**Journal of Innovation and Development**
ISSN: 2958-4752 | Vol. 8, No. 3, 2024

# An Experimental Study of Virtual Space Design for Emotional Intervention in Autistic Children with Eye Movement Technology

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**Abstract:** In this thesis, virtual technology is combined to study the eye-tracking status of children with Autism Spectrum Disorder (ASD) towards their preference for space. Aided by virtual technology, experimental research is conducted to capture the Eye-tracking data of the subjects, so as to determine their degree of preference for space. A one-week experiment of virtual space preference is performed on ten children with ASD aged 8-14, and the experimental data are collected and organized by the researcher from two parts, namely, eye-tracking data validity and spatial validity. By comparing the experimental data processing, it is figured out that the subjects are more inclined to Space 2 in the experiment, and most of the subjects show a strong interest in Space 2. These results preliminarily indicate that eye-tracking data of children with ASD can serve as a basis for judging their preferences.

**Keywords:** Virtual Reality Technology; children with ASD; emotional healing; eye-tracking.

## 1. Introduction

Autism Spectrum Disorder (ASD) is characterized by social and emotional disorders, as well as repetitive behavioral patterns[1]. As shown by medical evidence, ASD cannot be cured with medication and can only be intervened through various rehabilitation methods at present[2][3]. In this regard, the rehabilitation environment of loneliness has become a concern in the rehabilitation research stage. Research has revealed that the rehabilitation intervention environment for children with ASD can affect their level of intervention participation, and environmental design can be seen as a factor that affects the quality of life and learning of patients with ASD, especially in the educational environment. Changes in the physical environment are closely related to the task participation of children with ASD [4] [5]. Such patients may have differences in processing sensory information and may find certain aspects of the environment unacceptable，resulting in an inability to learn or live normally. Therefore, the rehabilitation environment of autistic patients plays an important role in training[6].

Eye-tracking refers to the tracking of eye movements by measuring the position of the fixation point of the eyes or the relative movement of the eyeball to the head[7]. It has a wide range of applications in research on the visual system, psychology, and cognitive linguistics. At present, eye-tracking technology has also been widely applied in autism rehabilitation research, such as the study of eye-tracking patterns in children with ASD[8].

Virtual Reality, referred to as VR technology, is a high-tech simulation system generated by a computer, which allows users to experience immersive feelings in an interactive three-dimensional environment through equipment. [9]As unveiled in research, due to the immersive nature of virtual technology, in the field of intervention for children with ASD, VR technology can effectively control audio-visual interference. Children can concentrate more in such an environment, and after intervention, they can better transfer the materials learned in the virtual space to the real world[10].

Intervention methods for children with ASD are becoming increasingly diverse, and current research mainly focuses on attention control and social games. For instance, the virtual reality system IVRS can create different emotional stories to exercise the emotional abilities of children with ASD, and use eye-tracking technology to study the Eye-tracking performance and information processing characteristics of children with ASD[11]. In terms of the rehabilitation environment for individuals with ASD, some studies emphasize that changes in perception of sensory stimuli and processing of information from the environment are one of the main issues with ASD [12]. Developing a conceptual sensory design for autism physical learning environments, children with ASD can continue to live with their peers who show typical development in an appropriate learning environment [13].

However, so far, the exploration of the specific relationship between spatial preferences and eye-tracking in children with ASD is still not deep enough. Previous studies mainly focused on individual element preferences of children with ASD, without using eye-tracking technology for in-depth research. Secondly, the research using virtual technology has not started from the spatial environment to specifically explore the relationship between the treatment of autistic children and environmental design, as well as the relationship between eye-tracking technology and the preferences of autistic children[14]. In this connection, to improve the problem on the basis of traditional intervention methods, VR technology is adopted in the study to fill the manpower gap, and use eye-tracking technology to investigate the preferences of children with ASD and conduct specific discussions, which will start with spatial design, using virtual technology to present the design plan to autistic children in the form of 3D simulation, and investigate the relationship between autistic children and the environment.

## 2. Research and Design

### 2.1. Experimental population.

According to the data, the research subjects in the experiment on children with ASD were all patients diagnosed with ASD in hospitals, with ABC scale scores above 70 points, and it was confirmed that the subjects had no intellectual problems[15]. In addition, the subjects were further screened before the study to exclude patients who experienced vertigo in 3D virtual scenes, patients who could not accept optical stimulation, and patients with a history of obvious movement disorders, or neurological disorders or psychiatric symptoms[16].

The questionnaire observation method was adopted to observe children's daily performance, investigate their basic conditions, and understand their emotional expression and emotional regulation abilities. And according to the above requirements, 10 children with ASD from Xianning Rainbow Dream Rehabilitation Hospital were selected. They aged 8-14 years old, with a certain intervention foundation, and were able to understand some simple language expressions, and complete some simple tasks under guidance. In addition, the permission of the parents of the children and the special education teachers of the institution had been obtained, and the experiment was conducted after obtaining the consent of the subjects.

**Table 1.** Subjects' basic information and performance

| participant (in a clinical trial etc) | Gender | (a person's) age | ABC Score | Main obstacles manifested |
|---|---|---|---|---|
| Participant 1 | Male | 10 | 77 | Presence of stereotypical behaviour, repetition of stereotypical speech |
| Participant 2 | Male | 13 | 84 | Speech impediment, poor coordination of limbs |
| Participant 3 | Male | 9 | 90 | Prolonged immersion in one's own world without interaction with others |
| Participant 4 | Female | 9 | 92 | Stereotypical behaviour, poor concentration, inability to perform simple attention tasks |
| Participant 5 | Male | 8 | 96 | Speech impediment, poor co-ordination, fussiness |
| Participant 6 | Male | 8 | 9 | Stereotypical behaviour, likes to go round in circles, treats peers unfavourably |
| Participant 7 | Male | 11 | 101 | Lack of concentration, speech impediment |
| Participant 8 | Male | 8 | 104 | Stereotypical behaviour, emotional outbursts, speech impediments |
| Participant 9 | Male | 8 | 128 | Speech impairment, poor concentration, poor finger coordination |
| Participant 10 | Female | 8 | 133 | Language barriers, not responding to questions from elders or teachers |

### 2.2. Experimental equipment.

The experimental display equipment used in this study is the HTC Vive Pro headset kit, with a binocular resolution of 2880 x 1600, including SteamVR tracking technology, G-sensor calibration, gyro gyroscope, proximity distance sensor, binocular comfort setting (IPD) and other sensors. The equipment kit includes a head mounted display, two controllers, and two locators, which can capture spatial positioning tracking of 5m x 5m; One headset can connect to 4 locators and capture a space of 10m x 10m.


**Figure 1.** VR equipment

## 3. Virtual Space Experiment

### 3.1. Space design

Before creating the space, the experimental group conducted a survey on the environmental and spatial preferences of children with ASD. The main elements in the space were selected and presented to the subjects in a three-dimensional simulation. The subjects were asked to select their favorite environmental elements in two experiments, naked eye and wearing VR glasses. After drawing conclusions, their favorite elements were added to the design

of the space.

Based on the preliminary experimental results of the experimental group, two different forest natural scenes were constructed (as shown in Figure 1), both containing the forest elements that the children with ASD preferred, but with different layout and design of the two scenes.

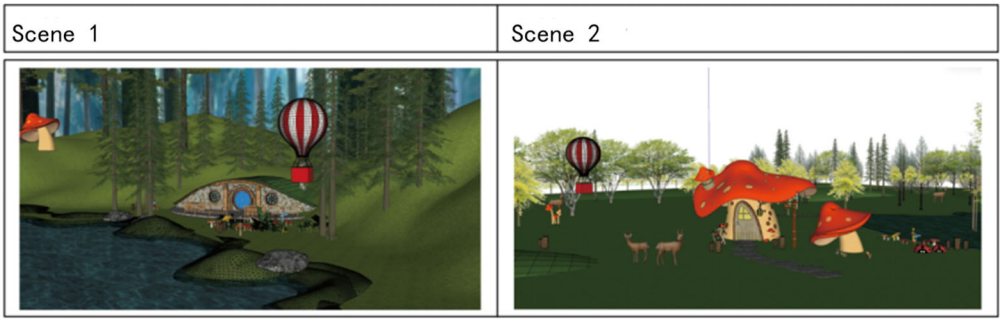


**Figure 2.** Spatial Scene Design

The scene was created in SU and imported into Unity for further processing. Virtual space was mainly based on visual perception, supplemented by auditory perception. The water in the forest was presented in a dynamic form, and the sound of water flow and forest animal calls were added to achieve the most realistic and immersive virtual space experience.

## 3.2. Preference for spatial experimental programs.

In the experiment of spatial eye-tracking preference, the eye-tracking data and spatial preference of subjects in two spaces were mainly investigated into. A total of three experimenters were required for the study, with one responsible for recording the status of the subjects, the second for guiding the subjects through the experiment, and the third for the normal operation of the equipment.

## 3.3. Pre-experimentation

Before the experiment begins, professional experimenters explained the experimental process and objectives to the subjects and calmed their emotions. After the subjects calmed down, they put on physiological wristbands and VR headsets, ensuring that they started the experiment in a calm state. At the beginning of the experiment, two forest natural spaces were presented to the children on the display for 30 seconds, and the subjects needed to observe the two natural spaces within 30 seconds. Meanwhilee, the backend was continuously recording the eye-tracking data of the subjects until 10 subjects completed the experiment.

Data recording of space eye-tracking preference experiment:

(1) Eye-tracking data of subjects during the experimental process included the time of first annotation, fixation frequency, and average fixation time.[17]

(2) Heat maps of subjects' eye movements in two spaces

(3) The entire experimental process was recorded on video to document the status of the subjects.

## 3.4. Space preference experiment results.

According to the above experimental steps, the subjects were guided to complete the experiment, and eye-tracking data of 10 subjects were extracted and subjected to preliminary data analysis. The eye-tracking data of Space 2 of the 10 subjects were all higher than those of Space 1, indicating that the 10 subjects preferred to observe Space 2 and Space 2 was more attractive to the subjects.

**Table 2.** Subject eye movement data

| | Scene 1 M(SD) | Scene 2 M(SD) | t | df |
|---|---|---|---|---|
| Gaze count | 25.56(24.86) | 32.33(23.04) | -0.56 | 8 |
| Gaze duration | 4944.33(5574.90) | 6978.44(5842.92) | -0.724 | 8 |
| Average gaze duration | 171.36(41.69) | 208.93(67.47) | -1.25 | 8 |
| first fixation duration | 6135.67(2428.53) | 11082.44(6116.57) | -3.29 | 8 |

After the experiment, the eye-tracking thermaldynamic chart of the 10 subjects was extracted (see Figure 3). As can be seen from the figure, the eyes of the subjects in the experiment were more concentrated to the right space, and they had a strong interest in the forest scene 2. Among them, subjects 5, 9, and 10 were all more interested in the mushroom house in the middle of the scene, while subject 7 preferred the Forest 1 scene. In the experiment, only a small portion of eye-tracking data was extracted from subject 4, indicating that subject 4 had a shorter fixation duration in both spaces, was not focused, and did not show any particular interest in a particular space.

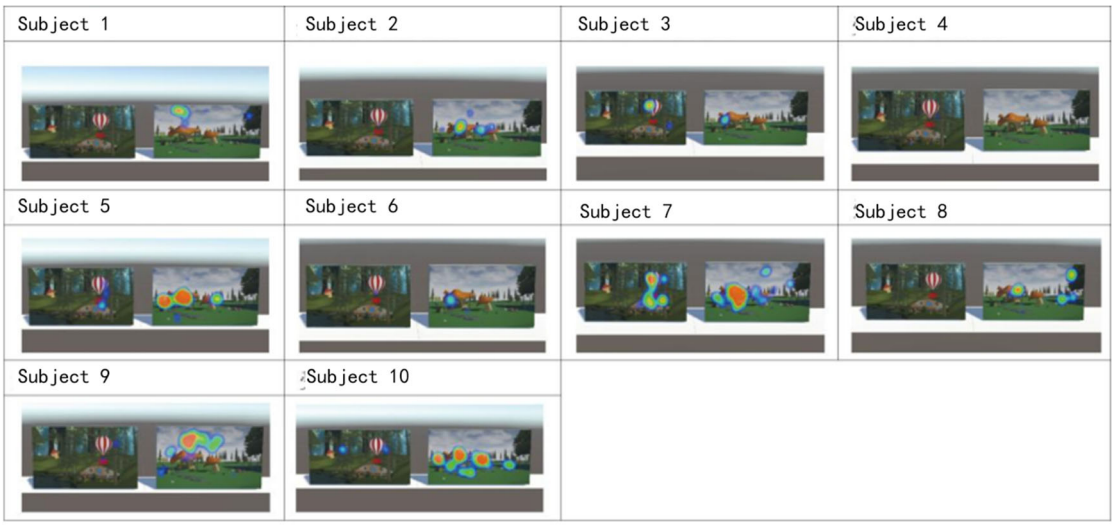


**Figure 3.** Comparison of Subjects' Eye-tracking

From the overall eye-tracking thermaldynamic chart, it can be seen that the subjects observed Space 2 for a longer period of time, and their first fixation in the experiment was also concentrated in Space 2. The longer the fixation time, the more interested the subjects were. Therefore, it is believed that all 10 subjects had a greater liking for the Forest 2 scene during the Eye-tracking experiment stage.

## 4. Conclusion

It is proposed to use VR technology to explore the relationship between autistic children's preferences and eye-tracking. First, two comparable virtual natural spaces were constructed, and suitable subjects were found for the experiment. In the experiment, it was necessary to record the eye-tracking data of the subjects in different spaces and record the entire process. Comparing eye-tracking data with the thermaldynamic chart, it was found that the subjects had a higher preference for Space 2, and most of the subjects in the experiment had a strong desire to explore Space 2. The average fixation duration in Space 2 was much longer than that in Space 1, indicating that the subjects preferred the scenes in Space 2 more.

In groups with ASD, disorders such as emotional disorders and stereotyped behavior seriously lead to behavioral challenges and obstacles in their daily life. If they are not allowed to develop without intervention, these problems will become more and more serious over time. Therefore, rehabilitation intervention for children with ASD is an area that requires more attention. We hope that this study can provide a new reference for the design or research of spatial environment preferences of children with ASD in the future, in order to determine that eye-tracking can be used as one of the criteria for preference selection in children with ASD.Future research could focus more on the design and development of virtual spaces and explore the role of virtual spaces in influencing groups of children with autism. In future experiments, as far as possible, children can be in the virtual space for emotional relief or emotional skills, with the aim of linking the emotional stress of children with autism and emotional management.

Additionally, it should be noted that prior to designing the virtual space, we conducted a survey experiment on the elemental preferences of children with ASD. Therefore, the elemental preferences of children in this study were all derived from the preliminary experiments conducted by our research group.

## Funded Project

Part of the National Social Science and Art Fund Project (Project Name: Research on the Therapeutic Space Design for children with ASD Based on Virtual Technology, Project Number: 20BG128)

Funded by: Hubei Provincial Department of Education Philosophy and Social Science Humanities Project: Research on Rehabilitation Environment Research and Design for Autistic Children in Hubei Province (20Y097).

## Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethic Institutional Review Board of Wuhan Polytechnic University (protocol code BME-2024-1-22 and date of approval 14 September 2024).

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