Tennis Teaching and Variation Pattern of Neurotransmitter Based on Electroencephalographic Testing Technology

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ABSTRACT

Tennis sport is a fast-changing sport requiring both strength and speed. To play tennis, players need to have excellent psychological quality and high-level control and anti-control abilities. However, in tennis teaching, it is difficult to accurately see how the players' psychological quality is. With the wide application of electroencephalographic (EEG) testing technology, the changes in brain waves and brain potential in tennis sport can be well detected. Based on the EEG testing technology, this paper studies the behaviouristics and neurology in tennis teaching, and the experimental results show that tennis teaching has a causal relationship with the improvement of players' anticipation abilities and that the teaching effect can be maintained for about five months. In EEG testing, the more concentrated the subjects were, the more suppressed α waves would be. In the rest state and the memory state, the neurotransmitter in the central nervous system changed regularly, and the brain also had regular fluctuations.

Key Words: Tennis Sport, Tennis Teaching, EEG, Neurotransmitter

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Introduction

Tennis is an elegant and charming sport that is popular around the world. It is not only a recreational activity, but also a way to improve people's health (Shin and Kwon, 2015). As an alternating aerobic and anaerobic exercise, tennis can maximise the satisfaction of people who like to exercise (Kellett and Hede, 2008; Zetou *et al.*, 2014). This sport can well coordinate the development of the body's strength, speed, endurance, flexibility and sensitivity and at the same time mobilise the accurate anticipation capability of the brain. In Summary, it has positive effects on all aspects of the body (Mowling *et al.*, 2017). Currently, tennis sport is booming in China, but tennis teaching in this country is still mostly applying the traditional tennis method, under which students passively learn, with very low classroom learning efficiency. With the teaching reform and the continuous renovation of courts and equipment, the teaching concept of "Play & Stay" is gradually applied to tennis teaching, which not only improves the comprehensive teaching abilities of tennis teachers but also greatly enhances students' interest in sports and improves their tennis skills (Schwager *et al.*, 2012; Garcã A-Contreras *et al.*, 2017).

In the course of "Play & Stay", students lack practical experience. As a result, the brain is in an alternate state of excitement and tension during training, which can easily lead to premature fatigue (Chen *et al.*, 2015). In tennis teaching, in order to improve students' abilities of aerobic metabolism and prevent them from suffering from premature fatigue in tennis sport, it is necessary to understand the physical characteristics of each student and adjust their

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abilities to make the storage of the excitatory neurotransmitter than that of the inhibitory neurotransmitter during exercise to make the students achieve great results in tennis training (Zafar *et al*., 2017; Yang *et al*., 2012). The electroencephalographic (EEG) testing technology is a testing technology reflecting the brain activity. Changes in brain waves reflect how active the brain is. Teachers can use different training methods based on each person's state of activity to optimise the students' exercise load (Maddirala and Shaik, 2016; Gould *et al*., 1999). Based on the EEG testing technology, this paper studies the neural mechanism affecting the movements of students during teaching, analyses the correlation between the behavioural data and the EEG data of students during tennis teaching and compares the changes in EEG indices and neurotransmitters, hoping to make the "Play & Stay" teaching method achieve even better effects.

Behavioural and neuroscience research in tennis sport

Behavioural research

In antagonistic events such as tennis, individual experience plays an important role in the players' anticipation capabilities in exercise. Compared with new learners or amateurs, experienced players have greater endurance, faster response, and higher performance (Melanie and Michael, 2004). What is most widely applied in the behavioural research is the professional-non-professional paradigm. Professional tennis players have significantly better behavioural anticipation capabilities than non-professional ones (Fujioka *et al*., 2014). In the behavioural anticipation of tennis sport, it is very important to extract and encode the information related to exercise anticipation. In order to better realise this function, there are two very important paradigms to study in cognitive psychology - recall and recognition. Professional players have a stronger advantage in cognition

In a tennis game, when making attacks, players need to perform quick visual search and structural analysis. In the course of an attack, the early identification of clues is crucial to the angle and speed of the next attack. The response time and action execution time of the players will affect their performance on the court. Some experts studied the capabilities of tennis players to anticipate the direction and strength of the ball using the probability of the scenario, analysed the players' field performance, their subjective evaluation of the opponents' probability of hitting the ball and their movements to catch the ball and asked the players if their actions were influenced by subjective probabilities. The study found that when players consider the probability of an event to be high, they will have also a high probability of making the corresponding attack (Wu *et al*., 2010).

Neuroscience research

With the extensive application of EEG and cognitive nerve technology, exploring the activity of cranial nerves during tennis sport can help better understand the intrinsic mechanism of players' anticipation capabilities. Many researchers combined psychophysical and EEG technologies to study the anticipation capabilities and potential neural mechanisms of players during tennis teaching. During training, obvious potential jumps can be detected in the hand at the very moment when the ball gets off the hand or the when the return stroke succeeds or fails. Chesterton *et al*., (2009) found in a study of tennis players that the inferior parietal lobule and inferior frontal gyrus are activated when the subject is anticipating whether the return is successful. Buszard *et al*. studied tennis players' abilities to anticipate the course of ball, and performed MRI scan of their brain functions to show that professional tennis players have more accurate anticipation than non-professional ones(Buszard *et al*., 2016).

Study on the neural mechanism affecting students' movement

Experimental method

In the tennis teaching process, the application of "Play & Stay" significantly improves the performance of trainees. In the experiment, college students who had no experience in tennis sport were selected as subjects. Event-related potential tests were performed to see whether the tennis teaching process would improve their movement anticipation capabilities.

A total of 60 college students (40 male students) were selected as the subjects, none of whom had received any tennis training before. These subjects were randomly divided into two groups - the training group and the control group. The training group required 12 weeks of tennis training, while the control group did not have to take any training. Five months after the first experiment, the training group needed to undergo another experimental test. During the EEG test, each individual's motions were recorded. With the moment of the contact between the tennis ball and the tennis racquet defined as 0ms, the author observed the changes in the brain potential of each subject during the process from -200ms to 800ms. The accuracy and response time of each subject were recorded online as his/her behavioural responses. In order to express the behavioural responses more accurately, the index of inverse efficiency score (average response time/percentage of accuracy) was introduced. The EEG experiment was performed using the Neurone EEG/ERP potential system, which consisted of a Neurone Model Black amplifier and a Neurone electrode cap (Ag/AgCl64-lead) with a sampling frequency of 500Hz. Through the digital signal amplifier and the acquisition and processing system, the signals were acquired and superimposed, forming EEGs and brain electrical activity maps (BEAMs).

Correlation analysis of behavioural data and EEG components

Table 1 shows the behavioural results of the subjects in the training and control groups before and after tennis teaching. It can be seen that after 12 weeks of tennis teaching, the accuracy of the training group was significantly higher than that before the experiment, while the accuracy of the control group did not change much. In order to effectively control the balancing effect of accuracy during the response, the author observed the inverse efficiency score (IES score) and found that the inverse efficiency scores of the training group before and after tennis teaching varied greatly. Figure 1 and Figure 2 show the IES and accuracy of the control group and the training group before and after training, respectively. The pre-test IES of the training group was higher than the post-test one, and the pre-test accuracy was lower than the post-test one. For the control group, the IES and accuracy did not change much before and after training.

Table 1. Results of the subjects in two groups before and after training

		Accuracy (M±SD)	IES (M±SD)
Training group	Pre-test	0.48±0.05	2473.2±1034.1
	Post-test	0.53±0.05	1783.8±443.0
Control group	Pre-test	0.50±0.06	2224.7±600.4
	Post-test	0.50±0.04	2157.6±451.5

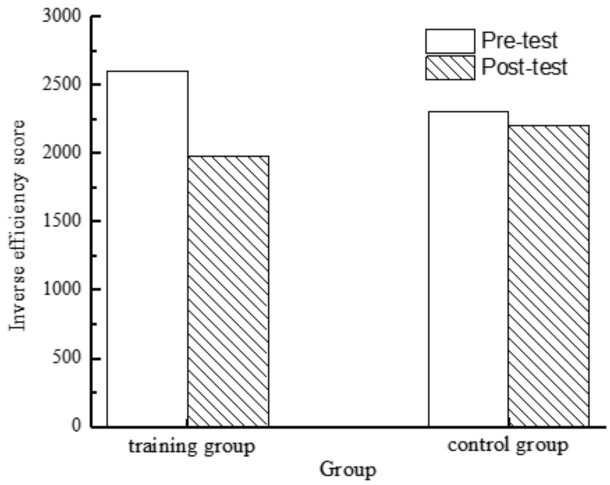


Figure 1. Inverse efficiency scores of the two groups before and after training

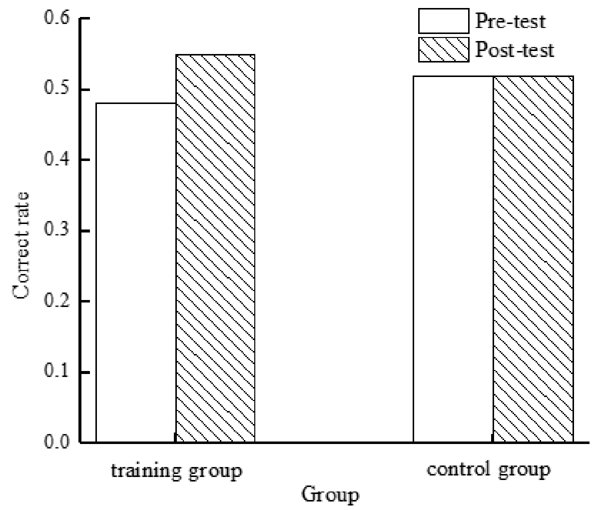
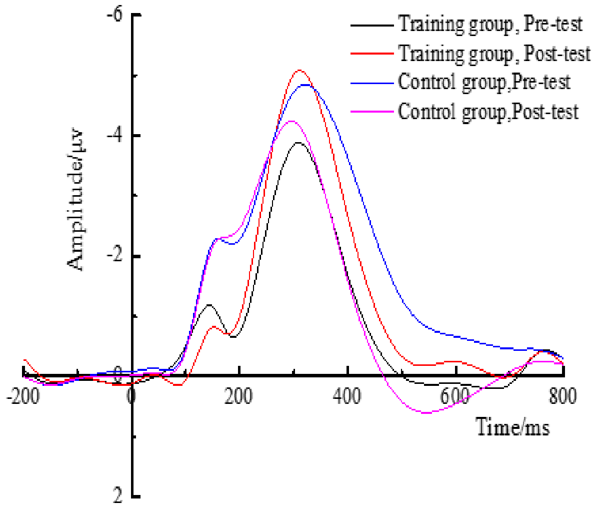


Figure 2. Accuracy of the two groups before and after training

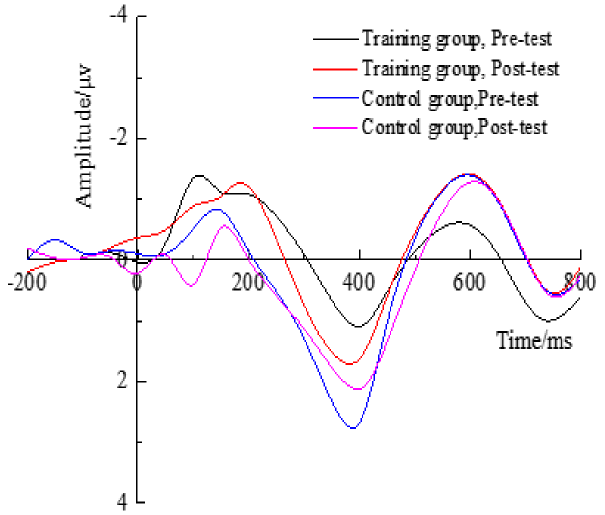
Table 2 shows the event-related potential results of the subjects in the training group and the control group before and after training. It gives the amplitude and latency of the two groups before and after training during the period 250~350ms and 350~450ms and that the amplitude during 250~350ms was obviously greater than that during 350~450ms. Figure 3 shows the total average waveforms of the two subject groups before and after training with the Fz (forehead) and Pz (parietal lobe) electrodes. From Figure 3(a), it can be seen that the position of the forehead reaches a peak about 300ms after the stimulus was presented. From Figure 3(b), it can be seen that the position of the parietal lobe peaked approximately 400ms after the stimulus was presented.

Table 2. ERP results of the subjects in the two groups before and after training

		Training group		Control group	
		Pre-test	Post-test	Pre-test	Post-test
Amplitude/μv	250-350ms	-4.23±1.86	-5.27±2.03	-4.14±2.0	-4.01±2.45
	350-450ms	1.26±1.47	2.13±1.77	3.45±1.75	2.44±1.33
Latency/ms	250-350ms	253±19	260±20	258±15	262±20
	350-450ms	380±24	382±33	387±31	374±33



(a) Fz electrode



(b) Pz electrode

Figure 3. Total average waveforms of the two groups before and after training

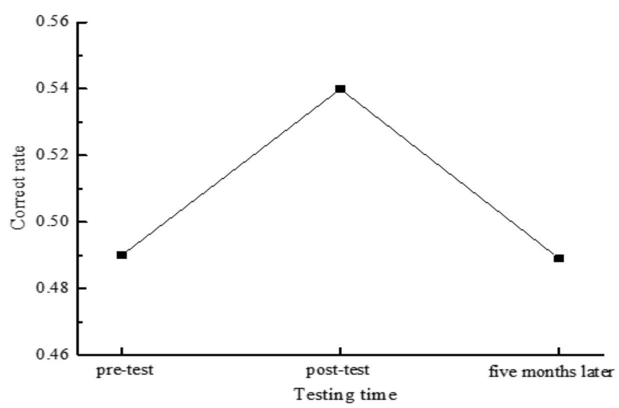


Figure 4. Variation trend of the accuracy of the training group in three tests

Figure 4 shows the variation trend of the accuracy of the training group in the three tests. The results indicate that the test time had a significant effect. The post-test accuracy was significantly higher than the pre-test one, but the accuracy five months later was lower than the post-test one and not much different from (slightly lower than) the pre-test one. Figure 5 shows the variation trend of the IES of the training group in the tree tests. The results indicate that the test time had a significant effect. The post-test IES was significantly lower than the pre-test one, and the IES five months later was also much lower than the pre-test one and slightly lower than the post-test one. Table 3 shows the correlation coefficient between the behavioural data and the event-related potential (ERP) of the subjects in the training group and the control group before and after training. According to this table, none of the behavioural data and EEG data are not significantly correlated, nor are the variation of the behavioural data and that of the EEG data before and after training.

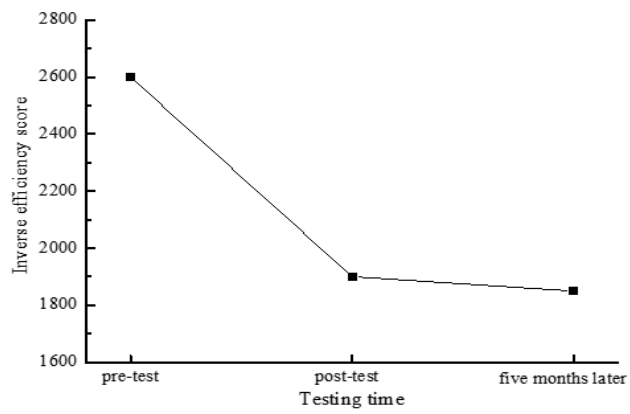


Figure 5. Variation trend of the IES of the training group in three test

Table 3. Correlation coefficients (r) between the behavioural data and the ERP results of the two groups before and after training

		Training group		Control group	
		ACC	IES	ACC	IES
Pre-test	250-350ms	0.138	0.175	-0.017	-0.337
	350-450ms	0.213	-0.223	-0.284	0.213
Post-test	250-350ms	0.021	0.028	-0.122	0.128
	350-450ms	-0.088	-0.087	0.019	-0.086

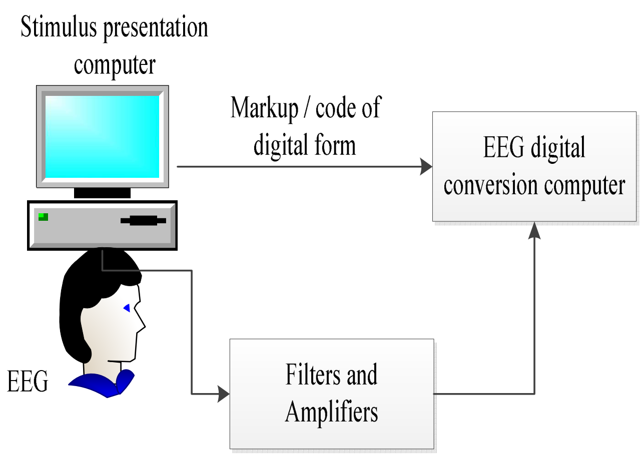


Figure 6. EEG data recording method

Study on the Changes of EEG and neurotransmitters during the "Play & Stay" teaching

Research subjects and method

The teaching content of "Play & Stay" includes classroom teaching, memory imaging simulation and practice. The study on the changes in neurotransmitters should not be conducted in strenuous exercise but rather in a quiet environment. This section studies the EEG and neurotransmitters in the memory imaging simulation during tennis teaching. In this experiment, a total of 16 professional tennis trainees were selected as subjects, half of whom were male and half were female. They were divided into 8 groups, with one man and one woman in each group. Before conducting tennis memory imaging test, the EEG and neurotransmitter data of the subjects in the rest state were first recorded, and then the subjects recalled the scenes of the tennis games. The details of the memory imaging included the surrounding environment, the situation before the game match and the scenes of the four most intense real games in the match and then the subjects returned to the rest state. EEG data were recorded in a way as shown in Figure 6. Noise stimuli were presented to the subjects, and the brain stimulation was transmitted through the filter and the amplifier to the EEG digital conversion computer. Finally, the EEG data were analysed through a number of measures, like filtering and EOG baseline correction.

Analysis and discussion of experimental results

Whether in professional or non-professional tennis teaching, psychological quality training is very important, but players are seldom tested for their mental quality. The psychological and physical changes of the players can actually reflected in the changes in the EEG index. Table 4 shows the dominant frequencies of the α waves in the whole brains of the professional tennis players in the eight groups in the rest state and the memory state. In the rest state, the dominant frequency of the α waves was lower than that in the memory state, and the frequency was mostly 10~11 times/second. Table 5 shows the amplitudes of the α waves of the professional tennis players in the eight groups in the rest state and the memory state. Amplitude can reflect the metabolism intensity of neural cells in the cerebral cortex. Experimental data show that the α wave amplitudes of all subjects changed in varying degrees and that the differences were significant although the values were not large. Table 6 shows the changes in the α index of the whole brains of the professional tennis players in the 8 groups in the rest state and the memory state. In the memory test, the nerve cells were under constant tension and inhibited the α waves. Therefore, it can be seen that the α index in the memory state was significantly lower than that in the rest state.

The experimental study of EEG and neurotransmitters of 16 tennis trainees in 8 groups in the tennis teaching process can verify the excitatory – inhibitory state of the trainees on the tennis court. Table 7 shows the changes in the neurotransmitters in the whole brains of tennis players during the rest state and the memory state. It can be seen that the excitatory neurotransmitter was inhibited in the memory state while the inhibitory neurotransmitter increased in the whole brain in this state. Table 8 shows the changes in neurotransmitters in the left and right brains of the tennis players in the rest state and the memory state. It can be seen that

Table 4. Dominant frequencies of the α-waves of the whole brains in the rest state and the memory state/μv

State	1	2	3	4	5	6	7	8	M±S
Rest	10.3	10.9	10.4	10.1	10.9	10.5	10.4	10.6	10.51±0.18
Memory	10.5	11.1	10.6	10.6	11.1	10.9	10.8	11.1	10.84±0.12

Table 5. α wave amplitudes in the rest state and the memory state $p<0.05$

State	1	2	3	4	5	6	7	8	M±S
Rest	40.6	39.0	39.8	40.0	38.8	40.3	39.5	43.6	40.18±1.41
Rest	42.4	40.9	41.0	42.1	40.5	42.4	41.1	45.0	42.19±1.33

Table 6. Changes of the whole brain α index in the rest state and the memory state $p<0.05$

Status	Rest	Memory	Status	Rest	Memory
1	74.07±6.98	55.12±13.56	5	55.07±2.64	50.37±1.28
2	77.16±12.05	58.56±10.45	6	54.23±4.40	53.67±2.62
3	57.46±4.44	53.36±4.94	7	53.60±3.28	51.96±2.08
4	58.5±10.14	47.56±14.93	8	76.60±5.08	63.81±3.13

Table 7. Neurotransmitter changes in the whole brain in the rest state and the memory state/%

M±SD	Serotonin	Acetylcholine	Strong excitement	Norepinephrine	Dopamine	Strong inhibition
Rest	2.64	4.64	2.02	12	7.64	10.27
	±0.45	±1.06	±1.14	±1.01	±1.17	±0.73
Rest	5.64	0.87	-0.62	12.02	5.64	13.52
	±0.88	±2.6	±2.72	±1.78	±1.28	±3.23

Table 8. Neurotransmitter changes in left and right brains in rest state and the memory state

Neurotransmitters	State and brain area	Left brain	Right brain	T test
Serotonin	Rest	1.9±0.65	1.77±0.88	P<0.01
	Memory	0.74±0.60	3.9±0.42	P<0.01
Acetylcholine	Rest	1.52±0.63	3.02±1.02	P<0.01
	Memory	1.52±1.47	-0.24±1.72	P<0.05
Strong excitement	Rest	0.64±0.60	1.4±0.82	P<0.05
	Memory	0.62±1.5	-1.14±1.72	P<0.05
Norepinephrine	Rest	7.14±1.28	5.64±0.93	P<0.05
	Memory	5.77±1.02	7.14±0.93	P<0.05
Dopamine	Rest	3.02±0.72	4.52±1.08	P<0.01
	Memory	3.9±1.20	1.64±0.93	P<0.01
Strong inhibition	Rest	3.9±0.82	6.02±1.25	P<0.01
	Memory	9.14±1.05	6.52±1.08	P<0.01

serotonin and dopamine changed significantly in the memory state, while in rest state, dopamine neurotransmitter in the left brain was more active, and acetylcholine did not differ much in the left and right brains under the two states.

Conclusions

This paper tests the psychological quality of tennis players in tennis teaching based on the EEG testing technology for the purpose of improving the performance of tennis teaching tasks and helping tennis players achieve the best state in exercise. The specific conclusions are as follows:

(1) Through the analysis of the behaviours before and after tennis teaching, it is found that, for the training group, the pre-test inverse efficiency score of the training group measured was greater than the post-test one, and that the post-test accuracy was greater than the pre-test one; and that for the control group, there was not much difference in the pre-test and post-test inverse efficiency and accuracy.

(2)From the changes in the neurotransmitters in the whole brain during the rest state and the memory state of the subjects, it can be seen that the excitatory neurotransmitter was inhibited under the memory state.

(3) In the EEG test, the more concentrated the subjects were, the more suppressed α waves would be. In the rest state and the memory state, the neurotransmitter in the central nervous system changed regularly, and the brain also had regular fluctuations.

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