

THEORETICAL DISCUSSION ON EYE MOVEMENT DIFFERENCES IN SERVICE ANTICIPATION OF COLLEGE TABLE TENNIS PLAYERS UNDER DIFFERENT EMOTIONS

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Abstract: Table tennis demands rapid visual processing and precise predictive judgment, where emotional fluctuations significantly interfere with cognitive processes such as attention allocation and information extraction. College table tennis athletes, as a key transitional group, exhibit distinct eye movement patterns in service anticipation under different emotional states. This study adopts a theoretical analysis method to systematically explore the eye movement differences and internal cognitive mechanisms of college table tennis players during service anticipation under positive and negative emotions, and further reveals the chain interaction relationship among emotion, eye movement and service anticipation. The results show that positive emotions promote efficient visual search characterized by concentrated fixation and reasonable saccade, improving anticipation accuracy; negative emotions trigger conservative search strategies with scattered attention and prolonged processing time, reducing anticipation efficiency. Athletic experience and mental skills play a moderating role in the emotion-anticipation relationship, and college athletes are more vulnerable to negative emotional interference. In conclusion, emotions reshape eye movement features to determine the quality of service information sampling, forming a chain mediation effect. Targeted emotional regulation and visual search training can effectively optimize college athletes' service anticipation performance.

Keywords: College table tennis players; Service anticipation; Emotion; Eye movement characteristics; Cognitive mechanism; Visual search

1 INTRODUCTION

Table tennis is renowned for its speed, precision, intensity, diversity and spin. Matches unfold in an instant, placing diverse demands on players' cognitive decision-making. Serving initiates a rally and shapes the course of the game, while winning or losing often hinges on instantaneous predictive judgment. This rapid cognitive process is largely dependent on opponents' behaviors and susceptible to emotional states.

College athletes undertake dual roles as students and competitors, whose emotions frequently fluctuate between positive and negative states. Existing studies have verified that emotions affect athletic performance, yet few have thoroughly explored how emotions interfere with the subtle cognitive process of service prediction. Positive emotions facilitate information processing, whereas negative emotions may narrow attention scope and consume cognitive resources, further leading to predictive errors.

Accordingly, this study theoretically explores the differences in eye movement activities during service prediction among college table tennis athletes under positive and negative emotional states. It further investigates the theoretical correlations among emotion, cognition and sports performance, aiming to provide scientific references for targeted psychological training.

2 SERVICE ANTICIPATION OUTCOMES UNDER DIFFERENT EMOTIONS

2.1 Service Anticipation Results

Excluding the interference of other factors, this section solely compares the differences in service placement anticipation between expert and novice players. Numerous existing studies have verified that expert players achieve higher accuracy rates and shorter reaction times in service placement anticipation. Experts adopt more efficient visual search patterns to acquire more valid information, which is mainly manifested in more orderly gaze trajectories, fewer fixation points and fixation areas, and longer fixation duration. They tend to focus more on body parts directly associated with service movements [1]. To boost anticipation accuracy, experts generally spend longer observation time to ensure higher judgment correctness. In contrast, novice players show irregular and disordered gaze trajectories with more fixation points and areas as well as shorter fixation duration. Novices mainly pay attention to the positions of the ball and racket, while experts concentrate on the shoulders, arms, ball and racket to obtain prior movement information and improve anticipation accuracy.

2.2 Service Anticipation Results under Different Emotions

Emotions affect athletic performance to a certain extent, and table tennis, a sport requiring high concentration, is particularly susceptible to emotional fluctuations. Compared with negative emotions, positive emotions exert weaker impacts on athletes and contribute to better competitive performance. The influences of emotions on table tennis players' performance can be explained through eye movement indicators and behavioral indicators.

In terms of eye movement indicators, athletes in positive emotional states show shorter duration of initial fixation and fewer fixation counts than those in neutral and negative emotional states, along with the largest saccade amplitude. Their visual search patterns are more adventurous, and they prefer smaller interest areas that provide advance cues, enabling more efficient information acquisition and better athletic performance. Under positive emotions, athletes mainly fixate their visual attention on opponents' hands, rackets and central visual field of the right upper arm. By contrast, in negative emotional states, athletes have longer total fixation duration and shorter quiet-eye duration, and adopt more conservative search strategies. They tend to focus on broad interest areas such as the head, torso and ball [2], failing to collect valid predictive information in advance. Scattered attention leads to passive responses and inferior athletic performance.

In terms of behavioral indicators, based on the logical correlation between eye movement characteristics and anticipation ability, athletes can fully extract visual information under positive emotions, thus achieving higher accuracy in anticipating service placements. Abnormal eye movement patterns and insufficient acquisition of key information under negative emotions markedly reduce anticipation accuracy. Relevant studies have confirmed that athletes obtain higher perceptual anticipation accuracy and shorter reaction time under positive and neutral emotions, while negative emotions lower accuracy and prolong reaction time [3]. Other researches also indicate that anxiety delays visual search reaction time without significant influence on judgment accuracy [4].

3 INFLUENCING FACTORS OF EYE MOVEMENT DIFFERENCES IN SERVICE ANTICIPATION

Factors affecting the quality of service anticipation can be categorized into three dimensions: athletes themselves, opponents and external environments. Among them, the controllable and research-oriented factors mainly lie in individual athletes. Therefore, this study elaborates the influencing factors of anticipation quality from three personal aspects: technical proficiency, competitive experience and psychological quality. Specifically, technical proficiency reflects athletic level, competitive experience shapes superior visual search patterns, and psychological quality represents the degree of susceptibility to external stimuli such as emotions.

3.1 Athletic Experience and Competitive Level

Athletic level exerts a significant impact on table tennis players' service anticipation performance. In service placement anticipation tasks, expert players outperform novice players with faster response speed and higher judgment accuracy. The classic expert-novice research paradigm has verified that higher competitive level corresponds to better anticipation outcomes.

Specialized sports experience facilitates athletes' comprehension of kinematic information, enabling them to achieve stable anticipation performance whether prior cues are consistent or inconsistent with actual movements. It also shapes decision-making tendencies: high-level athletes tend to make risky experience-based decisions, while low-level athletes prefer conservative descriptive decisions [5]. Distinct decision-making modes lead to different visual search strategies, thereby resulting in eye movement discrepancies. Even interfered by external stimuli such as emotions, experts still maintain better anticipation effects and are less affected by emotional fluctuations, which indicates that competitive experience plays a dominant role in anticipation.

3.2 Visual Search Patterns

Diverse visual search patterns are directly reflected in eye movement characteristics. In the research on return service visual search of table tennis players, Lu Xiaodan pointed out that experts spend longer fixation duration on key areas including opponents' heads and rackets compared with novices [6]. According to Jia Yue'e and colleagues, novices fixate longer on the table and rackets, whereas experts focus most on rackets and arms and achieve higher anticipation accuracy. High-level athletes are capable of dynamically adjusting visual search strategies in real matches [7].

Under practical competitive scenarios, Xie Tao et al. found that experts adopt rapid saccades to quickly locate effective fixation points during opponents' strokes, with longer fixation duration and more concentrated visual scope in areas of interest [8]. In addition, Zeng Jiayi discovered that 10-week systematic table tennis training can reshape children's visual search habits. Before training, children's fixation points on key areas were scattered with short duration; after training, their fixation became concentrated and lasted longer [9]. Accordingly, expert and novice players differ fundamentally in visual search patterns, which further leads to differentiated competitive performance.

3.3 Psychological State and Emotion

Emotions of different types exert varied effects on table tennis players' service anticipation. In service placement anticipation tasks, athletes achieve better performance with faster speed and higher accuracy under positive emotions. Emotions regulate anticipation efficiency by altering athletes' visual search behaviors.

Under positive emotions, athletes present shorter fixation duration, fewer fixation counts, smaller saccade amplitudes as well as simpler and more concentrated gaze trajectories, mainly focusing on opponents' hands, rackets and the central visual field of the right upper arm. By contrast, negative emotions make athletes vulnerable to peripheral visual interference and cause their visual attention to spread outward from core areas of interest [10]. Zhang Suting's research confirmed that participants gained higher anticipation scores under pleasant emotions than under sad emotions [11]. Furthermore, relevant studies have proven that moderate state anxiety can facilitate the exertion of visual search ability in sports anticipation.

4 MECHANISM OF EYE MOVEMENT PATTERN DIFFERENCES UNDER DIFFERENT EMOTIONS

Previous studies have shown that athletes exhibit prominent differences in visual search patterns during service anticipation across diverse emotional states, and athletic proficiency also moderates the emotional effects on individuals. Such discrepancies alter athletes' eye movement patterns by interfering with cognitive processes including attention allocation, information processing and decision-making.

4.1 Attention Allocation

The Limited Cognitive Resource Theory holds that human cognitive resources such as attention and working memory as well as mental energy are finite, and task performance hinges on resource allocation.

From the perspective of attention, anxiety diverts athletes' attention to internal threatening thoughts (e.g. worrying about failing to return the ball or losing points) and external threatening stimuli (e.g. opponents' imposing presence and on-site noises). This consumes cognitive resources, triggers inattention in cognitively demanding sports like table tennis, hinders the acquisition of core task-related information, and ultimately impairs anticipation performance.

In a relaxed state, college table tennis players have sufficient cognitive resources. They adopt visual search features with shorter fixation duration, fewer fixations and smaller saccade ranges, and mainly focus their visual attention on opponents' hands, rackets and the central visual field of the right upper arm. Under negative emotions, athletes' fixation points are interfered by peripheral vision, leading to expanded areas of interest, slower anticipation speed and lower judgment accuracy [4]. It has also been confirmed that negative emotions scatter athletes' visual fixation and impede effective information acquisition [12]. In short, negative emotions occupy excessive cognitive resources, disperse attention and further change anticipation outcomes.

In terms of working memory, the Processing Efficiency Theory states that anxiety seizes partial working memory resources, resulting in insufficient resources to fulfill ongoing tasks. To complete tasks smoothly, anxious individuals tend to make more efforts via prolonged and repeated visual fixations to obtain more valid information, which prolongs reaction time, reduces information processing efficiency and causes significant differences in eye movement indicators.

4.2 Information Processing

Intense negative emotions such as nervousness raise athletes' arousal level. In accordance with the Yerkes-Dodson Inverted-U Law, excessively high arousal level declines cognitive efficiency.

Furthermore, nervousness induces physical stress responses including muscle tension, which impairs the function of the prefrontal cortex governing cognitive activities and physically limits the acquisition of visual information. Consequently, athletes obtain less valid visual information and suffer weakened information processing ability. Their eye movement patterns tend to be either sluggish with overly concentrated fixation distribution and irregular fixation duration, or hyperactive with scattered fixation points, short fixation duration and frequent saccades. Disperse attention further obstructs rational sports decision-making and undermines competitive performance.

4.3 Decision-Making

Anxiety affects anticipation performance by reshaping the thinking mode of information processing.

Firstly, the Attentional Control Theory indicates that anxiety impairs the inhibition and shifting functions of the central executive system, disrupts goal-oriented top-down attention, and shifts cognitive processing toward bottom-up attention. Indicators such as quiet-eye duration, fixation duration and fixation quantity can be adopted to assess changes in processing efficiency and attentional control. Accordingly, anxiety restructures athletes' visual search strategies via altering attention systems and reshaping cognitive performance.

Secondly, the Information Processing Theory suggests that individuals dominated by negative emotions mainly adopt bottom-up processing. This mode relies less on existing cognitive schemas, focuses more on real-time information integration, facilitates elaborate anticipatory judgment but consumes more time. By contrast, positive and relaxed emotions prioritize top-down information processing, which identifies objects based on accumulated sports experience. This strategy requires shorter fixation duration, fewer fixations and smaller saccade distances, and enables faster memory retrieval and recognition of stimuli [4].

Studies also prove that state anxiety prolongs the scanning and confirmation phases of visual search and deteriorates search task performance [13]. In table tennis anticipation research, Song Yanwei verified that anxiety disturbs athletes' top-down attentional processing, leading to prolonged total fixation duration, shortened quiet-eye duration, lower

anticipation accuracy and longer reaction time [14]. These findings all support the Processing Efficiency Theory, proving that nervousness-triggered neural patterns reduce information processing efficiency and raise error rates. In addition, anxiety rigidifies information processing modes. Negative emotions foster perceptions of hostile environments and heavy mental load, thus forming conservative thinking tendencies. Athletes tend to act cautiously and repeatedly verify details, which extends anticipation time and degrades judgment quality. Hence, visual search strategies under nervousness are both complicated and inefficient. For athletes at the same competitive level, high anxiety enhances sensitivity to threatening information while reducing attention to task-related cues, resulting in prolonged reaction time and low anticipation efficiency [15].

4.4 Deficiency in Experience and Mental Skill Regulation

Apart from technical proficiency, sports experience and mental skills also exert vital influences on athletic performance. Liu Jia's research revealed that under identical competitive state anxiety, expert players have shorter total fixation duration and fewer total fixations than novice players, with simpler and clearer fixation cluster distribution while novices present messy fixation trajectories [16]. Therefore, high-level athletes maintain better performance than low-level counterparts regardless of emotional interference.

Most college table tennis players lack sufficient competitive experience and systematic stress resistance as well as mental skill training. They are more vulnerable to emotional disturbances in major competitions, unable to stably implement pre-set techniques and tactics, and tend to regress to instinctive stress responses. This leads to distorted motor techniques and confused anticipatory logic.

Mental skill training is therefore indispensable. Researches confirm that athletes' psychological quality directly determines the exertion and application of techniques and tactics. Only with sufficient mental support can athletes fully display their sports skills, tactical awareness and sports intelligence in training and competitions [17].

5 CHAIN INTERACTION AMONG EMOTION, EYE MOVEMENT AND SERVICE ANTICIPATION

In the positive pathway, positive emotions prompt athletes to adopt more adventurous visual search patterns, broaden the span of attention, acquire more comprehensive information, and accordingly achieve higher anticipation accuracy.

In the negative pathway, negative emotions lead to conservative visual search strategies, narrow the scope of attention, result in insufficient information collection, and reduce anticipation accuracy.

Moreover, technical differences moderate this linkage. The more complex the service rotation (e.g. reverse rotation combined with underspin), the more prominent the amplifying effect of emotions on eye movement. Specifically, positive emotions can improve the anticipation accuracy of complex rotating serves, while negative emotions lower judgment accuracy or prolong reaction time.

To sum up, emotions reshape the temporal and spatial characteristics of eye movements to determine the quality of service-related information sampling, and ultimately systematically raise or reduce anticipation precision. Mastering and intervening in this chain can convert invisible psychological fluctuations into quantifiable, trainable and transferable competitive advantages.

6 CONCLUSION

Emotions influence anticipation performance primarily by reshaping cognitive processes. Specifically, emotions affect the availability of cognitive and attentional resources (e.g., negative emotions bias attention toward threats), reduce processing efficiency by interfering with working memory and arousal, and shift decision-making from experience-based top-down processing to detail-oriented bottom-up processing. These changes ultimately manifest in different anticipation outcomes.

For college athletes, limited competitive experience and mental skills make them more vulnerable to emotional fluctuations. As a result, negative emotions cause greater instability in their anticipatory performance.

Furthermore, emotion, eye movement, and anticipation form a chain mediation model. Eye movement patterns act as the core mediator. Positive emotions improve anticipation by promoting efficient visual search strategies, while negative emotions impair it by triggering inefficient search behaviors.

Based on these findings, two practical suggestions are proposed for college table tennis players. First, emotional regulation should be emphasized through mental skills such as cognitive reappraisal and attention control. Second, targeted anticipation training under simulated pressure should be strengthened to optimize visual search strategies, thereby stabilizing performance and enhancing service anticipation ability.

COMPETING INTERESTS

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