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Selective enhancement of attentional networks in college table tennis athletes: a preliminary investigation

Biye Wang [1] , **Wei Guo** [1] , **Chenglin Zhou** [Corresp. 1]

[1] Department of Sport Psychology, School of Kinesiology, Shanghai University of Sport, Shanghai, China

Corresponding Author: Chenglin Zhou
Email address: chenglin_zhou@126.com

The purpose of the study was to investigate the characteristics of the attentional network in college table tennis athletes. A total of 65 college students categorized as table tennis athlete group or non-athlete group participated in the study. All participants completed the attentional network test (ANT) which measured the alerting, orienting and executive control networks. The results showed a significant difference between the athlete and non-athlete group for executive control network ($p < 0.01$), while no differences were observed for alerting ($p > 0.05$) or orienting ($p > 0.05$) networks. These results combined suggest that college table tennis athletes exhibited selectively enhanced executive control of attentional networks.

Selective Enhancement of Attentional Networks in College Table Tennis Athletes: A Preliminary Investigation

Biye Wang, Wei Guo, Chenglin Zhou*
Department of Sport Psychology, School of Kinesiology, Shanghai University of Sport, Shanghai, China

*Corresponding author: Chenglin Zhou
Email: chenglin_zhou@126.com

Abstract

The purpose of the study was to investigate the characteristics of the attentional network in college table tennis athletes. A total of 65 college students categorized as table tennis athlete group or non-athlete group participated in the study. All participants completed the attentional network test (ANT) which measured the alerting, orienting and executive control networks. The results showed a significant difference between the athlete and non-athlete group for executive control network ($p < 0.01$), while no differences were observed for alerting ($p > 0.05$) or orienting ($p > 0.05$) networks. These results combined suggest that college table tennis athletes exhibited selectively enhanced executive control of attentional networks.

Keywords: attentional network, attentional network test, table tennis athlete

1 Introduction

The ability to selectively focus on the relevant information while ignoring others is a basic function of our brain to ensure that we can interact with environment effectively. This ability requires the participation of attention, which is a core function of cognitive system and regulates other cognitive functions such as memory and language (Posner & Petersen, 1990). More specifically, attention plays an important role in sports (Williams & Davids, 1999). Obviously, it is crucial for most athletes to choose the right information to process in an extreme short period of time in a competition context (Allard, Brawley, & Deakin, 1989). And it would be difficult to achieve any goals for athletes with easily disturbed attention. Thus, it is reasonable to speculate that attentional function may develop better in athletes, relative to non-athletes. Indeed, several studies have confirmed the possible relationship between athlete experience and attentional function in laboratory (Enns & Richards, 1997;

Memmert, 2009; Memmert, Simons, & Grimme, 2009; Nougier, Azemar, Stein, & Ripoll, 1992). However, these kind of studies yielded mixed results due to variation in laboratory attentional tasks (Voss, Kramer, Basak, Prakash, & Roberts, 2010). The attentional network test (ANT) developed by Fan et al. (2002) is one of the most dominant attention paradigms and seems to be appropriate for this kind of study (Fan, McCandliss, Sommer, Raz, & Posner, 2002). It is a short and simple computerized task that could measure the attentional networks independently. The task was based on the well-known attention network theory proposed by Posner and Petersen (Petersen & Posner, 2012; Posner & Petersen, 1990). According to this theory, attention system could be divided into three different networks: alerting network, orienting network and executive control network. Each of them representing a set of certain attentional function and little overlap between the three networks was revealed by a neuroimaging analysis (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). The alerting network is related to maintenance of certain levels of arousal and sustained vigilance, the orienting network allows selection of information from multiple sensory inputs, and the executive control network is related to the ability to monitor and resolve conflict (Petersen & Posner, 2012; Posner & Petersen, 1990).

Although few studies have explored the three attentional network of athletes in one experiment using the ANT, there is some evidence showing the characteristics of alerting, orientation or executive control in athletes in different studies. The alerting and orientation ability of athletes is mainly measured by the spatial cueing paradigm (Posner & Fan, 2008). For example, Enns and Richards (1997) used different cue-target intervals to investigate the alerting effect. The results revealed that athletes sustained a high level of alertness over the longest cue-target interval (Enns & Richards, 1997). Cereatti et al. (2009) observed athletes outperform non-athletes on the voluntary orientation of attention (Cereatti, Casella, Manganelli, & Pesce, 2009). Studies have also demonstrated athletes to exhibit higher proficiency on tasks testing executive function (Vestberg, 2012). For example, Jocobson and Matthaeus (2014) revealed that athletes performed better than non-athletes on a problem solving as well as an inhibition task, suggesting that athletes achieved better executive control ability (Jacobson & Matthaeus, 2014).

The present study aimed to investigate the characteristics of the attentional network in college table tennis athletes using the ANT. There are three reasons for choosing table tennis athletes as the participants. Firstly, table tennis is one of the fastest ball sports and the response window dictated by the ball speed is very brief. The table tennis athletes have to use advanced cues to decide what response is required as soon as possible (Padulo et al., 2015), and therefore, they would develop superior alerting and orienting ability. Secondly, table tennis is a highly developed tactical skill, involving creativity, concentration, competitiveness, apprehension, self-regulation, and will power (Raab, Masters, & Maxwell, 2005). Table tennis athletes compete in a dynamically changing, unpredictable, and externally-paced environment which may lead to better executive control ability. Thirdly, table tennis is one of the most popular sports in China. Table tennis athletes are trained systematically and have a high competition level, so they are the perfect samples to investigate the relationship between athlete training experience and attentional function. Although previous study have indicated that chronic exercise and acute exercise improve the performance on ANT in non-athletes (Chang, Pesce, Chiang, Kuo, & Fong, 2015; Pérez, Padilla, Parmentier, & Andrés, 2013), this was the first study to our knowledge to adopt athletes as the participants. It was hypothesized that athletes would perform better on the alerting, orientation and executive network than non-athletes.

2 Method

2.1 Participants

A total of 65 individuals categorized as athlete group or non-athlete group participated in the study. They were recruited through advertisements posted in the campus of Shanghai University of Sport. The athlete group was composed of 31 table tennis players (mean age = 21.9, ranging from 19 to 25) whom satisfied all of the following criteria: (1) had 5 or more years of professional training experience, (2) qualified as the National Player at Second Grade or above, (3) trained more than three times a week in the last 2 years, (4) trained for 2 or more hours each time. The non-athlete group was composed of 35 students (mean age =21.9, ranging from 19 to 25) majoring in psychology or kinesiology. This served as the control group. The non-athlete group matched the athlete group in age and education, but they had no experience of playing table tennis, nor any professional sports training. All the participants were right-handed and had normal or corrected to normal visual acuity. No individuals reported having a history of neurological or psychiatric disorder. Written informed consent was obtained from each participant prior to the study. All participants received a payment of approximately $10 for taking part in the experiment. Table 1 shows the main characteristics of the subjects. This study was approved by the Ethics Committee of the Shanghai University of Sport (No. 2015014).

2.2 Attention network test

Attention network test (ANT) was designed to assess the function of the three different attention networks (J. Fan, McCandliss, Sommer, Raz, & Posner, 2002). A fixation cross was presented in the center of a computer screen at the onset of each trial. After a random interval of 400 to 1600 ms, cues would present in one of the four possible conditions: no cue, center cue (the fixation cross was replaced by an asterisk), double cue (two asterisks were respectively displayed above and below the fixation cross), or spatial cue (an asterisk were displayed either above or below the fixation cross). The cues remained visible for 100 ms. The presentation of asterisks provided temporal information about the appearance of target stimuli. The asterisk in the spatial cue condition provided additional information about the location of target stimuli. The spatial cues were always valid. The fixation cross was displayed alone for 400ms after the disappearance of cue. Then a target stimulus was presented above or below the fixation cross according to the indication of the previous cue. The target stimulus consisted of five horizontally arranged arrows or lines. Participants were required to press the corresponding key to indicate the direction of the central target arrow. The other four arrows or lines served as flankers in the task with three possible conditions: congruent condition (arrows pointed in the same direction as the central arrow), incongruent condition (arrows pointed in the opposite direction of the central arrow), or neutral condition (lines with no direction information). The target stimulus remained on the screen until the participant responded or for 1700ms if no answer was given.

The participants were instructed to concentrate on the fixation cross throughout the task. A numeric keyboard was placed in front of the participant and the participant was required to lightly put his index finger of left hand on key “1” and index finger of right hand on key “3”. Once target stimuli were presented, participants were instructed to respond as fast and accurately as possible by pressing the key "1" for left directed central target arrow and pressing the key "3" when the direction was right.

Four blocks were included in this test. Each block contained 48 trials based on the combination of four cues conditions (no cue, center cue, double cue, and spatial cue), three flankers' conditions (congruent, incongruent, and neutral), two directions (left or right directed target arrow) and two locations (target displayed above or below the fixation cross). Each trial was presented only once in a block. The stimuli were presented and the data were recorded using Psychtoolbox (Brainard, 1997) (see Fig.1).

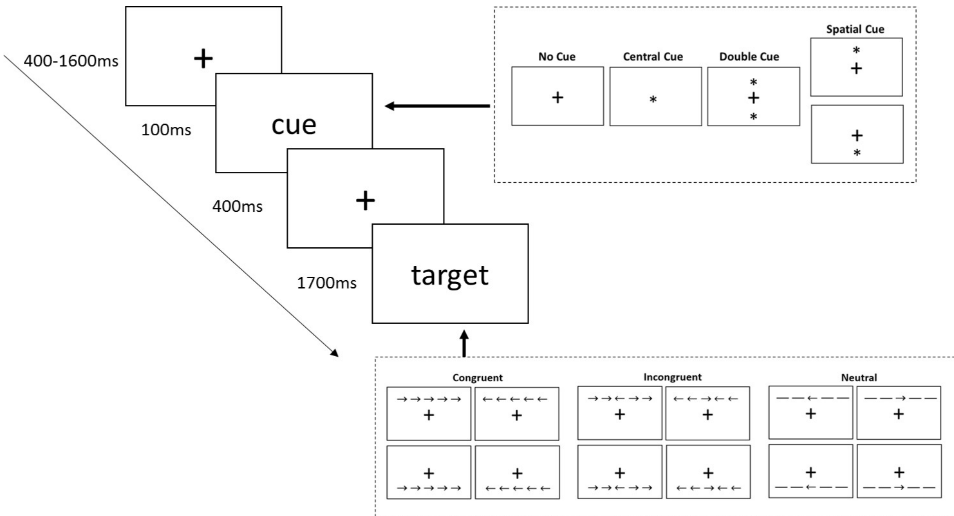

Fig. 1 Stimuli and experimental paradigm of Attention Network Test (ANT)

2.3 Procedure

As a requirement of the advertisements, all the participants had to contact the researchers by telephone first. A survey about the demographic data of participants was conducted during the call. Athlete participants were further asked about their training experiences. Participants who met the criteria (see 2.1 Participants) were invited to our laboratory on another day to participate in the experiment. They were instructed to abstain from alcohol for 24 hours and from caffeine-containing substances for 12 hours before the experiment.

After arriving at the laboratory, participants were asked to sign an informed consent form and assessed by Taiwan version of the International Physical Activity Questionnaire (IPAQ) (Liou, Jwo, Yao, Chiang, & Huang, 2008). Then the purpose of the study and the instruction of ANT were introduced to them in written form. After participants reported understanding the instructions, they performed the ANT task individually in a dimly lit and quiet room. At first, they had to perform a practice block with 24 random trials. If their response accuracy reached 80%, they could perform their next 4 experimental blocks of 48 trials in each; otherwise, they would perform another practice block until their accuracy reached 80%. Participants were allowed to rest between each block, and they could start the next block by pressing any keys once they felt adequately rested. Completing the whole task required about 17 minutes, including both practice and experimental blocks.

2.4 Design and statistical analysis

A mixed factors design was adopted in the study. The athlete and non-athlete group was a between-subjects variable, the cue type (no cue, central cue, double cue and spatial cue) and flankers type (neutral, congruent, incongruent) were within-subject variables. The dependent variables were response times (RTs) and accuracy rates. They were analyzed with a 2 (group) ×4（cue type）× 3（flanker type）mixed-design ANOVA.

The three components of attentional network were computed as follows: no cue RTs versus double cue RTs for alerting, central cue RTs versus spatial cue RTs for orienting and congruent flankers RTs versus incongruent flankers RTs for conflict resolution. A t-test carried out in order to explore the effect of athlete experience on each component of attentional network

3 Results

3.1 Participant characteristics

No significant differences were observed in age ($F_{(1, 63)}$ =0.00, p =0.98), height ($F_{(1, 63)}$ =3.29, p =0.07), weight ($F_{(1, 63)}$ =2.92, p =0.09), BMI ($F_{(1, 63)}$ =0.64, p =0.43), average reaction time ($F_{(1, 63)}$ =1.53, p =0.22) and accuracy rate ($F_{(1, 63)}$ =0.25, p =0.62), and as expected, a significant difference was observed in physical activity level (overall score on IPAQ) ($F_{(1, 63)}$ =4.29, p <0.05) of the two groups (see Table.1).

Table.1 The main characteristics of the subjects in different groups

	athlete group(n=31)	non-athlete group(n=34)
Female	11	14
Age(yr)	21.90±1.72	21.91±1.80
Height(cm)	1.73±0.08	1.69±0.10
Weight(kg)	65.18±9.38	61.13±9.67
BMI(kg/m^2)	21.69±1.72	21.32±1.95
IPAQ(METs)		
Vigorous(METs)	3587.09±2372.72	2037.65±5109.58
Moderate(METs)	1597.42±1659.15	927.06±1386.74
Walking(METs)	1448.47±1763.65	1297.68±1261.23
Overall(METs)	6632.99±3808.16	4262.38±5229.69
Reaction time(ms)	474.33±48.86	487.25±34.56
Accuracy(%)	96.69±1.92	96.92±1.82

Note. BMI =body mass index, IPAQ= International Physical Activity Questionnaire, METs= metabolic equivalents.

3.2 Mean RTs

For the RTs analysis, the wrong trails or the trails which were 3 standard deviations from the individual mean were excluded. Results showed a significant main effect of cue type ($F_{(3, 189)}$ =147.56, p <0.01, η_p^2 =0.70), the RTs were the longest in the no cue condition, and the shortest in the spatial cue condition. A significant main effect also observed in flanker type ($F_{(2, 126)}$ =373.52, p <0.01, η_p^2 =0.86). The RTs were longer in the incongruent condition than in the congruent or neural condition. Furthermore, there were significant interactions between flanker type and cue type ($F_{(6, 378)}$ =6.95, p <0.01, η_p^2 =0.10), group and flanker type ($F_{(2, 126)}$ =5.90, p <0.01, η_p^2 =0.09). There were no significant main effect of group ($F_{(1, 63)}$ =1.53, p =0.22, η_p^2

=0.02), group × cue type ($F_{(3,\ 189)}$=0.51, p =0.68, η_p^2=0.01) or group × cue type × flanker type ($F_{(6,\ 378)}$=0.60, p =0.73, η_p^2=0.01) interaction. The description data of the mean RTs and standard deviations of athlete and non-athlete group according to the cue and flanker type are shown in Table.2.

Table.2 Mean RTs (ms) and standard deviations of athlete and non-athlete group according to cue and flanker type

	Congruent		Incongruent		Neutral	
	Athlete	Non-athlete	Athlete	Non-athlete	Athlete	Non-athlete
No cue	478.5±50.9	488.1±37.2	529.4±55.9	551.1±42.2	479.9±53.4	489.3±41.3
Central cue	456.9±48.9	462.1±36.8	517.6±62.2	534.5±43.8	455.6±47.4	464.9±40.6
Double cue	460.8±50.1	464.4±39.3	515.5±55.8	539.6±43.0	456.0±49.6	463.9±41.3
Spatial cue	434.6±52.9	445.5±36.1	472.4±51.4	500.8±43.3	434.5±48.4	442.8±37.0

3.3 Accuracy

For the accuracy analysis, significant main effects of cue type ($F_{(3,\ 189)}$=9.72, p <0.01, η_p^2=0.13), and flanker type ($F_{(2,\ 126)}$=48.29, p <0.01, η_p^2=0.43) were revealed. Furthermore, there were significant interactions between flanker type and cue type ($F_{(6,\ 378)}$=4.80, p <0.01, η_p^2=0.07). There were no significant main effect of group ($F_{(1,\ 63)}$=0.25, p =0.62, η_p^2=0.00), group and flanker type ($F_{(2,\ 126)}$=1.60, p =0.21, η_p^2=0.02), group × cue type ($F_{(3,\ 189)}$=0.87, p =0.50, η_p^2=0.01) or group × cue type × flanker type ($F_{(6,\ 378)}$=1.66, p =0.13, η_p^2=0.01) interaction. The description data of the mean accuracy and standard deviations of athlete and non-athlete group according to the cue and flanker type are shown in Table.3.

Table.3 Mean accuracy (%) and standard deviations of athlete and non-athlete group according to cue and flanker type

	Congruent		Incongruent		Neutral	
	Athlete	Non-athlete	Athlete	Non-athlete	Athlete	Non-athlete
No cue	97.0±4.5	97.8±5.3	93.1±5.9	92.3±6.7	97.4±4.2	98.3±2.8
Central cue	98.8±2.5	98.7±3.0	90.9±9.0	93.2±7.4	98.0±3.0	98.9±2.4
Double cue	99.4±1.9	97.2±4.9	92.5±8.3	94.7±5.4	98.2±2.9	97.4±3.8
Spatial cue	99.6±1.6	98.0±4.3	96.6±4.8	97.4±5.4	98.8±3.0	99.1±2.2

3.4 Differences of athletes and non-athletes on the 3 components of attentional network

Independent samples t-tests were carried out for each component of the attentional system (alerting, orienting, and executive networks). Results showed a significant difference between athlete and non-athlete group on executive network ($t_{(63)}$=2.78, p <0.01), while no differences were observed on alerting ($t_{(63)}$=0.36, p =0.72) or orientation ($t_{(63)}$=-1.13, p =0.27) networks (see Fig.2).

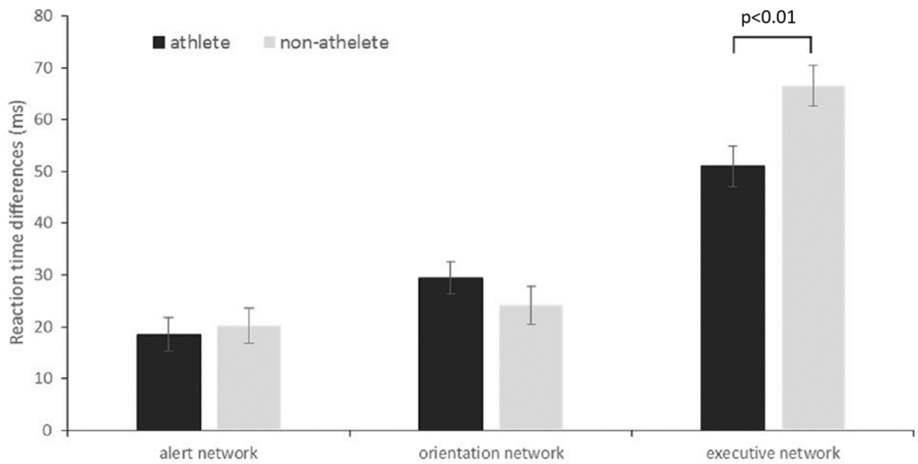

Fig.2 Reaction time differences that reflect the efficiency of the three attentional networks of athlete and non-athlete group

4 Discussion

It is a basic question in brain plasticity research whether an individual's experience can affect the attentional process. Athletes are one of the most suitable models to investigate this question because of their unique experience. Compared with non-athletes, most of them trained with larger amount regularly for several years. This study was designed to investigate the association between sports training experiences and the modulation of attentional network functions. Although it seems that previous studies have already focused on this topic for decades, the present study and these studies differ in many aspects. Firstly, athletes from one of the typical open-skilled sports, table tennis, served as the athlete group in this study. Previous studies mainly explored the attentional function of athletes from closed-skill sports (e.g. swimming, running) rather than athletes from open-skilled sports (e.g. tennis, table tennis). Compared to closed-skill sports, open-skill sports require individuals to invest higher cognitive effort in the unpredictable environment. It has been shown that open-skill athletes are more flexible in visual attention, decision making, inhibition, and working memory, compared to closed-skill athletes (Voss et al., 2010; Wang et al., 2013). Secondly, the attentional network test (ANT) was adopted in this study to evaluate the efficiencies of the three attention networks in one experiment, it is more efficient than the battery of attention test mainly used in previous studies because the ANT requires only about 15 min to complete, and there are very little overlaps among the three networks. It has been widely used in certain clinical populations, however few studies have investigated the differences between athletes and non-athletes on the ANT. To the best of our knowledge, this is the first study to investigate the characteristics of table tennis athlete's attentional networks with the ANT.

The aim of the present study was to investigate the relationship between sports training experience and the attentional network using the ANT. Our results showed that the athlete group reached a higher score than the non-athlete group on the executive network component, which is consistent with previous findings that have confirmed a positive correlation between executive control and athletic ability (Jacobson & Matthaeus, 2014;

Vestberg, 2012). A possible reason for the superior executive network function of athletes may be mainly due to the cognitive benefit of physical activity. Also, it has been proposed that exercises performed in the cognitively challenged environment are more effective to induce neural and cognitive benefits than exercise alone (Fabel et al., 2009). Table tennis athletes train and compete in the kind of enrichment environment that includes both physical and mental challenges. However, the present study cannot infer a causal relationship between athletic experience and attentional network function. It is possible that individuals who develop strong executive control skills are more likely to become athletes. Vestberg et al. (2012) suggest that individuals with high executive control ability become athletes more often and the ability further improved with training (Vestberg, 2012). It is speculated that the observed differences in attentional network may, at least in part, result from athletic participation.

The alerting and orientation of attention are especially important for athletes because they have to keep alerted all the time and orientate their attention quickly to the relevant information in the sporting context. However, the efficiency of the alerting and orientation networks tested by ANT did not differ in athletes and non-athletes in the present study. These results were inconsistent with previous findings, which have revealed that athletes practicing open-skilled sports showed superior ability on the alerting and voluntary orientation of attention than their counterbalanced controlled non-athlete group (Enns & Richards, 1997; Nougier et al., 1992). Both of these studies measured the alerting effect by testing more than one stimulus onset asynchrony (SOA) between cue and target, and the orienting effect was measured by comparing the reaction time difference between target stimuli at attended and unattended locations. The efficiency of alerting and orientation network tested by ANT were equivalent in athletes and non-athletes in the present study. A possible reason for the inconsistency may be mainly due to the different experimental paradigms. The ANT used in this study is a relative simple task, and the response times for the measurement of orienting might have been affected by a ceiling effect. Also, the participants in the non-athlete group seemed to participate in regular physical exercise which could improve their cognitive function (Voss, Nagamatsu, Liu-Ambrose, & Kramer, 2011).

The selective enhancement of the executive control network in athletes is similar to previous studies focused on the effect of chronic exercise or acute exercise on alerting, orientation, and executive control using a similar version of the ANT. Pérez et al. (2014) found a difference between active and passive participants on the executive network while no differences were observed on the alerting and orientation network (Pérez et al., 2013). Along the same line, Chang et al. (2015) found that rather than eliciting general improvement, a single bout of acute exercise selectively enhanced executive control of attention (Chang et al., 2015).

The present study also revealed a significant interaction between flanker type and cue type, suggesting that the orientation cue was most effective when conflict resolution was required, while the alerting cue failed to increase the efficiency of executive control. It mirrored the pattern of interactions obtained in an earlier study with adults using the ANT (Fan et al., 2002). The interaction between group and flanker type was consistent with the result that athletes were more efficient on the executive network.

Some limitations existed in the present study. Firstly, the cross-sectional design revealed a possible relationship between athletic experience and the attentional network, but it can hardly conclude a causal relationship. Longitudinal studies are needed in the future. Also, the athlete participants in the study were qualified as the National Player at Second Grade. Athletes in different sport levels (e.g. elite and novice) should be enrolled in a future study to specify the relationship between attentional network and expertise in sports.

Conclusion

In conclusion, college table tennis athletes exhibited selective enhancement of execution control of attentional networks while no differences between athletes and non-athletes were observed in the alerting and orientation networks.

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Figure 1

Stimuli and experimental paradigm of Attention Network Test (ANT)

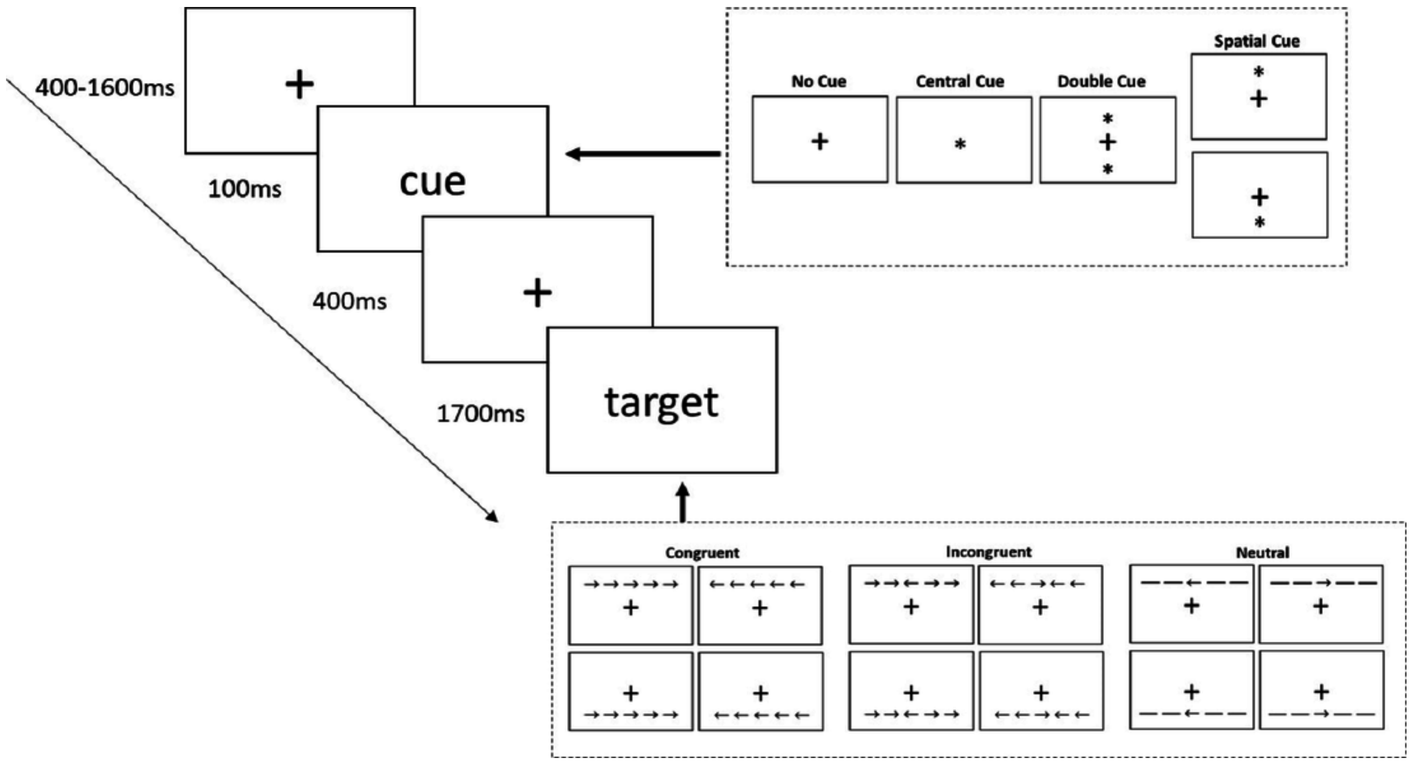

Figure 2

Reaction time differences that reflect the efficiency of the three attentional networks of athlete and non-athlete group.

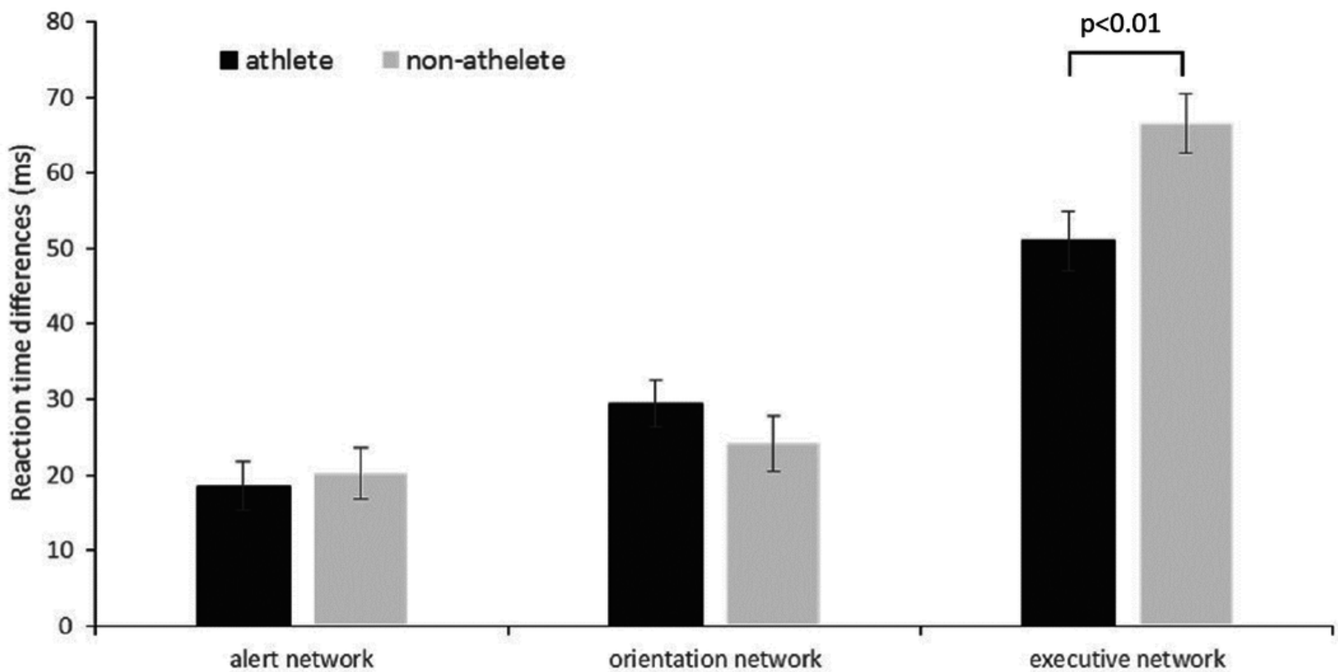

Table 1 (on next page)

The main characteristics of the subjects in different groups

Table.1 The main characteristics of the subjects in different groups

	athlete group(n=31)	non-athlete group(n=34)
Female	11	14
Age(yr)	21.90±1.72	21.91±1.80
Height(cm)	1.73±0.08	1.69±0.10
Weight(kg)	65.18±9.38	61.13±9.67
BMI(kg/m^2)	21.69±1.72	21.32±1.95
IPAQ(METs)		
Vigorous(METs)	3587.09±2372.72	2037.65±5109.58
Moderate(METs)	1597.42±1659.15	927.06±1386.74
Walking(METs)	1448.47±1763.65	1297.68±1261.23
Overall(METs)	6632.99±3808.16	4262.38±5229.69
Reaction time(ms)	474.33±48.86	487.25±34.56
Accuracy(%)	96.69±1.92	96.92±1.82

Note. BMI =body mass index, IPAQ= International Physical Activity Questionnaire, METs= metabolic equivalents.

Table 2 (on next page)

Mean RTs (ms) and standard deviations of athlete and non-athlete group according to cue and flanker type

Table.2 Mean RTs (ms) and standard deviations of athlete and non-athlete group according to cue and flanker type

	Congruent		Incongruent		Neutral	
	Athlete	Non-athlete	Athlete	Non-athlete	Athlete	Non-athlete
No cue	478.5±50.9	488.1±37.2	529.4±55.9	551.1±42.2	479.9±53.4	489.3±41.3
Central cue	456.9±48.9	462.1±36.8	517.6±62.2	534.5±43.8	455.6±47.4	464.9±40.6
Double cue	460.8±50.1	464.4±39.3	515.5±55.8	539.6±43.0	456.0±49.6	463.9±41.3
Spatial cue	434.6±52.9	445.5±36.1	472.4±51.4	500.8±43.3	434.5±48.4	442.8±37.0

Table 3(on next page)

Mean accuracy (%) and standard deviations of athlete and non-athlete group according to cue and flanker type

Table.3 Mean accuracy (%) and standard deviations of athlete and non-athlete group according to cue and flanker type

	Congruent		Incongruent		Neutral	
	Athlete	Non-athlete	Athlete	Non-athlete	Athlete	Non-athlete
No cue	97.0±4.5	97.8±5.3	93.1±5.9	92.3±6.7	97.4±4.2	98.3±2.8
Central cue	98.8±2.5	98.7±3.0	90.9±9.0	93.2±7.4	98.0±3.0	98.9±2.4
Double cue	99.4±1.9	97.2±4.9	92.5±8.3	94.7±5.4	98.2±2.9	97.4±3.8
Spatial cue	99.6±1.6	98.0±4.3	96.6±4.8	97.4±5.4	98.8±3.0	99.1±2.2