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SPORTS PERFORMANCE



How does mental fatigue affect soccer performance during small-sided games? A cognitive, tactical and physical approach

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ABSTRACT

Objectives: We examine how mental fatigue (MF) influences peripheral perception, tactical behaviour, and physical performance of soccer players during a standardized small-sided game.

Methods: Eighteen male university first-team soccer players participated. A modified Stroop task and the Vienna Test System were employed to induce MF and to evaluate players' peripheral perception, respectively. The FUT-SAT test was used to assess participants' tactical behaviour and physical performance was quantified using GPS technology.

Results: MF decreased players' visual field (pre-test = 189.9° and post-test = 181.6°). Additionally, MF constrained players to more frequently perform actions related to the tactical principles of penetration, depth mobility, and defensive unity, and less frequently perform actions of defensive coverage and balance. During MF, players showed decreased accuracy in actions related to the principles of offensive coverage, width and length, offensive unity, delay, balance, concentration, and defensive unity. Finally, under MF players covered higher total distance and at more moderate speed.

Conclusions: MF decreased players' peripheral perception, making them prioritize actions towards the opposing goal and protecting their own goal, while displaying more errors for most tactical actions. In summary, MF impaired several aspects of players' cognitive and tactical behaviours, causing a compensatory increase in physical performance.

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KEYWORDS

Football; cognitive fatigue; cognition; field of view; tactical behaviour

Introduction

Mental fatigue (MF) is often experienced during, or after, a prolonged period of cognitively demanding activity, characterized by the feeling of tiredness and lack of energy (Boksem & Tops, 2008; Marcora et al., 2009). Scientists have shown that mentally fatigued individuals display inferior performance in cognitive tasks that require hypothesis testing and action planning (Lorist et al., 2000; Van der Linden et al., 2003), inhibition of automatic responses (Lorist et al., 2005), and selective attention (Faber et al., 2012). Recently, research has identified negative effects of MF on physical performance in endurance tasks (Van Cutsem et al., 2017) and on aspects of performance known to contribute to competition outcome of sports characterized by high cognitive demands, particularly soccer (Coutinho et al., 2018).

It is likely that soccer induces MF through the continuous demand of perceptual-cognitive skills for the purpose of recognizing, interpreting, and processing various simultaneous pieces of information, while making decisions and anticipating actions of opponents in situations of high time and space pressure (Nédeléc et al., 2012; Walsh, 2014). In the course of an official match, for instance, players remain vigilant for long periods, adjusting strategic and tactical behaviours according

to the continuous changes in the game, by gathering information available in the environment (Roca et al., 2013). In a recent study, elite athletes and coaching staff have been reported behavioural changes as a consequence of MF, such as lack of attention to detail and an increased demand to concentrate (Russell et al., 2019). Therefore, it is reasonably suggested that players experience MF during competitive matches, which likely contributes to the performance decrement seen towards the later end of matches (Smith et al., 2018).

Vision plays an important role in sports such as soccer (Sternberg, 2010). Visual perception is investigated through central vision – characterized by reduced amplitude of information and higher image resolution – and peripheral vision, which enables higher amplitude of information gathered and sensitivity to movements, but lower image resolution (Bear, Connors & Paradiso, 2008). Also, it has also been argued that soccer players develop a special skill to rapidly zoom out visuospatial attention. It involves switching from a visual search strategy operated in a sequential manner on single visual information sources to a strategy that anchors the gaze and covertly distributes visual attentional resources over a larger area (Pesce et al., 2007). In relation to the contribution of peripheral perception to performance in soccer, researchers have shown that in order to perform efficient tactical

actions, players must present refined peripheral perception skills, as the motor responses observed during the game are performed through the collection of information from the environment (Gonçalves et al., 2017).

Smith, Zeuwts et al. (2016) investigated the effects of MF on visual search and decision-making in soccer simulations involving offensive phases of play. Their findings showed minimal effects of MF on central vision, from which it is possible to infer that, despite causing a decrease in accuracy and decision time, the gaze patterns (i.e., ball, empty space, and opponent) were not changed under MF. We argue that MF may harm peripheral perception and, consequently, decision-making. This is a plausible hypothesis, given that the sensitivity of peripheral perception in situations of high cognitive demand (Jahn et al., 2005) and its contribution to decision-making in sports are known (Ryu et al., 2013).

A recent study supports this hypothesis, while investigating the effects of MF on collective tactical behaviour in soccer (Coutinho et al., 2017). The authors found reduced synchrony values in lateral movements among players as well as in the team's speed of contraction when players were mentally fatigued (Coutinho et al., 2017). These results were attributed to the effects of MF, leading to the decrease in players' ability to pick up information from the environment, particularly from teammates and opponents. Therefore, the findings might indicate the importance of peripheral vision in order to perform synchronized movements, as there is the need to pick up information from broader movements and, at the same time, the sensitivity of peripheral perception to MF, although the authors did not directly measure this effect.

Regarding MF effects on physical performance in soccer, the increase of effort perception is the main argument to explain the detrimental effects (Smith, Coutts et al., 2016; Smith et al., 2015). In a test performed on a non-motorized treadmill, Smith et al. (2015) observed detrimental effects of MF on speed in periods of low-intensity and total distance covered, but did not find differences in higher intensities regarding the protocol. In another study by the same research team, this effect was observed through a decrease of performance in physical tests that induced players to maximum effort, such as Yo-Yo IR1 (Smith, Coutts et al., 2016). In physiological terms, it is postulated that prolonged cognitive activity could lead to an increase in extracellular concentration of adenosine in the brain (Lovatt et al., 2012), especially in the anterior cingulate cortex and, consequently, the perception of effort would increase during physical tasks (Martin et al., 2018; Smith et al., 2018). In addition to this hypothesis, the depletion of physiological resources in demanding cognitive activity (e.g., phosphocreatine) is also considered a likely contributing mechanism for MF. In demanding and prolonged cognitive tasks, the energy-supply capacity of the phosphocreatine (PCr) system would be insufficient and, therefore, other mechanisms would have to meet the energy demand through glycogen deviation and/or improvement of non-oxidative glycolysis (Shulman et al., 2001). With the purpose of investigating this hypothesis, Van Cutsem et al. (2019) resorted to creatine supplementation during 7 days (20 g/day) in active young people. In this study, the authors observed that

creatine supplementation may be capable to partially neutralize the deterioration of cognitive performance induced by MF.

Scientists that have reported the harmful effect of MF on physical performance were mostly carried out through the application of physical tests, despite the fact that during a soccer match, players are free to adjust their pace, and that their tolerance to physical exercise is usually not taken to its limit (Smith, Coutts et al., 2016; Smith et al., 2015). Consequently, it is possible that during a match MF is manifested not only as a decrease in physical performance, but rather as an inadequate investment of physical effort as a means of compensation (increase) at the expense of other performance components, such as tactics (Kunrath et al., 2018). Recent research on small-sided games suggests that MF reduces technical performance, as well as the ability of teammates to coordinate their movements (Badin et al., 2016; Coutinho et al., 2017, 2018). However, findings related to physical performance are still conflicting/unclear in more specific contexts (Badin et al., 2016; Coutinho et al., 2018; Kunrath et al., 2018).

Apart from high physical demands of soccer, cognitive factors are also pivotal to achieve high-performance levels. For instance, decision-making situations are based on the creation of scenarios appropriate to shooting at the opponents' goal and, conversely, in the avoidance of risky situations to one's own goal (Gréhaigne & Godbout, 1995; Teoldo et al., 2009). Consequently, the tactical component and cognitive processes underlying decision-making – peripheral perception among them – are considered essential requirements for soccer performance (McPherson, 1994; Teoldo et al., 2015). Once the importance of perceptual-cognitive skills for soccer performance is recognized (Gonzaga et al., 2014), it is expected that the effects of MF are evident in the tactical dimension. However, limited research has examined the effects of MF on aspects related to tactical performance (Coutinho et al., 2018; Kunrath et al., 2018).

Thus far, no studies have observed the effects of MF from cognitive, tactical, and physical perspectives in a single study. Hence, a holistic approach might provide a better comprehension about relevant factors in soccer practice. Consequently, taking into consideration the core tactical principles of soccer (Teoldo et al., 2009) could provide information about the tactical solutions found by players when mentally fatigued. Therefore, we examined how MF influences peripheral perception, tactical behaviour, and physical performance of soccer players during a standard small-sided game (SSG). Based on previous MF research and on our pilot study (Kunrath et al., 2018) we focused on cognitive, tactical and physical variables, it was hypothesized that MF will result in: i) impaired perception peripheral performance; ii) decreased on accuracy in tactical actions; and iii) greater distance covered during SSGs.

Method

Sample

Altogether, 18 male amateur soccer players (21.8 ± 02.5 years) participated. The athletes played for the University first team which participated in national and state league tournaments.

The criteria for player selection and team formation according to player tactical, technical, and physical levels (Casamichana & Castellano, 2010) were established by the team's head coach. In order to participate in the study, all players were required to regularly attend structured training sessions, at least three times a week, with a duration of 1 h and 30 min each.

This study was approved by the Research Ethics Committee of the Federal University of Viçosa (CAAE: 70,049,717.0.0000.5153) and met the norms established by the National Health Council (466/2012) and Declaration of Helsinki. Data collection was provided with the consent of the volunteers, who signed an informed consent form before the commencement of the study.

Experimental design

Participants visited the laboratory on three different days. On the first day, the participants visited the laboratory with the purpose of being briefed about the procedures related to the VAS, the PP test, and the Stroop task. During the same day and after a period of familiarization, the participants performed, in sequence, a cognitive battery of tests in the following order: i) PP test; ii) Stroop task; iii) PP test. Before and after the Stroop task, participants were asked to indicate their perception of MF at that particular moment by responding to the VAS measure.

On the second and third days, participants were evaluated in two conditions with a minimum interval of 48 h between assessments. More specifically, on the second day, named "Control" condition, all the participants watched a video documentary about social networking websites and the history of a technology company, lasting 30 min (no specific cognitive task was performed concurrently), and immediately after, participated in the field test "Goalkeeper +3 vs. 3 + Goalkeeper". On the third day, named "MF" condition, all the participants performed the Stroop task, and immediately after, participated in the field test "Goalkeeper + 3 vs. 3 + Goalkeepers". The interval between the Stroop task/video documentary and the field test was 3 min, approximately, which was sufficient for the participants move to the soccer field.

Participants were asked not to engage in any kind of physical exercise for 24 h before the interventions, as well as to have a minimum sleep time of 6 h on the previous night. The participants of the study were advised not to drink alcoholic beverages within the 24 h prior to data collection procedures. Although the same guidance was provided to participants with respect the drinks containing caffeine, the intake of up to 50 ml of strained coffee was allowed after lunch (at least 3 h prior to the study intervention). Such guidance takes into account participants' routine of studies due to their academic activities, as well as the local culture. Previous evidences have shown that habitual caffeine consumers are more tolerant of its physiological effects when compared with non-habitual caffeine consumers (Kennedy & Haskell, 2011; Hara et al., 2014). Instructions regarding the consumption of drinks were standardized and repeated in every phase of the study.

Data collection instruments

Visual Analogue Scale (VAS)

In order to assess the perception of MF, the VAS was employed only before and after Stroop task performed on the first day of data collection. This scale has unidimensional format, plotted in a straight line of 100 mm, anchored by extreme limits of "minimum" (0) and "maximum" (100) perception. Participants were asked to draw a vertical line, with a pen, on the horizontal line to determine their current perception of MF in the assessment. Before and after the Stroop task players individually responded to the question: "What is your perception of MF at this moment?".

Peripheral perception

The Peripheral Perception test (PP) – version S1, part of the Vienna Test System, was employed to assess participants' peripheral perception (Schuhfried et al., 2011). PP test was performed just before and after Stroop task on the first day of data collection. The Vienna Test System is a computerized system, comprised of the following devices: computer screen, computer CPU, peripheral panel, response panel, and pedals. The PP test consists of two simultaneous tasks: the first refers to the perception of peripheral light signals; and the other to the tracking of a circular object. During the test, the participant is asked to track the object's movements on the computer screen, while light stimuli are displayed on the peripheral panels. When a pattern of light signals is identified, the participant is asked to react quickly and press the pedal with his/her preferred foot. Prior to the start of the test, participants were allowed a period for familiarization with the task. The test had a duration of 10 min.

The main measure used in this test was the visual field (°). This measure is represented by the sum of the right and left visual angles, calculated from the individual's ability to react to stimuli at the edge of the visual field. The visual field is measured from the position of the visual stimulus, the target and the distance from the subject's head to the equipment. Additionally, other variables were measured including tracking deviation (s) – deviation time from the object to be chased on the screen, reaction time (s) – time spent to respond to the peripheral stimuli; and the amount of omitted reactions (no) – off reactions number.

Modified Stroop task

The modified Stroop task was performed with the purpose of inducing players' MF through a prolonged mental effort. Four words (red, blue, green, and yellow) were repeatedly displayed on a computer screen in a random order, with a duration of 1.5 s each. Participants were required to verbally respond to the stimuli, ignoring the meaning and taking into consideration only the colour of the word. In order to increase the difficulty, a rule was added, in which the words displayed in "red" colour would be responded to with the meaning of the word and not the colour of the word; thus, the word "green", displayed in "blue" colour would be correctly responded as "blue", whilst the word "green", displayed presented in "red" colour would be correctly responded as "green".

The task was conducted in a noise-free closed environment. Before performing the task, participants were informed of the standard task instructions. A period of 5 min was conceded to participants to familiarize themselves with the task. After the familiarization period, participants were encouraged to obtain their best possible performance. The total task time was 30 min, during which, 1200 stimuli were shown to participants.

Tactical assessment in soccer SSG's

The System of Tactical Assessment in Soccer (FUT-SAT) was used to assess participants' tactical behaviour through the soccer SSG standard field test "Goalkeeper + 3 vs. 3 + Goalkeeper" (Teoldo et al., 2011). The FUT-SAT provides information regarding the tactical behaviours performed by the participants in game situations based on the core tactical principles of soccer. This assessment takes the core tactical principles of soccer into account, five for the offensive and five for the defensive phases of play (Table 1).

The FUT-SAT is comprised of two Macro Categories. The Observation Macro Category refers to the variables regarding the Tactical Principles, the Place of Action in the Playing Field, and the Action Outcome. In turn, the Outcome Macro Category is related to the Tactical Performance Index (TPI), Tactical Actions, Percentage of Accuracy, and Place of Action Related to the Principles (PARP). In the present study, the FUT-SAT measures used to describe the efficiency and frequency of tactical actions were the percentage of accuracy and tactical actions, respectively.

The test was designed with a playing field of 36 metres in length and 27 metres wide and was performed with continuous 12 min duration. To perform this test, players were grouped in two teams, each of them with three outfield players and a goalkeeper (goalkeeper + 3 vs. 3 + goalkeeper), lined up with a defender, a midfielder, and a forward. During the application of the test, players were asked to play in accordance with the official laws of the game, including the offside rule. A period of 30 sec was conceded to participants for familiarization with the test. As a criterion for the analysis of tactical actions, the definition of ball possession proposed by Garganta (1997) was taken into consideration, which determines that a team/player is in possession of the ball by performing at least one of the following criteria: i) shooting at the opponent's goal; ii) making a successful pass, iii) making at least three consecutive ball touches.

For data analysis, the procedures proposed by Teoldo et al. (2011) were followed, and thus, after video recording the test,

the video material obtained was transferred in digital format to a laptop computer (Acer M5 Z09, Intel Core™ i3 processor). The analyses of the games were carried out by trained evaluators, who underwent training process that included the concepts, procedures, and methods of analysis with FUT-SAT. In order to be allowed to perform the analyses, evaluators performed a reliability procedure under the supervision of another trained evaluator. Additionally, the analyses of the games were performed using Soccer View® software, and evaluators were not aware of the players' condition during the test.

Monitoring of physical performance

A total of 18 units of a global tracking system (SPI-HPU – GPSports®, Canberra, AUS) were used for data collection. These units were attached to a triaxial accelerometer. This device has a sampling rate of 15 Hz for identification of players' positions on the field and of 100 Hz for the accelerometer. The GPS unit calculated the precise distance covered based on the reception of satellite signal and positional data. The players wore the same unit in both conditions to reduce any inter-device reliability issues.

The definition of the intensity zones of the distance covered were categorized as: Standing ($<0.7 \text{ km/h}^{-1}$), Walking (0.8 to 7.1 km/h^{-1}), Jogging (7.2 to 14.3 km/h^{-1}), Running (14.4 to 19.7 km/h^{-1}), High-Speed Running (19.8 to 21.1 km/h^{-1}), and Sprinting ($>25.1 \text{ km/h}^{-1}$) according to Bradley et al. (2009). The following parameters were also considered: Total distance covered (m), Average speed (km/h), and Maximum speed (km/h).

Data analysis

Descriptive analysis of data (means and standard deviation) was performed. Normal data distribution was tested through the Shapiro-Wilk test. Comparisons between groups were performed through Paired t-tests (perception of MF, visual field, tracking deviation, frequency of tactical actions regarding penetration, offensive coverage, width and length, defensive coverage, balance, concentration, defensive unity, offensive and defensive total actions, quality of actions regarding width and length, balance, defensive unity, offensive and defensive total actions; total distance covered, standing, walking, jogging, running, high-speed running, maximal speed, average speed) and Wilcoxon test (reaction time, amount of omitted reactions, frequency of tactical actions regarding depth mobility, offensive unity, and concentration, quality of actions regarding penetration, offensive coverage, depth mobility, offensive

Table 1. The core tactical principles of soccer. Source: I. Teoldo et al. (2009).

Category	Sub-categories	Variables	Definitions
Core tactical principles	Offensive	Penetration	Decrease in the distance between the player in possession and the goal or goal line.
		Offensive Coverage	Providing offensive support for the player in possession.
		Depth Mobility	Generating instability for the opponent's defensive organization.
		Width and Length	Use and increase in effective play space in width and length.
		Offensive Unity	Movements of offensive progress or support by the player(s) who comprise(s) the last transversal line(s) of the team.
	Defensive	Delay	Performing opposition to the player in possession.
		Defensive Coverage	Provide defensive support to the player performing delay.
		Balance	Numerical stability or superiority in the opposing relations.
		Concentration	Increase in defensive protection in the zone of greater risk to the goal.
		Defensive Unity	Decrease in the effective play space of the opposing team.

unity, delay, defensive coverage, concentration, and sprinting). A Friedman test was used to examine the effect of time on correct responses between time-points (six 5-min epochs) for the Stroop task. With respect to data obtained through the FUT-SAT, the test-retest method was conducted with the purpose of examining the reliability of the observations and analysis made by the evaluators. Cohen's Kappa values were used to describe reliability levels. Intra-evaluator reliability analyses were performed after a 21-day interval, in order to avoid task familiarity issues (Robinson & O'Donoghue, 2007). From the total of 2,423 tactical actions, 266 (11%) were reassessed, which is higher than the percentage (10%) recommended (Tabachnick & Fidell, 2007). Four evaluators participated in this procedure and the reliability values found were between 84% and 97% for intra-evaluator reliability, and between 83% and 93% for inter-evaluator reliability. These values are described in the literature as "almost perfect" (0.81 to 1), thus indicating the high level of agreement between evaluators (Landis & Koch, 1977).

In order to examine the effect size between the comparisons of means, the Cohen's *d* test was used, with the following classification: null (<0.20), small (0.21 to 0.60), medium (0.61 to 1.20), and large (>1.20). The significance level was set to $p < 0.05$. All statistical procedures were performed through SPSS (Statistical Package for Social Science), version 23.0.

Results

Cognitive measures

Participants displayed a higher perception of MF after the Stroop task ($M = 64.0 \pm 17.9$ AU) than before ($M = 22.20 \pm 12.3$ AU) ($t_{(17)} = -9.894$; $CI: -5.15$ to -3.34 ; $p < 0.001$; $d = 2.764$) (Figure 1). There was no interaction between time and correct responses throughout Stroop task ($p = 0.761$; $d = 0.031$). In the PP test, a decrease in the visual field was observed between pre-

($M = 189.9^\circ \pm 12.03^\circ$) and post-test ($M = 181.6^\circ \pm 7.69^\circ$) moments in 12 participants ($t_{(17)} = 2.309$; $CI = 0.92$ to 15.92 ; $p = 0.035$; $d = 0.821$) (Figure 2). No differences were found in the tracking deviation (M pre-test = 5.46; M post-test = 5.44; $t_{(17)} = 0.148$; $CI = -0.29$ to 0.33 ; $p = 0.884$), reaction time (median pre-test = 0.606; median post-test = 0.612; $z = -0.378$; $CI: -0.03$ to 0.02 ; $p = 0.705$), or number of omitted reactions (median pre-test = 5.59; median post-test = 5.00; $z = -0.235$; $CI: -1.48$ to 1.93 ; $p = 0.814$) between moments.

Tactical behaviour

In the offensive phase, the principles of Penetration ($t_{(17)} = -2.202$; $p = .042$) and Depth Mobility ($z = -2.833$; $p = .005$) displayed higher frequencies in the "MF" condition. In the defensive phase, lower frequencies of the principles of Defensive Coverage ($t_{(17)} = 4.362$; $p < .001$) and Balance ($t_{(17)} = 2.189$; $p = .043$) were found, besides a higher frequency of the principle of Defensive Unity ($t_{(17)} = -5.193$; $p < .001$; medium effect) in the "MF" condition (Table 2).

In the "MF" condition, reduced values of the percentage of accuracy were found for the offensive tactical principles of Offensive Coverage ($z = -3.290$; $p = .001$), Width and Length ($t_{(17)} = 4.242$; $p = .001$), and Offensive Unity ($z = -3.680$; $p < .001$). In addition, decreases were observed for the defensive tactical principles of Delay ($z = -3.006$; $p = .003$), Balance ($t_{(17)} = 8.276$; $p < .001$), Concentration ($z = -3.243$; $p = .001$), and Defensive Unity ($t_{(17)} = 4.001$; $p = .001$) (Table 3).

Physical performance

Higher values of Total distance covered ($t = -3.051$; $p = .008$), Jogging ($t = -3.930$; $p = .001$), and Average speed ($t = -2.446$; $p = .027$) were found in the "MF" condition. In contrast, the values for Walking ($t = 2.445$; $p = .027$) were higher in the "Control" condition (Table 4).

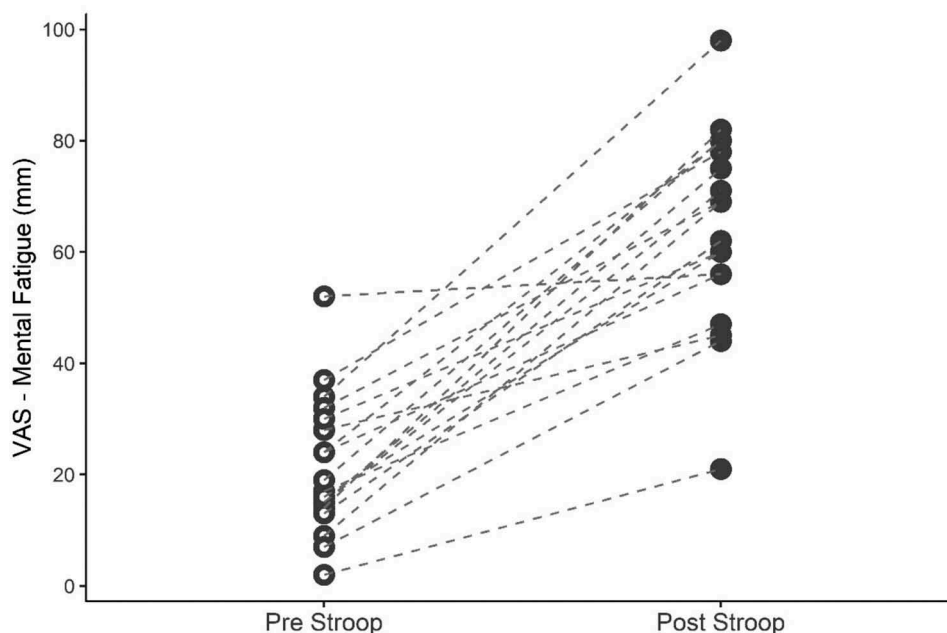


Figure 1. The subjective measures of mental fatigue before and after the Stroop test.

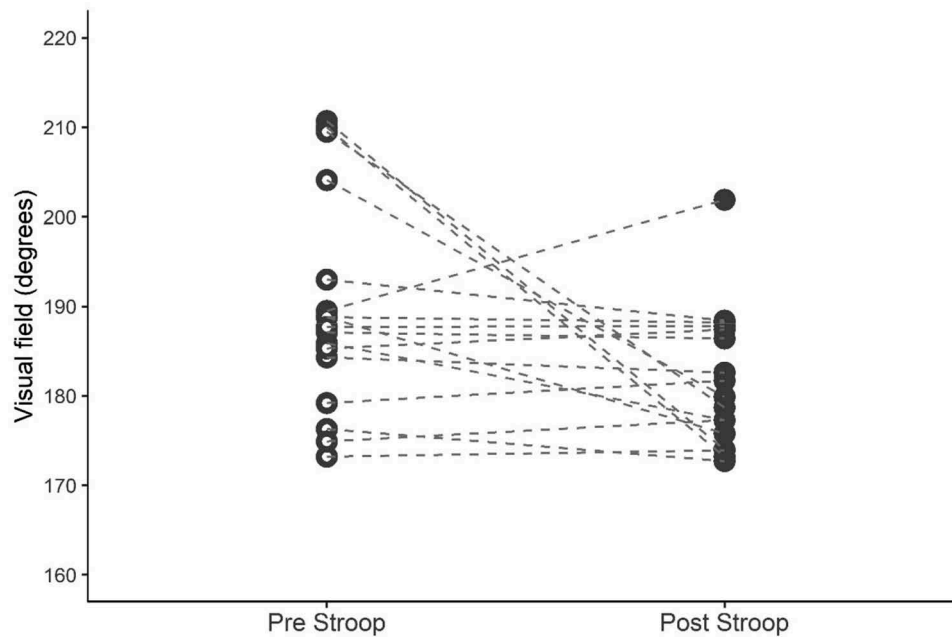


Figure 2. Individual scores of visual field (in degrees) before and after the Stroop test.

Table 2. Means and standard deviation of the frequency of tactical behaviour principles.

Tactical principles	Control	Mental Fatigue	CI 95%	<i>p</i>	<i>d</i>
	<i>M SD</i>	<i>M SD</i>	<i>Lower – Upper</i>		
Offensive					
Penetration	7.38 ± 04.53	10.16 ± 5.00*	–5.43 to –0.11	0.042	0.583
Offensive Coverage	19.50 ± 06.38	18.50 ± 6.20	–1.71 to 3.71	0.447	0.150
Depth Mobility	2.27 ± 01.36	4.38 ± 2.97*	–3.47 to –0.74	0.005	0.913
Width and Length	44.50 ± 13.62	40.61 ± 12.33	4.14 to 11.90	0.321	0.299
Offensive Unity	19.66 ± 08.31	23.00 ± 4.20	–7.97 to 1.30	0.245	0.507
Defensive					
Delay	20.27 ± 06.37	23.05 ± 7.08	–7.61 to 2.06	0.184	0.413
Defensive Coverage	9.11 ± 03.23	5.00 ± 2.44*	2.12 to 6.09	<0.001	1.430
Balance	29.22 ± 13.40	22.38 ± 7.17*	0.24 to 13.42	0.043	0.636
Concentration	12.11 ± 03.95	13.16 ± 5.00	–3.25 to 1.14	0.326	0.233
Defensive Unity	35.77 ± 09.89	45.00 ± 8.61*	–12.96 to –5.47	<0.001	0.995
Totals					
Offensive	93.33 ± 11.21	96.66 ± 15.84	–10.76 to 4.10	0.357	0.243
Defensive	106.50 ± 13.99	108.61 ± 17.50	–10.84 to 6.62	0.617	0.133

*Significant difference at $p < 0.05$.

Table 3. Means and standard deviations of the percentage of accuracy of tactical behaviour principles.

Tactical principles	Control	Mental Fatigue	CI 95%	<i>p</i>	<i>d</i>
	<i>M SD</i>	<i>M SD</i>	<i>Lower – Upper</i>		
Offensive					
Penetration	72.65 ± 32.23	77.19 ± 14.26	–23.30 to 14.28	0.913	0.182
Offensive Coverage	95.40 ± 05.79	77.31 ± 16.83*	9.79 to 26.38	0.001	1.430
Depth Mobility	68.52 ± 36.99	58.70 ± 28.09	–13.08 to 43.59	0.258	0.299
Width and Length	89.86 ± 06.68	74.83 ± 12.02*	7.55 to 22.50	0.001	1.460
Offensive Unity	90.10 ± 05.70	66.18 ± 15.78*	16.05 to 31.77	<0.001	2.010
Defensive					
Delay	79.53 ± 09.19	59.47 ± 17.64*	9.74 to 30.37	0.003	1.426
Defensive Coverage	76.37 ± 19.38	67.06 ± 28.98	–6.88 to 25.50	0.287	0.378
Balance	83.89 ± 07.36	59.14 ± 15.09*	18.44 to 31.05	<0.001	2.085
Concentration	92.25 ± 07.15	79.70 ± 13.52*	5.54 to 19.54	0.001	1.160
Defensive Unity	89.21 ± 09.57	69.92 ± 15.79*	9.11 to 29.46	0.001	1.478
Totals					
Offensive	89.53 ± 04.22	71.75 ± 09.88*	12.01 to 23.55	<0.001	2.340
Defensive	85.06 ± 04.19	67.26 ± 07.31*	13.55 to 2.05	<0.001	2.980

*Significant difference at $p < 0.05$.

Table 4. Means and standard deviations of physical data.

Physical variables	Control	Mental Fatigue	CI 95%	<i>p</i>	<i>d</i>
	<i>M SD</i>	<i>M SD</i>	<i>Lower – Upper</i>		
Total distance covered (m)	1335.9 ± 94.3	1375.4 ± 105.0*	–53.73 to –9.53	0.008	0.396
Standing (< 0.7 km/h-1)	4.6 ± 1.6	4.3 ± 1.3	–.74 to 1.33	0.556	0.214
Walking (0.8 to 7.1 km/h-1)	608.2 ± 48.9	575.8 ± 43.2*	–3.20 to 46.72	0.027	0.702
Jogging (7.2 to 14.3 km/h-1)	559.5 ± 87.8	623.8 ± 104.0*	–76.71 to –22.76	0.001	0.669
Running (14.4 to 19.7 km/h-1)	140.7 ± 42.1	144.8 ± 37.1	–13.71 to 9.83	0.731	0.102
High-speed running (19.8 to 25.1 km/h-1)	22.6 ± 14.4	26.0 ± 14.4	–13.98 to 4.39	0.284	0.236
Sprinting (> 25.1 km/h-1)	0.3 ± 1.5	0.6 ± 1.8	–1.22 to.32	0.180	0.247
Maximal speed (km/h)	22.7 ± 1.5	23.4 ± 1.6	–1.98 to.25	0.122	0.530
Average speed (km/h)	6.6 ± 0.5	6.8 ± 0.5*	–.29 to.02	0.027	0.380

*Significant difference at $p < 0.05$.

Discussion

We examined how MF influences soccer players' peripheral vision, tactical behaviour, and physical performance. The findings show that MF reduced players' peripheral perception. With respect to tactical behaviour, MF constrained players to more frequently perform the actions of penetration, depth mobility, and defensive unity, and less frequently perform the actions of defensive coverage and balance. When mentally fatigued, players were less efficient when performing actions related to the tactical principles. Also, players covered longer distances overall and at moderate speed under MF, without decreases in other more intense speed ranges.

In this study, the occurrence of MF was examined through objective and subjective responses provided by players after the Stroop task, which was performed in the first day of data collection. Although no decrement in performance was observed for variables such as tracking deviation, reaction time, and amount of omitted reactions, a decrease of players' visual field was found in the peripheral perception test, as well as higher values in the subjective responses regarding MF after the Stroop task. Also, no changes in the accuracy of the responses provided by the players during the Stroop task were found, which is in accordance with studies that resorted to this task with the same duration, with the purpose of inducing MF (Martin et al., 2016; Moreira et al., 2018). As in the aforementioned studies, unchanged accuracy suggests that players remained engaged throughout the cognitive task, which contributes to the onset of MF (Moreira et al., 2018). Although the present study does not include players' subjective and objective responses in control and experimental conditions (second and third days of data collection), it is possible to infer that the Stroop task of 30 min duration is an effective way to induce MF, since several studies employed similar methodological procedures and obtained such results (Coutinho et al., 2018; Smith, Coutts et al., 2016; Smith, Zeuwts et al., 2016).

In literature, peripheral perception is regarded as an important factor related to MF by traditional research fields that investigate the effects of workload on drivers and pilots (Desmond & Matthews, 1997). In these studies, a decrease in the participant's ability to identify peripheral information is generally observed according to the mental load experienced and the increase in the task's complexity (Jahn et al., 2005; Rantanen & Goldberg, 1999; Rogé et al., 2002). This phenomenon, known as "tunnel vision" assumes a reduction in the visual field and, consequently, a decrease in the ability to detect

peripheral information in conditions of high mental demand (Chan & Courtney, 1993; Williams, 1985).

In soccer, an important function of peripheral vision is perceiving information across the field of view, through the sensitivity to detecting movements and displacements of teammates and opponents located in closer or farther, lateral corridors (Bear et al., 2008). According to investigations in this field, players who possess superior levels of peripheral perception display higher efficacy of tactical behaviour (Gonçalves et al., 2017). In fact, players with a greater visual field are more efficient in offensive tactical actions (Gonçalves et al., 2017). Therefore, considering the importance that peripheral vision has for soccer performance (Williams et al., 1999), the reduction in the visual field caused by MF could limit the amount of information available on the playing field. In turn, the reduced amount of information could compromise perception, information processing, and, consequently, performance on the field.

With respect to tactical behaviour, findings indicated that MF constrained players to more frequently perform the offensive tactical actions of progressing with the ball and dribbling towards the opposing goal or goal line, as well as performing movements in depth or width "on the back" of the last line of defenders. In addition, under the effect of MF, players displayed less efficient tactical behaviour, thus making more errors in offensive actions aimed at generating space and passing lanes, by providing close support to the player in possession, expanding the effective play space, and attacking in block (Teoldo et al., 2009).

One explanation for these detected behaviours is related to the adverse effects of MF on cognitive performance, particularly regarding action planning and cognitive control (Van der Linden et al., 2003; Van der Wel & van Steenberghe, 2018). Published reports show that mentally fatigued individuals display a lower capacity to test hypotheses and plan actions, thus exhibiting a tendency to respond automatically (Lorist et al., 2000; Van der Linden et al., 2003). These consequences imply higher difficulty in exploring spaces in the playing field and favour less elaborate responses by the players. It is argued that the difficulty in generating spaces and passing lanes favourable to the participation of players in the offensive sequences is one reason for the preference for more direct and vertical behaviours. According to the results of the present study, it is likely that the narrowing of the visual field caused the omission of information about teammates located in lateral zones or in areas distant from the player in possession, thus encouraging

players to prioritize direct and vertical actions. These behaviours could have been motivated by cortical changes in frontal and pre-frontal areas, as a result of MF (Käthner et al., 2014; Wascher et al., 2014). According to previous studies, a likely mechanism that explains these changes could be related to the accumulation of brain adenosine in areas such as the prefrontal, orbitofrontal, and anterior cingulate cortexes (Lovatt et al., 2012; Qi et al., 2017). Possibly, this accumulation of adenosine could lead to a reduction in brain activation in these areas which, as a result, could decrease players' capacity to plan actions, inhibit automatic responses, and make decisions (Boksem & Tops, 2008; Van der Linden, 2011). However, other studies are necessary before concluding upon the precise mechanisms underlying MF and its effects on soccer performance.

With respect to the defensive tactical actions, MF constrained players to avoid movements aimed at obstructing passing lanes close to the players in possession and ensuring defensive stability in lateral zones in relation to the centre of play. In contrast, players prioritized more distant actions in relation to the ball, through movements aimed at decreasing the opponents' amplitude in width or depth, with the purpose of reducing the effective play space (I. Teoldo et al., 2009). Therefore, strengthening marking in more distant sectors in relation to the ball may demonstrate the players' concern about essential aspects of the game, by receding the marking and focusing on the protection of the goal. In relation to these behaviours, studies have shown that individuals performing demanding mental tasks display a tendency to prioritize crucial actions (such as protection of the goal) in detriment of less important actions (Sampaio et al., 2014; Van der Linden, 2011).

Based on the findings of the present study, it is possible to suggest that players preferred to perform defensive behaviours distant from the ball, due to the narrowing of the visual field and the impairment in superior cognitive resources caused by MF (Van der Linden, 2011). This aspect could be explained by the fact that the distance in relation to the actions would provide players with a better perception of game events and, in contrast, less involvement in actions that demand high perception, such as those in the centre of play. Similar results have been observed in investigations on the collective (Sampaio et al., 2014; Travassos et al., 2014) and individual (Moniz et al., 2020) behaviours of soccer teams in situations of numerical superiority and inferiority. In these studies, it was observed that in situations of numerical inferiority, for instance, players occupied more appropriate locations for shooting at goal, thus aiming for team compaction close to the goal.

Under MF, players also displayed a higher number of errors in tactical actions aimed at decreasing the opposing amplitude in width/depth, taking the opponent's play to riskier zones of the field, ensuring defensive stability in the lateral zones in relation to the centre of play and performing direct marking to the player in possession (Teoldo et al., 2011). Due to the contribution of perceptual-cognitive skills for soccer performance (Gonzaga et al., 2014), the decrement in cognitive performance caused by MF would help clarify the decreased efficiency in tactical actions displayed in our findings (Faber et al., 2012). In this context, studies show that MF does not determine the individuals' ability to complete tasks, although it

influences the difficulty in sustaining high-performance levels (Faber et al., 2012; Lorist et al., 2005).

With respect to physical performance, our findings demonstrated that when players were under MF they were found to cover greater distances overall and at moderate speed (7.2 to 14.3 km/h), besides lower distances walking (0.8 to 7.1 km/h). The findings of our study may be interpreted as a product of the difficulty displayed in managing the playing space, or a likely compensation due to the decrease in tactical behaviour efficiency displayed by the players under MF. Considering the reduced efficiency of tactical actions, this interpretation is taken into account due to the characteristic of SSG's, which allow the adjustment of rhythm/intensity in accordance with the performance or strategy adopted by players, opponents, or teammates (Badin et al., 2016; Kunrath et al., 2018). Taken as a whole, these findings are in accordance with those from the study of Kunrath et al. (2018) and Badin et al. (2016). In the latter, although the authors do not mention this hypothesis, it is possible to observe a higher number of repeated sprints under MF, thus corroborating the findings of the present study.

In literature, the main evidence shows negative effects of MF on tolerance to physical exercise, particularly in endurance activities (Van Cutsem et al., 2017). In fact, studies with soccer players confirmed this hypothesis, in which the results are interpreted according to a psychobiological model (Coutinho et al., 2018; Smith, Coutts et al., 2016; Smith et al., 2015). However, these studies do not consider soccer game characteristics' when interpreting the results, as well as the particularities of the physical/motor tests used in these studies. It is possible to observe that in SSG's of short duration, there is a tendency for the mentally fatigued players to cover longer distances (Badin et al., 2016; Kunrath et al., 2018) and, in contrast, shorter distances (or inconclusive results) in games of longer duration (Coutinho et al., 2017, 2018). Hence, it is reasonable to infer that the inferior performance in technical and tactical variables evident in the aforementioned studies have consequences for physical performance, especially to determine the investment of physical effort regarding the rhythm and intensity during the game. In other words, the physical performance in soccer games does not seem to be directly affected by MF, but rather conditioned by technical and tactical changes, which may cause an increase in physical demands of the game. However, it is known that exhaustive intermittent tasks resembling soccer movement patterns are impaired in response to MF (Smith, Coutts et al., 2016; Smith et al., 2015).

Consistent with the findings of the present study, coaching staffs are strongly encouraged to coaches to utilize instruments that allow the assessment of athletes MF levels (through subjective, objective and physiological markers of MF) in different moments across the season. Along with the measurement of (mostly tactical and physical) performance indicators, it is possible to track players' individual/collective responses and identify critical periods of performance decline throughout the competitive stage, by means of a holistic approach. In practical terms, players who show atypical variations in different performance indicators (e.g., distance covered and accuracy of tactical actions) may be undergoing the consequences of MF, according to findings reported in previous cross-sectional studies (Coutinho et al., 2018; Kunrath et al., 2018). Therefore, the engagement in cognitive tasks, including the utilization of

smartphones (Fortes et al., 2019), should be constantly monitored so that it does not damage performance in competitive matches to reduce the potential for a negative impact on aspects of sporting performance’.

The major drawback to be taken into account within the present study refers to the absence of cognitive measures performed before and after the Stroop task/video documentary in the second and third days of data collection, such as the feeling of MF and peripheral perception. Although performed at an early stage of data collection, along with the PP test, subjective measures were not repeated in control and MF conditions. This limitation demands careful interpretation of the findings, since there is no unambiguous evidence to endorse Stroop as a mentally stressful task. However, as the Stroop task was replicated with same participants in our study, and as these participants were encouraged to achieve the best possible performance, we presented reasonable evidence to infer about the potential of the Stroop task to induce MF. Given this limitation, behavioural changes observed in the present study may have been the result of prolonged mental effort prior to the field task, and not necessarily caused by the state of MF. In the study by Pageaux et al. (2014) we observed an example in which the authors did not find data that displayed the deleterious effects of MF on the subjective and objective responses of the Stroop task and used “mental exertion” rather than “mental fatigue”. In our study, we would rather use “mental fatigue” because we found data that support this claim, in the first day of data collection. However, as mentioned earlier in this section, previous studies which employed methods similar to those of the present research indicate strong evidences that corroborate these findings and that should also be accounted for (Badin et al., 2016; Coutinho et al., 2018; Moreira et al., 2018; Smith, Zeuwts et al., 2016). Still on this subject, although the intake of a small dose of coffee (50 ml) was allowed 3 h prior to the Stroop task, the half-life of caffeine in the body lasts between 1.5 and 9 h (Vanderveen et al., 2001), and may have had an effect that opposes mental fatigue and, consequently, influenced the results. Further limitations of this study are also worth considering, such as the absence of players’ motivational data, the lack of additional information regarding the Stroop task (i.e., reaction time), in addition to the non-randomized nature of data collection.

Due to the increasing relevance of mental aspects that influence soccer performance, future research could benefit from new discoveries in the field of training load control with special focus on the cognitive and mental characteristics of soccer. Under this perspective, the validation of instruments and design of evaluation protocols, which enable the assessment of MF in the practical context of soccer, such as those that allow measurement and monitoring of physical and physiological loads, are urgently required (Smith et al., 2018; Russell et al., 2019). Although there is consensus in the literature about MF physiological mechanism (Martin et al., 2018), it is also important to verify whether MF induced by cognitive tasks normally used for this purpose (i.e., Stroop, AXE-CPT) is comparable with MF caused by activities common to the players’ routine. For instance, daily activities such as attending lectures, virtual interactions in social networks and more specific in elite players’ routine as over-analysis of performance, post-game reflections and media engagement (Russell et al., 2019).

Lastly, the findings of the present study suggest that MF narrowed players’ visual field, thus compelling them to make mistakes when generating passing lanes, and to prioritize direct and vertical actions in the offensive phase, as well as to protect the goal in the defensive phase. Although the results showed an increase in total distance and jogging, we understand that covering greater distances as a consequence of poor tactical actions can be considered as a harmful effect. Therefore, it is concluded that MF impaired several aspects of players’ cognitive and tactical behaviours, causing a compensatory increase in physical performance.

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