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A Study on the Coherence Change of the Frontal Lobe Brainwave– Learning Heart Anatomy with VR

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Abstract:
***Background**: Interactive technology applications are developing rapidly, and the advancement of 3D virtual reality (VR) technology has also produced many innovative applications. However, this kind of interactive information is mostly used for entertainment, and its application in teaching is still to be developed. The impact of these virtual three-dimensional images on learners still needs to be explored. The learning responses of people with different sensory information processing characteristics also need to be understood. Considering the above factors, we can design a more suitable teaching material.*
***Materials and Methods**: A set of 3D VR cardiac physiology teaching materials were designed through the cloud-based online physiological system software. Under the same study preparation, the subjects used 3D VR software to study the heart physiological anatomy unit. The study time for each part was limited to 10 minutes, and the demonstration and practice lasted for 4 weeks. Take the test immediately after completing the learning cycle, and record the brain wave changes with the EEG brain wave meter.*
***Results**: The results of the study are as follows: Those with a preference for visual information have the least cohomology relationship between the left and right frontal lobes. The auditory information preference subjects have the most coherent relationship between the left and right brain connections. Kinaesthetic information preference, text information preference and multi-information preference are very similar to the cohomology relationship between the left and right frontal lobe and frontal lobe.*
***Conclusion:** 3D VR teaching materials should be presented in multiple ways. Learners with different information preferences give different content, and web links use multiple information methods. The interactive content presentation with text, images, and 3D VR meets the needs of different information processing learners.*
***Key Word**: **Coherence**; **3D Virtual Reality**; **Frontal Lobe**; **Heart Anatomy**.*

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I. Introduction

Experiential learning is the process of creating knowledge through experience transformation, and the experience generated during the learning process will be internalized and transformed into knowledge by the learner. Traditional physiology study textbooks are mostly based on 2D images, and the real world is presented in a 3D space. Are there any shortcomings in presenting three-dimensional information with flat information? It is just like the chemical reaction of Thalidomide to physiology more than 50 years ago. If the structure of the carbon atoms in the molecule can be presented in three dimensions, it is possible to recognize the different chemical reactions in advance and avoid the loss of life and property by understanding that the structure of physiological reactions is different. However, what is the impact of 3D images on learners still needs to be explored, especially the impact of people with different sensory information processing preferences on interactive graphics and visual information.

Traditionally, the right brain is in charge of image functions and the left brain is in charge of text. This type of research mostly focuses on energy changes in frequency, and seldom discusses the homology of 3D images in learners' brain functions. Brain waves mainly reflect the activity of the cerebral cortex, so we can understand the state of brain activity by observing the characteristics of the brain waves. Observe whether there is a difference between the frontal lobes of the left and right brains, and be able to understand how users with different information processing methods have different brain waves reflected in the P300 event in the 3D VR object. The method of brain wave analysis can be carried out in the time domain and frequency domain. Time domain analysis can obtain basic signal characteristics. Frequency domain analysis uses statistics and Fourier transform to find the information contained in the brain wave waveform in the frequency domain.

This study uses the principle of stimulus response to conduct experiments. This theory is often used in the experiments of cognitive psychological process situations. This cognitive process is based on the assumption that the causes of behavior changes depend on the reactions generated in the organism. These reactions are recorded to understand cognitive behaviors. At the same time, the brain wave frequency is used to observe the changes in the coherence of the frontal lobe to understand the activity status of the frontal lobe function of the left and right brain of the subject with different information processing characteristics.

In generally accepted definition of virtual reality (VR), which is a computer-generated digital environment that can be experienced and interacted with if this environment is real (p. 9)[1]. Generally, the most common commercial application is VR headsets for entertainment. Most people's VR experience comes from video games and other widely distributed media. The application of interactive technology in this way is developing rapidly, and the advancement of virtual reality (VR) technology has led to many potential new applications. Due to significant advancements in technology, including those now applied in mobile formats, VR technology allows users to view and interact with virtual environments and objects, allowing users to see and even hear the sounds of the 3D environment in some cases[2]. Other research shows that users can be regarded as internal connections through immersion and participation, and such contact can strengthen learners' participation[3]. Similar studies believes that the immersive environment can include any external reality or sensory movement experience, which can strengthen the user experience and help strengthen the memory effect[4]. Some scholar proposed the process relationship framework between experiential learning and brain function[5]. He believes that the specific experience comes from the sensory cortex, and the reflex observation is related to the temporal cortex. He also believes that new abstract concepts are generated in the frontal cortex, and actions and practices are related to the motor cortex of the parietal cortex.

Neuro informatics (NeuroIS) is a subfield of information systems (IS) research. It uses neuroscience and neurophysiology tools and knowledge to better understand the development and use of information and communication technologies and their impact on society[5]. On NeuroIS research, most of the neurophysiological data are collected in combination with questionnaire data to study the use and impact of existing systems, and to provide more practical information for the design of new systems[6]. Therefore, to understand the impact of technology on people after the introduction of technology, in addition to traditional questionnaire surveys, more diversified verification can be generated through physiological information feedback.

The sensory information processing preferences based on the theory of brain function symmetry and body sensory information preferences, generally called VARK[7]. The VARK questionnaire is that when learners receive information, they will receive it in different preferred ways[8]. V (Visual) represents visual preference, sensory information processing is done in graphics and symbols; A (Aural) represents hearing preference, sensory information processing is done in listening mode; R (Read/Write) represents information processing preference is printed out Text message; and K (Kinesthetic) represents kinesthetic information preference, sensory information processing preference is the use of experience and implementation, such as simulation or actual operation. This type of people accumulate experience through constant contact or repeated use, which is the best way to acquire knowledge and skills.

Coherence analysis is used to detect the relationship between two signals or data sets. Generally, statistics and Fourier transform are used to find the information contained in the brain wave waveform in the frequency domain. Traditionally, Fast Fourier Transform (FFT) is used to calculate the coherence between different EEG electrodes to determine the power of discrete frequencies over a long period of time [9]. The formula for calculating homology as follows[10]:

$$coh_{xy}(f) = \left| \frac{G_{xy}(f)}{\sqrt{G_{xx}(f)G_{yy}(f)}} \right|^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

The result of the formula, coh(f), is the correlation between the x and y electrodes at the frequency f, and the range of this value is a real number between 0 and 1. When the phase relationship of the signal remains constant for a fixed period of time, the value is 1 at this time, indicating that the functions of the two brain regions have great continuity. If the phase relationship does not change over time, the value is 0, which indicates the functional homology of brain regions[11,12]. The significance level is based on the threshold formula proposed as follows [13] :

$$threshold = 1 - \left[1 - \frac{\alpha}{100}\right]^{\frac{1}{(n-1)}} \quad \ldots\ldots\ldots\ldots (2)$$

Where n represents the number of all periods, and α is the 95% confidence level value.

II. Material And Methods

The stumulus-organism-response model is the psychological functionalist method first described by the American behavioral psychologist Robert Sessions Woodworth (1869-1962) in his publication of Dynamic Psychology[14]. It is often used in experiments of cognitive psychological process situations. This cognitive process is based on the assumption that the cause of behavior changes depends on the reaction in the organism[15]. The overall conclusion for the research reaction time and accuracy rate is that the response rate is fast and the accuracy rate is low[16]. Researcher shows that most behavioral measurements use reaction time (RT) or accuracy

(Accuracy) to describe the results of discontinuous events[17]. All sensory psychology research reports are based on the correctness of conscious cognition[18]. The concept of reaction time is defined as the selectivity of effects[19], which is the elapsed time between the presentation of a sensory stimulus and the subsequent behavioral response[20].

The test image content is designed to be presented in random order, and the test content is mainly based on the cardiac arteriovenous system unit. The experimental design allows the subjects to study the heart physiology and anatomy unit with 3D VR software under the same study preparation. The study time for each part is limited to 10 minutes, and the demonstration and practice lasts for 4 weeks. After completing the study, take a test immediately, and at the same time use the EEG brain wave meter to record the brain wave changes of the correct response and the incorrect response. The test component presents one 3D VR image at a time, and proceeds in sequence according to the subject's response until the presentation of all 3D VR images is completed. The brain wave data is collected synchronously through EEG, the data is analyzed using SPSS™ statistical software, and the brain wave coherence is analyzed using MATLAB™ software.

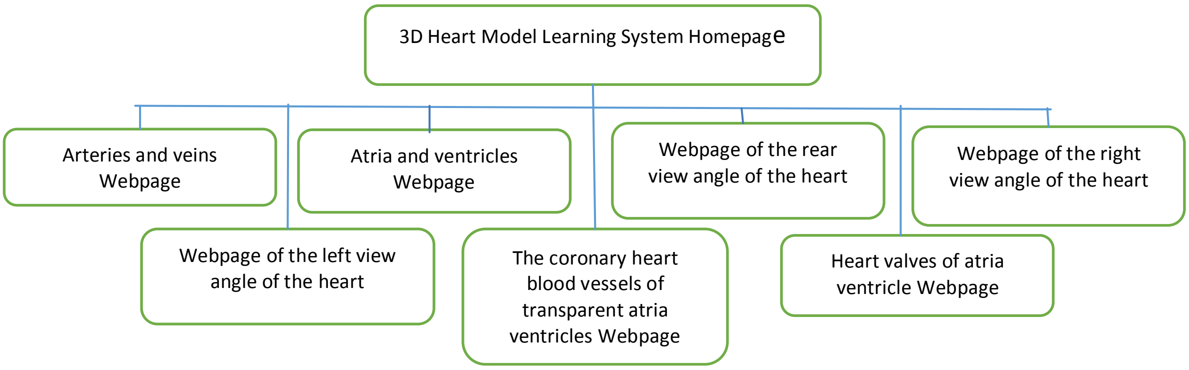


Figure no1: 3D-heart model learning website architecture

Teaching material design

The teaching materials are designed using the basic materials provided by the online interactive physiological system (BIODIGITAL™). In this environment, the human physiological anatomy system not only provides the co-writing function, but also allows users to have their own parts for teaching demonstrations. The textbook development uses BioDigital™ digital human body system to design 3D cardiac arteriovenous system unit and connect it to the cloud. After the participant accepts the case, he will go to the laboratory to open the link to the unit during the study plan to learn. Each system unit provides interactive functions, and users can interact to increase the learning effect. The structure of the teaching page of the 3D virtual reality heart model learning system is shown in the figure (Figure no1).

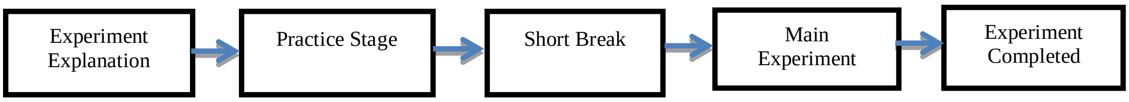
Experimental design

This study adopts the Oddball experimental method of the classic stimulus mode. The Oddball experimental mode refers to the use of two or more different stimulus contents, including sounds, images, animations, etc. to continuously and randomly present stimuli[21,22]. In the experimental mode, the probability of the stimulus content is designed to be different. The high probability is called the standard stimulus, and the low probability is called the target stimulus[23]. The stimulus content design ratio in this study is based on the classic experimental model and suggests that the target stimulus item should be less than 30%[24]. Therefore, the standard stimulus content presentation rate in this study is 75%, and the target stimulus content presentation rate is 25%. The experiment is conducted by letting the subjects respond to the standard stimulus and target stimulus, recording the response time, accuracy, and brain potential of different stimuli for analysis.

The trial design is to use ePrime™ software to design the experimental program, and carry out the experiment in two stages of fifteen minutes (Figure no2). The subject closed his eyes for 3 minutes after seated, and did not start until the prompt. At the beginning of the experiment, prompts and instructions appear, and then stage one is a set of practice experiments for the subjects to familiarize themselves with the experimental procedures and operations. Completion of stage one, there are prompts and rest time. It is up to the test subject to decide the next phase of the experiment to start, and the second phase is the real experimental phase until the experiment is completed. The whole process is about 15 minutes, and the testees who respond quickly or are familiar with application knowledge may complete it in advance.

EEG is characterized by freedom of action[25], suitable for mobile testing. It has a high time resolution when measuring brain function activation, and the minimum accuracy can reach milliseconds[26]. Compared with other tools, we believe that EEG equipment is relatively cheap and durable, and it can be worn by subjects conveniently[27]. The test subjects will try to wear the EEG brain wave device before the start to experience whether they can adapt. Those who have any discomfort can withdraw from the experiment at any time, and those who have no adverse reactions can continue to participate in the experiment. In this experiment, an EMOTIVE™ 14-channel electroencephalometer was used for brainwave signal collection, with the subauricular mastoid as the reference electrode position, and the signal sampling frequency was 128Hz. In order to facilitate the analysis and explanation of this research, the relationship between brain function area and electrode position is divided into four areas; these areas include frontal lobe AF3, AF7, AF4, AF8, F5, FC5, F4, F6, FC6, and parietal lobe includes P7, P8 ; The temporal lobe includes T7 and T8, and the occipital lobe includes O1 and O2[28]. The brain wave signal analysis tool uses MATLAB™ and eeglab function box[29] for brain wave analysis. Before the analysis, the brain wave signal is filtered in the range of 0 to 30 Hz, and the reference potential is adjusted at the same time, and then the brain electrode is matched with the scalp position.

Figure n02: Experimental process



III. Result

Results of behavioral response analysis

Table no1 show the actual number of cases was 30, of which 5 were males and 25 were females. The average age is 20 years old. The average computer experience is 4 years, and there are 12 people who have used VR, most of which are used in entertainment. All subjects are physically and mentally healthy, with normal or adjusted vision, and they are right-handed. Questionnaires on health and education background have been completed before participating in the experiment. Regarding the information processing mode of the testees, there are 5 people who prefer visual information, 5 people who prefer auditory information, 7 people who prefer text information, 8 people who prefer kinesthetic information, and 6 people who prefer multiple information processing.

The behavioral response results of the subjects in this experiment are shown in table no2. The average response time is 1993.89ms. The response rate is 42%, and the wrong answer rate is 58%. The correct rate for male users was 0.49, the standard deviation was 0.21, the error rate for male users was 0.51, and the standard deviation was 0.21; the correct rate for female users was 0.35, and the standard deviation was 0.13, and the error rate for female users was 0.65 and the standard deviation was 0.14. The response time measurement result of the correct response showed that the response time of male users was 2102.62 with a standard deviation of 195.01 milliseconds, and the response time of female users was 1884.20 with a standard deviation of 426.06 milliseconds. The results show that the correct rate of men is higher than that of women, and the error rate of women is higher than that of men; in terms of reaction time, men spend longer time thinking and reacting than women.

Table no 1: Subject's information

Information processing preference	Visual preference (V)	Auditory preference (A)	Text message preference (R)	Kinesthetic preference (K)	Multiple information processing preference
Number of people	5	5	7	7	6

Table no 2: Descriptive statistics of subjects' responses

Behavioral response results of testees	*Number of people*	*Correct rate and response time*		
		Correct rate	response time (ms)	Error rate
	30	42%	1993.89ms	58%

The coherence analysis in this study refers to the correlation of the frequency (f) between the two electrodes in the frontal lobe of the subject. The range of this value is a real number between 0 and 1. Under the 95% confidence level, based on the number of response intervals of a specific length event at a fixed frequency, the threshold of the significance level is calculated to identify whether it is coherent. According to formula (2), select α=95 at a fixed frequency, the threshold value of the correlation within the total response period of an event. Under 6Hz, n=29, α=95, according to the formula to calculate the threshold threshold=0.101466, the results of brainwave coherence analysis on the left and right brain waves of subjects with different information preferences are explained as follows.

The coherence analysis of the visual preference information processing type subjects in the left and right frontal lobes (Figure 3), with 6Hz, n=29, α=95, the threshold=0.101466. The results showed that in AF3-FC5, F7-F8, F3-F4, F3-F8, FC5-F4, FC5-F8, FC5-AF4 reached significance at frequencies from 2.5 Hz to 3 Hz (threshold>0.101466).

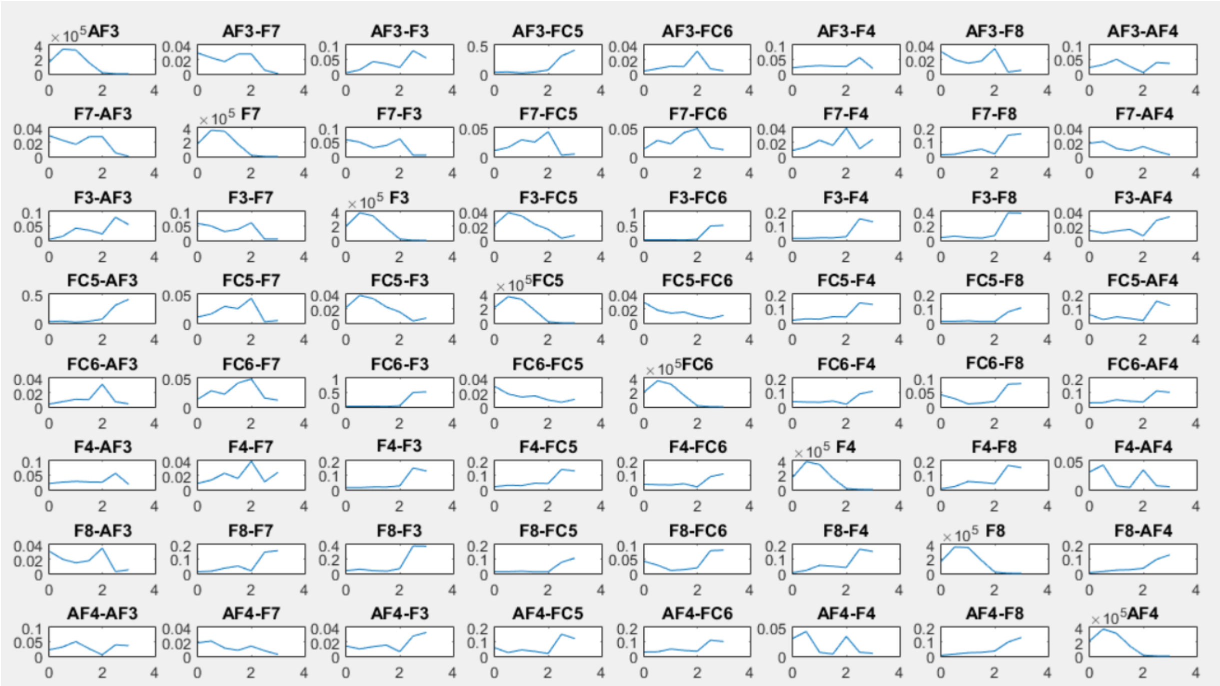


Figure no 3: Frontal cohomology of visual information processing patterns

The cohomology analysis of the subjects with the kinesthetic preference information processing pattern in the left and right frontal lobes in figure no4, with 6Hz, n=29, α=95, the threshold=0.101466. The results are displayed in AF3-F7, AF3-F3, AF3-FC5, AF3-F4, F3-F8, F7-F4, F3-FC6, F3-AF4, FC5-AF4, FC6-F4, FC6-F8, F4-AF4 It is significant (threshold>0.101466) at frequencies from 2.5 Hz to 3 Hz.

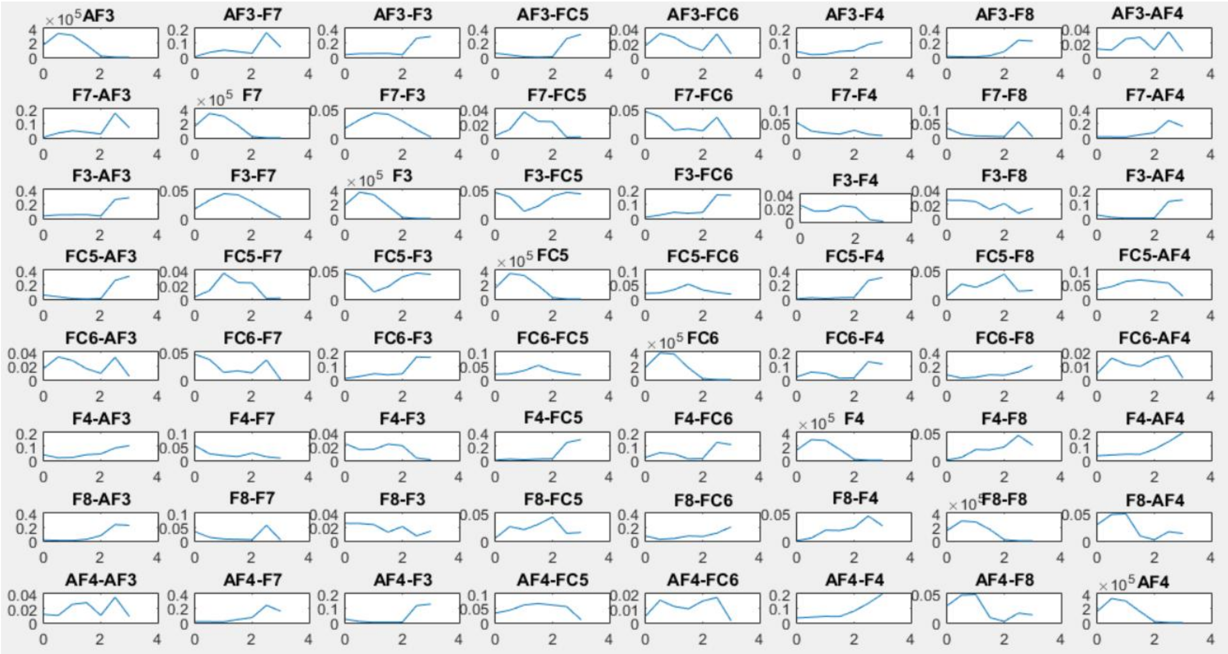


Figure no 4: Kinesthetic preference information processing type

The coherence analysis of auditory preference information processing type subjects in the left and right frontal lobes in figure no5, with 6Hz, n=29, α=95, then threshold=0.101466. The results are displayed in AF3-F3, AF3-F4, AF3-AF4, F7-F3, F7-FC5, F7-FC6, F7-F8, F7-AF4, F3-FC5, F3-FC6, F3-F4, F3-F8 , FC5-FC6, FC5-F8, FC5-AF4, FC6-F8, FC6-AF4, F8-AF4 reached significant values from 2.5Hz to 3.5H (threshold>0.101466).

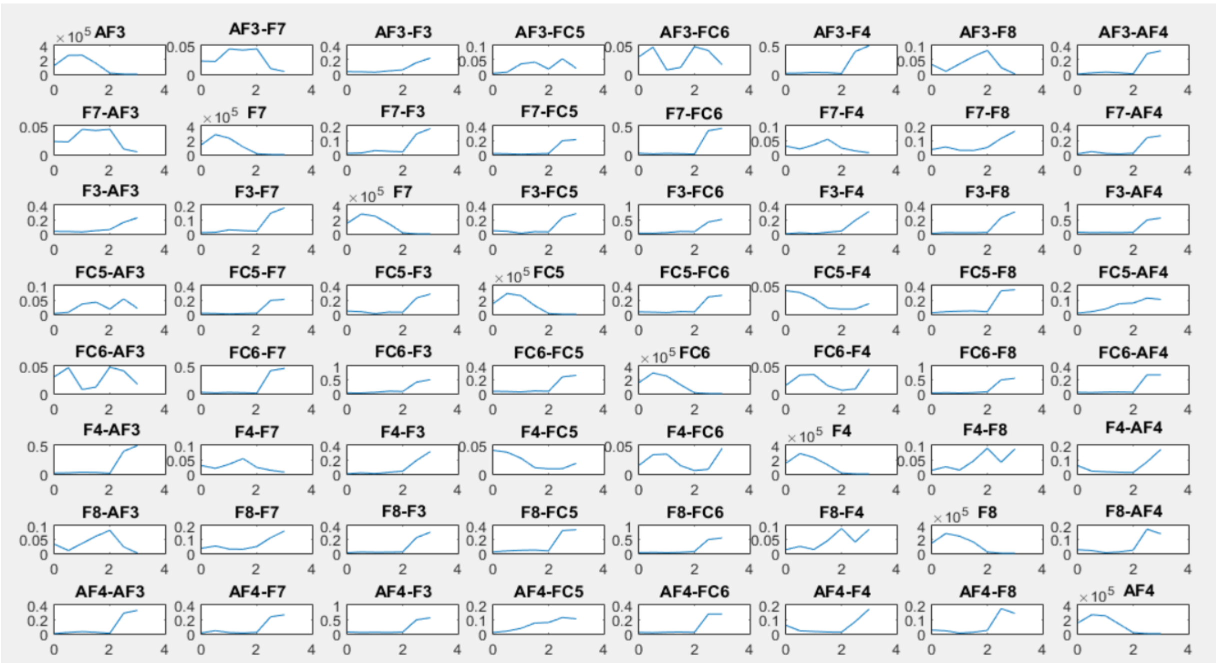


Figure n0 5: Types of auditory preference information processing

The coherence analysis of the text message preference information processing pattern in the left and right frontal lobes in figure no6, with 6Hz, n=29, α=95, the threshold=0.101466. The results showed that AF3-F7 and AF3-FC5 reached significance at 2 Hz (threshold>0.101466). AF3-F8, F3-AF7, F7-FC7, F7-F4, F7-F8, F3-F4, F3-F8, F3-AF4, FC5-FC6, FC5-F4, FC5-AF4, FC6-AF4, F8- AF4 reached significance from 2.5Hz to 3.5H (threshold>0.101466).

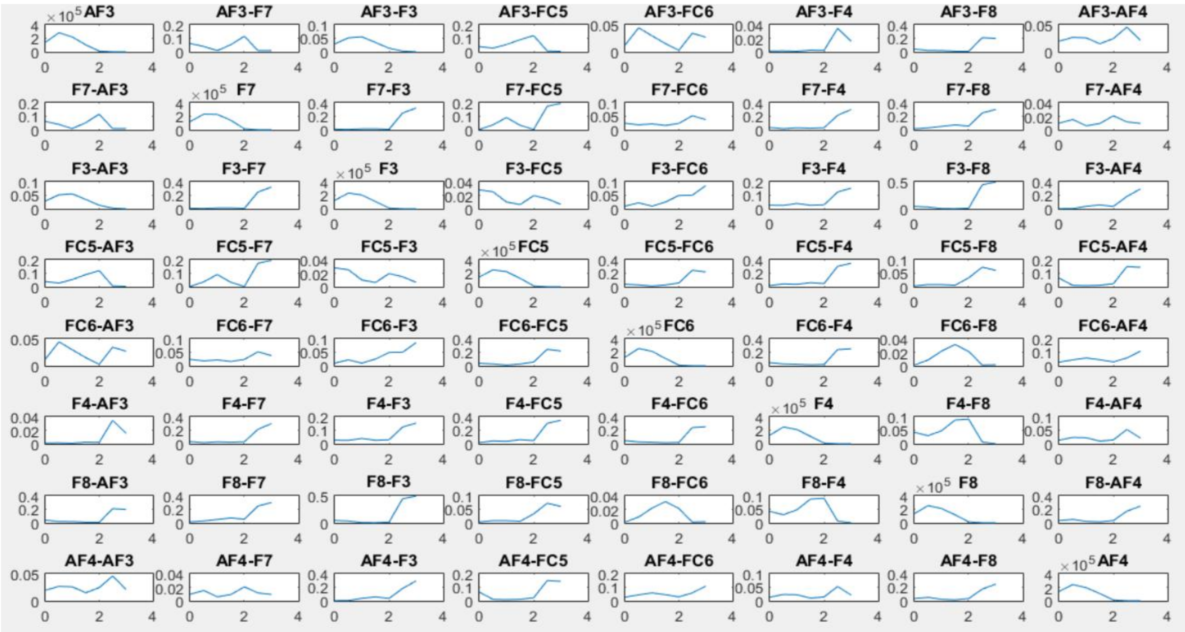


Figure no6 : Text message preference information processing type

The coherence analysis of the subjects with multiple information preference information processing patterns in the left and right frontal lobes in figure no7, with 6Hz, n=29, α=95, then threshold=0.101466. The results show that AF3-F7, AF3-F3, AF3-FC5, AF3-AF4, AF3-AF8, F7-AF4, F3-FC6, F3-AF4, FC5-F4, FC6-F4, FC6-F8, F4-AF4 are in Significant (threshold>0.101466) from 2.5Hz to 3.5H.

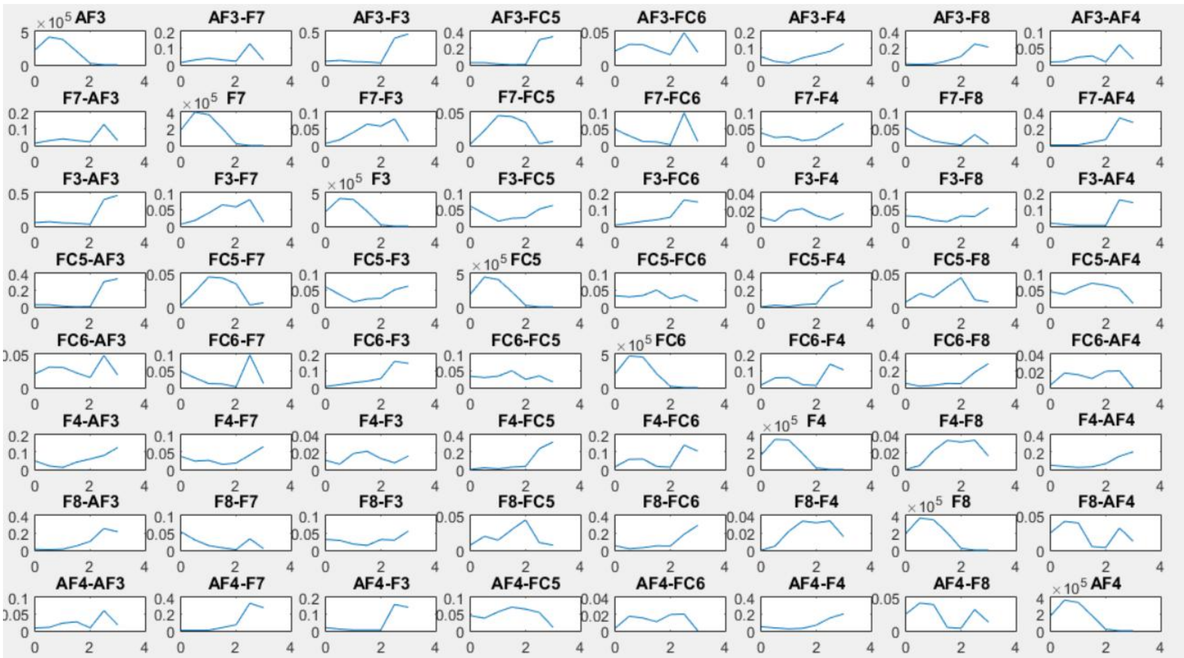


Figure no7: Types of information processing for multiple information preferences

IV. Discussion

The results of this study on the behavioral analysis of different information processing preferences in virtual reality-3D visual images show that the overall average response time is 1993.89ms. The correct response rate of males was 49%, and the correct response time was 2102.62ms; the correct response rate of females was 35%, and the correct response time was 1884.20ms. The correct rate of men is higher than that of women, and women's reaction time is faster than that of men. The research on reaction time and correct rate[16] believes that faster reaction speed tends to be lower correct rate, so men have higher correctness Rate but also spend more time on the connection of brain activities. The results are the same as previous studies, where different brain regions have different functions[10] . It is believed that the human brain does not work independently, but performs tasks through the connection and integration of complex neural circuits. Dr. Sperry in his research, he concluded that the left hemisphere of the brain is dedicated to language and text, while the right hemisphere is the function of graphics[30]. Broca (1865) also confirmed that the left hemisphere is mainly related to language functions[31].

In this study, the coherence analysis of 3D image visual information on subjects with different information processing types mainly focused on the coherence relationship of electrodes in the frontal lobe AF3, AF7, AF4, AF8, F5, FC5, F4, F6, and FC6. Table 3 shows the coherence relationship of 3D VR image vision to different information processing preferences of subjects in the frontal lobe. The visual information prefers the left and right brain frontal lobe to have the least cohomology relationship, and the auditory information prefers the left and right brain connections to have the most cohomology relationship. Kinesthetic information preference, text information preference, and multiple information preference have the same coherence relationship between the frontal lobe and the frontal lobe of the left and right brain.

V. Conclusion

The above analysis results give us a good reminder that the design of 3D VR teaching materials should be presented in multiple ways. Learners with different information preferences give different content, and web links use multiple information methods. The interactive content presentation with text, images, and 3D VR meets the needs of different information processing learners.

Table 3 Brain-frontal coherence analysis results of different information preference processing types

Visual Information preference	Kinesthetic information preference	Auditory information preference	Text information preference	Multiple information preference
AF3-FC5	AF3-F7 AF3-F3 AF3-FC5 AF3-F4	AF3-F3 AF3-F4 AF3-AF4	AF3-F8	AF3-F3 AF3-FC5 AF3-FC6 AF3-AF4
F7-F8	F7-F4	F7-F3 F7-FC5 F7-FC6 F7-F8 F7-AF4	F7-FC7 F7-F4 F7-F8	F7-FC5 F7-FC6 F7-F4 F7-AF4
F3-F4 F3-F8	F3-F8 F3-FC6 F3-AF4	F3-FC5 F3-FC6 F3-F4 F3-F8	F3-AF7 F3-F4 F3-F8 F3-AF4	F3-FC6
FC5-F4 FC5-F8 FC5-AF4	FC5-AF4	FC5-FC6 FC5-F8 FC5-AF4	FC5-FC6 FC5-F4 FC5-AF4	FC5-FC6 FC5-F8 FC5-AF4
	FC6-F4 FC6-F8	FC6-F8 FC6-AF4	FC6-AF4	FC6-AF4
	F4-AF4			F4-F8
		F8-AF4	F8-AF4	

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