Int. J. Sport Psychol., 2021; 52: 267-280
doi: 10.7352/IJSP.2021.52.267

The influence of emotional state on perceptual anticipation of tennis players in Stalemate Stage

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The purpose of the present study was to explore the influence of emotional state on perceptual anticipation of tennis players in stalemate stage. Fifty tennis players were recruited in this study, participants completed an experiment which complied by E-prime to measure their reaction times and prediction accuracy. The experiment included 180 batting tasks which were divided into four blocks, and a positive, neutral or negative emotion-inducing video would be played for about 4 minutes before each block. Results indicated that positive and neutral emotions produced better outcomes for reaction times (RTs) and prediction accuracy compared to negative emotions. And negative emotions reduced the accuracy of straight line and oblique line predictions compared to neutral emotions. Additionally, there was a triple interaction in the RTs between emotional valence, skill group and batting task. In conclusion, emotional valence had a significant influence on tennis players' perceptual anticipation. Therefore, tennis players should train harder, improve their technical and tactical skills, and consciously control their emotions during the competition, thereby improving perceptual anticipation ability and achieving excellent athletic performance in the competition.

Key Words: Accuracy, Ball hitting route, Emotional valence, Perceptual anticipation; Reaction times.

As professional tennis has become increasingly competitive, players have been forced to rely on the multi-beat stalemate stage to establish an advantage, and the ratio of athletes to one-point competition within one or two beats has greatly reduced. When Fan et al. (2010) studied the use of various skills and tactics in professional men's singles and their impact on gains and losses (forced errors and non-destructive errors), they found that the stalemate stage in the total score of the competitions studied accounted for 43% on average,

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thus the stalemate stage has become an important scoring stage in tennis tournaments, it means the process from the beginning of the third beat to the end of a point when the number of beats exceeds 5 during the competition for one point. Shangguan and his colleagues (2015) used the expert–novice paradigm to research the behavioral data of tennis players at different skill levels in the stalemate stage. The tennis professional athletes whose technical level of 5.5 or more belong to expert group, and the second-grade athletes belong to novice group, they found that the critical time for second-level players to judge the hit point in multi-round confrontations was earlier than that in the novice group, and also that the accuracy rate was higher (Shangguan & Fan, 2015). The reason can be explained by the following assumption: novice tennis athletes need to use greater attention and cognitive resources whereas second-level athletes can predict and identify key information quickly. Additionally, high-level athletes had better integration and classification abilities in a simulated situation and used their existing professional skills and knowledge to modify and match changes in the competition (Zhang, 2013; Shangguan & Wang, 2018; Shangguan & Che, 2018). And previous studies have rarely combined tennis and emotions. However, emotions affect the stability of tennis players' forehand and backhand, and positive emotions can awaken the sports performance and enhance confidence, thereby improving the speed of decision-making and the accuracy of shots. Negative emotions would interfere with the attention of athletes, resulting in deviation in the judgment of the opponent and the landing point of the ball, mistakes, psychological pressure, and then be controlled by the opponent, so emotion is important in tennis.

At present, the study of emotion and cognition in sport has become a particular focus. And ways of inducing and measuring emotions have matured in recent years with developments in cognitive neuroscience. Research on emotions and athletic performance had mainly investigated the emotions generated by athletes in competitions, and these emotional experiences (positive or negative emotions) would affect athletes' perceptual anticipation. Under positive emotion, athletes reacted faster and perceived higher accuracy in perceptual anticipation. Motion perception anticipation is a process in which athletes use advance information to predict unknown events, including information processing and decision-making. Fredrickson and Branigan (2005) showed that positive emotions (e.g., joy, happiness) could broaden an individual's range of attention, perception, thinking and action, and induce them to pay attention to the overall characteristics of things. And Anderson (2009) got the opposite result in negative emotions (e.g., sadness, anger). In a positive emotional state, soccer players were more inclined to choose long-range or highly difficult shots, whereas in a negative emotional state they were more likely to make a risk assessment of a shot and be more inclined to pass the ball as an insurance option (Dong, 2016). Generally, for participants in a range of sports, a negative mood has an interference effect on their information processing. For example, in a negative mood basketball players took longer to react to conflict situations, and significantly slowed down the movement speed (Huang & Zhou, 2013), so negative mood processing took up more cognitive resources and had a significant interference effect on the speed of movement (Li, 2017; Pereira et al., 2006).

In the fiercely competitive arena of tennis, where continuous decision-making is closely tied to the outcome of the match, emotions run throughout the game, so whether emotions affect an athlete's decision-making remains to be verified. Players may have an advantage if they can maintain their calm, make appropriate estimates or predictions of attack or defense, and take a reasonable corresponding approach when reacting. Therefore, tennis players must have a high level of emotional control in the stalemate stage. Stabilizing their emotions at each stroke under the influence of various uncertain factors can have an important impact on the outcome of the match.

The purpose of the current study was to investigate the behavioral response data of tennis players in various emotional states. The goals were to provide reference indexes for regulating effectively the immediate emotion of tennis players when they formulate and adjust their tactics, and to provide scientific suggestions for the psychological selection and perceptual prediction training of tennis players. Based on the theoretical basis that emotion-inducing influences the perception of movement, the study adopts the expert–novice paradigm and uses video of the stalemate stage in a real tennis competition as the simulation material. The study used different emotional videos as experimental materials to induce participants' emotion in order to explore the behavioral differences in perceptual anticipation between second-level and novice tennis players in different emotional states (e.g., positive, neutral, and negative). And assumed that skill level, emotional state and batting task would all have an impact on the players' perceptual anticipation, positive emotions would accelerate the reaction speed of the novices, and improve the accuracy of oblique ball anticipation.

Methods

Participants

A group of second-level athletes (25 male) from Hunan colleges and universities and the Hunan provincial team were selected as the expert tennis players. All had reached the national second-level or above. The average age was 19.7 years; the technical grade was 4.5 or above; the exercise age was 6.4±0.82 years. For the novice group, we selected 25 second-year students from the tennis class at the Institute of Physical Education, Hunan Normal University. The average age was 19.4 years; the exercise age was 1±0.66 years. Statistical analysis showed no significant difference in age between the two groups ($p>.05$), but a significant difference in the age of technical tennis training between the two groups ($p<.001$). All participants had normal vision or corrected vision, no color blindness or color weakness, and no physical diseases or psychological disorders. They were all right-handed and had not participated in such an experiment beforehand. For the study,all participants gave informed consent and were compensated for their participation with cash. The study protocol received approval from the Ethics Committee of Hunan Normal University.

Experimental Materials

Prediction Test Materials

Because still photographs cannot truly reflect the complexities of an actual sports situation, the study selected video as the experimental material and used videos of the 2015-2017 men's French Open tournament in order to measure the participants' perceptual anticipation. The experimental materials showed the stalemate stage before the match score. Video editing software was used to intercept the competition video, requiring the stimulation material to be terminated at the moment when the opponent hits the ball. The length of the stimulation material for each sports scene was 3000ms. Three tennis teachers from universities in Hunan and five professional tennis coaches from Hunan province evaluated 240 pieces of intercepted video materials, and chose 180 pieces in the final selection. Experts' screening criteria for perceptual anticipation materials were as follows: 1) the number of multi-shot stalemate was higher; 2) the video was terminated at the moment the opponent hits the ball; 3) the more classic return ball and the marked straight or diagonal return ball were eliminated. All materials were randomly presented by a testing program compiled by E-prime 2.0.

Emotion-inducing Materials

To induce positive emotions, we selected four segments from "Tom and Jerry" videos which included scenes of Tom and Jerry in tennis, surfing, golf, skating and other sports backgrounds. To induce neutral emotions, we selected four segments from a geographical documentary called "Planet Earth" which included scenes of changing seasons, mountains, islands, and so on. To induce negative emotions, we selected four segments from the films "Rape of Nanking" and "Nanjing! Nanjing!" to evoke anger. Each segment had an average duration of four minutes. The PANAS scale (Positive and Negative Affect Schedule) was used to score the emotional induction effect on 30 students who majored in tennis at a physical education institute. The SAM (Self-Assessment Manikin) scale was used to score the awakening degree and pleasure degree of the video selection. All three emotion-inducing materials had statistical significance in the pleasure degree, $F(2,9)=2680.90$; $p<.00$ (Positive: $M\pm SD=7.33\pm0.09$; Neutral: $M\pm SD=5.32\pm0.10$; Negative: $M\pm SD=2.28\pm0.11$), and kept in the awakening degree, $F(2,9)=3.57$, $p=.07>.05$ (Positive: $M\pm SD= 4.76\pm0.56$; Neutral: $M\pm SD=4.67\pm0.77$; Negative: $M\pm SD=4.77\pm0.73$).

The equipment used in the experiment was a Lenovo notebook operating at 2.5 GHz, and the operating system was Windows 10.

Experimental Design

The experimental design consisted of a 2 × 2 × 3 three factors mixed design, i.e., Skill Group: second-level athletes group, novice group; Batting Task: straight line, oblique line;

Emotional Valence: positive emotion, neutral emotion, negative emotion. Skill Group and Emotional Valence were the between-subjects variables, and Batting Task was the within-subjects variable. The dependent variables were predicted accuracy and reaction times (RTs). Each emotional valence was allocated 180 batting tasks which were divided into four blocks.A total of 180 batting tasks were divided into four blocks, and a positive, neutral or negative emotion-inducing video would be played for about 4 minutes before each block.

Experimental Procedure

Participants in each of the two skill groups were randomly assigned to one of the three emotional conditions: positive emotions, negative emotions, and neutral (control group) and then sit in front of the screen at a distance of about 60 cm. The experimenters then explained the tasks to the participants who were asked to confirm that they understood the test process before moving on to watch the instructions. In the instructions, participants were asked to imagine that they were playing against the player in the tennis match about to be shown on the screen and to predict the hitting route of their opponent. The key instructions were: "Please place your left and right index fingers on the F and J keys of the keyboard respectively. After

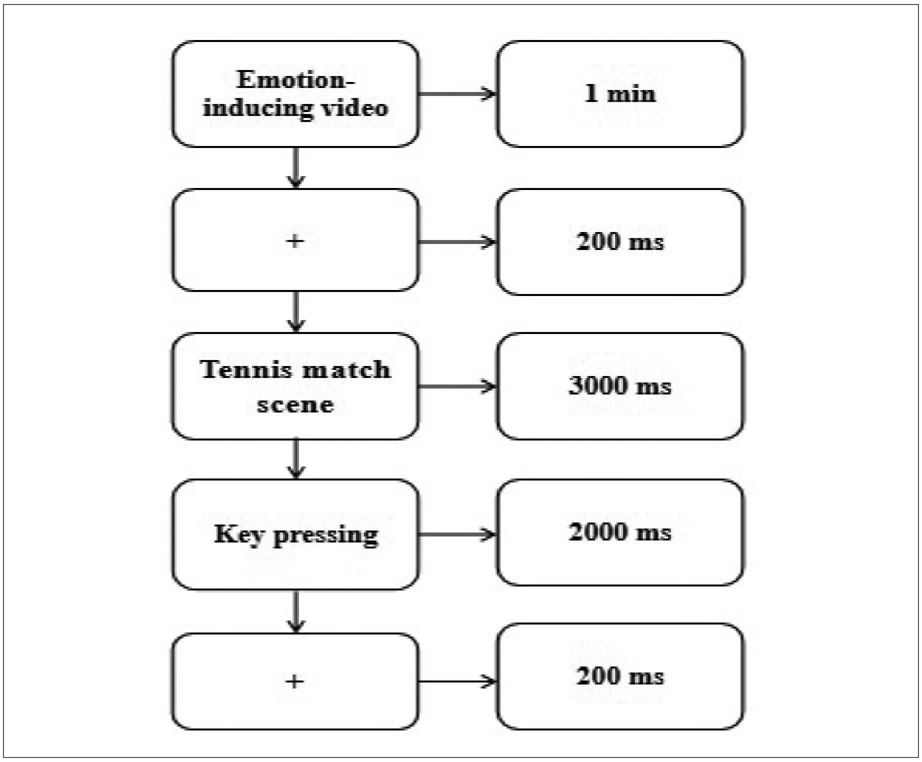

Fig. 1. - Schematic diagram of single trial.

the stimulus material appears, please press the key according to your prediction. If your prediction is a straight line, press the J key with your right index finger; if your prediction is an oblique line, press the F key with your left index finger. The task requires a quick and accurate response after the presentation of the video. The practice consists of 10 trials, and the practice material will not appear in the formal test material. The purpose of the test practice is to eliminate the occurrence of delay or erroneous reactions due to unfamiliar key press responses."

After the initial practice, participants could take the practice again if they were still unfamiliar with the experiment, but no more than three times, otherwise they would lose the opportunity to participate in this experiment. The formal part of the experiment started with further instructions. Participants were asked to read the emotion-reducing instruction carefully: "Please wear your earphones, check the tone quality and volume, and immerse yourself in the video." The emotion-inducing video was shown when the participants were ready.

The experimental process of a single trial was shown in Figure 1. Firstly, participants need to watch an emotion-inducing video about 4 minutes. Secondly, a blank screen with a gaze point "+" appears for about 200 ms. Thirdly, a random tennis match scene appears for about 3000 ms. Finally, participants need to press the appropriate key to estimate whether the route was a straight line or oblique line in 2000 ms. Otherwise, the next trial would start automatically. At the end of each block, participants can rest for 5 minutes to relieve fatigue and distractions in order to reduce errors in the experimental data. After a rest, participants watch the next emotion-inducing video and start the next block of the experiment.

Emotional post-test: The participants filled out a SAM scale to measure their current emotional pleasure as a baseline before the experiment, and then filled out the SAM scale again after watching the emotional inducing video to perform a post-emotional test. Excluding the participants who did not induce the corresponding emotions after watching the positive, neutral or negative video (i.e., the participants whose emotional pleasure decreased after watching the positive emotion video).

At the end of the experiment, we would perform prognosis treatment on the subjects to reduce the interference of negative emotions and make them return to the normal emotional state.

Results

Using SPSS 21.0, a one-way ANOVA was conducted to analyze the pretest and post-test SAM scores. Behavioral data were collected by E-prime 2.0, and the predicted reaction time and accuracy rate of the participants were extracted. Abnormal values outside of the mean plus or minus three standard deviations were excluded. The results of the experiment were used repeated analysis of variance.

Emotion-inducing Test

The pre-test and post-test SAM scores were analyzed in a one-way ANOVA. We observed a significant difference in the scores after affective priming, $F(2,147)=880.32$, $p<.00$ (Positive: $M=7.24$, $SD=0.56$; Neutral: $M=5.36$, $SD=0.27$; Negative: $M=2.28$, $SD=0.63$), whereas there was no significant difference in the scores before affective priming, $F(2,147)=1.31$, $p=.27$. These results showed that the stimuli were successful at inducing different emotions and that the emotion-inducing operation would be effective in the formal experiment.

Anticipation Accuracy

Table I showed the detailed results of the accuracy rate in the batting task for the second-level and novice athletes under different emotional states.

On the whole, the Repeated Measures Anova results showed a significant main effect of emotional valence ($p<.00$), a significant main effect of skill group ($p<.00$), and a significant main effect of batting task type ($p<.00$), thus verifying the experimental hypothesis. (See Table 2 for details.)

TABLE I
Anticipation Accuracy Of The Batting Task For Different Skill Groups under different emotional states.

Variable	Second-level Group		Novice Group	
	Straight line	**Oblique line**	**Straight line**	**Oblique line**
	M±SD	*M±SD*	*M±SD*	*M±SD*
Positive Group	0.65±0.05	0.71±0.04	0.56±0.04	0.59±0.05
Neutral Group	0.64±0.05	0.69±0.04	0.55±0.05	0.58±0.05
Negative Group	0.61±0.05	0.65±0.03	0.53±0.04	0.56±0.05

TABLE II
Repeated Measures Anova Of Emotional Valence, Skill Group And Batting Task Type In Anticipation Accuracy

Source of variation	**df**	**MS**	**F**	**p**	η_p^2
Emotional valence	2	.05	99.16	.00	.67
Batting task type	1	.11	49.13	.00	.50
Skill group	1	.71	95.25	.00	.67
Emotional valence * Batting task	2	.00	3.26	.04	.06
Batting task * Skill group	1	.02	6.91	.01	.13
Emotional valence * Skill group	2	.00	5.45	.01	.10
Emotional valence * Batting task * Skill group	2	.00	1.17	.31	.02

Note. Results were calculated using alpha = .05.

Marginal significance was found in the interaction between emotional valence and batting task type ($p<.05$) and in the interaction between batting task type and skill group ($p<.05$). The interaction between emotional valence and skill group in the anticipated accuracy rate for the task was significant ($p<.01$).

Reaction Times (RTs)

Table III showed the detailed results of the RTs for the second-level and novice groups when anticipating a straight ball and an oblique ball under different emotional states.

Table IV showed the details of the Repeated Measures Anova results. The results indicated that the main effect of emotion on RTs was significant

Table III
Reaction Times To Different Batting Tasks For Different Skill Groups Under Different Emotional States.

Variable	**Second-level Group**		**Novice Group**	
	Straight line	**Oblique line**	**Straight line**	**Oblique line**
	M±SD	*M±SD*	*M±SD*	*M±SD*
Positive Group	535.71±78.79	422.34±65.55	696.00±97.40	625.51±99.97
Neutral Group	552.67±91.20	443.05±77.44	713.65±86.90	639.98±81.71
Negative Group	717.86±101.93	550.94±107.71	871.81±71.96	857.92±83.28

Table IV
Repeated Measures Anova Of Emotional Valence, Skill Group And Batting Task Type In Rts

Source of variation	df	MS	F	p	η_p^2
Emotional valence	2	982572.38	156.70	.00	.77
Batting task	1	625518.26	151.73	.00	.76
Skill group	1	2912219.69	141.49	.00	.75
Emotional valence *Batting task	2	16.58	1.00	.75	.01
Batting task *Skill group	1	112008.09	27.17	.00	.36
Emotional valence *Skill group	2	20987.26	3.35	.03	.07
Emotional valence *Batting task *Skill group	2	26964.00	5.93	.00	.11

Note. Results were calculated using alpha = .05.

(*p*<.00). The main effect of skill group on RTs was also significant (*p*<.00), the reactions of the second-level athletes were faster than those of the novice group. The main effect of batting task type on RTs was also significant (*p*<.00), i.e., participants' reactions were faster when an oblique ball was hit compared to a straight ball, which verified the experimental hypothesis.

The interaction in the RTs between batting task and skill group was significant (*p*<.00), and that between emotional valence and skill group was marginal significant (*p*<.05). We also found a triple interaction in the RTs between emotional valence, skill group and batting task (*p*<.01).

Discussion

The study has adopted the expert–novice paradigm to investigate the perceptual anticipation of tennis players under different emotional conditions. Emotional valence and skill group were used as between-subjects variables, and batting task type was used as the within-subjects variable. The experimental results showed that emotional valence, batting task and skill group had significant main effects on prediction accuracy and reaction times, confirming the experimental hypothesis.

Influence of different emotional states on the accuracy of perceptual anticipation

The main task of the experiment was to predict the line of the ball in a tennis match confrontation immediately after being primed with different emotional valences, in line with our aim of exploring the influence of emotional valence on the participants' perceptual anticipation. Firstly, the results for prediction accuracy showed that the main effect of emotional valence was significant. Compared with positive and neutral emotional groups, the accuracy rate in the negative emotional group was significantly lower, indicating that the quality of an athlete's anticipation was reduced under the influence of negative emotions whereas the predictions of athletes in a positive or neutral emotional state were more accurate. According to the theory of attention resource competition, there was a competitive relationship between an individual's cognitive activities and emotion, such that negative emotions attract more attention resources (Luck et al., 1994). Therefore, a tennis player's cognitive processing was more likely to be disturbed in a negative emotional state. Using ERP techniques, Lu (2018) found a significant interaction between groups (positive emotions and negative emotions) and the activation location in brain regions. Under positive emotions, athletes could mobilize more resources when processing perceptual information, whereas under negative emotions the processing of perceptual information is inhibited. In a tennis match situation, negative emotional states would have a negative impact on a player's ability to assess an opponent's tactical intentions and the search for key information on an opponent's hitting actions and stance in a continuous multi-shot confrontation.

Secondly, the results of the current study showed a significant interaction between emotional valence and batting task type. The accuracy rate for oblique ball predictions was higher than that of straight ball predictions in all three emotional states. For straight ball predictions, there was no significant difference in accuracy between the positive emotional group and the neutral emotional group, but the rate was higher than that of the negative emotional group. For oblique ball judgments, the accuracy rate in the positive emotional group was higher than the rate in the neutral emotional group, which in turn was higher than the rate in the negative emotional group. Fredrickson et al. (2013) found that when athletes performed a simple task, emotions such as happiness, well-being and satisfaction were especially prominent so they could complete the task successfully. In contrast, when athletes performed complex and demanding activities, they should try to understand or overcome in advance negative emotions such as sadness (Chen et al., 2019). When athletes experienced performance decline and setbacks, depression dominated, thus affecting their decision-making processes. Our results showed that it was more difficult to predict straight balls than diagonal balls, and that positive emotions cannot improve the accuracy rate when performing a difficult task. As the difficulty of decision-making tasks increased (e.g., predicting straight balls was more difficult than predicting oblique balls), the negative effects of negative emotions became more obvious, thus reducing the athlete's perceptual anticipation ability.

Thirdly, this study also found a significant interaction between emotional valence and skill group in the rate of accurate predictions. The accuracy rate of the second-level athletes was higher than that of the novice group in positive, neutral and negative emotional states. Second-level athletes also showed a significant difference in accuracy between positive and neutral emotional states, but the difference in reaction time was not significant. This revealed that within a certain RTs the predictions of second-level athletes in a positive emotional state were more accurate compared to those in a neutral emotional state, indicating that their cognitive processing was more efficient and that a positive state was more conducive to making accurate predictions. This result was consistent with the "positive affect" proposed by Labroo et al. (2003). Under the influence of positive emotions, an individual's cognitive ability would be improved correspondingly and attention to irrelevant stimuli would be reduced. This helped athletes to focus on the current task situation, processed the key information, and found ways to solve immediate problems.

Influence of Different Emotional States on the RTS of Perceptual Anticipation

The results of our experiment showed a significant main effect of emotional valence on the reaction time of the athletes' perceptual anticipation. Both skill groups responded faster under positive and neutral emotional conditions compared to those under negative emotional conditions. This result indicated that emotional state played an important role in perceptual anticipation and responded in the multi-stroke confrontations in the stalemate stage of tennis. Compared with negative emotions, positive emotions could save cognitive resources, promote faster decision making, and produce greater accuracy. The results of this study were consistent with previous studies. Research on emotion in the field of sports cognition has confirmed that positive emotion played a role in promoting athletes' decision-making tasks in basketball and badminton, whereas negative emotion had the opposite effect (Sun, 2016; Chi et al., 2012).

Our results also showed a significant interaction between emotional valence and skill group in the RTs of the athletes' perceptual anticipation. For both skill groups, however, the RTs of athletes in a positive emotional state were faster than those in a neutral emotional state, which in turn were faster that those in a negative emotional state, indicating that both groups of athletes were affected by negative emotion. In a study of the impact of emotion on time perception, Droit-Volet et al. (2008) found that when individuals were highly alert to anger (a negative emotion), they would prolong the experience of subjective time perception, overestimate time, and spend more time thinking in a certain period of time compared to individuals in a positive emotional state. The anticipation ability of the second-level athletes in this experiment, though a significant improvement compared to the novices, had not reached the level of expert athletes. Under a negative emotional state, the second-level athletes must reduce anticipation speed to ensure accuracy. The trade-off between speed and accuracy perspective provided theoretical support for our experimental results. Comparing retrieval and extraction of exercise scenes with experience templates in the brain for pattern recognition prolongs decision making and relies more on exercise scenes for analysis, which is also affected by negative emotions. In contrast, individuals are much more relaxed when dealing with positive and neutral emotional stimuli.

In a word, perceptual anticipation is the process by which athletes use advance information to prejudge unknown events.In tennis, it is reflected in the direction of the ball and the landing point of the ball. So the experimental process used in the study can help to measure the perceptual anticipation ability of athletes, which will enable coaches to better understand the current situation of athletes, then improve the ability of spatial perception and the accuracy of hitting through reasonable training.

However, Our study had some limitations. First, Due to the limitation of age and grade, the number of participants found in this area was relatively small, which lead to the small sample size,so we would use the estimation programs to estimate the number of participants and expand the research area in the future research. Second, video clips such as Tom and Jerry and the Rape of Nanking were used as emotion-inducing materials, although the results showed that they had good emotion-inducing effect, but their ecological validity was still insufficient compared with sports-related materials, so we would choose more appropriate materials which were supported by empirical evidence in the sport context. Finally, This experiment was mainly through the computer to generate stimulation and calculate data, there may be a small gap with the actual tennis match, so in the future research, we would complete the experiment from a more real point of view.

Conclusion

The study had explored the effects of emotional valence and batting task on the perceptual anticipation of tennis athletes at different skill levels. The results were in line with expectations and also demonstrated the effectiveness of the emotion-inducing operation. The finding not only demonstrated that emotional valence, skill level and batting task were all important factors that affect the quality of a tennis player's perceptual anticipation, it also provided an experimental system to evaluate the perceptual anticipation ability of athletes. Last, The study indicated a new direction for perceptual anticipation in the field of sports and helped to monitor the mental control ability of athletes in different emotional states. However, more empirical research was needed to better explain this finding, and explore other potential factors of perceptual anticipation.

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