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ORIGINAL RESEARCH

The Effect of Emotion on Time Perception in Youth Athletes with Different Alerting Efficiencies

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Purpose: Time perception plays a critical role in executing movements in various competitions. However, less research has been conducted on the alerting component of attention in the processing of time perception, and that the effects of emotion on the alerting network show inconsistent effects. This study is aimed to explore the factors that may influence time perception in youth athletes and these relationships.

Methods: A total of 225 participants were recruited to assess alerting efficiency using the Attention Network Test and were divided into high and low alerting efficiency groups based on the front and back 27% of the ranked alerting scores as a dividing metric, and subsequently participants completed Time replication task under different emotionally induced conditions.

Results: Alerting efficiency had a significant effect on time perception, with the high alerting efficiency subjects having higher time estimation accuracy [F (1106) = 6.32, p = 0.013, $\eta^2 p$ = 0.10] and being more inclined to overestimate time perception [F (1106) = 12.64, p = 0.001, $\eta^2 p$ = 0.11]. An interaction was found between emotion and alerting efficiency on time replication ratio [F (2106) = 3.59, p = 0.031, $\eta^2 p$ = 0.08], and further simple effects analyses found that the low alerting efficiency subjects tended to overestimate time in the anger state relative to the happy and neutral states [F (2106) = 5.93, p < 0.01, $\eta^2 p$ = 0.10].

Conclusion: These findings suggest that high alerting efficiency in youth athletes is associated with greater time perception response advantage; The time perception of low alerting efficiency youth athletes was more likely to be affected by emotions. This study provides a reference for the training of time perception and specialized perceptual ability of youth athletes, enriches the index system of psychological selection of youth athletes.

Keywords: time perception, sport, attention, alerting, emotion, youth athletes

Introduction

Time perception is the process of perceiving and processing the sequence and continuity of objective events by the individual's sense organs and the perception of time is a universal, continuous experience.[1,2] The processing scale of time perception is extremely large, ranging from milliseconds to months, where accurate processing of temporal information in the range of hundreds of milliseconds to seconds is necessary for processes such as motor control and speech recognition.[2] Athletes' time perception is the core of athletes' specialized perception. In many sports, time perception plays a very important role, such as the requirement of "man to ball" when passing and catching the ball in ball sports, and the timing of jumping and opening the body in gymnastics and skating. Good time perception helps athletes to more accurately grasp the rhythm and optimal timing of the game, and to a certain extent determines the quality of the athletes' technical movements and athletic performance on the field of play.[3] Then, time perception ability has an important impact on athletes' competitive ability.

In ordinary life, there are many factors affecting time perception, such as attention, arousal, and emotion are all key factors affecting the inconsistency between subjective and objective time perception.[4–6] It has been argued that the crucial factor in explaining the discrepancy between actual and subjective time and the factors influencing it lies in the attentional mechanism.[7] The attentional gate model (AGM) explicitly considers the role of attention on time in anticipatory situations, arguing that attention can influence temporal perception by determining impulses to the accumulator.[8] According to the attentional gate

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model, an attentional gate also exists between the metronome and the switch during the individual's temporal information processing stage and opens as the individual perceives temporal stimulus information, and as the attentional gate opens to a greater extent, the more attentional resources are allocated to the temporal dimension of the stimulus, the more impulses go to the accumulator, and the longer time is perceived, and conversely the shorter it is perceived.

Researchers have distinguished between attention as selective attention and sustained alert attention. In exploring the relationship between attention and time perception, both in theoretical and experimental studies, most current research has focused primarily on the effects of selective attention on time perception,[9–11] which often neglects the study of the role of alerting attention in time perception. Alertness, as a special form of attention, is a continuous state of readiness of an individual for a stimulus that does not appear but may appear, and alertness is a kind of continuous attention with its important adaptive significance. On the field of competition, athletes are required to maintain a high level of alertness and accurate time perception, and to maintain a characteristic sensitivity to the time rhythm of the movement process. Recently, it has been found that individual differences in alerting function affect an individual's perception of time perception. Subjects in the high alerting group were more inclined to overestimate time perception and had higher accuracy of time estimation relative to subjects in the low alerting group.[12] Thus, for athletes, is it possible that a decrease in the level of alertness on the competitive playing field can lead to a deviation in time perception that affects performance? The answer to this question will help to understand the causes of athletes' errors on the sports field, which in turn will help athletes to maintain their characteristic sensitivity to the temporal rhythms of the sports process, to improve their sports performance, and to reduce the number of game errors.

It was found that people's perception of time perception also depends on emotional variables. Events that are perceived as pleasant tend to result in the experience of "time flying by", in contrast to emotionally distressing events that typically result in the experience of "time delaying" or, in more extreme cases, "time standing still".[13,14] Our perception of time is influenced by emotional factors such as anger, sadness, and fear.[15] Earlier studies have already suggested that emotions influence perceptions and judgements of time through two basic dimensions, arousal (high-low) and pleasantness (positive-negative).[16,17] The effect of emotional arousal on time perception can be explained by the arousal mechanism. According to the internal-clock model,[18] emotional arousal as an exogenous stimulus increases the pacemaker rate, which results in the accumulation of more impulses within the same physical unit of time, and thus longer perceived time for high arousal emotional stimuli.[19] The effect of emotional valence on temporal perception can be explained by the Attention Resource Model, which suggests that the more resources allocated to temporal processing, the longer the perceived time, whereas emotional processing takes up a certain amount of attentional resources resulting in fewer resources being allocated to temporal processing, and so the perceived time is shorter in the emotional condition.[20]

Emotions are known to affect individuals' attentional processes, such as the ability to focus, eliminate distractions, and shift attention.[21–23] Most research suggests that individual differences in emotion affect not only what individuals attend to, but also basic cognitive processes such as paying attention to things.[23,24] However, these previous studies have always considered attention as a single cognitive process and have tested attention as a holistic dependent variable without disaggregating attention functions.[25] According to Posner and Petersen (1990), attention is composed of three separate networks: alerting, orienting, and executive control.[26] Fan et al have designed the Attention Network Test (ANT), a single task that simultaneously assesses the efficiency of each attentional network.[27] Currently, a quite a few studies have found that the effects of emotion on attention are mainly through influencing specific attentional networks. Most studies have used the ANT attentional network paradigm to assess the effects of emotion on attention, for example, in a study examining how threat-related attentional biases affect the attentional system, anxiety was found to significantly modulate attentional network functioning, with state anxiety positively correlating with alerting efficiency, whereas fear and neutral emotions negatively correlated with alerting efficiency,[25] but in another study on the effects of emotion on attentional functioning, no modulation of the three attentional network functions by negative emotions was found.[28] Contrary to these findings, which showed that subjects in angry mood responded faster and showed greater alerting effects than the control group, the effects of anger on the orienting and executive control networks were not significant.[29] For simple tasks, threat (fear or anger) facilitated the orienting network more than the happy emotion but had no significant effect on the alerting network.[30] The inconsistent effects found in the above studies regarding the function of emotions on the three networks of attention may be related to the type of emotion, task difficulty, and stimulus duration.

These findings may be related to the arousal mechanisms of emotions, such as anger is a passive, high arousal level emotion, arousal enhances sensitivity to the environment by elevating the individual's cognitive and physiological arousal levels, which prompts participants to begin the process of physical preparation and self-awareness, another explanation may be physiological, the noradrenaline system mobilizes the state of arousal,[31] especially since angry negative emotions elicit a stronger norepinephrine response, so that angry emotional conditions induced the greatest alerting effect.[32] Meanwhile, Attentional Load Theory holds that distraction interference decreases in high perceptual load conditions but increases in high cognitive load conditions,[33] which to some extent may also explain these above-mentioned findings. Through the above studies we have found that the effects of emotions on the alerting network show inconsistent effects, and even for the same emotional stimuli (eg, anger), inconsistent findings of increase or decrease have been found.

In summary, time perception ability is an important specialized ability for athletes, and both attention and emotion are critical factors influencing subjective and objective inconsistencies in time perception. Alertness, as a form of sustained attention, has its adaptive significance for athletes and is crucial for successful athletic performance.[34,35] Athletes experience a wide range of emotions during and even before and after competition. Numerous studies have shown that emotions play an important role in athletes' game performance and competitive performance and can even affect their competitive state and thus change the outcome of the game.[36,37] It has also been found that the effects of emotions on attention are primarily mediated by influencing specific attentional networks, and that the effects of emotions on the alerting network have also shown inconsistent findings.[25,28,29]

Therefore, the present study aimed to investigate the effect of emotion on time perception in youth athletes with different alerting efficiencies through an experimental method, where subjects were divided into high and low alerting groups based on an attentional network test and randomly assigned to different emotion-inducing conditions, to examine whether there were any differences in subjects' time perception. In conclusion, we hypothesized that alerting efficiency would have a positive effect on time perception in youth athletes, that youth athletes with high alerting efficiency have better time perception, and that there may be an interaction between emotion and alerting efficiency on their time perception.

The study of this question will help us to explore the influencing factors of youth athletes' time perception and its changing law and provide certain scientific references and empirical evidence for youth athletes' psychological selection and special time perception training. This study will provide a certain role for the enrichment and improvement of the existing time perception theory of youth athletes' psychological selection index system and the improvement of the existing time perception theory.

Materials and Methods

Participants

To determine the minimum sample size, a priori analysis for a mixed analysis of variance (ANOVA) design (G*Power 3.1.9.7) was performed. In this study, a mixed factor design of 2 (alarm: high alerting efficiency vs low alerting efficiency) *3 (emotion: anger vs happiness vs neutral) *3 (Time interval length: 2000ms vs 1000ms vs 500ms) was used to explore differences in time perception in athletes under different conditions. We used the automatic direct method available in G*Power, With a medium effect size of 0.25, the significance level of $\alpha = 0.05$, power = 0.95. The sample size obtained using G*power3.1.9.7 was calculated to be at least 66 cases.

Two hundred and twenty-five highly fit youth athletes (98 females; mean age = 16.36; mean age = 1.26; 127 males; mean age = 15.59; mean age = 1.12) were randomly recruited through advertisements posted in a sports university and its affiliated sports schools in China. The type of sports is mainly round-based ball games (including badminton, table tennis and tennis). The subjects all met the following criteria: (1) three or more years of professional training experience; (2) qualified as the National Player at Second Grade or above; (3) more than three training sessions per week in the past two years; (4) more than two hours of training time per session; (5) right-handed, reported normal or corrected naked eye vision, and had no color weakness or color blindness; (6) did not report diagnosed psychiatric or neurological disorders, did not take medication that would influence central nervous system functioning, and (7) None had ever participated in Attentional Networks Test (ANT) testing before. Written informed consent was given in accordance with the procedures and protocols approved by the ethic committee of the of the affiliated sports university (protocol code 2022282H).

Stimuli and Tasks

Attentional Networks Test (ANT)

The Attentional Networks Test (ANT) was presented using E-Prime 2.0 software (Psychological Software Tools, Pittsburgh, PA, USA) to display the stimuli on a computer screen with a 19-inch monitor (screen resolution of 1024×768 pixels, refresh rate of 85 Hz). The subject's eyes were approximately 60 cm away from the computer screen. The E-Prime 2.0 software collects descriptive data.

Experimental Setup: First, a presentation of the steps of an ANT test was introduced to all participants. Participants were asked to be relaxed and sit 60 cm away from the monitor, focusing on the screen to be able to finish ATN practice. In a normal ANT test, a "+" gaze point is first presented in the center of the screen at the beginning of each trial, and then a "*" stimulus is shown above or below the gaze point, and there may also be arrows pointing to the left or right. There were four different cueing conditions: no cue, center cue, double cue, and spatial cue. In the no-cue condition, only the gaze point was randomly displayed for a duration of 350–650 ms. In the center cue condition, the point of view appears in the middle of the screen. In the double cue condition, both asterisks appear on both dots at the same time. In the spatial cue condition, the asterisk appears above or below the gaze point. The target stimulus consists of five small arrows, and the response consists of pressing the left mouse button with the left thumb when the central arrow points to the left. If the central arrow pointed to the right, they were instructed to press the right mouse button using the right thumb.

The attention network test contained three experimental blocks with 96 trials each, and each trial comprised five events: (a) first, a "+" gaze point was presented in the center of the screen for 400–1600 ms; (b) a cue "*" signal was presented for 100ms; (c) a gaze point was presented at the center of the screen for 400 ms; (d) afterwards, the target stimulus requiring a response was presented, and the target stimulus showing for no more than 1700 ms disappeared immediately once the subject pressed a key. However, the target gaze point kept showing in a variable time. The duration of the target gaze point after the response was 3500 ms minus the duration of the first gaze plus the response time; (e) The next trial was then started, and the total duration of each trial procedure was 4000 ms. All conditions in the experiment were equilibrated within the subject. During the experiment, the subjects were asked to look at the center of the screen and respond as quickly and accurately as possible. A total of 24 practice trials complete feedback were conducted prior to the formal testing. The ANT formal testing protocol consisted of 96 trials. Each of the four cue conditions was performed with two target locations plus two flanker conditions plus two central letters with three repetitions (see Figure 1).

The attentional network test can effectively distinguish network functions from alerting, orienting, and executive control, and use the difference between reaction times in different cue conditions to represent different attentional network functions. Alerting efficiency = $RT_{no\ cue}$ -$RT_{double\ cue}$; Orienting efficiency = $RT_{center\ cue}$ - $RT_{spatial\ cue}$; Executive Control efficiency = $RT_{incongruent}$ - $RT_{congruent}$.

Emotion Inducing Task

This study drew on Lerner et al's autobiographical recall task as an emotion induction method.[38,39] Subjects in the experimental groups (angry and happy) were asked to complete two tasks: Task 1: "Please try to remember and list three things that made you feel very angry or happy, eg, being betrayed by a friend (angry group)/getting a scholarship (happy group)". Task 2: "Choose one of the above experiences that made you most angry or happy and describe it in detail in writing. Let others understand why you feel angry or happy, and let others feel angry or happy by reading about this experience".

Control subjects were also asked to complete two tasks: Task 1: "Please list 3 things you usually do in the evening, eg, wash your face, etc"., and Task 2: "Describe in as much detail as you can how you spend your evenings, including describing the events in chronological order. Let others reconstruct how you spend your evenings through your descriptions". Previous research has shown that such autobiographical recall tasks are an effective way of inducing specific emotions.[40–43]

Time Replication Tasks

The perceptual reaction time of athletes on the sports field can be as low as milliseconds, and the process of replicating short time distances using the temporal replication method allows for a better examination of the sense of time and rhythm developed by athletes on the field of play, and then the temporal replication method was used in this study.

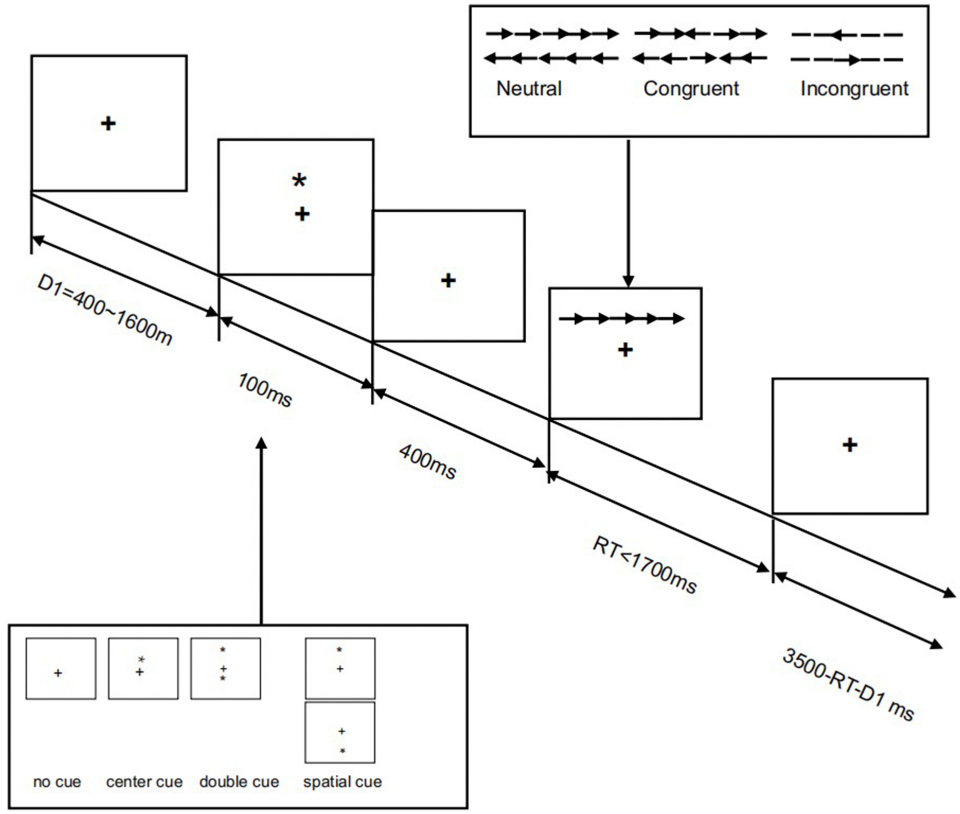

Figure 1 Schematic overview of the Attention Network Test (ANT) adopted in this study.
Notes: The symbol "*" indicated the cue, and the symbol "+" represented the fixation in the center of the screen.

Before the formal start of the experiment, subjects sat about 60cm in front of the computer screen, carefully read the experimental procedure and the experimental instructions, and subsequently and completed the practice phase of the temporal replication task to start preparing for the experiment. A total of 15 trials in the practice phase were randomly presented at 3 different temporal intervals, with each temporal interval occurring 5 times. The length of time that subjects spent replicating each type of stimulus was automatically recorded by the E-Prime 2.0 software.

For each trial in the formal experiment, a 500-ms white "*" gaze point was presented in the center of the black screen, followed by a randomly presented empty screen for 50 to 1050 ms, and then a 500ms/1000ms/2000ms white circular pattern with a diameter of 5 centimeters appeared as a visual stimulus on the computer screen, with the time from the appearance of the white circular pattern to its disappearance as the target time interval. The white circular pattern was then presented to the subject, who was asked to start replicating the standard stimulus just presented as soon as he or she saw it, and the white circular pattern disappeared after the key was replicated. The time interval between the end of a response and the next stimulus picture was randomized, with a time interval ranging from 1500 to 2300 ms. The set of formal experiments consisted of a total of 3 types of stimuli, each presented 20 times, for a total of 60 trials (see Figure 2).

Emotion Assessment Scale

The Emotion Assessment Scale is a self-administered scale that draws on previous research.[44] Subjects were asked to choose the scale that best expressed their level of feeling after 2 emotional words (0 = not at all ~ 8 = very strongly). Two words represented anger and two words represented happiness, with higher numbers indicating how strongly the subject felt about an emotion. Such self-report measures of emotional experience are often used to assess the effectiveness of emotion manipulation in studies of this type.[45,46]

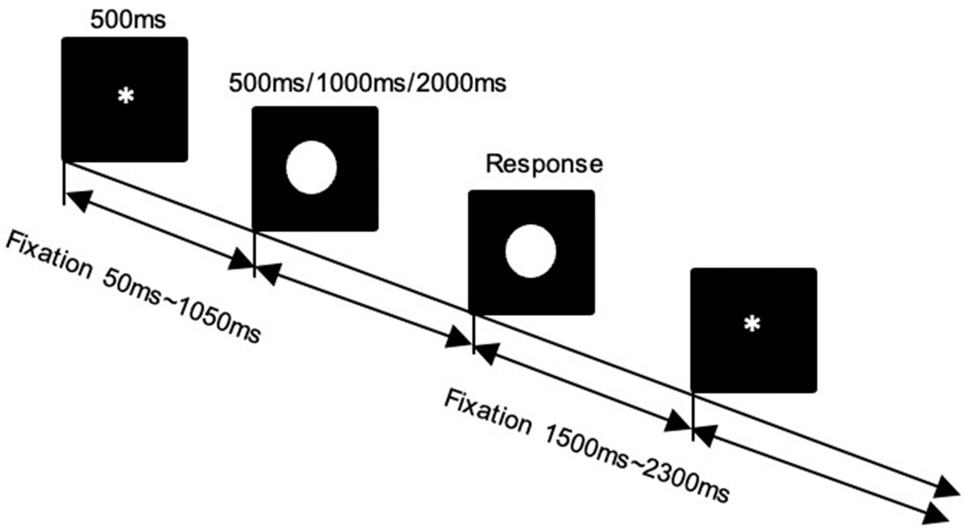

Figure 2 Schematic diagram of Time replication tasks.
Notes: The symbol "*" represented the fixation in the center of the screen, and the White circular pattern as target stimulus.

Procedure and Design

All participants first completed the Attention Network Test (ANT), which identified high and low subgroups based on the pre and post 27% of the alertness network scores as a dividing metric, and 120 volunteered to participate in the follow-up experiment. Next subjects were randomly assigned into experimental and control groups to complete the emotion induction task, and then proceeded to complete the Time Replication Tasks. Finally, they filled out the Emotional Assessment Scale and underwent an emotion manipulation test to confirm successful emotion elicitation. For the angry emotion group, appropriate post experiment treatment was provided. All participants received a certain amount of compensation upon completion of the experiment.

Additionally, as this study aimed to examine the impact of specific emotions on experimental variables, participants who indicated "not at all" on the target emotion dimension of the emotion manipulation test were excluded from the analysis. A total of 120 subjects participated in this experiment. Following the exclusion of invalid data, a total of 112 valid datasets were obtained (48 females), the participants were randomly assigned to one of six groups as follows: a. high alerting efficiency-happy group with 19 participants; b. high alerting efficiency-angry group with 18 participants; c. high alerting efficiency-control group with 18 participants; d. low alerting efficiency-happy group with 20 participants; e. low alerting efficiency-angry group with 20 participants; f. low alerting efficiency control group with 17 participants.

Statistical Analysis

The Shapiro–Wilk test confirmed normal data distribution. Mauchly's test was used to examine spherical data, and the Greenhouse–Geisser correction was used to analyse non-spherical data. Paired *t*-tests with Bonferroni corrections for multiple comparisons were used for post hoc analysis if the ANOVA showed significant interactions between different factors. Partial eta-squared ($\eta^2 p$) was used to determine the effect size of the variance. *p*-values < 0.05 were considered significant. The statistical analyses were carried out using the software package SPSS version 25.

A mixed-factor design analysis of variance (ANOVA) on the 2 (alerting) ×3 (emotion) ×3 (Time interval length) separately on Time replication relative error and Time replication ratio. Alerting, which includes high alerting efficiency and low alerting efficiency (2), and emotion, which contains angry, happy, and neutral (3), are intersubjective factors. Time interval length is a within-subject factor which has three factors: 2000ms vs 1000ms vs 500ms (3). The dependent variables used in the experiment include the Time replication relative error and the Time replication ratio, respectively.

The Time replication relative error is used to indicate the accuracy of the time estimates. Time replication relative error = | (subjective replication length - objective length) |/objective length. For each objective time interval, the closer this indicator is to 0, the more accurate the time estimate is. Time replication ratio is used to indicate the tendency to overestimate or underestimate time, with a replication ratio greater than 1 indicating an overestimation and less than 1 indicating an underestimation. Time Reproduction Ratio = Subjective Reproduction Time Distance Length / Objective Time Distance Length.

Results

Validation and Analysis of the Attention Network Test

The data obtained from the ANT test were analysed using a Pearson correlation test and bootstrap correlation confidence intervals were calculated to assess the independence of the three attentional networks, considering the effects of all three types, following the standard algorithm that computed the three attentional functions.[27] The results indicated that there were no significant correlations between the three attentional networks (see Table 1), which is consistent with existing national and international research.[47,48] This suggests that the Attention Network Test (ANT) is applicable in the group of youth athletes and can be used to classify groups with high and low alerting efficiency based on the alertness scores of the subjects. A significant difference in alerting efficiency was found between the high alerting efficiency group (65.00± 13.34) and low alerting efficiency group (24.30 ± 8.75), [t (110) = 19.16, p < 0.001, d = 1.62], indicating that the experimental groupings were reasonable.

Emotion Manipulation Check

To test the validity of emotion elicitation, the mean scores of two similar words were used to represent the happy and angry emotion scores, respectively. A one-way ANOVA on the emotion-evoked outcomes found a significant main effect of emotion type on the anger rating dimension, $F(2, 109) = 190.33$, $p < 0.001$, $\eta^2 p = 0.73$; and post-hoc multiple comparisons found that subjects in the anger group reported significantly higher anger rating scores (M = 5.32, SD = 1.52) than those in the happy group (M = 1.64, SD = 0.93) and control group (M = 1.21, SD = 0.86), $ps < 0.001$. The main effect of emotion type on the happy mood rating dimension was significant, $F(2, 109) = 169.70$, $p < 0.001$, $\eta^2 p = 0.76$; post-hoc multiple comparisons revealed that subjects in the happy group reported significantly higher happy rating scores (M = 5.46, SD = 1.30) than those in the anger (M = 1.67, SD = 0.75) and control groups (M = 1.39, SD = 0.78), $ps < 0.001$. The results suggest that emotion elicitation was successful. P-value is considered significant if it is less than 0.05.

Behavioral Results

Mixed factor ANOVA on Time replication relative error showed a main effect of alerting [F (1106) = 6.32, p = 0.013, $\eta^2 p$ = 0.10], with lower time replication relative error in the high alerting efficiency group than in the low alerting efficiency group (0.09 vs 0.12). No significant effects were found for emotion or time interval length, nor for interactions (See Table 2).

Table 1 Correlation Between the Three Functions of Attentional Networks in Experiments (N = 112)

Attentional Function		Alerting	Orienting	EC
Orienting	Pearson correlation	−0.092	–	
Bootstrap[c]	Lower	−0.401		
95% CI	Upper	0.175		
EC	Pearson correlation	−0.098	0.081	–
Bootstrap[c]	Lower	−0.336	−0.210	
95% CI	Upper	0.174	0.361	

Notes: [c]Bootstrap results are based on 5000 bootstrap samples.
Abbreviations: EC, executive control; CI, confidence interval, respectively.

Table 2 Main and Interaction Effects of Mixed-Measure ANOVA on Time Replication Relative Error

Time Replication Relative Error	*F*	*p*	η^2p	Effect Size
Time interval length	0.75	0.476	0.01	Small
Alerting	6.32*	0.013	0.10	Medium
Emotion	0.55	0.579	0.01	Small
Alerting×Time interval length	2.25	0.108	0.02	Small
Alerting×Emotion	1.07	0.348	0.01	Small
Time interval length×Emotion	0.51	0.731	0.01	Small
Alerting×Emotion×Time interval length	0.09	0.985	0.01	Small

Notes: * *p*<. 05.

Table 3 Main and Interaction Effects of Mixed-Measure ANOVA on Time Replication Ratio

Time Replication Ratio	*F*	*p*	η^2p	Effect Size
Time interval length	0.22	0.637	0.01	Small
Alerting	12.64**	0.001	0.11	Medium
Emotion	2.20	0.116	0.04	Small
Alerting×Time interval length	1.14	0.287	0.01	Small
Alerting×Emotion	3.59*	0.031	0.08	Medium
Time interval length×Emotion	1.51	0.225	0.03	Small
Alerting×Emotion×Time interval length	1.14	0.323	0.02	Small

Notes: * *p*<. 05. ***p* < 0.01.

Mixed factor ANOVA on time replication ratio showed a main effect of alerting [F (1106) = 12.64, p = 0.001, η^2p = 0.11], High alerting group tend to overestimate time more than low alerting group. Moreover, an interaction emotion × alerting [F (2106) = 3.59, p = 0.031, η^2p = 0.08] was found for time replication ratio (See Table 3). Further simple effects analysis revealed the low alerting efficiency group had higher time replication ratios in the angry state than in the happy state and neutral state [F (2106) = 5.93, p <0.01, η^2p = 0.10], suggesting that the low alerting efficiency group tended to overestimate time under the angry state (0.99 ± 0.02 vs 0.87 ± 0.02) (see Figure 3).

Discussion

The research results of this article show that individual differences in alerting efficiency have a significant impact on time perception in youth athletes. Compared with the low alerting efficiency group, the high alerting efficiency group have higher time accuracy and tends to overestimate time. This research result supports the research hypothesis. First of all, according to the theoretical framework of time perception, in terms of the internal clock model, attentional and arousal mechanisms are important factors influencing the subjective-objective inconsistency of an individual's time perception.[49,50] The model argues that the number of pulses in the accumulator is a key determinant of the length of the temporal distance. It has now been found that differences in alerting levels can influence temporal perception through the encoding of the internal clock.[12] Arousal state can modulate the pulse rate of the metronome during the clock phase,[51] and arousal level can speed up or slow down the metronome to regulate temporal processing,[18] with higher alertness to

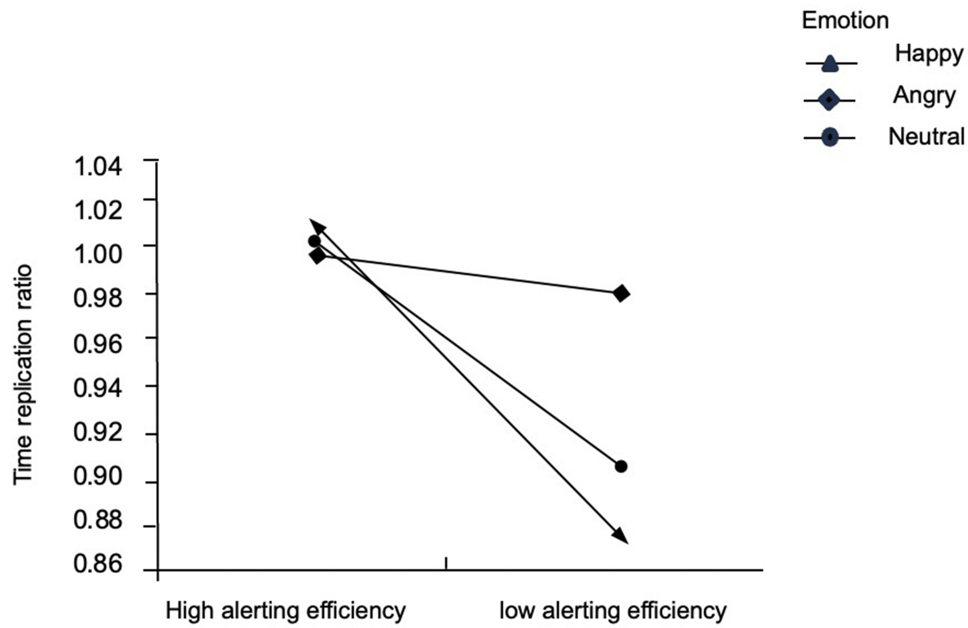

Figure 3 Interaction Emotion × Alerting on Time replication ratio.

the stimulus leading to higher arousal, which speeds up the metronome pulse rate. And the more pulses accrued leads to a longer subjective perception of time by the individual.[52]

So how do individual differences in alerting efficiency affect time perception through the encoding of the internal clock? On the one hand, Direct perception theory suggests that perception is a "bottom-up" process in which individuals acquire information directly from the external environment and develop a sense of their surroundings through their own continuous exploration. Alerting can be categorized into endogenous and exogenous alerting,[53,54] whereas endogenous alerting refers to the internal (top-down) control of the level of arousal of an organism that can be observed in a simple reaction time (RT) task, without a previous alerting stimulus. Whereas exogenous alerting refers to the relatively transient changes that occur in an individual during the preparation of the organism's cognitive system through the perception of an external cue or an alerting stimulus, it is also a "bottom-up" perceptual process.[26] Exogenous vigilance can be enhanced by stimuli such as alerting signals,[53,55] and alerting signals periodically increase an individual's arousal level.[56] In the time perception task of the current study, a 500ms gaze dot was presented in the center of the screen followed by a randomly presented 50ms to 1050ms empty screen in each trial during the formal experiment. The gaze dot acted as an exogenous alerting stimulus to serve as an alerting cue. It has been shown that subjects with higher levels of alerting are better able to utilize alerting signals to increase attention to information.[57] During experiments, although alerting signals typically provide little or no information about when the target is occurring, they confer a behavioural advantage relative to what would occur in the absence of alerting signals.[58] Thus, subjects with higher levels of alertness are more likely to maintain higher levels of internal arousal and be able to perceive upcoming stimuli faster and more efficiently when cued by external alerting signals with increased levels of exogenous alerting. On the other hand, from the attentional gate model, the attentional gate controls the number of impulses that the metronome sends into the totalizer, resulting in the number of outgoing impulses not all going to the totalizer to be summed up to produce a significant number of temporal representations, and it is only when the individual's attentional resources are allocated to the temporal stimulus that the attentional gate opens up to a greater extent, and the individual's subjective perception of the length of time becomes longer. There is also a switch located between the attentional gate and the accumulator that follows the all-or-nothing principle for the subjective perception and representation of time. Alertness, as a special kind of attention, underlies selective attention.[59] We suggest that athletes with different alerting efficiencies may affect time perception by encoding the internal clock due to differences in arousal states, and that the high-alerting efficiency group may be more likely to turn on the selective attention-controlled switch to modulate the processing of stimulus temporal latitude than the low-alerting efficiency group, and may be able to produce a more accurate estimation of time perception by having a shorter delay in switch opening or closing to complete the subjective perception of the target stimulus's physical time.

Regarding the findings that youth athletes with high alerting efficiency are more inclined to overestimate time, we hypothesize that the reasons are as follows. On the one hand, subjective temporal distance dilation is a holistic visual processing.[60] Exogenous alertness is the basis of selective attention,[61] and exogenous alertness can contribute to the holistic processing of an individual's vision as he or she perceives stimuli from the external environment,[57] and thus it is hypothesized that alertness can increase the holistic perception of a target task through the allocation of attention to external informative stimuli, and therefore Athletes with higher levels of alertness produce an overestimation of time perception of the target task as well as increase time estimation accuracy to some extent due to a higher allocation of attentional resources. On the other hand, the moderating effect of alertness on time may also be through influencing the allocation of selective attention to in turn affect the holistic processing of individual vision. For this reason, it has been found that increased attention to the target task leads to a longer subjective time span perceived by the individual for the target task, and that the more attention is engaged, the greater the amount of information processed leads to a longer subjective perceived time span,[62] whereas alertness, as a form of sustained attention, the higher the level of alertness, the higher the degree of sustained processing of the target information stimulus, and the more attention is engaged, leading to a longer time period for the subjective perceived time. The more attention is also involved, leading to an increase in the amount of information processed, which in turn leads to a longer length of time perceived by the individual subjectively and a tendency for time perception to overestimate time.

The study also found a significant interaction between emotion and alerting efficiency on time replication ratios, with the low alerting efficiency group tending to overestimate time in the anger state relative to the happy and neutral mood states, which suggested that time perception in low alerting athletes was more susceptible to emotion. The reason for this may be related to the moderating effect of angry emotions on alert attention. Several studies have found that emotions influence attention by acting on the alerting network and thus on attention.[25,28,30] In particular, the anger emotion induces the largest alerting effects.[29] From the internal clock model, the number of impulses in the accumulator is a key determinant of the length of the temporal distance,[8] exogenous alerting underlies selective attention,[61] there is a significant positive correlation between temporal discrimination and information processing rate, with the faster an individual's information processing rate, the stronger the temporal discrimination, and the information processing rate may be an internal indicator of clock rate.[15] Exogenous alerting can have a facilitating effect on the holistic processing of an individual's vision as he or she perceives stimuli from the external environment,[57] Therefore, in the angry emotional state, the low alerting efficiency group tends to overestimate the time perception of the target task due to the cueing effect of obtaining a greater alerting signal, faster information processing, faster metronome speed, and more accumulation of impulses in the accumulator, which leads to the perception of longer time for subjectivity and the tendency to overestimate the time perception of the target task.

The moderating effect of angry emotions on the functioning of the alerting network leads to individual differences in temporal perception, and we hypothesized that there is also the possibility that individual differences in alerting during angry emotional states affect temporal perception by modulating arousal and selective attention and thus metronome rhythms and the latency of switching on and off. Arousal is a general state of readiness,[53] which modulates the metronome pulse rate. Emotional arousal has been shown to distort time perception.[63] Anger is a passive, high-arousal emotion. According to scalar expectancy theory, more impulses accumulate at a faster rate due to emotional arousal, thereby increasing the length of perceived time.[64] Previous studies have found that angry faces are more threatening and activate fear-related defense mechanisms than fearful faces.[65] Thus, anger elicits a stronger norepinephrine response, and norepinephrine systematically regulates the arousal state.[32] The modulatory effect of anger on the functioning of the alerting network resulted in a stronger vigilance effect in subjects in the low alerting efficiency group during the emotional state of anger, and since the state of alertness affects the rate of perceptual processing in an individual and raises the temporal threshold of consciousness,[66] This resulted in an improved arousal state for subjects in the low alerting efficiency group, with faster metronome rates, which in turn led to an overestimation of time.

It is noted that no significant main effect of emotion on time perception was found in this study. It is well known that emotion is an important factor affecting time perception, and from the descriptive statistics we can find that the time replication ratios of subjects in both the anger and happy groups were higher than those of the control group, and that the anger group had a slightly higher time replication ratio than that of the happy group, tending to overestimate time perception. It has been previously demonstrated that arousal level and emotional valence are two important dimensions of emotion modulating time perception.[67] It has been suggested that emotions affect time perception mainly through arousal mechanisms, with subjects perceiving significantly longer times in high arousal moods than in low arousal moods.[68] In this study, we examined the results of emotional evocations, both happy and angry emotions, which are high arousal emotions. This is consistent with previous findings, where Gil et al used a verbal report method to have subjects estimate the temporal distance between the presentation of emotional pictures with different arousal levels and found that high arousal levels led to longer temporal distance judgments than low arousal levels, suggesting a role for arousal levels in subjective temporal distortions.[5] Meanwhile, emotional valence is another important influence of emotion in modulating time perception. Numerous studies have demonstrated that positive and negative emotions can have different effects on time perception.[69,70] For example, Noulhiane et al found that subjects judged positive and negative emotional voices as leading to longer time-distance estimates than neutral voices, and that this lengthening effect was more pronounced for negative emotions.[17] Lake et al explained the effect of emotional valence on temporal perception in terms of biological survival significance by arguing that negative stimuli, especially threat-related negative stimuli, are highly correlated with biological survival, and thus individuals' defense mechanisms are more likely to be activated.[64] Research evidence suggests that people's estimates of the temporal distance for angry faces are significantly longer than for neutral and happy faces, since angry faces are more threatening to individuals than fearful faces and are more likely to activate fear-related defense mechanisms.[65,71] This also confirmed the findings in the study that subjects in the emotion group were more inclined to overestimate time perception than subjects in the control group, and subjects in the anger group were more inclined to overestimate time perception than subjects in the happiness group.

In conclusion, the above findings provide support for our hypotheses. First, individual differences in alerting play a significant role in youth athletes' time perception, with the high alerting efficiency group showing some time perception response advantage over the low alerting efficiency group, and it can be inferred from the results of the study that youth athletes with high alerting efficiency are more inclined to overestimate time and have higher time estimation accuracy. High-alert group subjects were better able to utilize cueing cues in the environment to enhance attention to physical stimuli in the environment by increasing the length of perceptual time and improving the overall information processing process of vision. Both high alerting efficiency and time overestimation are beneficial for athletes to adapt to the complex and changing competition environment in sports competition. The results of the study found that high alerting efficiency youth athletes have 2.4% higher time accuracy and about 7.1% higher time overestimation than low alerting efficiency youth athletes, which is undoubtedly an overwhelming advantage for competitive sports. So, alerting efficiency can be considered as one of the objective indicators for evaluating and diagnosing athletes' time perception ability. It is noteworthy that some studies have confirmed that acute exercise can enhance the overall cognitive function of an individual, especially including the function of attention network.[72,73] And for athletes, they can consciously improve the efficiency of alertness through sports training, and better utilize their time perception advantages. For coaches, they should continuously improve the sports intervention program, combine the individual differences of athletes, and formulate appropriate sports training programs to improve the athletes' alerting efficiency, which can promote the athletes to better perform their sports performance.

In addition, our findings support the notion that time perception in youth athletes with low alerting efficiency is more susceptible to emotions. Then, for athletes, especially those with low alerting efficiency who are in an angry emotional state in competition situations, timely and effective use of emotion regulation strategies (eg, cognitive appraisal) can better utilize their own time-perceived response strengths; and for coaches, they should pay more attention to athletes' psychological state in the current specific situation during daily training and competitive games, and combine the athletes' own characteristics to adopt appropriate emotion regulation strategies, so that athletes can always maintain a good emotional state and sports performance.

This study provides a reference for the training of time perception and specialized perceptual ability of youth athletes, enriches the index system of psychological selection of youth athletes, and provides scientific reference and empirical evidence for the psychological selection and specialized perceptual training of youth athletes.

Limitations and Future Research

Our study is not without limitations, which should be addressed in future studies. First of all, this study lacked some objective physiological monitoring metrics, and future research should consider some indicators of people's emotional responses, such as skin conductance, heart rate variability, facial muscles, and other non-invasive measures. In addition, the ANT study benefited from the use of event-related functional magnetic resonance imaging to explore brain regions associated with the attentional system,[33] as well as brain oscillatory and power spectral analyses.[47] Thus, further research is necessary to explore the effects on spatial perception in athletes with these methods, as well as the neural mechanisms that interact with ERP and fMRI. In addition, this research was conducted in a laboratory setting, and while rigorous research methods can ensure internal validity, on the other hand, external validity may be limited by these methods. As the characteristics of the selected sample (eg, athlete grade level, sport type) may lead to limitations in the generalizability of the findings, future studies should expand the sample size of athletes from different regions, sport specialties, and sport levels, and further refine the research paradigm to incorporate the characteristics of the sample and the sport context to improve the ecological validity of the experimental study. Meanwhile, the current study mainly focused on table tennis, badminton, and tennis, considering that time perception, attention, and alertness also affect sports performance and risk of sports injuries, future research could include information on time perception, injury risk, and performance in sports such as weightlifting, taekwondo, and judo, which require a high degree of attention and unique time management, and where the sports injury risk is high.

Secondly, we did not control for moderating variables or possible confounders. It has recently been argued that motivational orientation is a factor that drives time perception, and that positive and negative affects with different motivational orientations have different effects on time perception.[74] Thus, the motivational direction of emotions could be considered for inclusion in future research. In addition, although we claimed that only healthy youth athletes participated in this study, the level of mental health of the participants was not specifically measured, as it has been found that health conditions can also affect an individual's perception of time perception.[75] Future research should include health conditions as covariates to ensure that these potential confounding variables do not undermine the internal validity of the study. There are more research paradigms for time perception, which are categorized into time-distance scale method and time-distance discrimination method, the time replication method used in this paper, is a type of time-distance scale method, and time-distance discrimination methods such as time comparison method and time confirmation method can be explored in future research for the study.

Finally, this study used an autobiographical recall task as an emotion induction task, and previous research has demonstrated the effectiveness of autobiographical recall tasks for inducing specific emotions.[40,42] However, given the specifics of sport, we could try using virtual reality (VR) technology, which is an effective affective medium for generating the target emotion and the target state of mind, and allows people to immerse themselves in social situations or scenarios from a first-person perspective, allowing subjects to be more present in the "emotional" environment.[76]

Conclusion

In conclusion, the results of this study showed that the Attention Network Test has good validity in the athlete population. Individual differences in alerting had a significant effect on the time perception of young athletes, and the high alerting efficiency group showed some time perception response advantage over the low alerting efficiency group, and the high alerting efficiency youth athletes were more inclined to overestimate the time and had higher time estimation accuracy. Meanwhile, the time perception of low alerting efficiency youth athletes was more likely to be affected by emotions, which was shown that low alerting efficiency youth athletes were more inclined to overestimate the time under the anger emotional state. This suggests that among the influences on time perception, there is a correlation between emotion and the regulation of alerting network function.

Data Sharing Statement

Study data are available upon request from correspondence author LianWang (lian.wang@awf.gda.pl).

Ethics Approval and Consent to Participate

All participants provided their informed written consent. The study was conducted in accordance with the Declaration of Helsinki and approved by Chengdu Sport University Ethics Committee (protocol code 2022282H).

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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