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Effects of Mental Fatigue on Memory Function of Expert Chess Players

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Abstract

Mental fatigue is a factor that may influence performance of chess players. However, effects of mental fatigue on performance of chess players are rarely investigated. Therefore, the aim of this study was to explore the effects of exposure to a mental fatigue protocol on memory function (pattern recall performance) of expert chess players. Thirty expert chess players (55-65 years-old) were randomly assigned into mental fatigue and control groups. Participants in the mental fatigue group were asked to (re-)place observed ordinary and random chess positions on a blank chessboard before and after exposing to a 30-minutes' mental fatigue protocol. The control group followed the same procedure but they read a text about history of chess instead of exposing to mental fatigue protocol. Two ordinary and two random chess positions were used to measure pattern recall performances in pre- and post-tests. Visual Analogue Scale was used to measure the subjective rating of mental fatigue and motivation for upcoming pattern recall task. Results showed that exposing to mental fatigue protocol increased the subjective rating of mental fatigue significantly in the mental fatigue group. Moreover, motivation was not different between the groups before performing pattern recall task in posttest. Also, results revealed that exposing to mental fatigue protocol impaired pattern recall performance of expert chess players. Finally, expert chess players performed significantly better in recalling ordinary positions than random positions. Findings of the study can add to the existing knowledge on effects of mental fatigue on a variety of sporting context and also provide support for Chunking Theory of Memory and Template Theory.

Keywords: Chess, mental fatigue, memory, ordinary and random positions, pattern recall

Introduction

Chess as a sport is considered as a highly demanding cognitive activity as it requires focused attention for a long time and throughout the match to select the best moves using well-established rules to win the game (Nejati & Nejati, 2012). Chase and Simon (1973) proposed the Chunking Theory of Memory and stated that masters in chess access information in long-term memory rapidly by recognizing familiar constellations of pieces on the board, the patterns acting as cues that trigger access to the chunks. A chunk is a symbol of a chess player's long-term memory that has certain parameters and properties and can be used as a processing unit. Each chunk can be retrieved by a chess player through a simple recognition procedure. Chase and Simon (1973) suggested that skilled chess players can easily and quickly retrieve information stored in long-term memory by identifying the composition of the pieces on the chessboard. In fact, patterns depicted from compositions of the pieces in memory of an expert chess player serve as signs that facilitate access to the chunks. Because these chunks are associated with possible moves in the game of chess, expert chess players are generally able to find the best moves in the game with only moderate look ahead search. Because storing one chunk in short-term memory gives access to a number of pieces, masters in chess perform remarkably well in recall tasks.

Gobet and Simon (1996 a & b, 2000) developed the Chunking Theory of Memory and proposed the Template Theory. According to this theory, chess players learn large chunks of chess pieces called "templates" through practice and play during many years. The concept of template is different from the concept of chunk in two ways. First, the template is larger than the chunk, and second, the template contains spaces for unknown pieces on the chessboard as well. Since storing a chunk or template in the short-

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term memory allows the chess player to access to a large number of pieces, master chess players generally perform very well in recalling chess patterns. Pattern recall in chess involves low-level cognitive processes to identify the position of the chess pieces relative to each other (Gobet & Simon, 2000; Lane & Chang, 2018; Linhares, Freitas, Mendes, & Silva, 2012; van Harreveld, Wagenmakers, & van der Maas, 2007). Therefore, in chess-related research, researchers have used pattern recall task as a tool to measure the function of a chess player's memory as well as examining the influence of different factors on the performance of chess players (Gobet & Simon, 1996 a & b, 1998, 2000; Gong, Ericsson, & Moxley, 2015; Lane & Chang, 2018; Linhares et al., 2012). The results of these studies have generally shown that expert chess players perform better than amateur chess players in pattern recall tasks as well as they recall ordinary chess patterns (derived from an official chess game) better than random chess patterns (in which the chess pieces are randomly placed on a chessboard) (Chase & Simon, 1973; Connors, Burns, & Campitelli, 2011; Gobet & Simon, 1996 a & b, 1998, 2000).

Because chess is a highly demanding cognitive activity, exposure to highly demanding tasks for a long time during the match may induce psychological stress and mental fatigue in chess players which may impair chess performance (Troubat, Fargeas-Gluck, Tulppo, & Dugue, 2009). While the effects of many determinants (e.g., time pressure, speed) on chess performance have been previously investigated (Burns, 2004; van Harreveld et al., 2007), the effect of mental fatigue on chess performance is rarely investigated. Mental fatigue refers to a psychobiological condition occurs after a long-term exposure to a cognitive-demanding activity which is associated with lack of energy and tiredness as well as reduction in attention, reaction time, and task planning (Boksem & Tops, 2008). The evidence showed that mental fatigue similar to physical fatigue had negative impacts on performance in many sports. It has been shown that mental fatigue impairs speed and accuracy of soccer-specific decisions (Smith, Zeuwts, Lenoir, Hens, DeJong, & Coutts, 2016), physical and tactical performances in soccer (Coutinho, Gonçalves, Travassos, Wong, Coutts, & Sampaio, 2017), running, passing, and shooting in soccer (Smith, Coutts, Merlini, Deprez, Lenoir, & Marcora, 2016), speed and accuracy of the ball in table tennis (LeMansec, Pageaux, Nordez, Dorel, & Jubeau, 2017), 1500-m swimming performance (Penna, Filho, Wanner, Campos, Quinan, Mendes, Smith, & Prado, 2018), and endurance performance (Martin, Meeusen, Thompson, Keegan, & Rattray, 2018; Pageaux & Lepers, 2016).

Due to lack of research on the effects of mental fatigue on chess performance, the present study aimed to investigate this issue experimentally in high-level chess players. Therefore, the present study explored the effects of inducing a 30-min mental fatigue protocol on recall performance of high-level chess players on ordinary and random positions in chess. In this study, it was hypothesized that: 1) exposing to a 30-min mental fatigue protocol would impair pattern recall performance of expert chess players; and 2) expert chess players recall ordinary chess positions better than random chess positions.

Method

Participants

The participants were 30 expert chess players (including 24 males and six females) aged 55 to 65 years-old who participated in over 55 national chess competition in 2019 in Iran. Based on a national ranking according to the Iranian Chess Federation, the participants were ranked from 1500 to 2000, which corresponds to a high level of skill among Iranian chess players. The participants were randomly assigned to two equal groups including mental fatigue (n = 15, consisted of 12 males and three females) and control (n = 15, consisted of 12 males and three females) groups. The protocol was performed in accordance with the Declaration of Helsinki and was approved by the university's institutional review board. The participants gave written consents.

Instruments

Pattern Recall Task

As it is presented in Figure 1, two ordinary (one position for pretest and one position for posttest) and two random (one position for pretest and one position for posttest) chess positions were used in the present study. These positions were adopted from Gobet and Simon (1996). Each position contained 24 chess pieces including 12 black and 12 white pieces. Pattern recall task was to observe the chess position for 10 seconds on the laptop and (re-)place it as accurately as possible on a blank chessboard. Number of correct (re-)placed pieces was considered as pattern recall score which could be from zero to 24.

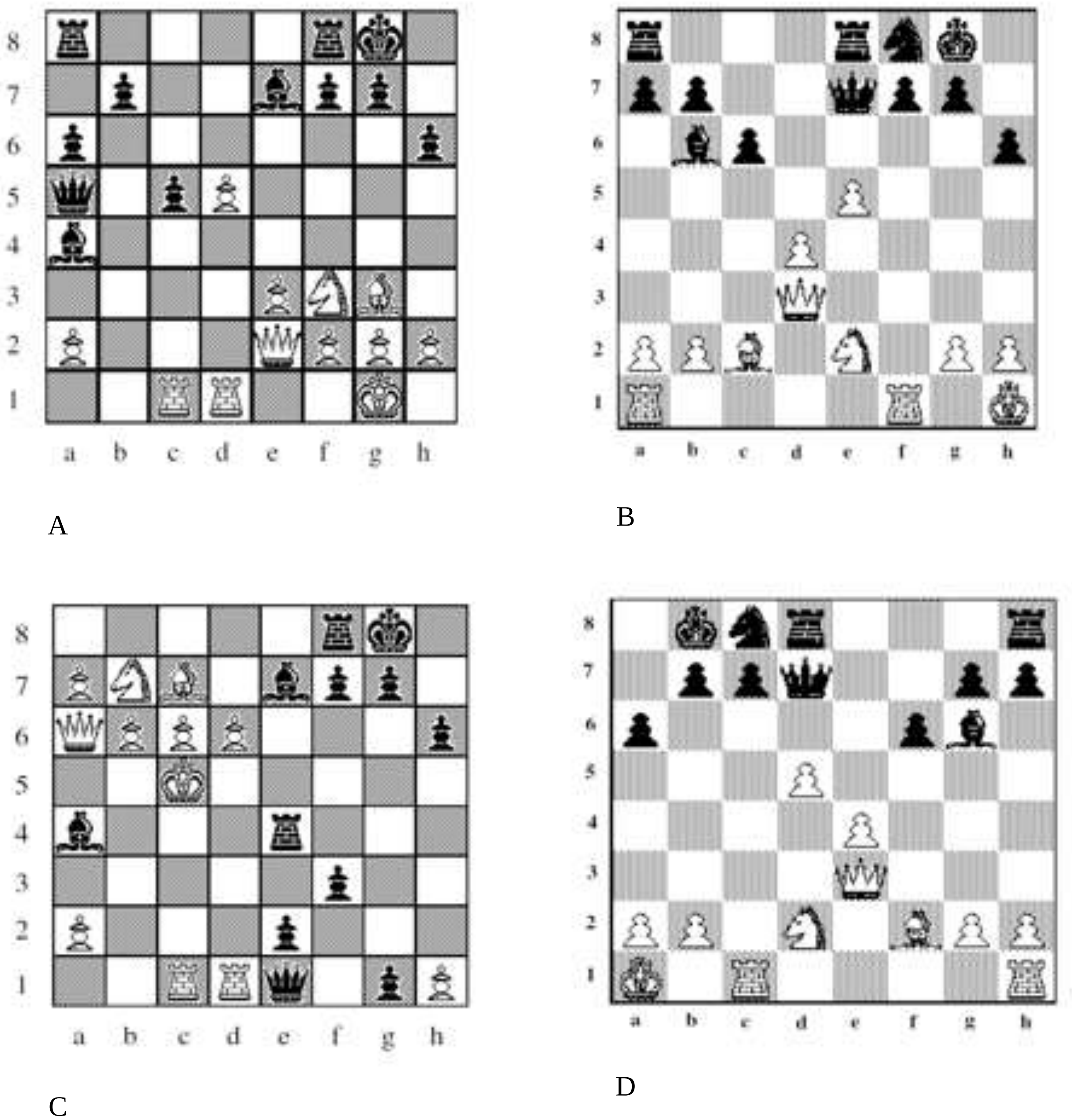

Figure 1. Ordinary and Random Chess Positions. Position A: Ordinary Position in the Pretest; Position B: Ordinary Position in the Posttest; Position C: Random Position in the Pretest; Position D: Random Position in the Posttest.

Mental Fatigue Protocol

A serial subtraction arithmetic task was used to induce mental fatigue. The participants were provided by a number (e.g., 195) and were asked to verbally count backward by seven as quickly and accurately as possible (e.g., 195, 188, 181, 174, etc.). Each time the answer was wrong, the experimenter provided the correct answer and the participant used this number to continue the protocol. The arithmetic task is a common method for inducing mental fatigue and has been used in many studies (Carter, Kupiers, & Ray, 2005; Mehta, Nussbaum, Agnew, 2012; Mehta & Parasuraman, 2014). There was no final score for this protocol and it was only used to mentally tire the participants.

Subjective Mental Fatigue

To serve as manipulation check in the present study, a 100-mm Visual Analogue Scale (VAS; Wewers &

Lowe, 1990) was used to assess subjective ratings of mental fatigue and motivation. The response continuum consisted of a 100-millimetre line with the anchors ranging from 'none at all' to 'maximal'. Participants were asked to "please mark X on the line the point that they felt represented their perception of their current state of mental fatigue". Scores were calculated by measuring the distance in millimeters that the 'X' was placed from the left side of the scale. Subjective ratings of mental fatigue were measured prior to (Pretest) and after (Posttest) mental fatigue protocol. Moreover, motivation was measured only at Posttest and referred to the upcoming pattern recall task. The VAS was used in previous research to assess subjective ratings of mental fatigue, mental effort and motivation in sport and exercise context (Harris & Bray, 2019; Penna et al., 2018; Smith et al., 2016).

Procedure

The participants were tested individually in a completely silent room. Prior to data collection, participants were given general information of the experimental process. Following presenting general information, they completed the pretest in which they first observed related ordinary position for 10 seconds and immediately completed the pattern on the chessboard and, then, they observed related random position for 10 seconds and immediately completed the pattern on the chessboard. There was no time limit and the participant was asked to say "Finish" when he felt that he had completed the pattern. Following the pretest, the participants in mental fatigue group were exposed to a mental fatigue protocol for 30 minutes, and those in the control group read a text about history of chess for 30 minutes. Following the protocol, the participants performed the posttest similar to the pretest in which they observed ordinary and random positions for 10 seconds and completed the patterns on the blank chessboard. The number of correct (re-)placed positions on the chessboard was calculated as pattern recall scores.

Data Analysis

Descriptive analysis such as mean and standard deviation (SD) were used to descriptively report the data. Paired-sample *t* test and independent *t* test were used to analyze the subjective ratings of mental fatigue. Independent *t* test was used to analyze the motivation scores. Performances of participants in the pattern recall task across pretest and posttests were analyzed by a 2 (GROUP: mental fatigue vs. control) × 2 (POSITION: ordinary vs. random) × 2 (TIME: pretest vs. posttest) analysis of variance (ANOVA). When there were significant group differences, partial eta squared (εpar^2) was calculated as the effect size. Significance level was set at $p < .05$.

Findings

Means and SDs of participants' age of mental fatigue and control groups are presented in Table 1.

Table 1.
Means and SDs of Age of Participants of Research Groups

Groups	Mental Fatigue		Control	
	Males	**Females**	**Males**	**Females**
N	12	3	12	3
Mean (Years-Old)	61.08	59.00	59.41	60.00
SD	2.71	4.35	2.39	2.64

Subjective mental fatigue

As shown in Table 2 and Figure 2, there was no significant difference between groups in the subjective rating of mental fatigue in Pretest (t = 0.03, df = 28, sig = 0.97). However, results of paired-sample *t* test showed that mental fatigue group reported a significant increase from Pretest to Posttest (t = 30.62, df = 14, sig = 0.000), but no significant increase was observed in control group (t = 0.71, df = 14, sig = 0.48). These results indicate that a 30-min mental fatigue protocol was able to increase the feeling of mental tiredness in the mental fatigue group.

Table 2.
Means and SDs of Subjective Rating of Mental Fatigue of Research Groups

Groups	Mental Fatigue		Control	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Mean	14.53	73.3	14.46	14.73
SD	2.02	3.10	1.93	1.88

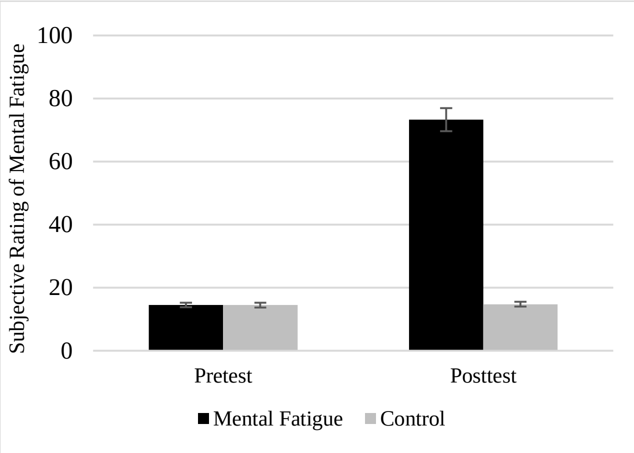

Figure 2.
Subjective Rating of Mental Fatigue in Mental Fatigue and Control Groups across Pretest and Posttest

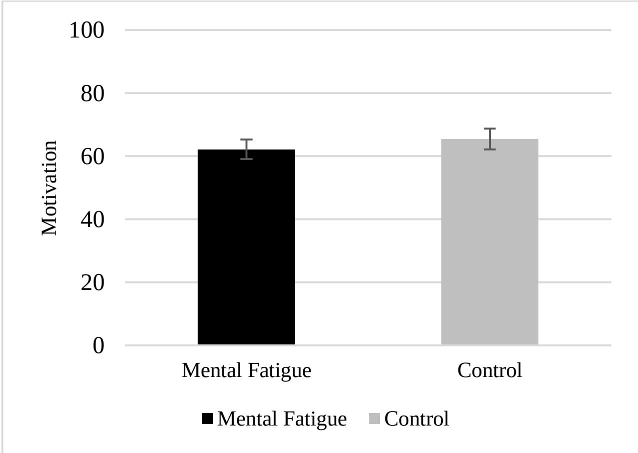

Figure 3.
Motivation Scores in Mental Fatigue and Control Groups in Posttest

As it appears in Figure 3, there was no significant difference between groups in motivation for the upcoming pattern recall task in Posttest (t = 0.67, df = 28, sig = 0.50).

Pattern recall performance

Mean and standard deviations of pattern recall performances of mental fatigue and control groups are presented in Table 3.

Table 3.
Means and SDs of Pattern Recall Performances of Research Groups

Groups	Pretest		Posttest	
	Ordinary Position	Random Position	Ordinary Position	Random Position
Mental Fatigue	19.26±1.27	15.60±2.22	16.46±2.64	13.20±2.39
Control	19.33±1.95	16.26±2.15	19.20±1.65	15.80±2.39

Regarding to pattern recall performances, results of ANOVA showed that there were significant main effects for GROUP, $F_{1,\ 112}$ = 14.87, p = .000, εpar^2 = .11, POSITION, $F_{1,\ 112}$ = 72.55, p = .000, εpar^2 = .39, TIME, $F_{1,\ 112}$ = 13.59, p = .000, εpar^2 = .10, and GROUP × TIME interaction, $F_{1,\ 112}$ = 8.55, p = .004, εpar^2 = .07. However, GROUP × POSITION, TIME × POSITION, and GROUP × POSITION × TIME interactions were not significant, $p > .05$. As it appears in Table 1 and Figures 2 and 3, pattern recall performance of mental fatigue group in both ordinary and random positions decreased significantly from pretest (19.26) to posttest (16.46) while no significant decrements were observed in control group from pretest to posttest. These results indicate that exposing to a mental fatigue protocol impaired pattern recall performance in expert chess players.

In addition, as shown in Table 2 and Figures 4 and 5, both mental fatigue (19.60 vs. 15.60 for ordinary and random positions, respectively) and control (19.33 vs. 16.26 for ordinary and random positions, respectively) groups performed significantly better on pattern recall task of ordinary positions than random positions.

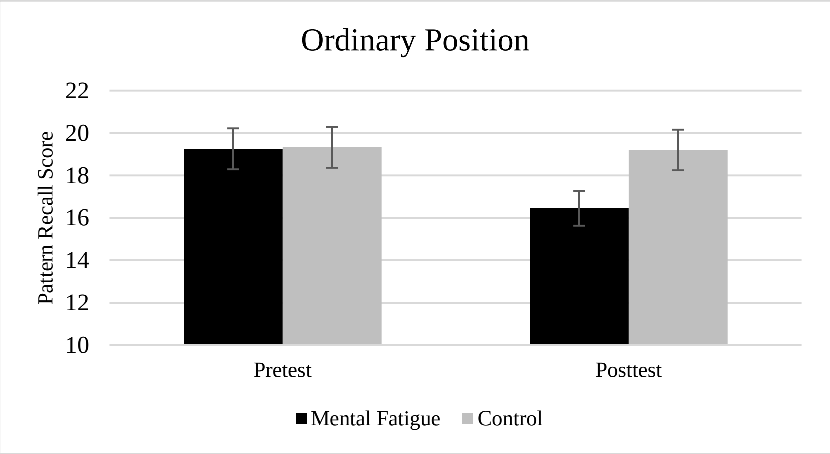

Figure 4.
Pattern Recall Scores of Mental Fatigue and Control Groups in Ordinary Position across Pretest and Posttest

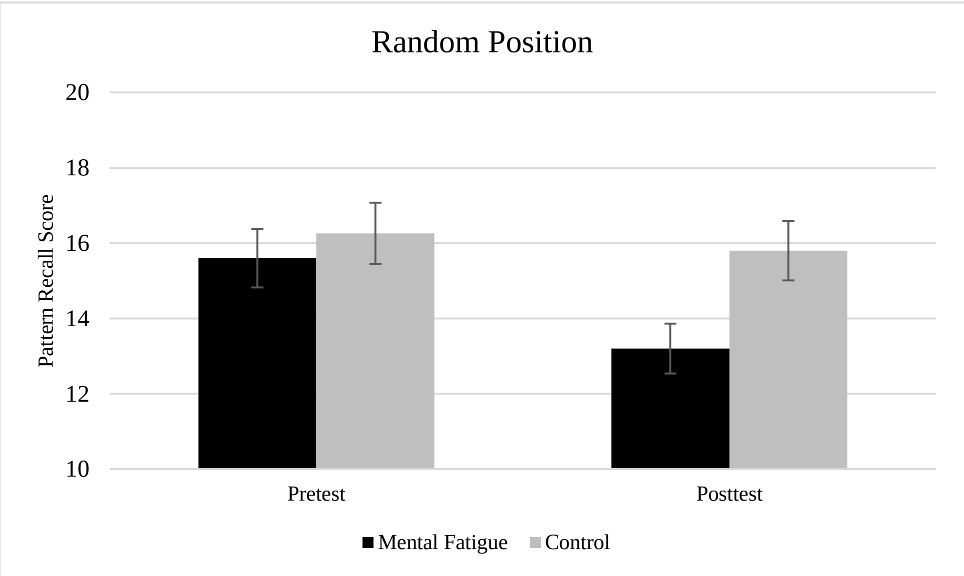

Figure 5.
Pattern Recall Scores of Mental Fatigue and Control Groups in Random Position across Pretest and Posttest

Discussion and Conclusion

Because a chess player exposes to highly demanding tasks for a long time during a match, it may induce mental fatigue in chess players. Therefore, the primary aim of the present study was to explore the effects of mental fatigue on memory function (pattern recall performance) of expert chess players. Moreover, the secondary aim was to replicate previous results indicating that experts have superior pattern recall performance in ordinary chess positions than random chess positions. It was hypothesized that: 1) mental fatigue would impair pattern recall performance; and 2) expert players have superior pattern recall performance in ordinary position than random positions.

Considering the first hypothesis, the results showed that exposing to a 30-minutes mental fatigue protocol impaired pattern recall performance in both ordinary and random positions in the mental fatigue group; however, no impairments were observed for the control group (Figures 2 and 3). Thus, the results confirm our hypothesis and are consistent with those of previous studies which showed that mental fatigue has negative effects on performance of a variety of sporting skills (Coutinho et al., 2017; LeMansec et al., 2017; Martin et al., 2018; Pageaux & Lepers, 2016; Penna et al., 2018; Smith et al., 2016). However, to the best of our knowledge, this is the first study assessing the effects of a mental fatigue protocol on chess performance. A possible explanation for decreased performances in memory function of expert chess players following exposure to a 30-minutes mental fatigue protocol might be that exposing to mental fatigue impaired conflict control and attention in chess players. Conflict control is an important element for chess players as they confront with many conflicts during the game which are constantly changing and developing (Golf, 2015a). Regarding the attention, neurocognitive studies have shown that selective attention processes activate the anterior cingulated cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC) (Smith & Jonides, 1999). In addition, Atherton, Zhuang, Bart, Hu and He (2003) showed that structures of chess cognition are located in these brain regions. Finally, research has shown that general fatigue is associated with ACC and DLPFC (Carter & van Veen, 2007; Caseras, Mataix-Cols, Rimes, Giampietro, Brammer, et al., 2008; Paus, 2001). As a result, it might be possible that exposing to a mental fatigue protocol impaired memory function and cognitive performances (e.g., pattern recall) of a chess player through impaired functions in these brain regions which consequently reduced attention and conflict control (Golf, 2015a).

Regarding the second hypothesis, the results of the present study demonstrated that expert chess players performed significantly better in pattern recall of ordinary positions than in random positions. These results support our hypothesis and are in accordance with previous studies showing a superior recall performance in ordinary positions in comparison to random positions for expert chess players (Chase & Simon, 1973a, 1973b; Connors et al., 2011). These results, also, indirectly support the Chunking Theory of Memory (Chase & Simon, 1973a, 1973b) and the Template Theory (Gobet & Simon, 1996, 2000) which hold that expert chess players recognize perceptual and conceptual clusters of chess pieces which are stored as a template in long-term memory through experience, practice and study. It is assumed that templates are linked to possible moves, evaluations, and plans (Gobet & Simon, 1996, 2000). So, chunks or templates enable chess players to make a superior decision based on previous experiences. The superiority in ordinary positions might be because of the fact that expert chess players find more templates in ordinary positions than random positions and therefore are able to recognize more pieces.

In previous research, it has been suggested that mental fatigue decreased the level of motivation and it may subsequently affect sport performance. However, the results of the present study showed that there was no significant difference between mental fatigue and control groups before to executing the pattern recall task in the posttest. Thus, the impaired pattern recall performance after exposing to a 30-min mental fatigue protocol in mental fatigue group cannot be explained by changes in motivation. This result is in accordance with those of Penna et al., (2018) and Smith et al., (2016) and might indicate that mental fatigue is not always associated with task disengagement or reduced motivation.

Finally, although this study is, to the best of our knowledge, the first study that investigated the effects of mental fatigue on chess performance, there are some limitations. First, this study used old chess players (55 to 65 years old) as the participants. Age could be an effective factor on cognitive performance (Murman, 2015). Therefore, the effects of mental fatigue, as applied in the present study, on chess performance of young chess players remained unclear. Further research is needed to investigate this issue. Second, the participants were expert chess players at the level of national competitions. Using chess grandmasters as the participants can better capture the effects of mental fatigue on chess performance. It can be suggested that future research use chess elites and grandmasters as the participants. Third, this study only measured pattern recall performances and no psychophysiological variables were measured before, during and after mental fatigue protocol. Assessing the psychophysiological variables can clarify the mechanisms underlying the influence of mental fatigue on chess performance. Future research should examine the psychophysiological variables before, during and following mental fatigue protocol in chess players.

In summary, the present study can add to the existing knowledge on the effects of mental fatigue on a variety of sporting context by finding that mental fatigue impairs memory function of expert chess players. Moreover, this study indirectly supports Template Theory by finding that expert chess players are able to recall ordinary positions better than random positions. In addition, the preset study has developed an experimental setting that could be useful for further investigations. The present findings have practical implications, too. Due to the negative effects of a 30-minutes mental fatigue protocol on memory function of expert chess players, this study suggests that chess players do not engage in any cognitive-demanding activity for at least 30 minutes before the match because it may induce mental fatigue and consequently impair their performance. Moreover, regular physical exercise, a proper nutrition, mental training, and meta-cognitive training could be of interest for coping with mental fatigue during the match (Golf, 2015b).

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Conflict of interest

None declared.

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