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The Effect of Mental Fatigue on the Planning and Preparation of Alerting and Orienting Attention Networks in Athlete Students; A Non-Controlled Clinical Trial

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Original Article

Abstract

Introduction: Mental fatigue following long-term mental activity is a reason for the performance decrement in sports. Considering the importance of the effect of mental fatigue on selective attention and performance of athletes, the present study aimed to determine the effect of mental fatigue on the effectiveness of alerting and orienting attention networks among athlete students.

Materials and Methods: This quasi-experimental study with pre- and posttest design was done to collect the data from 22 athlete students selected using convenient sampling method. Attention network test was used to evaluate the effectiveness of alerting and orienting networks before and after mental fatigue. In addition, they performed the Stroop test for 60 minutes in order to create mental fatigue. Then, repeated measures ANOVA (3 × 2) was utilized for analyzing the data at the significance level of 0.05.

Results: A significant increase in reaction time was observed in the speed processing of orienting network in mental fatigue (P = 0.016), while mental fatigue improved the reaction speed in the alerting network (P = 0.280). In addition, the error rate decreased in both alerting networks (P = 0.870) and orienting (P = 0.600), although it was not significant.

Conclusion: It may be concluded that mental fatigue could alter cognitive performance and negatively affect both accuracy and speed of the alerting and orienting networks, due to its goal-directed and up-down control. Therefore, it seems that athlete students probably sacrifice the speed for maintaining accuracy in the orienting network, and reduce accuracy for maintaining speed in the alerting network.

Keywords: Alerting network, Mental fatigue, Speed processing, Accuracy of response

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Introduction

Fatigue is defined as a decrease in the ability and efficiency of mental or physical activity that takes place with excessive mental and physical activity or because of an illness, and is often associated with a state of discomfort, a tendency to rest, decreased motivation, difficulty starting or maintaining voluntary activity (1). Mental fatigue is a psychological-biological state formed by a sharp increase in the mental fatigue or a severe decrease in the cognitive performance through long periods of cognitive activity (2). This acute fatigue is associated with long-term mental effort and differs from the chronic fatigue and cognitive disorder related to aging or illnesses. It is believed that the tasks that cause mental fatigue negatively affect an individual's cognitive performance. As a result, it is better to use the term cognitive fatigue rather than mental fatigue (3,4). However, some researchers prefer the term mental fatigue, as in addition to recognition, it encompasses excitement and motivation as well (5).

The results of numerous studies have shown that mental fatigue affects attention in various ways, such as selective visual attention and focus on the task execution time. Attention is one of the most important cognitive functions in sports indicating the ability of athletes to collect peripheral information such as field of vision, the ball, the teammates, or an object's

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position (6). For instance, an Olympic archer should be able to direct his visual attention to the center of the target he is targeting. The results of investigations suggest that athletes perform better than non-athletes in tasks of visual orientation, selective attention, and distributed attention in tasks that measure the processing speed, as there is a strong association between motor performance, attention, and high cognitive performance levels (7).

Selective attention is one of the executive functions comprising of three functionally distinct attention subsystems, including “alerting, orienting, and executive control neural networks”. The alert network consists of two modes: tonic (maintaining attention for a long time) and phasic (being on the alert and readiness to respond to an alarm signal) (8). This network affects the norepinephrine arousal system by detecting the alarm signals related to the activity planned in the Locus coeruleus (9). In order to process information, the orienting network pays attention to the special spatial situations or prioritizes some sensory inputs over other inputs (10). In the orientation, the acetylcholine neurotransmitter is mainly activated (8). The activity of this network may lead to changes in the automatic (exogenous) or voluntary (endogenous) attention (11).

Mental fatigue is one of the most important causes of performance loss in sports and accidents (12), in such a way that most sports fields such as American football or baseball that are accompanied by cognitive scenarios, can cause mental fatigue and they can decrease the ability to ignore the factors of attention impairment by affecting attention (2). Therefore, investigating the effect of mental fatigue on the performance of alerting and orienting neural networks, which play an important role in sports competitions, seems necessary (13). In a study on the effect of mental fatigue on decision-making skills in the soccer skills assessment functional test, it was found that mental fatigue leads to lower decision-making accuracy and longer response time (14).

In fact, it can be claimed that mental fatigue prevents the effective allocation of attention to the relevant information (15). However, a distinction must be established between the effects of mental fatigue in the goal-directed and stimulus-driven attention. The goal-directed attention is negatively affected by mental fatigue, whereas the stimulus-driven attention is often not influenced by it (15). These results lead to increased lack of mood and decreased flexibility in behavior, which is characteristic of the tired individuals (16). As a behavior becomes increasingly stimulus-driven, the prominent stimulus has a greater impact on behavior (13). In these conditions, the goal-directed control over the behavior is reduced and causes the behavior to be guided by the automatic stimuli by the response coupling (15). Thus, lack of performance flexibility in match conditions results in the loss of game positions and poor performance.

Exercise improves cognition (17). High processing speed is essential for fast and accurate reactions in ball sports (14). Previous studies have examined mental fatigue on the athletes’ performance and attention among individuals, in which the attention skills have been mainly measured in the functional area (4,14,18). For example, in the cricket sport field, the effect of mental fatigue on the accuracy of bats of the individuals as a functional attention index has been studied, but limited studies have analyzed the attention system from the perspective of the distinct neural networks (alerting, orienting, and executive control individually). Meanwhile, no study has been performed regarding the examination of the role of mental fatigue in athlete students with more cognitive capability of responding quickly and accurately compared to the inactive students.

Due to the lack of access to skilled athletes in a particular sport field, the present study was carried out on athlete students who had a significant degree of regular activity in one or more sports fields, and inevitably individuals active in several ball sports were recruited. The subjects were not divided into two groups in order to maintain the study power and eliminate the variance created by the individual differences, rather their information was compared with their baseline. Therefore, the present study was accomplished with the objective of investigating the effect of mental fatigue on attention neural networks among the athlete students in order to answer the question of whether mental fatigue can affect the reaction time (RT) and error percentage of the alerting and orienting networks of athletes.

Materials and Methods

This quasi-experimental clinical trial study without a control group was conducted in December of 2016 for one month. The call for study was made through publishing an announcement at the championship sports center of Shahid Beheshti University, Tehran, Iran, as well as the academic teams. All study stages were approved by the ethics committee for research at Shahid Beheshti University (Code of Ethics: SBU.ICBS 96.021) and were registered in the Iranian Clinical Trial Registration System (IRCT20130615013672N2).

The study population consisted of the skilled athlete students with at least 5 years of continuous and competitive activity in sports such as football, volleyball, and basketball, so that all athlete students were active in at least the second or third national league. The sample size was estimated to be 22 people using G*Power software version 3.1.9.4 (designed for statistical power computation by Heinrich Heine University of Dusseldorf, Germany) for the intra-group repeated measures analysis of variance (ANOVA) studies taking into account the type I error of 0.05 and power of 0.8 using previous studies (19,20). By volunteer sampling, 22 students of Shahid Beheshti University participated in the study. All participants were right-handed. The inclusion criteria included lack of visual, auditory, and motor problems based on self-report, membership of the academic team according to the report of the championship sports center and confirmation of professional coaches of the desired fields at Shahid Beheshti University, and having at least 5 years of professional sports activity in ball sports. Based on the reports in various studies, after three years of continuous activity, the individuals become skilled in a sport field (2,21,22). Skilled individuals are capable of performing movement skills with minimum energy and time and maximum confidence (23). The study exclusion criteria included a head trauma, participating in other studies, a history of taking narcotics and psychotropic drugs, playing computer games for several hours a day, and lack of enough sleep at night. The above-mentioned criteria were similar to those of the previous studies, each of which somehow influencing the performance of the individuals (24,25).

Data were collected using questionnaires as self-reporting by the participants. It should be noted that no guidelines on the purpose and hypotheses of the study were provided to the subjects by the examiner to prevent the individuals' bias. 28 athlete students of Shahid Beheshti University voluntarily participated in the study and all of them signed a written consent form. The Stroop test was used to create mental fatigue. The test-retest reliability and validity of this test were reported as 0.82 and 0.85, respectively (26). The visual analogue scale (VAS) was exploited to measure mental fatigue (27). This tool was validated by Lee et al. in the United States on adults aged 18 to 57 years (27). In addition, the validity and reliability of VAS were measured after the mental fatigue in specific football athletes [a specific category of football skills used as a measure of football skill measurement method (14)] and non-athlete individuals (28). The Cronbach's alpha coefficient of the mental fatigue questionnaire for the 13-item fatigue subscale and 5-item energy subscale was reported as 0.91 and 0.94, respectively. In Iran, the concurrent validity of this questionnaire has been examined and verified (29). The validity and reliability analysis of this tool is being published by the research team and its content validity was assessed before the start of the study. The content validity ratio (CVR) based on the study by Lawshe (30) and content validity index (CVI) based on the study by Lynn (31) were utilized to determine and validate the content validity. To determine CVR, a number of experts were asked to choose one of the three options of "a. The item is necessary, b. The item is useful, but not necessary, and c. The item is not necessary" for each question. Moreover, in order to determine CVI, 10 experts in the field of sport psychology and motor behavior were asked to select their desired option in a four-point Likert scale in relation to the four criteria of "relevance, clarity, simplicity, and ambiguity"; CVI was obtained as 0.72. The Attentional Network Test (ANT) was applied to examine attention functions in the alerting and orienting network (32).

The study was conducted at the Behavioral Sciences Laboratory, Institute for Cognitive and Brain Sciences, Shahid Beheshti University. For this purpose, the athletes sat in a low-light room on a comfortable chair at a distance of 50 cm from a 30-inch LCD television screen and performed ANT in the first session in the E-Prime software (version 2) (developed at the Learning Development Research Center, University of Pittsburgh, Pittsburgh, USA, which has been designed for psychology tests) for 30 minutes. The second session included mental fatigue that was held at least 48 hours after the first session to prevent the effect of sequencing (exercise effect: growing improvement in function and fatigue effect: progressive decrease in function) (33). At this session, mental fatigue was developed through the Stroop test (28) and the participants did not receive any feedback from the test results until the end of the study. Before performing the Stroop test, the subjects completed the mental fatigue questionnaire and then performed the test for 60 minutes. In the next step, they completed the mental fatigue questionnaire again in one minute immediately after completing the test and then started conducting ANT. To prevent the effect of daily time on task performance, all participants performed both tests from 12 to 4 pm (28).

In the current study, the modified Stroop task test was employed to investigate the selective attention and inhibition of information processing at the two automatic and controlled levels. The test has two convergent and non-convergent forms including word color, word meaning, and shape color. In the Stroop task as the word color, regardless of the word meaning, the participants had to press one of the four color keys on the keyboard (yellow, red, blue, and green) that matched the color of the word ink. This method focuses on the attention control process (word color naming) and automatic control (reading). The interference of the word color naming with the reading process results in a Stroop effect and cognitive inhibition (34). For the word meaning, the participants had to ignore the previous instructions and pay attention to the word rather than the color of the ink. For example, in the yellow word that appeared in red, the participant had to press the key corresponding to the written word, i.e. the yellow key.

ANT consisted of three signs (no signs, binary signs, and valid spatial signs) in two conditions (convergent and non-convergent). In each attempt, the participants observed a row of five black arrows on a gray background. The central arrow was the target and the other four arrows were flankers with equal probability. If the target arrow was pointing to the left or right and the flanker arrows were in the same direction with the target arrow (convergent conditions), the participants would right-click with the index finger and if the flanker arrows were in the opposite direction of the target arrow (non-convergent conditions), the participants would left-click with the index finger. The alerting network and the orienting network were also measured respectively by the difference between the sign-free and dual sign conditions and by the difference between the dual sign and the valid sign conditions in the convergent and non-convergent conditions. In the convergent conditions, the time alerts are formed and the processing speed is faster, but in the non-convergent conditions, in addition to involvement, the alerting network involves spatial orientation and executive function, hence reducing the processing speed and prolonging RT. Mean RT and response accuracy for each computation condition and fault attempts (incorrect and missing responses) were calculated by calculating the mean RT and response accuracy. The responses between 200 and 1700 ms (long RT) were defined as RT and accuracy outlier data (32) that were eliminated through the task program.

The descriptive data were reported as mean and standard deviation (SD), moreover, the Shapiro-Wilk and Levene tests were applied to check the data normal distribution and equality of variances, respectively. Furthermore, the paired t-test was employed to compare VAS, RT, and error percentage of each network before and after mental fatigue as well as to examine the study statistical power (effect size) by measuring the percentage change using the mean alerting and orienting networks before and after the mental fatigue. The repeated measures ANOVA test (time × network) (2 × 3) was used to examine the interaction between time and alerting and orienting networks. Finally, the data were analyzed in SPSS software (version 21, IBM Corporation, Armonk, NY, USA) and $P < 0.050$ was considered as the significance level.

Results

Of the 28 participants, 4 withdrew from the remaining of the study and information of 2 subjects were identified as outliers at the time of data analysis and were excluded from the data analysis. Ultimately, the data of 22 individuals were analyzed. The dropout rate during the study and the demographic characteristics of the participants are illustrated respectively in figure 1 and table 1. The VAS questionnaire showed a significant increase in the mental fatigue level after the Stroop test ($P = 0.001$, $t_{(1,21)} = -6.09$).

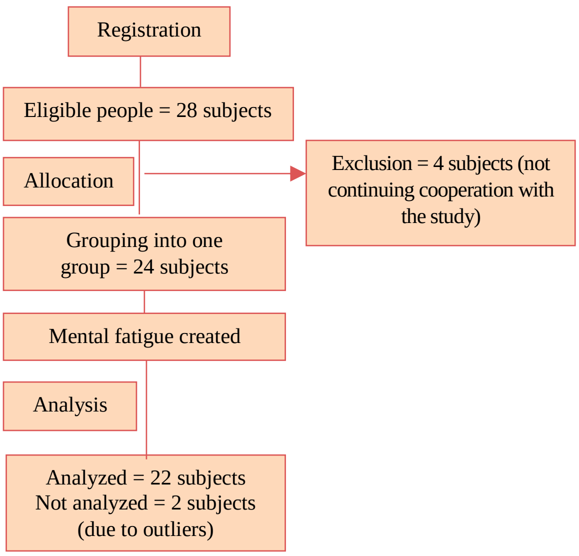

Figure 1. CONSORT flowchart of participants

The mean RT and error percentage were calculated before and after the mental fatigue. The repeated measures ANOVA results showed that RT varied in both conditions given the type of sign and target. In fact, the sign and target type significantly affected the processing speed and increased RT.

Table 1. Demographic characteristics of the participants

Number	Age (year)	Exercise experience (years)	Exercise type		Gender		Mental fatigue before Stroop test (%)	Mental fatigue after Stroop test (%)
22	23.34 ± 3.45	6.56 ± 1.41	Volleyball	8	Female	Male	40.56 ± 5.14	49.26 ± 6.01*
			Football	7	7	14		
			Basketball	8				

* Significant difference with conditions prior to the Stroop test

The main effect of the sign type (P = 0.001, $F_{(1,21)}$ = 207.33, Partial η^2 = 0.90) and the target type (P = 0.001, $F_{(1,21)}$ = 401.63, Partial η^2 = 0.95) was significant. The main effect of time was significant and RT changed significantly (P = 0.008, $F_{(1,21)}$ = 8.63, Partial η^2 = 0.29).

Table 2 presents RT and the error percentage in conditions with and without mental fatigue for the convergent and non-convergent targets in the alerting network. As expected, before the Stroop test (fatigue-free conditions) and in both sign-free and dual-sign conditions, RT in the non-convergent condition was significantly higher than the convergent condition (P < 0.001 and P < 0.001, respectively). 0 > P). The reason for this finding can be cognitively stated that processing of the incompatible information takes longer than the compatible information and of course, the mental fatigue did not change this pattern and the above differences (P = 0.088). The same pattern was observed for the sign-free error percentage in the non-convergent conditions and the mental fatigue and dual sign state (P = 0.068 and P = 0.280, respectively).

The significant decrease in RT in the convergent condition when comparing the non-fatigue and fatigued conditions (P = 0.007, t = 3.02) and also in the non-convergent condition (P = 0.034, t = 2.27) along with the error percentage increase (P = 0.770, t = -0.29 in the convergent condition and P = 0.068, t = -1.92 in the non-convergent condition) confirmed the occurrence of the mental fatigue with the Stroop protocol in the sign-free condition. A similar pattern was observed for RT (P = 0.071) and error percentage (P = 0.098) in the convergent and non-convergent conditions (P = 0.960 and P = 0.280, respectively) in the dual-sign condition. The paired t-test results indicated that mental fatigue had a significant effect on RT (P = 0.290, $t_{(1,21)}$ = 1.09) and the error percentage of the alerting network (P = 0.870, $t_{(1,21)}$ = -0.145).

Table 3 demonstrates RT and the error percentage in conditions with and without mental fatigue for the convergent and non-convergent targets of the orienting network. As expected, before the Stroop test (fatigue-free conditions) in both dual and valid sign states, RT in the non-convergent condition was significantly longer than the convergent condition (P < 0.001 and P < 0.001, respectively). This finding was due to the faster processing speed in the convergent conditions compared to than in the non-convergent condition, however mental fatigue did not change this pattern and the level of these differences (P = 0.088). The same pattern was also observed for the error percentage (P = 0.280 and P = 0.230, respectively).

The RT reduction in the convergent condition when comparing the fatigue and non-fatigue states (P = 0.071, t = 1.90) and also in the non-convergent condition (P = 0.098, t = 1.73) along with the error percentage increase (P = 0.960, t = -0.39 for convergent conditions and P = 0.290, t = -1.093 for non-convergent conditions) confirmed the occurrence of mental fatigue with the Stroop protocol under the dual sign condition. In the valid sign condition, a similar pattern for RT (P < 0.001 and P = 0.002, respectively) was observed for the error percentage (P = 0.680 and P = 0.230, respectively).

Table 2. Reaction time (RT) and error rate in conditions with and without mental fatigue in signs

Variable	Conditions	Adaptation	Sign-free	T value	P value	Dual sign	T value	P value	Valid sign	T value	P value
RT (ms)	Without mental fatigue	Convergent	649.0 ± 55.0	-13.77	0.001*	610.0 ± 53.0	-14.65	0.001*	579.0 ± 56.0	-	0.001*
		Non-convergent	797.0 ± 55.0			743.0 ± 49.0			693.0 ± 62.0	10.58	
	With mental fatigue	Convergent	626.0 ± 64.0	-13.16	0.001**	588.0 ± 63.0	-10.60	0.001*	545.0 ± 51.0	-	0.001**
		Non-convergent	760.0 ± 62.0			720.0 ± 61.0			647.0 ± 57.0	15.42	
Error rate (%)	Without mental fatigue	Convergent	0.6 ± 1.5	-3.07	0.006*	0.6 ± 2.0	-2.60	0.016	0.7 ± 1.6	-2.42	0.024*
		Non-convergent	4.5 ± 5.6			2.4 ± 3.7			2.0 ± 2.9		
	With mental fatigue	Convergent	0.9 ± 1.8	-3.07	0.001**	0.9 ± 2.6	-2.65	0.015	0.8 ± 1.6	-4014	0.001**
		Non-convergent	6.0 ± 6.3			3.8 ± 4.8			3.6 ± 4.0		

RT: Reaction time

* Significant difference with goal adaptation in conditions without mental fatigue; ** Significant difference with goal adaptation in conditions with mental fatigue

Table 3. Reaction time (RT) and error rate in convergent and non-convergent states in the signs

Variable	Conditions	Adaptation	Sign-free	T value	P value	Dual sign	T value	P value	Valid sign	T value	P value
RT (ms)	Without mental fatigue	Convergent	658.0 ± 60.0	3.02	0.007*	619.0 ± 57.0	2.50	0.020	583.0 ± 56.0	4.04	0.001*
		Non-convergent	623.0 ± 63.0			589.0 ± 61.0			544.0 ± 51.0		
	With mental fatigue	Convergent	793.0 ± 46.0	2.27	0.034**	744.0 ± 50.0	1.78	0.088	696.0 ± 62.0	3.46	0.002**
		Non-convergent	758.0 ± 63.0			723.0 ± 56.0			647.0 ± 56.0		
Error rate (%)	Without mental fatigue	Convergent	0.7 ± 2.0	-0.29	0.770	0.9 ± 3.0	-0.039	0.960	0.9 ± 2.6	0.42	0.670
		Non-convergent	0.9 ± 1.7			0.9 ± 2.4			0.7 ± 2.0		
	With mental fatigue	Convergent	3.8 ± 5.6	-1.29	0.068	2.6 ± 5.5	-1.09	0.280	2.5 ± 4.6	-1.23	0.230
		Non-convergent	6.2 ± 6.6			3.8 ± 4.8			3.6 ± 3.8		

RT: Reaction time
* Significant difference in convergent conditions with and without mental fatigue; ** Significant difference in non-convergent conditions with and without mental fatigue

The paired t-test results suggested that mental fatigue had a significant effect on increasing the orientation RT (P = 0.016, $t_{(1,21)} = -2.60$), however the reduction in the percentage error (P = 0.660, $t_{(1,21)} = -0.52$) was not significant.

The sign analysis indicated that the sign-free RT was longer than that of the dual sign (P = 0.001, $t_{(1,21)} = 9.32$) and valid sign (P = 0.001, $t_{(1,21)} = 16.95$) states, besides, RT of the dual sign state was also longer than that of the valid sign (P = 0.001, $t_{(1,21)} = 10.25$). moreover, mental fatigue caused prolongation of signs relative to each other, so that in the mental fatigue condition, the sign-free RT was longer that of the dual sign state (P = 0.001, $t_{(1,21)} = 5.65$) and valid sign state (P = 0.001, $t_{(1,21)} = 18.60$), and RT of the dual sign state was longer than that of the valid sign (P = 0.001, $t_{(1,21)} = 7.83$).

The paired t-test analysis results revealed that the error percentage in the alerting and orienting networks was affected by mental fatigue, resulting in a decrease in their accuracy in the orienting network (P = 0.600, $t_{(1,21)} = -0.53$) and in the alerting network (P = 0.870, $t_{(1,21)} = 0.15$) with respectively 48% and 45%, but these changes were not significant. The repeated measures ANOVA test results indicated that the error percentage in both conditions varied according to the type of sign and target. In fact, the processing accuracy was significantly influenced by the type of sign and target, leading to an increase in the error percentage. The main effect of the sign type (P = 0.016, $F_{(1,21)} = 4.59$, Partial $\eta^2 = 0.18$) and the main effect of the target type (P = 0.001, $F_{(1,21)} = 22.94$, Partial $\eta^2 = 0.52$) were significant. Therefore, the main effect of time was significant and the error percentage increased (P = 0.038, $F_{(1,21)} = 4.88$, Partial $\eta^2 = 0.19$). The sign analysis indicated that the error percentage in the sign-free state was higher than that in the dual sign state (P = 0.039, $t_{(1,21)} = 2.20$), with the effect size 70% and the valid sign with 85% increase (P = 0.440, $t_{(1,21)} = 2.14$). There was no difference between the dual sign and the valid sign in the error percentage in conditions without mental fatigue (P = 0.670, $t_{(1,21)} = -0.42$) with 8.9 error percentage and with mental fatigue (P = 0.560, $t_{(1,21)} = 0.59$); the effect size was 8.6%. Furthermore, mental fatigue reduced the accuracy of signs relative to each other, with the higher error percentage of the sign-free state as respectively 22 and 34 compared to the dual sign (P = 0.170, $t_{(1,21)} = 2.51$) and valid sign (P = 0.091, $t_{(1,21)} = 1.78$) states, however this difference was not significant.

Discussion

Mental fatigue is a very common phenomenon that can be along with a huge negative impact on the daily task performance. The tired individuals often encounter problems in focus that are easily recognizable. The present study was carried out with the purpose to investigate the effect of mental fatigue on the performance of alerting and orienting networks among the skilled athletes. The study findings revealed that mental fatigue negatively affected RT of the orienting network and error percentage of both networks as respectively 40% and 45%, but it improved the processing speed in the alerting network with reduced accuracy. The results imply that athletes experience problems with concentration after mental fatigue and are easily distracted, which is observed in the processing speed of the orienting network and the response accuracy.

Mental fatigue tasks, such as the Stroop task, which is among the cognitive processes of selective attention and inhibition, are used to examine information processing at the two automatic (word reading) and controlled (word color naming) levels. When there is inhibition in the response selection due to the word meaning and word color and is unpredictable, the anterior cingulate cortex (ACC), which is part of the prefrontal cortex (area involved in inhibitory tasks), is activated. Thus, the challenge is unpredictable and is strongly activated by the ACC and the lateral prefrontal cortex before the actual error (35), that is, prior to responding to a Stroop stimulus that may be correct or incorrect, planning and predicting are performed and these areas are activated. In fact, this cerebral region receives an input from the primary motor cortex, the premotor cortex, and the supplementary motor area (SMA) (36) and leads to the generation of spinal cortical projections (37) that terminate in the middle region of the spinal cord (37). Therefore, ACC requires motor control (38). The goal-directed behavior cognitive function is affected by the top-down modulation (24). In the present study, during RT, the orienting network as a cognitive function was one of the goal-directed cognitive mechanisms affected by mental fatigue and this change was observed with a decrease in the processing speed and a decrease in the alerting network. Accordingly, it can be declared that with increasing mental fatigue, the cognitive performance top-down modulation decreased, which is consistent with the results of the study by Lorist et al (38).

An important issue in examining mental fatigue is related to the relationship between fatigue and factors such as motivation and fatigue (24). It is claimed that at least part of the effects of mental fatigue are due to a lack of motivation (39). Tired people who are motivated can control their actions in an appropriate way. However, if they are mentally tired and motivated, they will not be able to improve their speed and accuracy and, on the other hand, perform poorly on one feature while improving another function (15). In the present study, the error rate decreased with increasing the reaction speed in mental fatigue conditions in the orienting network. Increased motivation and mental effort to maintain cognitive task performance in the presence of mental fatigue is associated with increased sympathetic nervous system activity (40).

When people are tired, the selection of actions is controlled through high-level regulatory control processes (38). Tired people have problems focusing attention, planning, and adapting to changing strategies (41). In fact, they have less ability to respond and have difficulty maintaining attention and ignoring irrelevant information and less correct their incorrect responses (15). In the present study, in addition to the mental fatigue effects observed, behavioral results indicated convergence effects. Frequently, in the flanker task, the slower responses with less accuracy have been reported for non-convergent efforts versus the convergent ones (13). In fact, if the increased mental fatigue prevents the suppression of irrelevant information, one can expect that the responses will be increasingly formed based on the inappropriate information (13). Under the convergent conditions, this may lead to a slight facilitation (13). Thus, when people are mentally tired, they have problems in blocking irrelevant stimuli, increasing the number of errors (15).

In terms of speed, performance in the alerting network is not affected by time, but in the orienting network, mental fatigue results in a slower processing speed for the input information, resulting in a higher RT, but the error percentage does not change; this coincides with the speed-accuracy trade-off proposed by Fitts and Peterson. This law states that the performance accuracy is maintained by reducing speed (42). This result on the accuracy decline was in line with the findings published in previous studies, as with increased mental fatigue, participants were increasingly inclined to respond to irrelevant information (2,13,28). It seems that with practice, the selection of information is performed mainly automatically and the task requirements decrease with time and mental fatigue. If these effects reflect learning, useful effects will be observed on the alerting network performance. However, mental fatigue may fail executively to maintain and optimize performance in the hectic conditions, but maintaining the compensatory cognitive effort results in a performance that is lower and more variable than the individuals' optimal ability (43).

The participants of the present study had a high ability to quickly process the stimuli presented in the sports environments (convergent and related stimuli) due to their experience of sports activity, but their performance decreased in the response accuracy and attention to the irrelevant and non-convergent stimuli. This phenomenon may lead to the decreased attention, reduced processing capacity, and reduced perception and action coupling with increased the perceived fatigue level, resulting in the reduced motivation to perform the task.

Limitations

The limitations of the present study included the lack of control over the mental state and sleep level of the participants during the test, because when the subjects are not in a good mood, their attention and accuracy of implementation of tasks are affected. Additionally, a good night sleep can affect an individual's alertness and reaction speed. Therefore, if the individuals do not have a sleep deep, their daily fatigue will not be eliminated and their daily and cognitive function will change (14,44,45). Given the quasi-experimental nature of the present study, there was a limited possibility to generalize the results to other groups of society. Therefore, it is recommended that this experiment be repeated in a field form taking into account generalizability. Ball sports are considered as cognitive-motor skills in terms of range of motor skills and are also played as a team. Due to the lack of access to professional athletes in a particular field and their unwillingness to participate in the study, the participants of the current study were selected from athlete students who had a significant history of regular activity in one or more sports. Thus, the subjects were inevitably chosen from several non-homogeneous ball sports.

Recommendations

Since the participants' mental factors were not controllable, it is advisable to examine their moods in future studies, and since brain activities change during mental fatigue and may indicate sleepiness, it is recommended that the electrophysiological indices of participants be examined before and after mental fatigue in future studies. Since the study population consisted of athlete students from three fields of football, volleyball, and basketball, it is advisable to investigate each specialized sport separately in future studies.

Conclusion

Given that ball sports require a great amount of cognitive and motor effort to correctly identify the stimuli and rapid responses and their performance is affected by mental fatigue, the cognitive effort which causes fatigue is recommended not be performed in the exercise of these fields and before starting the game.

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Authors' Contribution

Sahar Mohammadzadeh: Study design and ideation, manuscript arrangement, study support and executional services, providing study equipment and samples and data collection, data analysis, specialized statistics services, responsibility for maintain the study integrity from the beginning to the end and responding to referees' questions; Alireza Farsi: Study design and ideation, expert evaluation of the manuscript in scientific terms, and manuscript confirmation before submission to the journal, Reza Khosrowabadi, assistance in the specialized analysis and evaluation of the manuscript in scientific terms and manuscript approval before submission to the journal.

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Conflict of Interests

The authors declare no conflict of interest. Sahar Mohammadzadeh has been a Ph.D. student in the Department of Motor Behavior, Shahid Beheshti University since 2014. Alireza Farsi was the associate professor of the School of Sport Sciences, Shahid Beheshti University, and Reza Khosrowabadi was the assistant professor of the Institute for Cognitive and Brain Sciences, Shahid Beheshti University and the advisor of the thesis.

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