

An Experimental Study of the Relationship Between Healing and Environmental Design Factor Characteristics of Children with Autism under Virtual Reality Technology

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Abstract. The study explores the correlation between features of environmental design and healing in autistic children between the ages of 8-12 with an ABC score of 53 or higher. Sensory experiments were conducted through virtual technology. The investigation has demonstrated that the green color of the environmental design factor was more effective in promoting healing. A white light source provided comfort across various design factors of the lighting environment. Considering the link between healing properties observed in autistic children and the attributes of environmental design, we developed a healing model of visual perception scenes. This model serves as a foundation for the investigation of suitable healing spaces for individuals with autism.

Keywords: Children with autism; virtual reality technology; environmental design factors; healing.

1. Introduction

1.1 Background of the study on the healing properties of environmental design factors for children with autism

According to a 2019 study titled "China Autism Education and Rehabilitation Industry Development Status Report III," there are over 10 million people in China on the autism spectrum, with over 2 million of them being children. This number is growing at a rate of 10% to 15% annually. Unfortunately, most of these individuals will be unable to be cured for the duration of their lives [1]. As the number of autistic individuals in China continues to increase annually, creating a comfortable healing environment for autistic children has become a pressing societal concern. German physiologist Helmholtz suggested that people experience exquisite visual enjoyment from harmonious and beautiful colors. On the other hand, chaotic and disorderly colors often lead to visual fatigue and negative impact on human emotions [2]. Color is a crucial design element in environmental design. Autistic children's healing is influenced by environmental factors, and they exhibit heightened sensitivity to color perception, unlike typical children (Cao Shuqin, 2012 [3]; Ma Xinrong, 2012 [4]; Zhao Yuwan, Zhang Bingchen, and Li Chuang, 2020 [5]). The hue of light can stimulate the vision of autistic children and cause fatigue and irritability in uncomfortable light-intensity environments (Colman R S, Frankel F, Freeman E R J, 1976 [6]; Yang Jian, Zheng Jianhong, Li Jibo, 2021 [7]; Chen Libin, Guo Jing, and Xu Zhao, 2019 [8]).

Thus, it is imperative that autistic children have the opportunity to select the colors and light tones incorporated in the environmental design. By doing so, an appropriate healing perceptual rehabilitation environment can be created [9]. Independent selection of comfortable environmental design features is recommended for best results. However, research and analysis suggest that environmental color design for autistic children in China is inadequate. There are limited visual perception environment designs that cater to the healing effect of autistic children. The experimental study analyzed the correlation between the environmental design elements of color and light and the healing traits of autistic children. Comfort design factors were scientifically analyzed using the experimental data. The resultant design principles were utilized to optimize the selection of environmental design factors in high-frequency healing perceptual environments.

1.2 A study on the application of virtual technology in the rehabilitation of children with autism

Virtual reality is a technology that incorporates computer, electronic information, and simulation technologies. Its primary application entails a computer simulation of a virtual environment, which elicits a sense of immersion within the environment [10]. The virtual reality world allows users to experience the most realistic sensations and simulate domain effects. It possesses a certain level of authenticity that enables people to experience immersion, compared to the real world. Virtual reality technology has the same perceptual functions as humans, including hearing, vision, touch, taste, smell, and other sensory system. With its advanced simulation system, it enables human-computer interaction, allowing users to obtain accurate feedback on the environment during operation.

The use of virtual reality technology in the design of rehabilitation environments for children with autism was first proposed and utilized by foreign scholars. Jorge Fernández Herrero et al. (2019) submitted a design and application of immersive virtual reality, incorporating multisensory and interactive features, using head-mounted displays (HMD). This technology can assist in training social and emotional disorders in autistic children. Immersive virtual reality is an effective educational tool for improving the social skills of children with autism [11]. While domestic exposure to the technology has been relatively late compared to foreign countries, it gradually began to rise in China in the 1990s. While domestic exposure to the technology has been relatively late compared to foreign countries, it gradually began to rise in China in the 1990s. Since then, domestic scholars have extensively studied the use of virtual reality in rehabilitation interventions for autistic children, and these interventions have shown promising results. Qian (2010) examines how virtual technology has been used by scholars to research social, cognitive, and social skill disorders in autistic children and how this has led to positive results in their rehabilitation interventions [12]. Yujin (2021) proposes that VR interventions are effective in promoting visual-perceptual focus and reducing stereotypical behaviors in children with autism. Virtual technology interventions are more effective than conventional interventions and can develop varied intervention scenarios based on the symptoms of children with autism. Their advantages are evident [13].

Amidst the current trend of scientific and technological development and informatization, virtual reality technology is experiencing a rise in demand and has emerged as a critical player in the fields of education, medicine, and design. It has become a distinct field of science and technology, having broken away from traditional innovation patterns, thereby stimulating the thinking and potential of creators. Practically, virtual technology is not limited by spatial constraints. Virtual reality technology can effectively replicate natural environments and utilize human sensory capabilities [14]. Due to the sensory sensitivity that autistic children possess, which differs from that of neurotypical individuals, there has been a gradual increase in research investigating the use of this technology as part of rehabilitation interventions for autistic children.

2. Methods

2.1 Participants

Autistic children's poor ability to adapt to the outside environment is an outcome of their unique physiological and behavioral characteristics, leading to their dependence on familiar individuals and surroundings. Any changes in these factors can result in anxiety [15]. Hence, the institutions where the subjects are residing will serve as the ideal location for conducting this experiment. The selection of experimental subjects follows the principle of voluntariness, and preference is given to students familiar with the experiment. To prepare autistic children for the investigation, appropriate environmental design factors are used to familiarize them with the procedure and environment prior to the experiment. For children with lower ability, special education teachers can adjust their approach to the experiment and work with them to provide clear instructions. This will ensure the investigation runs smoothly and the data collected is accurate.

Relevant experimental studies involving autistic children both domestically and internationally have screened subjects between the ages of 4-16 who received a diagnosis of autism at a hospital. Autistic children aged between 8 and 12 years old were chosen as participants for the study from the Wuhan Wonderful Home Family Support Center for the Mentally Handicapped and Wuhan Snail Home Service Center for the Mentally Handicapped. The participants were diagnosed with autism in the hospitals and had previously completed the Autism Rating Scale (ABC), with scores of ≥ 53 points. Those with IQs below 70 were excluded from the study. The children involved in this exploratory research were given a clear explanation of the experimental procedures by the coordinating special education teachers prior to the commencement of the study.

2.2 Experimental materials

The materials used before the experiment consisted of the VIVE PRO EYE virtual reality technology device, comprising the Vive headset, Vive joystick, streaming box and laser localizer (Figure 1). The design session will entail designing the environment for the various experimental factors in Sketch Up, followed by processing in UE4 and using a head-mounted display device to experience an immersive virtual scene. Technical abbreviations will be clarified upon first use. Finally, the experiment was recorded using camera equipment to capture both the process and the subjects' behavioral performance.



Figure 1. Virtual reality technology (VR) equipment schematic diagram source: network

The healing and environmental color design factor experiment for children with autism mainly used the standard chromatographic principle to make seven different color elements of red, orange, yellow, green, cyan, blue, and purple according to the change of warmth and brightness [16]. The objects were created to be of identical size and placed in the same setting. The colors that best suited the subjects were designated with corresponding numbers for comparison and selection. The experiment was set up as a three-to-one design which included a participant, operator and recorder. Participants were selected based on identical color elements during the study and were then randomly assigned to two groups: one group wore virtual reality glasses before and after the experiment, while the control group data was recorded twice consecutively. In contrast, the study on the impact of healing and environmental light design factors on children with autism emphasized the importance of using indoor elements in a rational manner to produce differing light spectrums such as white, blue, and warm lights. Each kind of light is also presented in the scene with the same size. According to the three light element options, participants selected the most comfortable option and evaluated the changes before and after wearing virtual reality glasses. The resulting data was analyzed for both groups.

Regarding the experimental design aspect of the virtual scene for visual perception in the rehabilitation of autistic children, after conducting sensory experiments and identifying relevant environmental design factors for the subjects, the procedure then involves calculating and summarizing the color and light elements that promote comfort for the children with autism. Through the integration of the design research and analysis, the different modular visual spatial scenes are

constructed. Virtual technology enables autistic children to have authentic experiences and helps them carry out sensory training.

2.3 Experimental procedures

The study investigated the relationship between characteristics of the physical environment and healing among children with autism. A hierarchical ranking method was used with the primary investigator conducting individual interviews for 5-10 minutes to establish a rapport with the participants before the formal experiment. The participants were also familiarized with the corresponding experimental procedures to ensure the smooth implementation of the investigation. To prevent any issues arising, the formal experiment was carried out with the principal subject and one other participant in a quiet room. Data were collected in two ways: with and without the device. A group of color blocks were presented, and the subject's micro-expressions were observed throughout the experiment. Participants were instructed to select their preferred colors from seven color blocks displayed on the screen. The color names were either directly stated or pointed to with a finger. After the first choice was made, participants were asked to select another favorite from the remaining six colors, and so on, until all options had been chosen. Once a participant completed their selections, the next participant began the task, and the above steps were repeated. The primary researcher objectively recorded and analyzed all colors based on degrees of preference. Following the selection of a group of color experiments, the subsequent group of light experiments replaced them. These light experiments were also conducted following the aforementioned experimental procedures. Finally, the frequency of color and light selection during the investigation was analyzed, evaluated and integrated. Furthermore, comfort design factors for autistic children were adequately utilized to develop a virtual visual perception scene for their rehabilitation, providing an entirely new therapeutic experience in the rehabilitative spatial environment.

2.4 Data analysis

SPSS 12.0 was used to conduct statistical analysis and gather data from sensory experiments with autistic children, utilizing a score recording approach. The subjects were given corresponding scores based on their selected results from various environmental design factors in order to identify the distinctive correlation between autistic children and related environmental design factors. The experiment utilized a research method that involved photographing and video-recording throughout the procedure. The objective scientific data collected was analyzed for the healing assessment. Comfort was a crucial factor in the experimental design and was implemented in virtual environmental scenarios aimed towards the rehabilitation and healing perceptions of autistic children.

3. Experimental results and design applications

3.1 Relationship between the healing of children with autism and the characteristics of environmental design factors

When designing interior spaces, various environmental factors can be utilized to create a conducive healing environment. According to the design cases of autistic children's rehabilitation space, it is necessary to fully understand the sensory characteristics of autistic children and meet the actual needs of autistic children to design a suitable rehabilitation space environment for them [17]. For the design of interior spaces, smell and taste are of lesser relevance and difficult to control. Consequently, this experiment primarily employs the perceptual element of vision, resulting from the human eye's direct response to light and being the most representative sensory system among the five senses. Some children exhibit greater sensitivity to vision, even adding exceptional processing components to visual perception [18]. Thus, the implementation of the program design should consider the relevant characteristics of children with autism. Specifically, the focus should be on the two spatial visual elements of color and light. Two experimental groups were established, and

changes before and after wearing virtual glasses in each group were analyzed to identify appropriate indoor environmental design factors for children with autism.

(1) VR Experiment 1: Healing and environmental color design factors for children with autism

The color itself has the potential to heal and enhance children's vision due to its unique and stimulating properties. This may result in positive impacts on their physical and mental development. When exposed to various colors in an indoor spatial environment, children's visual perception of surrounding colors can gradually improve. Properly designed color environments may lead to an excellent emotional state [19]. Overly intricate colors can hinder the visual perception of autistic children, which is not favorable for their recovery. The main objective of the color element experiment is to investigate the distinctive correlation between the recovery of autistic children and the factors connected to environmental color design. Identical squares of seven colors were depicted in the same setting, and the participants made their selection (Figure 2). The experimental results were recorded through the oral and physical expressions of autistic children during the study. The data was thoroughly examined, and each color value was evaluated and analyzed to create a strictly data-based conclusion.



Figure 2. VR Experiment 1: Drawing of the experimental protocol for the healing and environmental color design factor for children with autism. Source: self-painted

The experiment comprises red, orange, yellow, green, cyan, blue, and purple as primary color elements. Subjects were then asked to select the first of seven colors, which were subsequently scored in increasing order (1 to 7), and data was collected in two sets, namely: before and after the use of virtual reality devices. The study aims to statistically analyze the results. The study found that when autistic children wore virtual glasses, they gave a higher rating to the healing properties of green when selecting color elements independently. Therefore, when designing the indoor virtual healing environment for autistic children, designers should prioritize green as a key factor in creating a healing perception space. This will ensure a calming and restorative atmosphere for the children.

(2) VR Experiment 2: Healing and environmental lighting design factors for children with autism spectrum disorders

Light may be invisible, but it has a significant impact on people's health. Sufficient light can help people to see objects clearly and further form visual perception, providing a safe living environment. Autistic children are particularly sensitive to the light environment, and therefore, it is essential to consider various index parameters, including brightness, color temperature, color rendering index, and color gamut, when designing indoor lighting. It is crucial to control both the quantity and quality of indoor light to minimize the potential for visual fatigue and damage. The provision meets the requirements of autistic children for physiological light environments, promoting rehabilitation within an optimal indoor light environment. The main objective of the light element experiment is to investigate the correlation between healing and environmental light design factors. Three unique light elements were produced using essential indoor elements and were of the same size for presentation in the scene (Figure 3). The appropriate light elements for children with autism were chosen by comparing their experiences, and the selection process was documented similarly to the color element experiment.



Figure 3. VR Experiment 2: Drawing of the experimental protocol for the exploratory design factor of healing and environmental light for children with autism. Source: self-painted

This experiment uses essential common light elements such as white light, blue light, and warm light. The participants who scored 1, 2, and 3 points respectively were selected to wear virtual reality glasses before and after the recordings for the two groups. The same scoring method from experiment one was used. Experimental data from the spatial light element were recorded based on detection data, with observations of body language for some participants with unclear verbal expressions. The experiments reveal that the autistic children, when wearing virtual technology glasses, experience comfort while independently choosing the white light source. Autistic children are naturally inclined towards light, and the well-ordered guidance of light can enhance their cognitive abilities. As a result, when designing the indoor spatial environment for autistic children, it is important to consider using comfortable white light sources as a factor in facilitating the healing environment.

3.2 Research on the design of healing sensory space for autistic children based on virtual technology

Based on research into indoor rehabilitation spaces for children with autism, some of these spaces offer a safe indoor setting but can also lead to social isolation. To create ideal indoor spaces, designers must consider the actual needs of those who seek outdoor stimulation. Meanwhile, insufficient focus has been dedicated to the physical and behavioral traits of children with autism and the challenges they encounter in their daily lives. To summarize the aforementioned issues, it is imperative to approach the design process from a child with autism's viewpoint whilst abiding by the patient-centered design philosophy. Further, it is necessary to leverage the theory of human factors to grasp the distinctive features of children with autism, along with the minute details of their daily lives, before commencing the design [20]. Through conducting experiments on the relationship between the therapeutic properties of autistic children and environmental design factors, distinct restorative indoor design factors are incorporated into visual scenes in order to scientifically explore suitable restorative perceptual spatial environments for autistic children. This is to ensure an improved quality of life for the children and to subtly assist their rehabilitation treatment.

This scheme focuses on the visual healing perception elements of color and light. The color green, which receives a high score for its therapeutic properties, is selected for extraction. The light source chosen is white, which is found to be comfortable for healing. This scheme is implemented in rehabilitation spaces designed for autistic children. Allowing individuals with autism to wear virtual reality (VR) equipment in a peaceful setting and employing VR technology to create a tactile healing environment provides an immersive experience. When constructing the scene model, the color elements of VR Experiment 1 were utilized to select the environmental aspects of the healing perception rehabilitation space. Green was chosen as the best evaluation of the healing properties of autistic children wearing VR within different color environmental design factors. The culture wall, the wall, and the bookshelf all incorporate comfortable color elements of green. For the lighting design, we selected the light components from VR experiment 2, considering the white light source's comfort and different light environment design factors for autistic children after wearing VR. The design utilized these light elements, including starry sky lights, wall spotlights, and aisle downlights, all formed with the comfort of the white light source as illustrated (Figure 4). It is hoped that through

the simulation of perceptual rehabilitation scenarios, patients will utilize the visual devices to attempt to produce a therapeutic effect on both their visual sensory system and cognitive abilities.

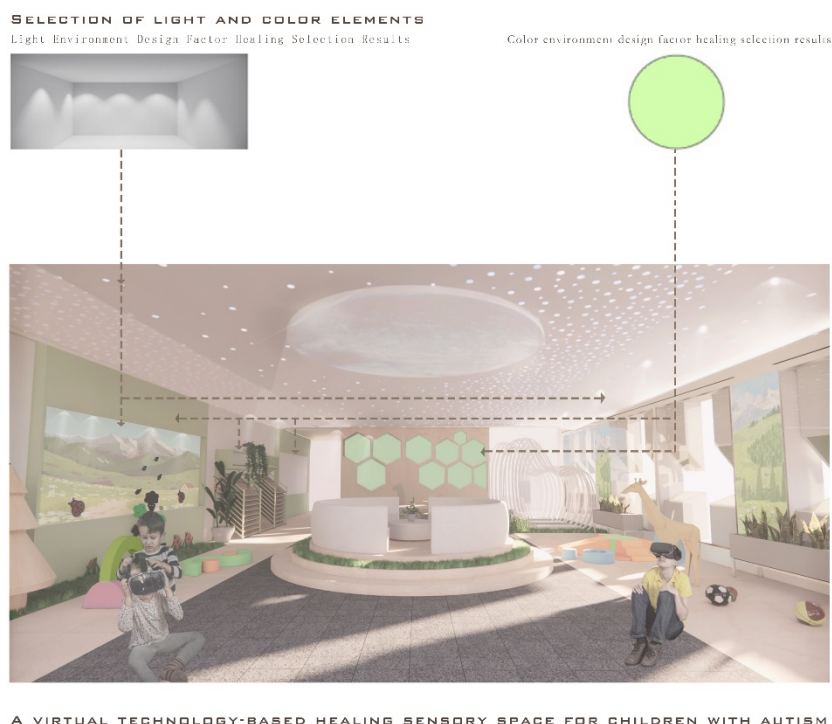


Figure 4. The effect of healing sensory space for autistic children under virtual technology. Source: self-painted

4. Conclusion

From the study examining the correlation between the therapeutic properties of autistic children and environmental design factors, the initial virtual reality (VR) experiment tested the effects of color on healing properties. Specifically, autistic children wearing VR headsets within indoor environments were found to rate green as the most beneficial color choice among other environmental design factors. The second virtual reality (VR) experiment, examining the impact of different light sources on autistic children wearing VR in an indoor environment, demonstrated that a comfortable white light source had a healing effect. Possible underlying reasons for these experimental findings could relate to the unique characteristics of the participants and their underlying brain functioning. When creating a virtual environment for rehabilitating autistic children, environmental design factors and visual sensory experiences cooperate to positively influence the psychology and physiology of autistic children. This results in a stimulating and suitable atmosphere for rehabilitating the children. As virtual technology is advancing rapidly, the research on sensory rehabilitation spaces utilizing this technology for autistic children is still in its infancy. Various technical challenges hinder its development, but the technology's reach is not limited by geography and has a positive impact on both the physical and mental health of the children. Therefore, the research on combining virtual technology and rehabilitation space for autistic children has a broad development prospect.

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