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Improvement of cognitive function by virtual spatial cognitive training based on spatial cognitive scales and synchronous intensity analysis for EEG signals

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Cognitive impairment is a chronic degenerative disease of the central nervous system that seriously affects the quality of life of patients and places a heavy burden on society and families. Among various intervention methods, cognitive training has been widely applied in studies on cognitive improvement in the elderly because of its standardization, systematization, operability, and few side effects. Computerized cognitive training, introduced in recent years, has been used in intervention studies for various cognitive disorders due to its ease of operation and high therapeutic efficiency. Moreover, numerous studies have shown that immersive virtual reality training can improve spatial ability more effectively than traditional computer-based training. In this study, a spatial cognitive training experiment was designed to explore the effects of immersive virtual reality and 2D computer game training on spatial cognitive ability. Thirteen cognitively healthy elderly individuals were recruited and assigned to either the Virtual Community game experimental group or the 2D Angry Birds game control group. Twenty-eight days of cognitive training, along with five sessions of the Virtual City Walking testing game and assessment using spatial cognitive scales, were conducted to evaluate the training effects of the VR game and the 2D game. The experimental results indicated significant differences in spatial cognitive scales, Phase-Locking Value (PLV), and brain networks based on EEG synchronization intensity in the experimental group before and after training. The findings also confirmed that the virtual reality training game developed in this research could effectively enhance the spatial cognitive abilities of the elderly.

Keywords: *spatial cognition; virtual reality; brain network; phase-locking value.*

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1. Introduction

From 1990 to 2019, the incidence and prevalence of Alzheimer's disease and other dementias increased by 147.95% and 160.84%, respectively [1]. The increasing number of people with dementia is accompanied by increasing care and medical costs. Interventional research on cognitive impairment mainly falls into two categories: pharmacological research and non-pharmacological research. Studies on the efficacy of cognitive impairment improvement drugs have found that drugs cannot significantly improve cognitive function and may even increase drug-related adverse reactions [2, 3]. As a result, there has

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been an increase in research on non-pharmacological therapies for people with cognitive impairment, including cognitive training, cognitive stimulation, aerobic physical exercise, music therapy, and dietary modification. The aim of these studies is to improve the cognitive function and life skills of people with cognitive impairment through non-pharmacological interventions, thereby improving their quality of life [4]. Among them, cognitive training has been widely used in the study of cognitive improvement in the elderly because of its standardization, systematization, operability and few side effects.

Cognitive training refers to the training of different cognitive domains and cognitive processing through various tasks, and the use of cognitive plasticity to improve cognitive function and increase cognitive reserve. Numerous studies have shown that cognitive training can not only improve the cognitive function decline of the elderly [5,6]. Moreover, the improvement in cognitive function through cognitive training can be maintained for up to 5 years [7].

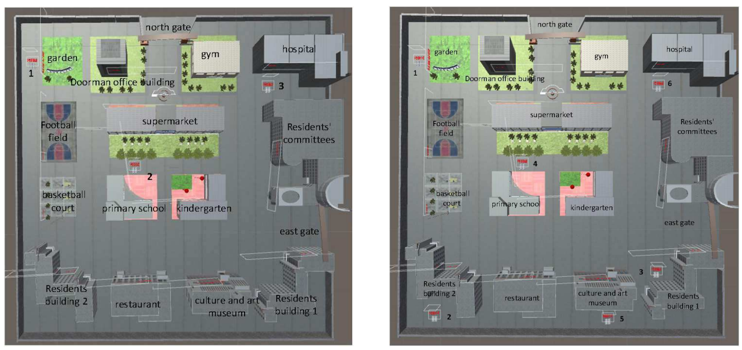
In addition to the traditional 2D computer cognitive training, the development of virtual reality technology in the field of cognitive rehabilitation provides a new method for cognitive training, especially spatial cognitive training. Dang et al. (2023) created realistic virtual scenes and used mobile phone virtual reality to capture real behavioral data [8]. The results showed that people with reconnaissance style were better able to extract information from evacuation maps and use it correctly, and had a better sense of direction and awareness of evacuation scenarios. White et al. (2016) designed a spatial navigation treatment scheme based on the virtual reality environment, which can effectively improve the navigation ability of Alzheimer's patients [9]. Carbonell et al. (2017) combined VR technology with Google Street View to develop virtual city scenes, effectively improving the spatial positioning ability of college students [10]. Yuan (2019) designed a spatial cognitive training and evaluation system integrating brain-computer interface and virtual reality, using the Virtual Morris Water Maze paradigm as a training game to evaluate the effectiveness of training from behavioral data and EEG signals, respectively [11]. Bauer and Andringa (2020) VR may provide a particularly effective tool for spatial cognition training in the elderly [12].

In this research, the effects of immersive virtual reality (VR) training on spatial cognitive ability were studied by using a spatial cognitive training experiment. The effects of virtual reality and two-dimensional computer cognitive training on brain function and structure were evaluated by spatial cognitive scales and studied by using the phase locking value (PLV) to characterize synchronization intensity.

2. Materials and methods

2.1. Training game

Combined with spatial orientation and spatial memory theory, in the experimental group, a training game of Virtual Community was designed to meet the actual living environment of the elderly [13]. The idea was mainly embodied in guiding users to search for multiple target points in the virtual scene according to the sequence. This game placed 16 kinds of virtual buildings in the scene to help users refer to the buildings to locate their position. The user first remembered the relative position of the target points, and then searched for each target point according to the memory in the specified order. Figure 1 shows the radar map of the Virtual Community game.



a (Three target point version) ***b*** (Six target point version)

Fig. 1. Experiment group training game Virtual Community: (***a***) is the version with 3 target points, and 1, 2, and 3 are the locations of target points; (***b***) is the version with 6 target points. Numbers 1, 2, 3, 4, 5, and 6 are the locations of target points.

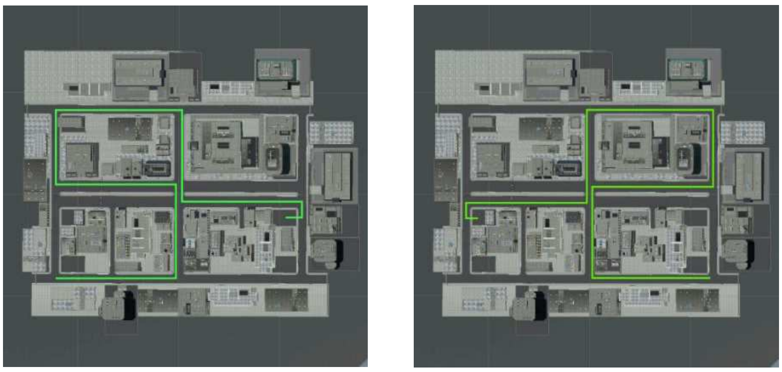
The initial position of the user entering the game and the radar map provided by the game would be changed every time during training. The user needed to remember the map before the game officially started. After the user found the corresponding target point in the specified order, he would find the next target point according to the voice prompt. The upper limit of the game time was set at 15 minutes. To ensure the enthusiasm of the elderly to participate in the game, the experimental group was divided into two different levels of difficulty: "finding three target points" and "finding six target points".

Fig. 2. Control group training game Angry Birds.

In order to verify that the game designed by the experimental group can be used to improve the spatial positioning and spatial memory ability of the elderly, the 2D game Angry Birds, which represents non-spatial cognitive training, was developed as the control game, to ensure that the training of the control group users did not contain any spatial training elements (see Figure 2). The 2D game Angry Birds was played as follows: stretched back the slingshot with the bird, and then launched the bird forward from the slingshot to hit the green pig. When all fat pigs were hit, the user passed this level and entered the next level. In order to ensure the participation and fun of the experiment, the game adopted the mode of multiple levels, and the difficulty of the levels gradually increased. Each game was capped at 15 minutes, with no limit on the number of levels that could be passed.

2.2. Testing game

In order to evaluate the effectiveness of spatial cognitive training, the Virtual City Walking (VCW) game developed by Yuan (2019) was used to evaluate users in the experimental group and control group [11]. As shown in Figure 3, in the learning stage, users roamed in the virtual city according to the defined visible route guidance. Users were required to remember the reference buildings and routes along the way. In the testing phase, the original route was hidden and the user was asked to retrace the learning route from memory. The testing was conducted five times. The training experiment lasted four weeks. The first testing was conducted before the start of the training, and then the second to fifth testing were conducted after each week's training. In order to keep the difficulty of each test consistent, each test route was symmetrized once, as shown in Figure 3.



a (The first, third and fifth testing routes) ***b*** (The second and fourth testing routes)

Fig. 3. Testing game Virtual City Walking: (***a***) and (***b***) in the figure represent the virtual city top view for the test task, where the green line represents the path of the test task.

2.3. Experiment process

Thirteen subjects underwent 28 days of spatial cognitive training tasks in a quiet room in four sessions of seven days each. The experiment process was divided into three stages.

(1) Pre-training test. Before the start of the first session, all subjects were evaluated with the preliminary questionnaire survey, cognitive assessment and spatial cognition scales. They wore an

OpenBCI EEG acquisition device and HTC Vive Focus headset VR glasses to carry out the game test task to test their spatial cognition ability before training.

(2) Training and phased testing. The experimental group and the control group carried out four sessions of training, and one testing task every other session. Among them, in order to ensure the enthusiasm of the elderly to participate, the experimental group was trained to use the "three-point goal" version of the Virtual Community in the first week, and the "six-point goal" version in the last three weeks. The control group was trained to use Angry Birds, and the difficulty of each game was chosen according to their own situation.

(3) Post-training test. At the end of the last session, all subjects were assessed with the spatial cognition scales and tested with the testing game. Then the results of the spatial cognition scales and EEG signals were stored to evaluate the effectiveness of training.

2.4. Data acquisition

The OpenBCI EEG device was used to collect the EEG signals of participants during the experiment. The sampling rate of the device was 125 Hz, and the electrode impedance was less than 10KΩ. Two 8-channel Cyton amplifiers were used to realize the synchronous acquisition of 16-channel EEG signals, and the data was transmitted to the computer through the Bluetooth dongle jack. After reviewing the relevant literature on spatial coding and retrieval using EEG signals [14,15], the most commonly used electrode positions were determined. Sampling electrodes included FP1, FP2, F7, F3, Fz, F4, F8, FCz, C3, Cz, C4, P7, Pz, P8, O1, O2, sample reference electrodes A1 and A2 of the bilateral lobe mastoid process. The position of the sampling electrode is shown in Figure 4. Electrodes are placed according to the international standard lead $10-20$ standard electrode placement method, among which the blue electrode is the sampling electrode in this experiment.

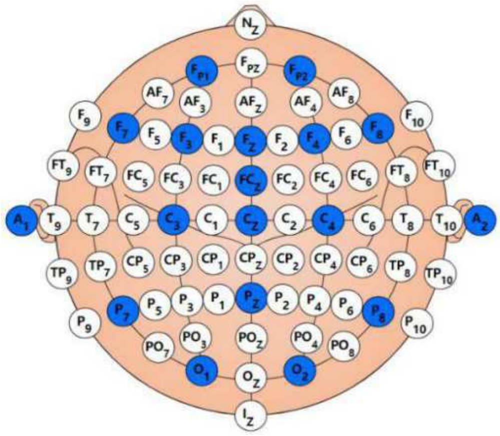


Fig. 4. Location distribution of sampling electrodes.

2.5. EEG preprocessing

In order to ensure the reliability of the data, it is necessary to preprocess the collected EEG signals. In this study, EEGLAB [16] was used to preprocess the EEG signals, mainly including the following steps.

(1) Channel positioning. In order to ensure that independent component analysis (ICA) could estimate the source location of independent components of data, the relative coordinates information of each channel needs to be imported.

(2) Bandpass filtering. A $1-50$ Hz bandpass filter was used to filter out signal attenuation outside the range of this frequency band.

(3) Artifact removal. In order to ensure a high signal-to-noise ratio, it is necessary to remove the motion artifacts, EOG and EMG from EEG. In this study, the independent component analysis plug-in provided by EEGLAB was used to calculate independent components and remove artifacts.

(4) Data segmentation. The key events in the testing game were taken as event markers, and the EEG signals were divided according to one second before and after the event markers. The EEG data of subjects undergoing 5-minute VR testing was sliced with a 2-second window. Here, the waiting data in the early and late stages of the testing game was deleted.

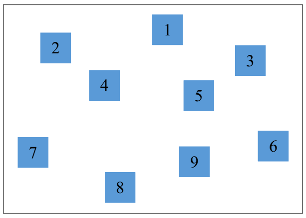
(5) Baseline correction. The purpose is to eliminate the EEG noise caused by spontaneous EEG activity. Usually, the data before 0ms is taken as the baseline. Part of the spontaneous EEG noise can be eliminated by subtracting the average value of each point data before 0 ms from the data after 0 ms.

(6) Extracting frequency band. In this research, the EEG signals were divided into seven frequency bands: Delta (1 − 4 Hz), Theta (4 − 8 Hz), Alphal (8 − 10.5 Hz), Alpha2 (10.5 − 13 Hz), Betal (13 − 20 Hz), Beta2 (20 − 30 Hz), and Gamma (30 − 50 Hz).

2.6. Spatial cognition scales

Before and after the training, the subjects in the experimental group and the control group also need to carry out the spatial cognition scales test, including the CBTT scale, GZSOT scale, and PTSOT scale, within the specified time. The following is a brief introduction to these three spatial cognition scales.

(1) Corsi Block-Tapping Task (CBTT) [17]. The CBTT scale is commonly used to evaluate short-term visuospatial memory in clinics. Figure 5*a* shows a Corsi block test task. Each block was numbered and faced the subjects.



a (Corsi block)

(1) 8-5
(2) 6-4
(3) 4-7-2
(4) 8-1-5
(5) 3-4-1-7
(6) 6-1-5-8
(7) 5-2-1-8-6
(8) 4-2-7-3-1
(9) 3-9-2-4-8-7
(10) 3-7-8-2-9-4
(11) 5-9-1-7-4-2-8
(12) 5-7-9-2-8-4-6
(13) 5-8-1-9-2-6-4-7
(14) 5-9-3-6-7-2-4-3
(15) 5-3-8-7-1-2-4-6-9
(16) 4-2-6-8-1-7-9-3-5

b (The test sequence)

Fig. 5. Test scenario of CBTT scale.

The experiment assistant pointed out the order of the blocks in Figure 5*b* with his finger and then asked the participant to point out all the blocks in the same order. The more order the subjects could point to, the higher the score. The specific score was the product of the question number and the number of numbers in the question.

(2) Guilford-Zimmerman Spatial Orientation Test (GZSOT) [18]. This scale is composed of seven tests. The spatial positioning test was selected as the experimental test. Experimental subjects needed to judge the position change of the ship in the two landscape pictures. There were 60 questions in the test, with one point added for a correct answer and 0.25 points deducted for a wrong answer. Figure 6 shows the experimental scenes during the GZSOT scale test.

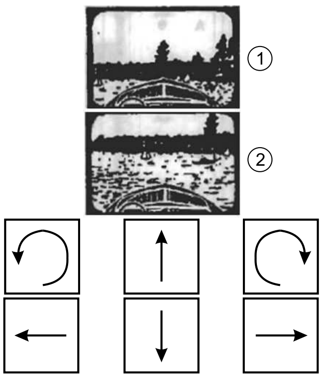


Fig. 6. Test scenario of GZSOT scale: ① presents the first landscape; ② presents the second landscape picture.

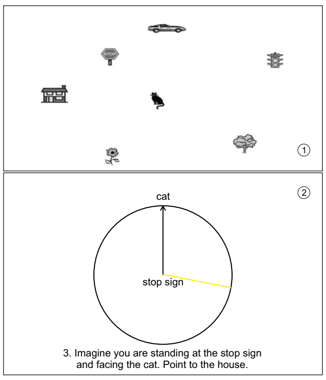


Fig. 7. Test scenario of PTSOT scale.

(3) Perspective Taking Spatial Orientation Test (PTSOT) [19]. The ability of spatial imagination and spatial orientation was tested by PTSOT scale. The subjects need to determine the relative position relationship between objects according to the text prompts. Subjects looked at figure ① and imagined themselves standing next to a stop sign, facing the cat, indicating the location of the house in their relative position. The general direction was indicated by the yellow line in the figure ②. There were 12 questions in the scale, which were required to be completed within 5 minutes and scored as a percentage of the average error. Figure 7 shows the experimental scenes during the PTSOT scale test.

2.7. Brain network based on PLV

Synchronization intensity refers to the degree to which activities between different neurons or groups of neurons in a neural network are coordinated in time. When the activity of neurons is synchronized in some specific frequency range, they may transmit information and coordinate functions more efficiently.

An increase in the intensity of synchronization may lead to an increase in the synchronicity of neuronal activity in the network, while a decrease in the intensity of synchronization may lead to more irregular or unsynchronized activity.

Phase synchronization is a phase-locking phenomenon of different signals in a specific frequency band over a certain period of time. The phase synchronization between neuron groups can promote the integration of information in different brain regions. The concept of PLV was originally proposed to calculate the phase synchronization relationship between two neural electrical signals, and is now used to calculate the phase synchronization relationship between different channels [20]. Here are the steps for the calculation of PLV. First, obtain the phase $\Phi_x(t)$ and $\Phi_y(t)$ of the two signals $x(t)$ and $y(t)$ and compute phase difference $\Delta\Phi(t)$,

$$\Delta\Phi(t) = \Phi_x(t) - \Phi_y(t). \tag{1}$$

Then convert the phase difference into a complex number and calculate the mean of these complex numbers over time,

$$\mathrm{PLV} = \left| \frac{1}{N} \sum_{t=1}^{N} e^{i(\Phi_1(n)-\Phi_2(n))} \right|. \tag{2}$$

In Eq. (2), N is the length of the time point, and the value of PLV ranges from 0 to 1. When the PLV is equal to 0, it indicates no phase synchronization between the two signals; when the PLV value is equal to 1, it means that the two signals are completely phase synchronized.

Brain network analysis is an important method in brain science research. A brain network is defined as a network pattern formed by the integration of cortical regions with different spatial locations in the brain through structural or functional connections [21].

In this study, PLV was used to construct effective brain networks, which describe the synchronization intensity between the nodes. The process of PLV brain network analysis is divided into three steps. (1) Calculate the PLV feature index between brain regions. (2) Convert the connection matrix into a graph. (3) Use graph theory to study the topology of the brain network.

3. Results

3.1. Information about the experimental subjects

With the approval of the Ethics Committee of Qinhuangdao First People's Hospital, China, 13 elderly subjects were recruited in the communities near the hospital by posting posters. Seven subjects participated in the Virtual Community game as members of the experimental group. Six participants played Angry Birds as the control group. According to the preliminary questionnaire survey, 13 subjects who had normal visual acuity or corrected visual acuity, no color blindness, right-handed, without mental illness, and never participated in such spatial memory game training, volunteered to participate. The mean age, the ratio of males to females, and the average education level of the experimental group and that of the control group were calculated in Table 1. Statistical analysis and calculation by SPSS showed that there was no significant difference among the three indexes. At the start of testing and training, the widely used Montreal Cognitive Assessment (MoCA) [22] was administered on the two groups of subjects. The MoCA results showed that two groups of subjects' cognitive functions were normal, and there was no significant difference between groups.

Table 1. Statistics of subjects in control group and experimental group.

Subjects information	The control group	The experimental group	P value
Age (year)	65 ± 2.89	67 ± 6.81	0.460
Gender (male: female)	1 : 5	2 : 5	0.646
Education Level (year)	10.86 ± 3.13	10.5 ± 3.02	0.839
MOCA	24.71 ± 2.56	24.83 ± 1.94	0.670

3.2. Spatial cognition scale analysis

In order to effectively analyze the effectiveness of training, the spatial cognition scales and EEG signals of the experimental group and the control group in the first and last testing were analyzed. Table 2 shows the scores of most used spatial cognitive scales CBTT, GZSOT and PTSOT before and after training for the experimental group and the control group in the form of mean ± standard deviation, and the significance was analyzed by paired-sample t-test. According to Table 2a, the p-values for the three spatial cognition scales were all less than 0.05 in the experimental group before and after training, showing significant differences.

The average score of CBTT increased from 37.14 points before training to 50 points after training, with a large range of improvement. The average GZSOT score increased from 4.86 before the training to 9.89 after the training, with a wide range of change. The average error angle obtained by PTSOT decreased from 35.75 points before training to 19.32 points after training, with a wide range of decrease. Since the scores of CBTT and GZSOT scales were positively correlated with spatial cognitive ability, and the scores of PTSOT scales were negatively correlated with spatial cognitive ability. The experimental subjects showed improved spatial cognitive ability after VR spatial cognitive training.

Table 2. Statistical analysis of spatial cognitive scales before and after training.

(a) Experimental group			
Scale	Before training	After training	P value
CBTT	37.14 ± 16.48	50 ± 6.83	0.048
GZSOT	4.86 ± 5.16	9.89 ± 6.20	0.034
PTSOT	35.75 ± 9.81	19.32 ± 7.72	0.001
(b) Control group			
Scale	Before training	After training	P value
CBTT	36 ± 13.67	37.17 ± 9.79	0.814
GZSOT	9.33 ± 6.12	8.83 ± 5.13	0.397
PTSOT	48.22 ± 21.69	48.84 ± 19.90	0.852

While the P values of the three spatial cognition scales in the control group are all greater than 0.05 before and after training, showing no significant difference (see Table 2b). Thus, through the analysis of the statistical results of the three spatial cognition scales, the experimental group participants' spatial cognitive ability was significantly improved after 28 days of training using the Virtual Community game. The control group, which had the same day of training using the Angry Birds game, had no significant improvement in spatial cognitive ability.

3.3. Comparison of PLV

In addition to the spatial cognitive scales, pre-processed EEG signals were also used for feature extraction by Python. After feature extraction by calculating PLV, the synchronization intensity between electrodes could be obtained. Therefore, the significance of PLV changes before and after training in the experimental group and the control group could be calculated using paired-sample t-test. The following Figure 8 shows the P value of PLV changes in the experimental group and the control group of seven frequency bands before and after the training. Only p-values less than 0.01 are marked in Figure 8 and Table 3.

Table 3. The number of electrode pairs that changed significantly after training for PLV.

Group	Delta	Theta	Alpha1	Alpha2	Beta1	Beta2	Gamma
Experimental group	44	66	78	36	184	164	162
Control group	0	6	44	12	42	74	56

The results in Figure 8 and Table 3 show that at a significance level of 0.01 the significant electrode pairs of PLV in the experimental group before and after training were more than those in the control group in all seven frequency bands. After spatial cognitive training, EEG synchronization intensity for the experimental group had a great change indicating the effect of spatial cognitive training was evident. In particular, the PLV of Beta1, Beta2 and Gamma frequency bands for experimental groups showed significant changes after training, where 184 164 162 electrode pairs of PLV values changed respectively.

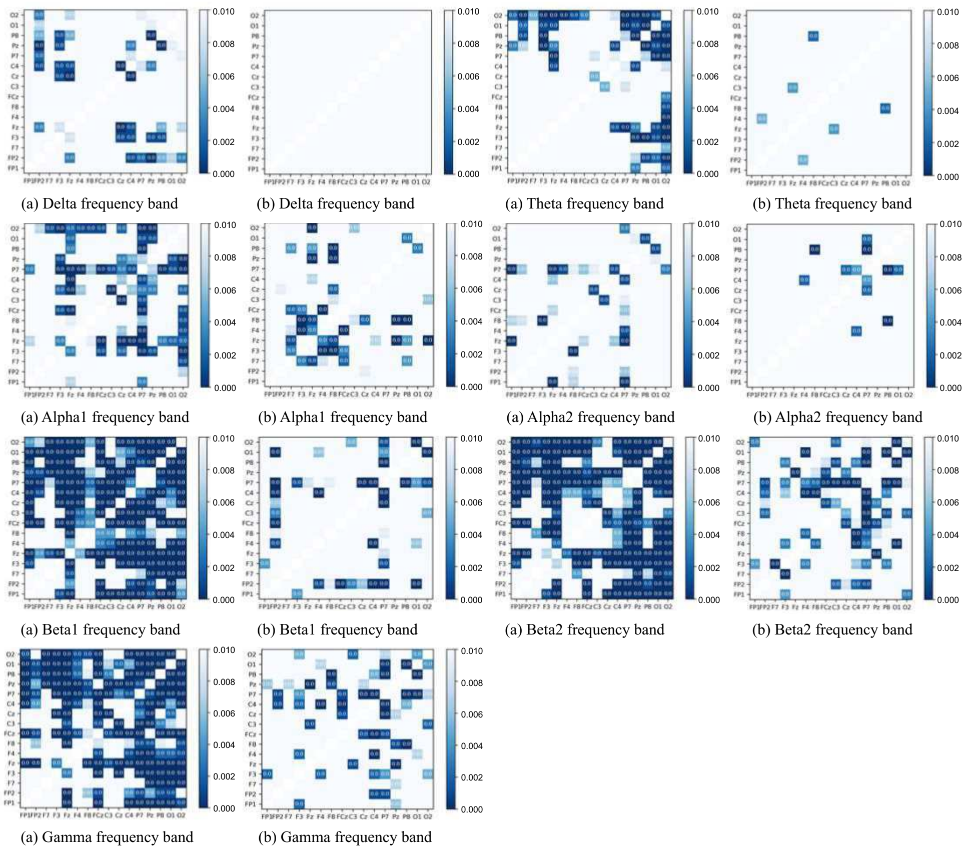


Fig. 8. Thermal maps of PLV values between electrode pairs before and after training in experimental group and control group in seven frequency bands: (***a***) represents the results of the experimental group, (***b***) represents the results of the control group.

3.4. Changes in PLV brain network

In this section, a brain network matrix was built using PLV values in the BrainNet Viewer toolbox of Matlab [23]. BrainNet Viewer is a powerful visualization tool for brain networks. Input 16 electrode coordinates into the node file according to the international standard lead $10-20$ standard electrode placement method. The average increment PLV value was then input after training of the subjects in seven frequency bands for the experimental group and the control group into the edge file. The axial diagram of the brain electrodes could be drawn through the BrainNet Viewer, as shown below. As shown in Figure 9, if the line segment is connected between the electrodes, it indicates that the PLV value of this electrode pair, which is the synchronization intensity, has increased after training. The color of the line segment shows the range of the PLV value increase, with red indicating a large increase and blue indicating a small increase. The specific increase ranges of the PLV values for the experimental group and the control group are shown in the Figure 9.

As can be seen from Figure 9, after training, the experimental group had more electrode pair connections in the brain network maps than the control group, which indicates that the phase locking values of the experimental group for seven frequency bands increase more than those of the control group. In addition, the experimental group has more red electrode pairs connected in each frequency band in the brain network map than the control group, showing that the increase in PLV for the electrode pairs in the experimental group is larger than that of the control group after training. In particular, for the Theta, Beta1, Beta2, and Gamma frequency bands, the PLV increment of the experimental group after training can reach 0.141, 0.186, 0.192 and 0.217. These results indicate that the synchronization intensity of EEG signals has greatly improved after VR spatial cognitive training. In addition, it can be seen from the figure that the synchronization intensity of Fp1, F3 and Fz electrodes increased significantly in seven frequency bands. Therefore, Fp1, F3 and Fz electrodes, which are

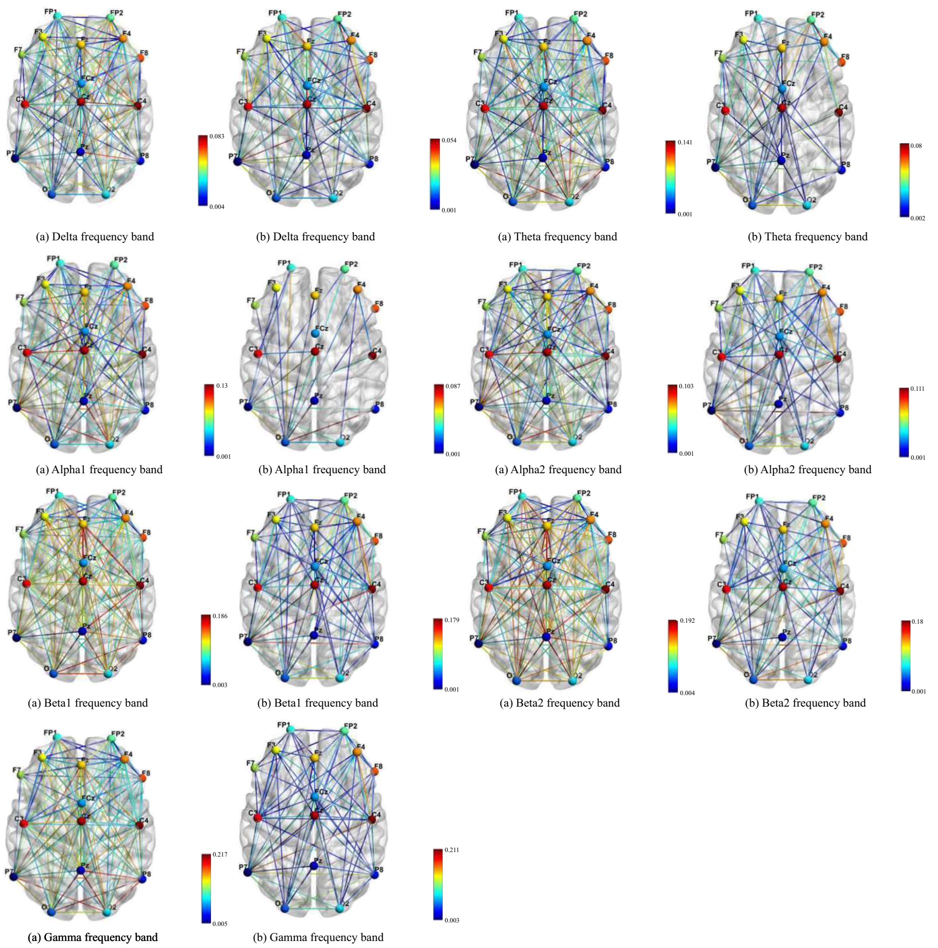


Fig. 9. Brain network maps of increased PLV values after training in experimental group and control group for seven frequency bands: (***a***) represents the results of the experimental group, (***b***) represents the results of the control group.

distributed in the frontal lobe of the brain, are related to spatial cognitive function. Consistent with the literature, the frontal lobe of the brain plays an important role in spatial cognition. Especially the frontal lobe relates to higher cognitive processes such as planning, decision-making, and performing spatial tasks [24].

4. Discussion

In this study, CBTT, GZSOT and PTSOT scales were used to evaluate the spatial cognitive ability of the experimental group and the control group at the early and late stages of training. The results of the paired-sample t-test showed that there was no significant difference in the scores of CBTT, GZSOT and PTSOT in the control group before and after training. But for the experimental group, there were significant differences before and after the training, which was consistent with the results of Wen et al. (2023), which proved that the Virtual Community training game can indeed improve spatial ability [13].

The difference between the experimental group and the control group was analyzed based on the functional brain network of the phase-locking value (PLV). PLV is a method used to study the degree of phase synchronization in EEG signals. Results of the paired-sample t-test showed that the significant electrode pairs of PLV values in the experimental group after training were more than those in the control group in all seven frequency bands. Thus, the virtual community cognitive training may enhance the degree of phase synchronization between different brain regions, leading to an increase in PLV values. This may reflect more efficient coordination and information transfer in brain networks after training [25].

Besides, in the brain network matrix built using PLV values, the experimental group of seven frequency bands had more electrode pair connections in the brain network map than the control group after training. The synchronization intensity values of the experimental group with seven frequency bands increased more than that of the control group, especially for the Theta, Beta1, Beta2 and Gamma frequency bands. These results indicate that the synchronization intensity of EEG signals has been greatly improved after VR spatial cognitive training. These are consistent with the research conclusion of the previous literature [26–28]. Theta wave activity is closely associated with spatial navigation and cognition and involved in information integration and adjustment during memory, orientation and spatial navigation [26]. Beta wave activity is associated with the regulation of attention and working memory in spatial cognition [27]. Gamma wave activity plays an important role in spatial navigation and cognition. During spatial navigation, gamma wave activity may be related to the transmission and synchronization of information between different brain regions [28].

Although only 13 subjects were compared in this paper (the sample size is not large) the robustness of the sample has been tested in the previous paper [13]. The subjects' spatial cognitive ability improved significantly after 28 days of Virtual Community training, indicating that VR spatial cognitive training was effective. In addition, in the past three years, many studies have verified the effectiveness of integrating virtual reality training into cognitive rehabilitation environments from multiple perspectives [29, 30].

Going forward, it will be necessary to recruit more participants to assess its efficacy. In future research, this kind of training could be used to help patients with cognitive impairment for spatial cognitive rehabilitation. And practical applications of integrating virtual reality training into cognitive rehabilitation settings could be considered.

5. Conclusion

In this research, spatial cognitive training experiment was designed to explore the effect of immersive virtual reality and 2D computer game training on spatial cognitive ability. 13 elderly people were recruited to participate in the experiment. Spatial cognition scales and EEG signals were used to evaluate the effectiveness of training. The results showed that the experimental group had significant differences in spatial cognitive scales, PLV values and brain networks based on PLV after training, while the control group did not. The experiment designed in this study can effectively improve the spatial cognitive ability of the elderly. In the future, a VR training game like Virtual Community may be used in the spatial cognitive rehabilitation of patients with cognitive impairment.

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Покращення когнітивних функцій за допомогою віртуального просторового когнітивного тренінгу на основі просторових когнітивних шкал та синхронного аналізу інтенсивності EEG-сигналів

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Когнітивні порушення є хронічним дегенеративним захворюванням центральної нервової системи, що значно погіршує якість життя пацієнтів та створює серйозне навантаження для суспільства та родин. Серед різноманітних методів втручання, когнітивне тренування широко застосовується у дослідженнях покращення когнітивних функцій у літніх людей завдяки його стандартизації, систематичності, операбельності та мінімальній кількості побічних ефектів. Комп'ютеризоване когнітивне тренування, запроваджене в останні роки, використовується у дослідженнях втручання при різних когнітивних розладах через легкість його використання та високу терапевтичну ефективність. Численні дослідження показали, що імерсивне тренування у віртуальній реальності значно ефективніше покращує просторові здібності, ніж традиційне комп'ютерне тренування. У цьому дослідженні було розроблено експеримент з тренування просторового пізнання для вивчення впливу імерсивної віртуальної реальності та 2D комп'ютерних ігор на просторові когнітивні здібності. Було залучено тринадцять літніх людей з нормальним станом здоров'я, яких розділили на експериментальну групу (гра "Virtual Community") та контрольну групу (2D гра "Angry Birds"). Протягом 28 днів проводилося когнітивне тренування, а також п'ять разів тестування за допомогою гри "Virtual City Walking" та скринінг за шкалами просторового пізнання, щоб оцінити ефекти тренування VR-грою та 2D-грою. Експериментальні результати показали, що в експериментальній групі спостерігалися значні відмінності за шкалами просторового пізнання, значенням фазової синхронізації (PLV) та мозковими мережами, заснованими на інтенсивності синхронізації, до та після тренування. Результати також підтвердили, що тренувальна гра у віртуальній реальності, використана в цьому дослідженні, може ефективно покращувати просторові когнітивні здібності літніх людей.

Ключові слова: *просторове пізнання; віртуальна реальність; мозкова мережа; значення фазової синхронізації.*