Neural Mechanisms of Tactics Decision-making

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Abstract—The purpose of the study was to explore the neural mechanisms of tactics intuition predominance of elite fencers. This study selected 39 fencers. Event-related potential (ERP) recording technique was collected to compare between different level fencers. The behavioral data indicated that the task responses of elite, level-1 and level-2 fencers belonged to intuition decision-making. ERP data indicated that the pointing focus degree of exogenous attention and the updating degree of mental token of judging tactics intention of elite fencers were higher and their neural mechanisms of performance predominance maybe the nerve activity level of P1, P3 and PSW evoked at the special cerebral cortex were higher and the evoked time of P3 and PSW were earlier during the process of tactics decision-making.

Keywords—fencing; tactics; decision-making; neural mechanisms; ERP

I. INTRODUCTION

A competitive sports is a special kind of occupation, in which the movement of each performer is completed in command of his brain, the brain is the decision-making center of performance behavior. For those more complicated sports items, the effects of thinking in decision-making directly impacts on the performance and the outcomes.

Fencing is the combat item of high antagonism and competition impetuousity, which has a good name of Match of Speed and Wisdom. With its fast and frequent attack and defense, fleeting match opportunities and the daedal match situation, Athletes must make nice and efficient judgment, fast and flexible decision-making according to the variety of their opponents and match fields in a very short time. Although the researches have well indicated that the differences between the expert and novice athletes existed in the special perception abilities and the cognitive process of visual searching, perceptual anticipation and sports decision-making [1-4], the studies on the neural mechanisms of cognitive predominant characteristics of expert athletes are few for the restrictive reasons of experimental situation and techniques at present. In recent years, with non-invasive brain imaging technology widely used, especially in known technique of event-related potentials with high temporal resolution widely used, it can be likely to reveal the neural mechanism of performance predominance of sports experts.

Therefore, with the theoretical guidance of acquired experience theory of cognitive predominance of sports experts, and with the cut-in point of sports cognitive processes, adopting the research paradigm of expert-novice, mainly using recording technology of event-related potentials (ERP), the study purpose was to tentatively explore the characteristics and its possible neural mechanism of tactic intuition predominance, which determined the performance and outcomes of high level fencers.

II. METHODS

A. Participants

Thirty-nine fencers (17 male, 16 female) in Shanghai and Jiangsu province fencing team voluntarily participated in this experiment, aged 15-29 yrs. According to the skill level which was evaluated by China Sport General Administration according to their best athletic results, all subjects were divided into four group, in order of descent, that is elite fencers group (referred to as Elite group), level 1 fencers group (referred to as Level-1 group), level 2 athletes group (referred to as level-2 group) and no level athletes group (referred to as Non-level group). Natural situation of athletes in each group was shown in Table I. Elite group included four male and female athletes respectively; Level-1 group included six male and eight female athletes; Level-2 group included seven male and four female athletes. Prior to take part in this experiment, subjects provided written consent on a form approved by the institution’s human subjects review board.

B. Experimental equipments

Recording equipment of EEG is 64-channel ERP recording and analysis system of German Brain Products Company. Ag/AgCl recording electrode was fixed on electrode cap; electrodes were oriented by 10-20 international standard electrode system. Reference electrode placed on the nose tip, a fronto-central electrode was used as a ground. The horizontal electro-oculogram (HEOG) was monitored from electrodes at the outer canthi of the eyes, and the vertical electro-oculogram (VEOG) was monitored above and below the orbital region of the left eye. Electrode impedances did not exceed 10 kΩ. The EEG signals were recorded continuously by the amplifiers;
filter bandwidth was of 0.016–100Hz, sampling frequency was of 500Hz/channel.

C. ERP experiment

1) Stimuli. The original materials were video of some fencing individual and team foil matches of the 2005 Fencing World Cup in Spain, Paris, Portuguese, Bosnia and Herzegovina, and Venice stations. We used software of Ulead Video Studio 10.0, based on the research needs, intercepted matches video segments from one side to start an attack until the end of this round of confrontation. Then, to use image editing software of Ulead Video Studio 10.0 again to intercept the video of before the defensive side athlete has not yet made an effective response to the offensive side attack into 5 match pictures, according to every interval of a frame. In the end, we selected total 120 pictures of 24 video segments as primary experimental stimuli, and dealt primary experimental stimuli for unification specifications of 750 (Wide) × 576 (High) pixels by software of Batch Image Resizer, and eliminate the influence of differences in color, brightness and contrast of each picture on ERP experiment as far as possible by software of Photoshop 10.0.

2) ERP Procedure. The ERP procedure was designed by software of E-prime (See Fig. 1). The whole experiment had 3 blocks and each block included 24 trails. Subjects were informed to response speedily and accurately at the same time.

For examine the differences between groups in behavior responses and ERP data, ANOVA and MANOVA having the accuracy (percent of correct responses), the reaction time (RT) and peak latency, mean amplitude, peak amplitude as dependent variables, having the independent factors of athletic level (elite athletes, level-1 athletes, level-2 athletes) and that of gender (female athletes, male athletes) were performed. An alpha level of .05 was used as significant level. LSD was used for post hoc test comparisons (P<0.05).

III. RESULTS

A. Behavioral data

The behavioral data of tactical decision-making of different groups was presented at Table II. The ANOVA analysis of reaction time (RT) and accuracy presented that there was no difference of RT ($F_{2,30}=0.702$, $P>0.05$) and accuracy($F_{2,30}=0.292$, $P>0.05$) were observed between groups.

<table>
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<tr>
<th>Group</th>
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<th>RT (ms) Mean</th>
<th>Accuracy (%) Mean</th>
<th>SD</th>
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<tbody>
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<td>643.81</td>
<td>179.45</td>
<td>65.03</td>
</tr>
<tr>
<td>Level-1 Group</td>
<td>14</td>
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From the Fig. 2, it could be seen that P1, P2, P3, N1, N2 and PSW of ERP components were evoked at cerebral cortex during the process of tactics decision-making of different level fencers.

1) P1, N1. The results of mean amplitude of P1 and N1 recording from the electrodes of Fz, FCz, Cz, CPz, Pz, Oz and POz in time windows of 80-130ms and 130-200ms showed that the P1 mean amplitude of POz was highest (-1.18±1.02µV), and that of FCz was lowest (-0.22±1.22µV). MANOVA analysis of P3 peak electrode of POz (10.31±5.37µV), its latency was about 380-390 ms at middle and posterior part of brain scalp, namely PSW which evoked after P3 component. The PSW presented that there had gender main effect at the electrodes of Fz(F1,31=11.088, P<0.01), FCz(F1,31=8.294, P<0.01), Fpz(F1,31=8.731, P<0.01), AF3(F1,31=8.000, P<0.01), AF4(F1,31=6.686, P<0.05), F3(F1,31=10.047, P<0.01), F5(F1,31=6.825, P<0.05), FC3(F1,31=10.211, P<0.01), FC4(F1,31=7.982, P<0.01) and had no significant group main effect and interaction of group with gender. T-test analysis showed that the P3 peak amplitude of male fencers was higher than that of female fencers. Moreover, there had group main effects at the electrodes of AF8 (F1,31=4.584, P<0.05), F8 (F1,31=4.256, P<0.05), FT8 (F1,31=5.327, P<0.05) and C6 (F1,31=4.652, P<0.05). Post hoc analysis showed that the P3 peak amplitude of Elite group and Level-2 group were higher than that of Level-1 group, and there was no difference between Elite group and Level-2 group.

4) PSW. From the grand average ERP waveforms of FCz and Pz electrodes for right responses (see Fig. 2), it could be seen an positive slow wave at about 470 ms and 370 ms, namely PSW which evoked after P3 component. The PSW peak latency was presented that there had group main effect at the electrodes of AF3 (F1,31=3.677, P<0.05), AF7(F1,31=3.695, P<0.05), F5 (F1,31=3.455, P<0.05), F7 (F1,31=3.447, P<0.05) and Post hoc analysis showed that the peak latency of PSW evoked at left prefrontal lobe and frontal-central region of Level-1 group was longer than that of Elite group, and there was no obvious difference between Level-1 group and Level-2 group. Moreover, the main gender effect was observed at the electrodes of CP4(F1,31=5.728, P<0.05), CP6(F1,31=5.762, P<0.05), Pz(F1,31=4.187, P=0.050), P4(F1,31=5.730, P<0.05), P8(F1,31=4.524, P<0.05), POz(F1,31=4.486, P<0.05), PO4(F1,31=4.817, P<0.05), PO8(F1,31=3.598, P<0.05), Oz(F1,31=6.965, P<0.05), O1(F1,31=5.818, P<0.05), O2(F1,31 =7.832, P<0.01). T-test analysis showed that PSW peak latency of male fencers was shorter than that of female fencers. MANOVA analysis of PSW peak amplitude showed that there has significant group main effect (FT8:F1,31=3.533, P<0.05; C4:F1,31=3.398, P<0.05) and no significant gender main effect and interaction of group with gender at the recording electrode of FT8 and C4. Post hoc analysis showed that the peak amplitude of PSW evoked within right temple-frontal lobe region (F8, FT8, T8), right central region (C2, C4, C6) and right central-parietal region (CPz, CP1, CP2, CP4) of Elite group and Level-2 group were higher than that of Level-1 group obviously, but there were no obvious differences between Elite group with Level-2 group.
IV. DISCUSSION

A. Behavior Strategy of tactics decision-making

The behavior results showed the accuracy of tactics intuitive decision-making of high level athletes was slightly better than that of general ones; the speed of decision-making was much slower than that of general ones. These results were consistent with findings of Yong-Min Cheng study. The results of this study showed that the elite fencers tended to mainly adopt the accuracy-oriented strategy of decision-making; the general fencers tended to mainly adopt the speed-oriented strategy of decision-making. In actual games, the higher level athletes firstly observe the opponents' characteristics of body morphology; movement and movement speed and so on, and then carry out the corresponding tactics movements in accordance with the characteristics of opponents, as well as tactical intention. On the contrary, the lower level athletes with relatively insufficiency of sport knowledge and experience vaguely judged the power and tactical intention of opponents due to their fewer years of training. Therefore, the high level athletes win faster under the premise of guaranteeing the certain veracity, the general level fencers adopted the speed-oriented strategy with expense of accuracy, and guessed randomly or relied on subjective assumes.

B. Neural Mechanisms of perception of tactics decision-making

In this study, the ERPs results of time windows of 80-130ms (the latency of P1) showed that the mean amplitude of ERPs evoked at the parts of the frontal lobe, the frontal-central region and central region of cerebral cortex of elite athletes were significantly higher than that of Level-1 and Level-2 athletes. According to the previous researches finding, the study results indicated that the centralizing degree of attention focusing on target location of elite athletes were higher than that of general ones when they perceived the location of offensive athlete. The elite athletes could distribute the limited attention resources to both-sides athletes rapidly and point to related action cues quickly; however, there was no difference between elite athletes and general level athletes in the speed of distinguishing the tactic types of offensive player and mental operation resources occupied.

The behavior results of this study showed that the accuracy of intuitive tactics decision-making of elite athletes were slightly higher than that of Level-1 and Level-2 players, it indicated that the quantity and usefulness of searching and perceiving cues of elite athletes were all superior to general ones. Naturally, the mental operation resources occupied of elite athletes was more than that of general ones.

As a result of the experimental tasks which gave by presenting the match pictures in short time, it was difficult to determine the time characteristics (latency) of early ERPs. However, according to the findings of Fu et al. that the valid prompts could activate higher amplitude and longer latency of P1 and the ERP result of more mental operation resources occupied of elite athletes to perceive the attack side athletes in this study, it was speculated that the elite athletes maybe cost more time to search for and perceiving the offensive athletes than general ones.

C. Neural Mechanisms of judgment of tactics decision-making

According to the previous researches during the process of judging the tactical intention of offensive athletes, the latency of P3 evoked at cerebral cortex mainly reflects the time required to evaluate and classify the stimuli; the amplitude of P3 reflects the updating degree of token in working memory.

The ERPs results of this study showed that the P3 peak amplitude of elite and Level-2 athletes were obviously higher than that of Level-1 athletes. These results indicated that the total time (from stimulus appearance to judgment finish) is with no difference. The difference only existed in updating degree of token in working memory. Due to the higher centralizing level of its attention which focused on the offensive athletes, high-level athletes searched more useful action clues when they perceived offensive athletes. Moreover, the experimental task can not be separately recorded RT in different of stages cognitive processing. Combining with the above-mentioned speculated time which cost in perceiving offensive athletes, thus, the real time to judge the tactical intention of elite athletes may be less than general ones.

The athletes utilize sport knowledge stored in their minds to make decisions in matches every time. The view of Symbol-oriented sport cognitive psychologists is that knowledge includes declarative knowledge and procedural knowledge. McPherson studied the problem token of tennis experts - novice by using the method of verbal report, pointed that experts have more total concept, conditional concept, movement concept and more diverse and complex goal concept and action concept than novice. Yong-Min Cheng also found that excellent badminton players have obvious predominance of declarative knowledge. The above findings show that in sports situation, the experts appear the predominance of number and level in concepts of mental token of sport knowledge when comparing with the novices.

In the experimental task of this study, the tactical intentions of offensive athletes determined by fencers were driven by the presetting mental goal (judging the offensive athlete). Therefore, they mainly carried on mental token by declarative knowledge, such as the action schema, imagery, mental model and so on. The more abundant of athlete’s sports knowledge and experience, the more abundant and accurate of action schema, imagery or mental model stored in their long-term memory system. So, the quantity, level and quality of action schema and action imagery of level-1 athletes were inferior to elite athletes because of their years of training were not longer. In this line, the speculation that P3 amplitude maybe reflects the quantity and levels of declarative knowledge should be true. However, the reasons of P3 peak amplitude of level-2 athletes were higher than that of level-1 athletes, were mainly concerned with the task difficulty.

In addition, this study showed that the peak amplitude of P3 of male athletes was obviously higher than that of female athletes, this indicated that the updating number of knowledge token of tactics intention in male athletes’ working memory
were significantly more than that of female athletes. As we all know, there are significant differences in athletic ability and sports performance between female and male athletes for each sports item. According to this study results, despite of inherent body shape and body function, the reasons caused above differences should included the cognitive processing abilities in sports situation.

D. Neural Mechanisms of anticipation of tactics decision-making

The behavioral results showed that there was no significant difference in accuracy rate between different level fencers. Subjected to the rules of fencing competition “right of priority judgment”, in actual games if athletes located in a passive state, they would always obtain the “right of priority judgment” through defense tactics, and then attack effective parts of opponents. Therefore, fencers were too likely to adopt defense tactics in actual games to usually choose defense tactics in experimental task regardless their grade of athletic skill. In addition, the possible results of tactical decision-making task in experiment just were defense and counterattack, and the total number of 2/3 was decision-making tasks with defense tactics choice. As a result, accuracy of decision-making of different group athletes showed no significant difference.

The research conducted by Jing-Han Wei et al.[11] found that PSW not only reflects the completion of information processing, but also relates to cognitive multiprocessing. ERPs results in this study showed that the PSW peak latency of elite athletes was significantly shorter than that of general ones, but the PSW peak amplitude of elite and level-2 athletes was significantly higher than that of level-1 athletes. The results indicated that the anticipation speed of high level athletes was faster than that of general ones, but the mental operational resources occupied was much more than the general ones. The possible mechanisms of tactical anticipating were the time evoked PSW at the certain regions of cerebral cortex was earlier, the level of PSW nerve activity of evoked at the certain regions of cerebral cortex was higher.

Fencers also make use of traditional sports scenarios knowledge and experience stored in their memory to process mental token when they carry out tactical anticipation. The above findings by McPherson and Yong-min Cheng were that expert athletes had obvious predominance of conceptual declarative knowledge. However, in order to meet the needs of complex, changing, fast and uncertain competition scene, athletes should token sports knowledge and experience to more schemas, imagery, a mental model and rules and so on. Therefore, the quantity and level of token forms of procedural knowledge is an important factor to interpreting difference of tactical anticipation between different level fencers. With the years of training for high level athletes getting longer, The procedural degree and automation degree of procedural knowledge stored in long-term memory system of high level athletes are obviously higher than that of general ones, the number of production rules and level of internal composition of production rules of high level athletes are also obviously more than that of general ones. Therefore, high level athletes occupied more mental operational resources to make correct decisions and the peak amplitude of PSW was higher. It can be speculated that the PSW amplitude maybe reflect the quantity and level of production rules of procedural knowledge tokens.

In a word, the modern sports fencing game is not just a contest of physical strength, but also a bout of knowledge.

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REFERENCES