and the discovery of personal emotions and feelings. This involvement promotes self-discovery, stress reduction, relaxation and self-regulation.

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Art healing has gained increasing public acceptance in recent years, largely due to the diverse characteristics of the medium [4]. With advances in media technology, VR, AR and other media forms are transcending their initial limitations, using multi-sensory channels to create 'interactive' and 'immersive' art content that offers visitors a holistic mind-body experience.

However, the integration of new digital media into the art healing process requires further research and evidence to assess the continued efficacy of traditional healing methods. At present, the therapeutic value of two-dimensional painting in art healing has been scientifically proven [12]. However, even though virtual reality technology has expanded the application of painting healing, there remains a lack of studies that comprehensively explore this emerging healing approach. To address this issue, this paper explores the healing effects of mandala painting in virtual reality (VR) environments, drawing on the traditional healing aspects of mandala art. Following instructions, users can paint freely with virtual brushes in a three-dimensional virtual space. Compared to flat painting, virtual reality technology reduces the distance between users and their artwork, enhancing the expressiveness of their creations. Therefore, virtual reality technology broadens the forms of implementation of painting therapy and has good therapeutic practice value.

### **1.1 Mandala**

In Sanskrit, mandala signifies circle or center, and for a long time, the circle has been imbued with religious symbolism of the entire universe. Consequently, mandalas are also considered tools that can help concentrate the mind, reflect on oneself, establish internal order, and achieve harmony [5]. Jung assumed that mandala painting could serve as an intermediary between negative emotions between a painter and a painter, conscious and unconscious. Moreover, Mandala painting provides an opportunity for individuals to externalize negative emotions, thus establishing mental separation from negative emotions [9]. Individuals realize that their negative emotions are frequently challenging to manage and chaotic; Nevertheless, mandala paintings can express these negative emotions in healthy forms.

### **1.2 Flow**

The concept of flow, initially proposed by American psychologist Mihaly Csikszentmihalyi, refers to a positive emotional state attained when a person is engaged in an activity, accompanied by a loss of self-awareness and insensitivity to the passage of time [3]. Novak and Hoffman categorized the characteristics of flow experience into three categories based on the process of flow experience, namely, conditional factors, experience factors, and outcome factors [6].

Distinct individuals engage in distinct behavioral activities into distinct flow states. The balance between the activity challenge level and the participants' skill level significantly affects an individual's flow state, on the condition that the activity challenge level is balanced with the participant's skill level, the participant will easily become concentrated and enter the flow state; Tasks that are too challenging or de-

manding can be counterproductive: tasks that frustrate participants can have a devastating effect on mood improvement [11].

### 1.3 Cognitive needs

In the field of cognitive psychology, the challenge level of an activity refers to the extent to which the activity can mobilize the cognitive demands of participants. The concept of cognitive demand was first proposed by Cohen in the 1950s, and Cacioppo provided a more authoritative understanding, suggesting that cognitive demand is the individual's tendency to engage in and enjoy thinking. When people are exposed to a new activity, the more complex the activity is, the higher the difficulty for participants to learn, and thus a higher level of cognitive demand is mobilized; conversely, a lower level of cognitive demand is mobilized. Therefore, when people face a new task, the cognitive demand level of the task can be measured by the difficulty of learning.

According to Albert Bandura's observational learning theory, the learning process can be divided into four stages: attention, memory, initiation, and motivation [7]. First, people need to notice and identify the object of learning. Second, people need to remember the learning objective and understand it through continuous observation and memory. Then, people need to implement this new task and grasp the essence of the learning object through continuous practice. Finally, motivation is also an important reason for people to engage in learning behavior, which can be the final learning outcome or immediate feedback at each stage. From this theory, the more content a task carries in the learning process, the higher the difficulty of learning, and the higher the level of cognitive demand the task mobilizes.

Based on Bandura's observational learning theory, this study proposes three tasks of different difficulty levels for the VR painting activity: copying, coloring, and free painting. For the copying group, participants' goal is to accurately replicate a pre-designed mandala template, first identifying and memorizing the template, then observing and memorizing the basic painting skills used in VR space, and finally completing the copying task. For the coloring group, participants' motivation is to create works through color matching, first identifying and memorizing the pre-designed mandala structure, then observing and memorizing the basic painting skills used in VR space, and finally completing the mandala color creation task. For the free painting group, participants' motivation is to freely create their own works, first observing and familiarizing themselves with VR space, then observing and memorizing various painting skills and combinations in VR space, and finally completing the painting creation based on the imagined image in their minds (refer to Table 1).

**Table 1.** Mandala painting tasks in VR space with distinct levels of cognitive demand

| Learning Process | Copying                            | Coloring                                   | Free Drawing                                               |
|------------------|------------------------------------|--------------------------------------------|------------------------------------------------------------|
| Attention        | identify the template              | identify the template                      | create work satisfied with color matching and distribution |
| Memory           | memorize basic skills and the tem- | memorize basic skills and the structure of | memorize various types of skills and combination           |

|             | plate                                                  | template                                                   | effects;                              |
|-------------|--------------------------------------------------------|------------------------------------------------------------|---------------------------------------|
|             |                                                        |                                                            | memorize images envisaged in the mind |
| Initiations | replicate the mandala template                         | create works through color matching                        | realization of the envisaged content  |
| Motivation  | accurately replicate the pre-designed mandala template | create work satisfied with color matching and distribution | create own unique work                |

From the perspective of the learning process, the three groups of mandala painting tasks pose different cognitive demands on participants at each stage of observational learning [10]. Based on the amount of content carried in the learning process, in terms of cognitive demand level, the free painting group mobilizes relatively higher cognitive demands, followed by the coloring group, while the copying group mobilizes relatively lower cognitive demands.

For psychotherapeutic practice, the main impact of tasks with different levels of cognitive demand is the variation in therapeutic outcomes, which is reflected in the emotions of the participants. Assuming that participants are in a negative emotional state before performing the task, when engaging in tasks with a moderate level of cognitive demand, participants' attention will shift to the current task, thereby alleviating their emotions. When engaging in tasks with too low cognitive demand, participants will rely on past experiences to solve them easily, and their attention will remain in a negative emotional state, failing to achieve the therapeutic goal. When engaging in tasks with excessively high cognitive demand, participants may feel frustrated during the learning process, which exacerbates emotional stress and fails to achieve the therapeutic goal.

It is evident that the three groups of mandala painting tasks put forward distinct requirements for cognitive requirements of learners at each stage of observational learning, among which the free painting group mobilized relatively high cognitive needs, subsequently, the coloring group and the copying group mobilized comparatively low cognitive needs.

Taking painting therapy in virtual reality space as the research theme, based on flow theory and cognitive needs research, this paper aims to demonstrate the following hypotheses by organizing a series of mandala painting experiments in VR space:

H1. Mandala painting activities in VR space can considerably enhance participants' emotional state:

H1a. Mandala painting activities in VR spaces can induce positive feelings in participants.

H1b. Mandala painting activities in VR spaces can alleviate participants' negativity.

H2. Among the three distinct VR painting activities, the mandala coloring group had the greatest curative effect:

H2a. Mandala coloring activities were able to dramatically improve the emotional state of participants.

H2b. Mandala coloring activities can facilitate a positive flow experience for participants.

## 2 Experiment Design

### 2.1 Participants

In this study, 18 cases were selected from individuals of distinct ages in Guangzhou, Shanghai, and Anhui, and the conditions for inclusion of the study subjects were set: (1) interested in painting activities; (2) No motion sickness occurs within 15-20 minutes after wearing VR glasses; (3) Voluntary participation in this research.

### 2.2 Experimental Samples

The mandala template utilized in this study is selected from 'The Path of the Heart: Mandala Growth Self-healing Picture Book'. This paper employs the template of differentiation chapters in the picture book, such mandala graphics are characterized by divergence, which can improve self-awareness and distinguish psychological function, increase one's sense of self and meticulousness, strengthen the adaptive function of the mind, and contribute to helping participants enhance their mood [8].

### 2.3 Experimental Tools

The hardware device for this study selected the 6DoF VR all-in-one PICO Neo 3 of ByteDance's VR brand PICO released in 2021, displaying a resolution of 3664×1920, a refresh rate of up to 90Hz, a Qualcomm Snapdragon XR2 processor, and two hand controllers. Besides, the software equipment uses Multibrush, and the system includes an extensive assortment of painting creation tools, which can be adopted for professional creation. Prior to the intervention officially beginning, the researchers created the three-dimensional mandala material necessary for the experiment in Multibrush beforehand.

### 2.4 Experimental Procedures

In the first place, in the preparation phase of the experiment, the researchers decided whether the participant wore the ankle or arm based on the consistency of the carotid Bo and the measurement results. Moreover, participants were required to self-report their mood levels at baseline, which was employed to collect data on the starting point of mood changes.

At the beginning of the experiment, through 3-5 minutes, the researchers informed the participants to describe some stressful circumstances they were experiencing, and subsequently completed the self-report measurement of emotional levels again. Consequently, the researchers randomly assigned participants a painting task including copying, coloring and free painting. After the task assignment was completed, the researchers assisted the participants put on the VR equipment, entered the beginner's tutorial, and assisted in teaching the painting operation until participants indicated they were ready for the next step.

In the experimental stage, prior to beginning the painting task, the participants needed to relax and take a few deep breaths. Upon completion of the painting, the participants were instructed to place the work well, and the researchers assisted to take off the VR equipment.

At the conclusion of the experiment, participants completed self-report measurements and flow measurements of post-painting emotional levels, accompanied by feedback interviews.

## 2.5 Control Conditions

It is noteworthy that some users may experience discomfort while wearing a Virtual Reality Head-Mounted Display (HMD), with common symptoms including nausea, vomiting, headaches, and eye fatigue. These symptoms, induced by the virtual reality environment, are collectively referred to as Cyber Sickness (CS). The duration of exposure to the VR space is a primary factor inducing CS symptoms. The longer the user is in the VR space, the more likely they are to experience CS symptoms. According to relevant research, participants need more than 15 minutes to truly appreciate the essence of flat mandala painting activities. Therefore, in the process of designing the intervention plan, we considered the mechanism of action of flat mandala painting, the feelings of pre-experimental participants, and other related studies, ultimately limiting the time for each painting task to between 10-20 minutes, striving to find a balance between the depth of painting immersion and user experience.

## 2.6 Experimental measurements

**Emotional level measurement.** The study took advantage of the Positive Affect and Negative Affect Scale (PANAS), which set 10 words to describe positive emotions and 10 words to describe negative emotions correspondingly to assess participants' feelings, on a scale from 1 to 5 to indicate how intensely they felt each emotion, with 1 being very mild or none at all and 5 being extremely intense.

**Flow measurement.** This study employed the Flow State Scale, and selected the 2010 Chinese edition of Liu's localized and simplified "Simplified State Flow Scale," which consists of nine questions corresponding to nine flow characteristics: clear goals and rewards, the balance of challenges and skills, immediate feedback, integration of action and awareness, focus on tasks, sense of control, loss of self-awareness, distortion of time, and self-purpose experience, which is adopted to assess participants' flow levels and on a 5-point scale, participants rate their level of emotion in each dimension.

**Heart Rate Measurement.** In this study, EZON's Bluetooth optical heart rate band was utilized to collect the real-time heart rate of the participants. As an essential physiological indicator of the human body, heart rate can accurately reflect the individual's emotional state.

**Statistical Methods.** Collate and enter data into SPSS26.0 statistical software for descriptive statistics and ANOVA.

### 3 Results

#### 3.1 Subjective Evaluation Indicators

**User Sentiment Values.** Taking the painting task with distinct levels of cognitive need as the independent variable and the PA and NA values as the dependent variables, the user sentiment values comparing before and after the painting task, and the descriptive statistics yielded the following results: (refer to Table 2).

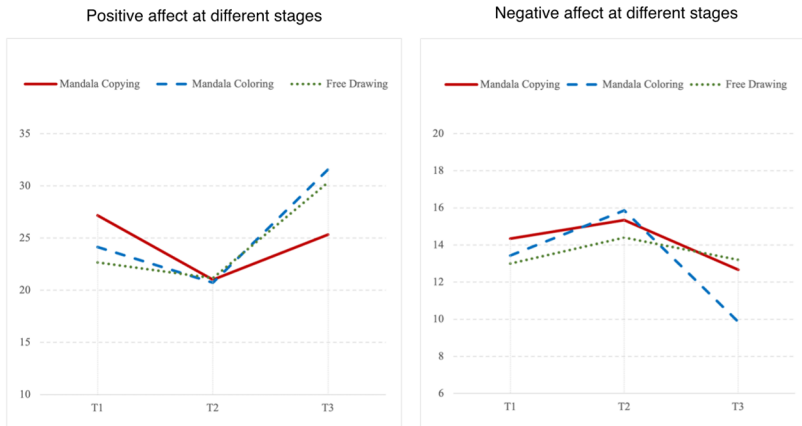
**Table 2.** Effects of mandala painting tasks at distinct levels of cognitive need on users' emotional states (PA, NA).

|                 |                  | Pretest |      | Posttest |      | n |
|-----------------|------------------|---------|------|----------|------|---|
|                 |                  | M       | SD   | M        | SD   |   |
| Positive Affect | Mandala Copying  | 21.00   | 7.59 | 25.33    | 8.34 | 6 |
|                 | Mandala Coloring | 21.33   | 6.74 | 31.17    | 4.22 | 6 |
|                 | Free Drawing     | 21.17   | 7.81 | 30.33    | 4.76 | 6 |
|                 | Total            | 21.17   | 6.95 | 28.94    | 6.27 | 6 |
| Negative Affect | Mandala Copying  | 15.33   | 3.83 | 12.67    | 4.97 | 6 |
|                 | Mandala Coloring | 15.67   | 7.71 | 9.67     | 1.63 | 6 |
|                 | Free Drawing     | 15.33   | 5.01 | 12.50    | 4.72 | 6 |
|                 | Total            | 15.44   | 5.40 | 11.61    | 4.08 | 6 |

Regarding the effect of painting tasks with distinct levels of cognitive need on users' positive emotions (PA), the mandala copying group  $t=-4.282$  and significance  $p=0.007$  met the one-sample t-test. Besides, the mandala coloring group  $t=-4.301$  and significance  $p=0.008$  satisfies the one-sample t-test; the free painting group  $t=-2.760$  and significance  $p=0.040$  satisfies the one-sample t-test.

Regarding the effect of painting tasks with distinct levels of cognitive need on users' negative emotions (NA), the mandala copying group  $t=1.195$  and significance  $p=0.286$  did not meet the one-sample t-test. Moreover, the mandala coloring group  $t=2.139$  and significance  $p=0.085$  did not satisfy the t-test for a single sample; the free painting group  $t=1.488$  and significance  $p=0.197$  did not satisfy the one-sample t-test.

During the experiment, three-time points were set to measure the user's emotional state based on the task stage, namely: baseline measurement T1, stress-induced T2, task completion T3, as well as the changes of positive emotions and negative emotions in distinct task stages, was recorded as follows (refer to Figure 1a and Figure 1b, respectively).



**Fig. 1.** The effect of mandala painting tasks with distinct cognitive need levels on user sentiment in VR space

According to statistics, the PANAS scale used in this study was cloned back  $\alpha=0.898$ , which had high reliability. The significance of the Bartlett sphericity test was less than 0.01, and the validity of this test was high.

**User Flow Manifestations.** Taking painting tasks with distinct levels of cognitive need as independent variables and user flow performance as the dependent variable, the flow evaluation results of distinct painting tasks were compared, and the descriptive statistics yielded the following results: (refer to Table 3).

**Table 3.** Flow experience evaluation of mandala painting tasks at distinct levels of cognitive need

|                     | Copying |      | Coloring |      | Free Drawing |      | n  |
|---------------------|---------|------|----------|------|--------------|------|----|
|                     | M       | SD   | M        | SD   | M            | SD   |    |
| Flow Antecedent     | 13.00   | 1.15 | 12.67    | 2.43 | 10.00        | 1.73 | 18 |
| Flow Characteristic | 13.50   | 1.26 | 13.83    | 1.07 | 12.83        | 1.46 | 18 |
| Flow Consequence    | 11.67   | 1.25 | 14.00    | 1.15 | 12.50        | 2.57 | 18 |
| Overall flow        | 38.17   | 3.02 | 40.50    | 4.43 | 35.33        | 5.56 | 18 |

Based on statistics, the clonal Bach  $\alpha=0.820$  of the flow questionnaire used in this study has high reliability. Besides, the results of this test were KMO=0.672, the significance of the Bartlett sphericity test was  $<0.01$ , and the validity was high.

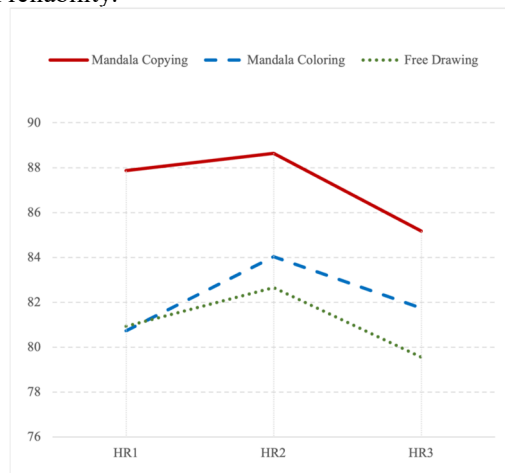
### 3.2 Objective physiological data

Taking the painting task with distinct levels of cognitive need as the independent variable and the average heart rate of the user as the dependent variable, the following are the descriptive statistical results: (refer to Table 4).

**Table 4.** Effects of mandala painting tasks at distinct levels of cognitive need on user heart rate

|                  | Pretest |      | Posttest |       | n |
|------------------|---------|------|----------|-------|---|
|                  | M       | SD   | M        | SD    |   |
| Mandala Copying  | 83.19   | 6.24 | 85.18    | 11.74 | 6 |
| Mandala Coloring | 79.07   | 8.37 | 80.13    | 9.07  | 6 |
| Free Drawing     | 81.2    | 7.29 | 80.47    | 8.83  | 6 |
| Total            | 82.82   | 7.98 | 81.93    | 9.66  | 6 |

During the experiment, three time periods were set to measure the user's heart rate, namely: emotion-induced HR1, task HR2, and task completion HR3, and the user's heart rate changes in distinct periods were recorded as follows (see Figure 2). Based on statistics, the card meter clonal bach  $\alpha=0.827$  of the cardiac flow table utilized in this study has high reliability.

**Fig. 2.** Heart rate recording at distinct stages (unit: bpm)

## 4 Discussion

The psychological healing effect of mandala pattern drawing in the plane has been verified by a large number of practices for a considerable amount of time. In this study, the mandala pattern was given a three-dimensional presentation in VR space to determine whether its psychological healing effect can be extended to the three-dimensional virtual space. In terms of results, the mood of the mandala group improved significantly.

#### **4.1 Mandala Paintings in Virtual Reality Spaces Have an Emotional Healing Effect**

The results from the PANAS scale indicate that in terms of positive emotions, all groups showed a significant increase after completing the designated painting tasks in VR space; in terms of negative emotions, all groups exhibited a noticeable decline.

From the perspective of flow theory, groups with mandalas as the object of creation have better conditions for inducing flow, with these groups having moderate difficulty, clear goals and rewards, and fast task feedback, while participants in the free painting group are more likely to feel confused and frustrated. All groups reported that the VR space painting activities provided them with a good sense of immersion. Through the organization of subjective reports, participants unanimously recognized the emotional improvement effects of VR painting activities with mandalas as the object of creation.

Looking at the heart rate statistics at various stages, all groups experienced an acceleration of heart rate while performing painting tasks in VR space, and the heart rate returned to a stable level after the task was completed. Regarding the reason for the acceleration of heart rate, combined with relevant interview records, it is known that at the beginning of the task, participants generally expressed anticipation and curiosity about the unfamiliar VR space. During the task execution phase, their anticipatory emotions transformed into feelings of novelty and excitement, leading to an acceleration of heart rate. Until the task completion phase, participants were able to temporarily disconnect from real-life pressures during the VR space painting activities, resulting in a slowdown of heart rate. At the physiological data level, the emotional improvement effects of VR painting activities were further verified.

Combining self-report scales with physiological data results, the therapeutic effects of the psychotherapy program combining mandala painting healing with VR technology have been validated. The success of VR technology in the field of painting therapy can be explained by the way VR technology is implemented. In many psychotherapy practices, the environment has always been an important influencing factor: quiet and serene environments can calm behavior and reduce emotional fluctuations and conflicts. VR technology helps users detach from real life visually and auditorily, creating an ideal solitary environment for them, which helps to exclude external distractions and become more immersed in the act of painting therapy itself. With the maturation of VR technology, this sense of immersion will become even more intense.

#### **4.2 Mandala Painting has a Healing Effect in a Virtual Reality Space**

After in-depth consideration of the PANAS scale, cardiac flow meter, and average heart rate before and after the intervention, we can investigate whether hypothesis H2 can be true, i.e., how the healing effect of the mandala coloring group manifests in three distinct painting tasks.

Regarding the 20 feelings covered by the PANAS scale, the mandala coloring group performed well in helping their participants improve their emotions. In terms of

positive emotions, the performance of the mandala coloring group was able to arouse participants' positive emotions to a considerable extent. In terms of negative emotions, the decrease in the mandala coloring group was less noticeable.

From the perspective of flow, the mandala coloring group received high evaluations in the conditions, experiences, and outcomes of flow. Regarding the conditions for initiating the flow state, task difficulty is the primary factor, determining the degree of freedom and the timeliness of feedback in the task. The mandala copying group was considered to have a lower difficulty level, the mandala coloring had a moderate difficulty level, and the free painting group was considered to have the highest difficulty level, validating the task difficulty settings established by this study based on observational learning theory. For participants who are trying to paint in VR space for the first time, tasks with lower difficulty, clear goals, and rewards are more likely to induce a flow state. Regarding the process feelings of the flow state, the task design of coloring group showed better smoothness. Regarding the outcome of the flow state, the mandala coloring task received a near-perfect score, indicating that this group of tasks could bring a deep immersive experience to participants, making them feel a temporary loss of self-awareness in real life.

Supplemented by heart rate data at each painting stage, comparing the three stages of emotion induction (HR1), during the task (HR2), and post-painting interview (HR3), it was found that the mandala coloring task not only stimulated the participants' excitement but also effectively alleviated their tension. During the HR2 period, all groups showed an acceleration of heart rate, with the mandala copying group having the most significant increase; during the HR3 period, all groups showed a slow-down of heart rate, with the mandala coloring group having the most significant decrease; comparing the HR1 and HR3 periods, it was concluded that after the painting task in VR space, the heart rate of the coloring group became the most stable.

Among the three groups, the overall heart rate change of the free painting group was less noticeable, possibly because the creative act itself brought a certain level of executive and emotional pressure. For participants who have not yet been exposed to VR space, it is easy to have thoughts of self-doubt when facing this task.

Overall, across multiple evaluation dimensions, the mandala coloring task showed a significant improvement in emotions, leading to the conclusion that Hypothesis H2 is valid.

## 5 Conclusion

After years of technological development and application, the virtual reality market is now open to the general public. Despite the fact that the application scenario is still game-based, from the perspective of user experience, virtual reality technology can enable us to expand our design horizons in other domains. In the field of psychological healing, this study attempts to combine virtual reality technology with existing healing programs, verifying the therapeutic value and feasibility of VR painting activities. In future research, further exploration can be conducted regarding the characteristics of virtual reality spaces and their therapeutic effects, such as: how the therapeutic

tic effects of virtual spaces compare to those of real spaces; whether the deep immersion experience presented by virtual reality helps to enhance the therapeutic effects of healing activities in virtual spaces.

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