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Effect of exposure time to smartphone apps on passing decision-making in male soccer athletes

Leonardo S. Fortes*, Dalton Lima-Junior, José R.A. Nascimento-Júnior, Eduardo C. Costa, Marcelo O. Matta, Maria E.C. Ferreira

Graduate Program of Physical Education, Federal University of Paraíba, João Pessoa, Brazil

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ABSTRACT

Background: Soccer is a dynamic sport of high unpredictability that requires appropriate decision making for success, but intervening factors such as exposure time to smartphone applications can lead to a decline in cognitive performance and consequently in psychomotor tasks.
Purpose: The objective of this study was to analyze the effect of exposure time to smartphone applications on the passing decision-making performance in professional soccer athletes.
Method: The participants were 20 soccer athletes aged 18–35 years (M = 24.7 ± 3.6). This study was a controlled and randomized experimental within-subject investigation, consisting of four visits with a 1-week interval. Male soccer athletes participated in four randomized conditions throughout the four visits: control (CON), 15-min smartphone (15SMA), 30-min smartphone (30SMA), and 45-min smartphone (45SMA). The Stroop Task assessed the level of induced mental fatigue before and after each experimental condition. Then, the athletes played a simulated soccer game. The game was filmed for further analysis of passing decision-making performance.
Results: A condition effect ($p < .001$) was identified for passing decision-making performance, with impairment in 30SMA ($p = .01$, $h^2 = 0.6$) and 45SMA ($p = .01$, $h^2 = 0.6$) conditions.
Conclusion: We conclude that at least 30 min of smartphone application exposure caused mental fatigue, which impaired passing decision-making performance in male soccer athletes.

Soccer is an unpredictable dynamic sport with fast muscular actions and several changes in direction (Coutinho et al., 2018; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). Nowadays, success in soccer depends on well-developed physical (sprint, anaerobic and aerobic power, and agility) and cognitive abilities (attention, cognitive flexibility, working memory, emotional control, and decision-making) (Bangsbo, 2015). Moreover, among the cognitive abilities required to perform cooperative sports with unpredictable characteristics, decision-making stands out according to the multifactorial model of sports performance (Bangsbo, 2015).

In soccer specifically, passing decision-making is important because a good pass may reach a member of the team who is directly or indirectly unmarked and therefore create a goal-scoring chance, or it may reach a member who is in the most advantageous position (Fortes, Nascimento-Júnior, Mortatti, Lima-Júnior, & Ferreira, 2018b). To achieve success in decision-making performance, athletes need to enhance perception-action couplings that improve their attention to perceptual variables and clarify which actions are or are not possible to perform according to each performer's capabilities (Travassos et al., 2012a). Ecological dynamics of decision-making performance might be evaluated using informational variables that sustain emergent functional behaviors (Travassos et al., 2012a). Thereby, it has been observed that players couple their actions in both space and time, looking for the best way to comprehend the environment and task restrictions during performance (Travassos, Duarte, Vilar, Davids, & Arajo, 2012b). The best methods to evaluate decision-making performance are using an eye-tracking system and video analysis. The main measurement for decision-making performance by video analysis is the Game Performance Assessment Instrument (GPAI, Memmert & Harvey, 2008), which measures the game performance behaviors that demonstrate tactical understanding, as well as the player's ability to solve tactical problems by selecting and applying appropriate skills.

* Corresponding author.
E-mail addresses: leodesousafortes@hotmail.com (L.S. Fortes), limajunior.dalton@gmail.com (D. Lima-Junior), jroberto.jrs01@gmail.com (J.R.A. Nascimento-Júnior), ecc.ufrn@gmail.com (E.C. Costa), marcelo.matta@ufjf.br (M.O. Matta), caputoferreira@terra.com.br (M.E.C. Ferreira).

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It is important to highlight that cognitive brain mechanisms are related to decision-making performance (perception, attention, anticipation, and working memory) (Araújo et al., 2015; Vestbergh et al., 2012). On one hand, studies have shown that motor imagery training (Fortes et al., 2018a) and small-sided games (Davids, Araújo, Correia, & Vilar, 2013) are strategies that may increase decision-making performance. On the other hand, dehydration (Fortes et al., 2018b), physical (Royal et al., 2006) and mental fatigue (Smith et al., 2016a) may impair decision-making performance.

Mental fatigue is a psychobiological state defined by feelings of tiredness and a lack of energy induced by prolonged periods of cognitive activity demand (Smith et al., 2018). A systematic review revealed a detrimental effect of mental fatigue on athletes' physical performance (Cutsem et al., 2017). In addition, mental fatigue may impair the player's ability to perceive information, which is likely to affect the players' tactical behavior. Coutinho et al. (2017) showed that mental fatigue influenced the ability to perceive and maintain their decisions based on the information from the environment, which resulted in different positioning and collective synchrony. Coutinho et al. (2018) also revealed that mental fatigue resulted in a decrease in tactical variables in amateur youth soccer players, such as a decrease in the team stretching index and the time that players spend to synchronize longitudinal displacements. Considering the technical performance, mental fatigue impairs performance in soccer athletes. Badin, Smith, Conte, and Coutts (2016) showed mental fatigue impaired several technical performance variables in young soccer players. Regarding decision-making performance, Smith et al. (2016a) showed mental fatigue led to a decrease in soccer-specific decision-making performance in soccer athletes. To the best of our knowledge, only the study conducted by Smith et al. (2016a) has evaluated the effect of mental fatigue on passing decision-making performance. However, this study analyzed soccer-specific (e.g., passing, shooting, and dribbling) decision-making performance altogether. Moreover, the Stroop Task and the measurement of decision-making performance (performance of players analyzed on a screen) were not representative of soccer passing, which compromised the ecological validity. Perhaps conducting a study with an experimental design closer to reality may show the effect of mental fatigue on decision-making performance.

Cognitive demanding tasks which require inhibition response and sustained vigilance (e.g. the Stroop Task) induce mental fatigue (Smith et al., 2018). These tasks aim to activate similar neural pathways, such as the anterior cingulate cortex, dorsolateral prefrontal cortex, pre-supplementary motor area, inferior frontal gyrus, and medial superior parietal cortex (McMorris, Barwood, Hale, Dicks, & Corbett, 2018). Although it has not been investigated in the scientific literature, long-term use of smartphone apps might lead to mental fatigue. Interestingly, social network applications demand cortical activity in the frontal cortex; however, despite reading and writing depending on organizing and processing information, the anterior cingulate cortex, dorsolateral prefrontal cortex, and pre-supplementary motor area also manage those functions (Zheng, Xia, Zhou, Tao, & Chen, 2016). It is common for soccer athletes to use social network apps (e.g., Facebook, WhatsApp, and Instagram), especially before official matches. As such, the excessive use of social network apps may cause mental fatigue, and thus it is reasonable to assume that passing decision-making performance may be impaired. However, it is necessary to conduct an experimental study to confirm this hypothesis.

From a practical standpoint, the effect of exposure time to social network smartphone apps on decision-making performance might indicate if the team's technical committee should prohibit smartphones before official matches. Thus, the objective of this study was to analyze the effect of exposure time to smartphone apps on the passing decision-making performance in professional soccer athletes. In addition, we developed the following hypothesis: higher exposure time to smartphone applications leads to higher impairment in passing decision-making in professional soccer athletes.

1. Materials and methods

1.1. Experimental design

This study was a controlled, randomized, and within-subject investigation. It consisted of four visits with 1-week intervals. Male soccer athletes participated in four randomized conditions throughout the four visits: control (CON), 15-min smartphone (15SMA), 30-min smartphone (30SMA), and 45-min smartphone (45SMA).

Simple randomization was adopted. According to the randomization, the chief experimenter used a manually generated number to determine the allocation of the group in each condition. The randomized distribution between conditions (CON, 15SMA, 30SMA, and 45SMA) was performed using a website (www.randomizer.org). The final order of the experimental conditions was 15SMA, CON, 45SMA, and 30SMA. The participants were randomized as a group. Therefore, all the players were under the same treatment conditions during the experiment. The stroop task.

The Stroop Task was used to assess the mental fatigue level before and after each experimental condition. Next, the athletes played a simulated game of soccer (two halves of 45 min, totaling 90 min), adopting the official rules of the sport. The matches were recorded using a CANON® camera (SX60 model, Yokohama, Japan) for further analysis on passing decision-making performance according to the Game Performance of Assessment Instrument (GPAI) (Memmert & Harvey, 2008). It is noteworthy that the number of decision-making opportunities across conditions (CON, 15SMA, 30SMA, and 45SMA) was not controlled. However, the number of passes were similar ($F_{(3, 22)} = 1.30$, $p = .43$) between the experimental conditions.

The head coach divided the players into two balanced teams according to his perception of the athletes' skill levels in ball passing, ball control, shooting, and game knowledge. The division of the teams was the same in all the experimental conditions. The players were told that the simulated games would be used to select the main team for the competitive season in order to them motivated in all experimental conditions.

The participants warmed-up using the ball for 5 min before the simulated game. The interval between the two halves was 15 min. Urine osmolarity, perceived recovery, and heart rate variability (HRV) were measured before the simulated game. The Rate of Perceived Exertion of the session (RPE-session) was obtained after 30 min of the match. All experimental procedures are illustrated in Fig. 1.

The Institutional Review Board of the Federal University of Pernambuco in compliance with the Brazilian National Research Ethics System Guidelines approved the procedures of the study. Written informed consent was obtained from each participant before participation.

1.2. Participants

Participants were 20 professional soccer athletes (24.7 ± 3.6 years, 78.2 ± 6.9 kg, 1.7 ± 0.07 m, and 13.2 ± 4.8 body fat percentage) belonging to a Third Division team of the Brazilian Soccer League. The athletes had a similar level of expertise in soccer (10.2 ± 2.1 experience years as a soccer player). All the positions but goalkeepers took part in the investigation.

Players were habitually involved in one training session per day (~180 min per session) on a weekly basis, 5 days per week. In addition, the participants played an official match during the first week. Training sessions usually consisted of soccer drills, tactics, sprints, intermittent running exercises, and specific conditioning work including weight and plyometric training.

To be included in the study, the athletes should: a) have been a soccer player for at least three years; b) systematically be training soccer for at least 10 h per week; c) be enrolled in the State Soccer League.

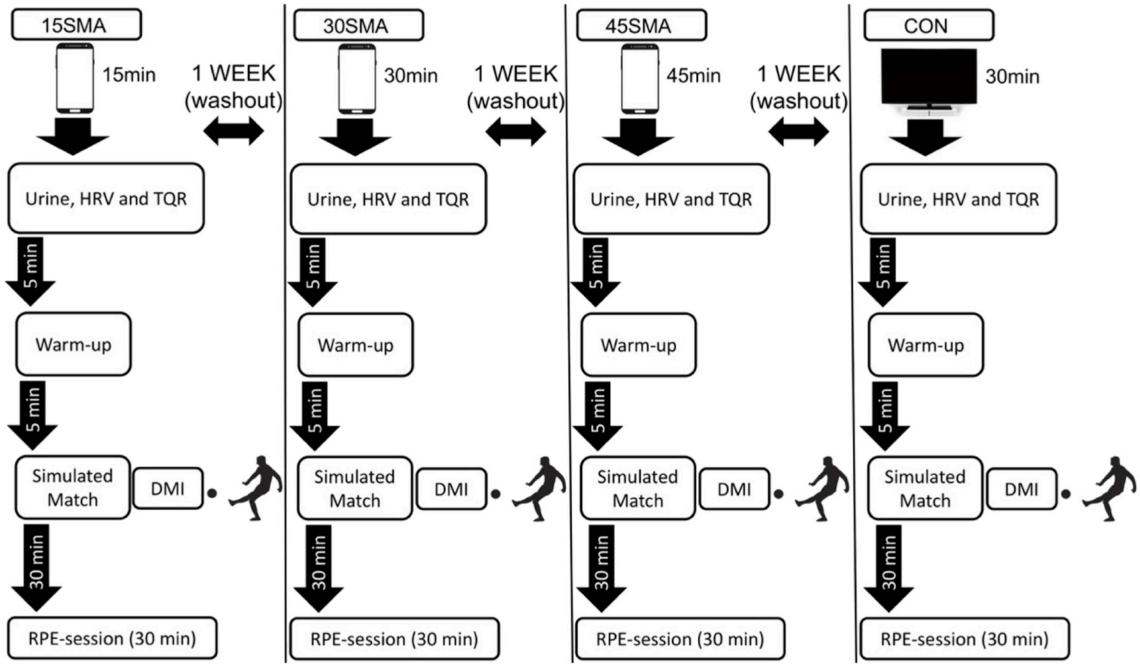

Fig. 1. Experimental design, *Note*. SMA = smartphone; CON = control; TQR = Total Quality Recovery; HRV = heart rate variability; DMI = decision-making index; RPE = rated perceived exertion.

1.3. Interventions

1.3.1. CON, 15SMA, 30SMA, and 45SMA

It was recommended that the athletes ingest fluid ad libidum up to 2 h before each experimental session. Smartphone usage 2 h before each experimental session was not permitted. The CON condition consisted of watching coaching videos for 30 min on an 84-inch tv screen (smartphones were not allowed in the room). The SMA conditions consisted of using social networking apps (WhatsApp, Facebook, and Instagram) with 15 (15SMA), 30 (30SMA), and 45 (45SMA) min duration. The smartphone use was supervised by the researchers to ensure that the athletes only used the social networking apps. All participants remained in the same room while using their smartphone or watching the video. The participants were not allowed to speak amongst themselves.

1.4. Variable measurements

Decision-making index. The decision-making was evaluated during games. The participants played two halves of 45 min, adopting the official rules of soccer. The entire game was recorded with a CANON® camera (SX60 model, Yokohama, Japan). The analysis and categorization of actions were based on the GPAI (Memmert & Harvey, 2008). Memmert and Harvey (2008) highlight that the GPAI evaluates the appropriate decisions about what to do with the ball during a game. The passing decision-making components proposed by Romeas, Guldner, and Faubert (2016) were adopted. Thus, appropriate decision-making was considered as when the pass went to one of the members of his team who was unmarked and: a) directly or indirectly created a chance to score or; b) it was for a member of his team that was in a better position than their opponent was. Any other passing decision-making different from those indicated above was classified as inappropriate.

The obtained data (videos) were analyzed using open-license video analysis software (Kinovea 0.8.15 for Windows). The soccer pitch (7.000 m^2) was divided into 12 quadrants in equal sizes (583.3 m^2). Unmarked players were defined when their direct opponent was not in the same pitch quadrant (space in 583 m^2). The better position was defined as when the member of the player's team was positioned in an area of the pitch nearer to the opponent's goal than the player who performed the pass, and without an individual marker at the moment of the pass. Another study utilized the same passing decision-making components in soccer (Fortes et al., 2018b).

The passing decision-making index (DMI) was calculated according to the formula below, following the modifications suggested by Memmert and Harvey (2008). Two experienced researchers analyzed the game actions (they watched the videos carefully on an 84-inch tv screen) and categorized it as appropriate or inappropriate. The investigators who reviewed the video footage and categorized decision-making actions were blinded to the experimental treatments [15SMA vs. 30SMA vs. 45SMA vs. CON] to decrease bias. The acceptable coefficient of agreement for the DMI (*kappa* = .97, p = .001) was calculated by the main researcher for the scores of the two specialists.

$$\text{DMI} = \frac{A_a}{A_a + I_a} x100$$

Aa = appropriate actions
Ia = inappropriate actions

Stroop Task. The Stroop Task (Graf, Uttl, & Tuokko, 1995) was adopted to assess inhibitory control and selective attention, with both considered as components of cognitive function. Therefore, two assessments (pre and post-time exposure to smartphone) were performed in each experimental condition. The tests were carried out on a full-HD screen (1800 × 1260 pixels) laptop (MacBook Pro, A1502 model, USA). On the test, the participants answered the word color or according to its name, since the color of the words might be different from what is typed (e.g. the word "blue" might show up in "red" color, the word "green" in "blue", and so on). A stimuli of 62 words with 200 ms of interval were provided between the response and a new stimulus, totaling 155.0 ± 9.2 and 164.3 ± 10.7 s in pre and post-time exposure to their smartphone, respectively. Moreover, the stimulus did not fade from the screen until any response was given. Stimuli vary between congruent (word and color have the same meaning), incongruent (word and color have a different meaning) and control (colored rectangle with one of

Table 1
Demographic characteristics of participants, number of passes, induced mental fatigue (accuracy and time response), perceived recovery level, hydration state, HRV, internal load, and weather conditions.

Participants				
Age (years)	24.7 ± 3.6			
Body mass (kg)	78.2 ± 6.9			
Height (m)	1.7 ± 0.07			
BF%	13.2 ± 4.8			
			Mean ± SD	
	CON	**15SMA**	**30SMA**	**45SMA**
Number of passes	37.5 ± 10.4	38.9 ± 9.1	39.3 ± 9.0	35.0 ± 10.2
Mental Fatigue Induced				
Accuracy (Δ%)	0.9 ± 1.0	−0.1 ± 1.1	−3.7 ± 0.7*,#	−3.8 ± 0.7*,#
Time response (s)	0.9 ± 1.7	0.4 ± 1.7	6.2 ± 1.4*	7.0 ± 1.8*
Perceived Recovery Level	18.2 ± 2.8	18.5 ± 2.2	17.9 ± 3.0	17.5 ± 2.3
Hydration state (osmolarity)	1.6 ± 0.9	1.6 ± 0.7	1.5 ± 0.8	1.8 ± 1.0
SDNN (ms)	83.6 ± 24.0	76.4 ± 21.7	80.1 ± 23.6	75.3 ± 20.5
RMSSD (ms)	59.4 ± 18.1	54.1 ± 15.0	50.3 ± 17.2	56.7 ± 16.7
Internal load (a.u.)	737.9 ± 145.3	726.0 ± 158.4	781.2 ± 173.0	754.5 ± 180.6
Weather conditions				
Temperature (°C)	28.0 ± 1.9	29.2 ± 2.4	28.8 ± 2.1	29.0 ± 2.6
Relative humidity (%)	78.1 ± 3.7	72.9 ± 3.0	75.3 ± 2.8	74.2 ± 2.5

Note. Values are presented as mean ± standard deviation; SD = standard deviation; CON = control condition; 15SMA = 15-min smartphone; 30SMA = 30-min smartphone; 45SMA = 45-min smartphone; *$p < .05$ different from CON; #$p < .05$ different from 15SMA.

the colors of the test: red, green, blue, and black). The keys D (red), F (green), J (blue), and K (black) were used for answering the questions. The stimulus disappeared when the answer was correct, and then a new one was set. An X showed up on the screen in case of incorrect answers, and a new stimulus subsequently appeared. The accuracy of the correct answers and response time were collected at the end of the test. The evaluator was blind for all the assessments and had previous training for the test.

Hydration state. The athletes had their urine samples collected immediately before each condition in a transparent container to determine the urinary color index. The urine color index was determined by Armstrong's scale (2007). This scale adopts eight different urine colors that range from light yellow (color 1) and brownish green (color 8).

Total Quality Recovery (TQR). The Total Quality Recovery (TQR) scale proposed by Senttä and Hassmén (1998) and validated to the Brazilian context by Osieck Osiecki, Burigo, Coelho, and Malfatti (2015) was used before each experimental condition to assess the level of perceived recovery. TQR is a scale that ranges from six (nothing recovered) to 20 (fully recovered). The higher the value, the higher the level of perceived recovery.

HRV. The R-R intervals were obtained using a portable heart rate monitor (Polar® RS800cx, Kempele, Finland) at 1000 Hz continuously for 2 min, with the athlete sitting in a room with a temperature of 27 °C. Data were visually inspected to identify ectopic beats (< 3%), which were removed and replaced by interpolation of the adjacent R-R ranges. The R-R values were transferred to the computer via the Polar software program (Polar® ProTrainer, Kempele, Finland) and exported to the HRV time-domain analyses using the Kubios v2 software program (Polar® Kubios v2, Kuopio, Finland). The analyzed variables were as follows: the standard deviation of all NN intervals (SDNN) and the difference of the quadratic mean of the successive R-R normal intervals (RMSSD).

Analysis of internal game load. The internal load was quantified by RPE-session (Foster et al., 2001). The athletes answered the following question 30 min after the end of the GPAI analysis in each of the experimental conditions (CON, SMA, and VID): "How was your training?". The athlete was asked to demonstrate the intensity perception of the session from the 10-point Borg scale (0 = rest to 10 = maximum effort) according to the method developed by Foster et al. (2001). The product of the values demonstrated by the RPE scale and the total time in minutes of the session was calculated, thus expressing the internal load of the training session. The athletes were familiarized with the RPE-session method for a period of 30 days before beginning the investigation.

Weather condition. Data on the weather conditions were obtained by means of a heat stress monitor (Instrutemp®, São Paulo, Brazil). Data were recorded at the beginning and end of each simulated game to obtain the ambient temperature and the relative air humidity.

1.5. Statistical analysis

The Shapiro-Wilk and Levene tests analyzed the distribution and homoscedasticity of the data, respectively. A two-way ANOVA of repeated measurements with a mixed design was used to analyze the condition (CON vs. 15SMA vs. 30SMA vs. 45SMA) × time interaction (pre-app exposure vs. post-app exposure) for accuracy and response time in stroop test. Repeated measures ANOVA with one fixed factor (condition) compared the number of passes, weather conditions (temperature and relative humidity in air), urine osmolarity, perceived recovery level, HRV, internal game load, and DMI between the conditions (CON, 15SMA, 30SMA, and 45SMA). Bonferroni post-hoc analysis was conducted if any difference was indicated in the repeated measures ANOVA to find the differences. The effect size revealed differences from a practical view. According to the Rhea (2004) guidelines for highly trained athletes, the following criteria were used: $h^2 < 0.25$ = trivial, $0.25 \le h^2 < 0.50$ = low, $0.50 \le h^2 < 1.0$ = moderate and $h^2 \ge 1.0$ = large effect size. The data were analyzed in SPSS 21.0 software (IBM Corp., Armonk, NY, EUA) and a significance level of $p < .05$ was adopted.

2. Results

The findings revealed normal distribution and homogeneity of variance for the data. The descriptive demographics data (age, body

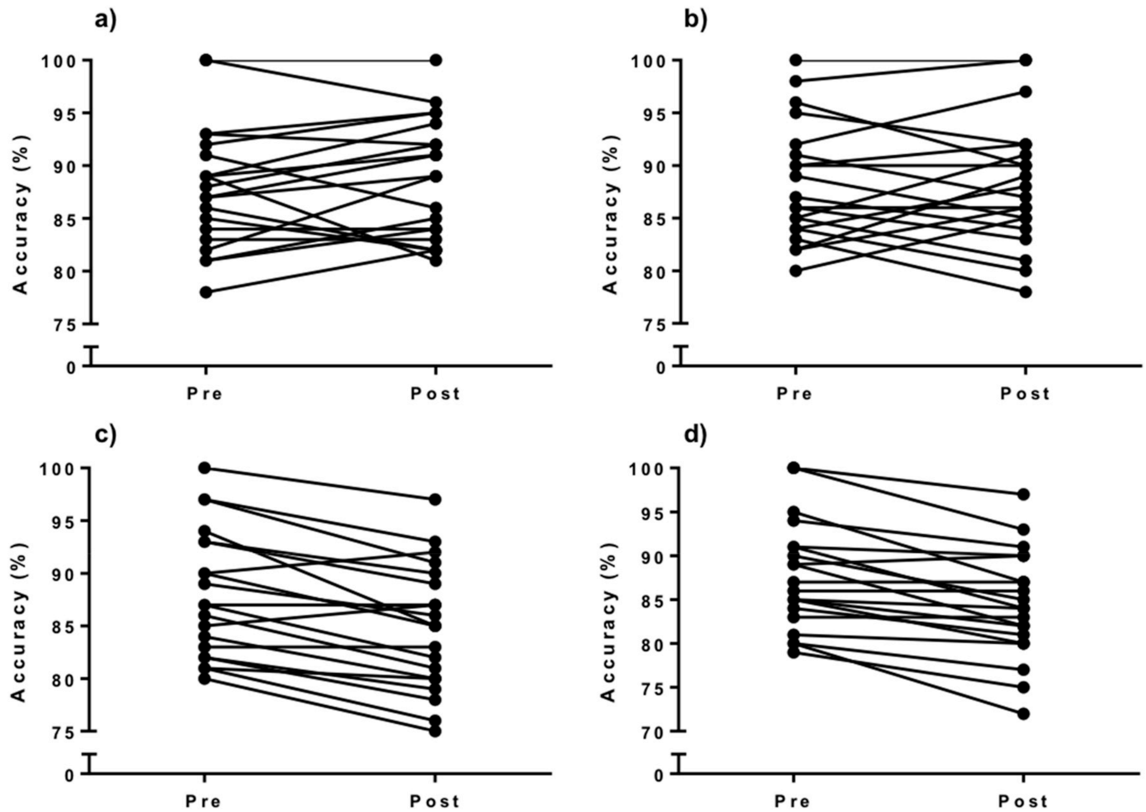

Fig. 2. Individual analyses for accuracy (Stroop Test). *Note.* a) control; b) 15-min smartphone; c) 30-min smartphone; d) 45-min smartphone.

mass, height, and %BF) can be seen in Table 1. The number of passes ($F_{(4, 18)} = 1.61$, $p = .42$), perceived recovery level ($F_{(4, 18)} = 1.58$, $p = .36$), hydration state ($F_{(4, 18)} = 1.93$, $p = .53$), SDNN ($F_{(4, 18)} = 2.07$, $p = .30$), RMSSD ($F_{(4, 18)} = 1.45$, $p = .38$), internal load ($F_{(4, 18)} = 1.80$, $p = .32$), temperature ($F_{(4, 1)} = 2.13$, $p = .26$), and relative air humidity ($F_{(4, 1)} = 1.36$, $p = .40$) were similar between the CON, 15SMA, 30SMA, and 45SMA conditions.

About the induced mental fatigue (Stroop Task), interaction (time vs. condition) was found for accuracy (Fig. 2, $F_{(6, 16)} = 18.7$, $p = .01$). 30SMA ($p = .01$, $h^2 = 0.5$) and 45SMA ($p = .01$, $h^2 = 0.5$) showed impaired performance when compated to CON and 15SMA (Table 1). Also, interaction (time vs. condition) was observed for response time (Fig. 3, $F_{(6, 16)} = 21.4$, $p = .01$). 30SMA ($p = .01$, $h^2 = 0.6$) and 45SMA ($p = .01$, $h^2 = 0.6$) presented higher response time when compared to CON and 15SMA (Table 1).

Table 2 presents the results for DMI between conditions. A condition effect ($p < .001$) was identified, with impairment in 30SMA ($p = .01$, $h^2 = 0.6$) and 45SMA ($p = .01$, $h^2 = 0.6$) conditions.

3. Discussion

The objective of this study was to analyze the effect of exposure time to smartphone applications on the passing decision-making performance in professional soccer athletes. The main findings indicated a reduction in DMI for the 30SMA and 45SMA conditions, corroborating the hypothesis of the present investigation.

The results presented similarity in the number of passes, hydration state, HRV (SDNN and RMSSD), internal training-load, perceived recovery, and weather conditions between experimental treatments. Therefore, the experimental sessions were conducted under the same atmospheric conditions.

Unlike other investigations (Marcora, Staiano, & Manning, 2009; Pageaux, Marcora, & Lepers, 2013; Smith et al., 2016a), our study induced mental fatigue using smartphone applications, which might be considered more representative. Moreover, several studies which analyzed the effect of mental fatigue on athlete's performance adopted the visual analog scale (VAS) (Brownsberger, Edwards, Crowther, & Cottrell, 2013; Smith et al., 2016a; Smith et al., 2016b). The use of VAS to measure the mental fatigue presents some limitations, considering that a lot of athletes do not understand what mental fatigue is. Moreover, the experimental approach with cross-over design might produce an addictive response (Thompson et al., 2018), that is, following the first condition, the participants might be habituated to the answers. However, familiarization procedures were performed the reduce this effect. Thus, Thompson et al. (2018) recommend using objective measures to evaluate mental fatigue. Interestingly, the Stroop Task is commonly used to induce mental fatigue; however, in the present study, the Stroop Task assessed the mental fatigue caused by the exposure to smartphone applications. The most affected brain region by mental fatigue appears to be the anterior cingulate cortex (ACC) (Smith et al., 2018). Mental fatigue seems to increase adenosine and reduce dopamine in ACC (Smith et al., 2018), which causes a reduction in attention, focus, and inhibition control performance. Thus, the Stroop Task may be considered suitable to measure mental fatigue. It is important to highlight that the duration of the Stroop Task in the present study varied between 155.0 ± 9.2 and 164.3 ± 10.7 s (pre and post-time exposure to smartphone), unlike other investigations which used the Stroop Task to induce mental fatigue with a 30-min duration (Smith et al., 2016a; 2016b). Therefore, the decision-making performance during the game was unlikely affected by the accumulated mental fatigue from the exposure to the smartphone plus the Stroop Task, but only by the smartphone. Thus, the design of the present study is similar to a real match.

Nowadays, close to 100% of athletes have accounts in social networks (Instagram and/or Facebook) and utilize some kind of smartphone application for communication. In addition, it is common for athletes to use their smartphones before official matches, i.e. on the bus on the way to the stadium and in the changing room. Our results

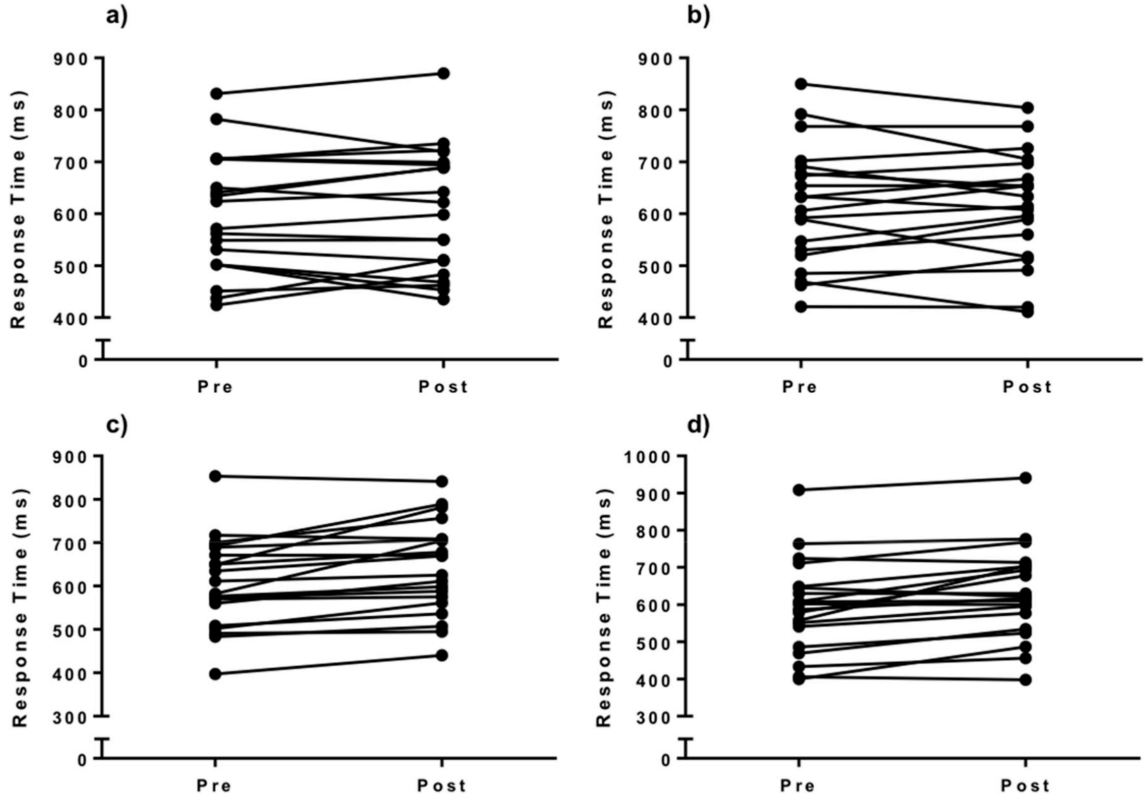

Fig. 3. Individual analyses for response time (Stroop Test), Note. a) control; b) 15-min smartphone; c) 30-min smartphone; d) 45-min smartphone.

showed that 15 min of using apps was not enough to induce mental fatigue; nevertheless, 30 and 45 min impaired the Stroop Task performance. According to Cutsem et al. (2017), the minimum cortical activity time to induce mental fatigue is 30 min, which may explain the results.

According to passing decision-making performance, the findings showed impairment in 30SMA and 45SMA, but not in 15SMA and CON conditions. Smith et al. (2016a) showed a detrimental effect of mental fatigue (induced by 30 min of the Stroop Task) on decision-making performance in amateur soccer players. A detrimental effect might occur in long exposure time to mental fatigue, for example 45 min of smartphone application exposure might decrease decision-making performance even more when compared to less exposure in soccer athletes. However, the 45 min exposure time was similar to the 30 min for the decision-making scores.

It seems that mentally fatigued athletes might not interpret (sports perception) nor anticipate (frontal cortex) the match situations, hence, decreasing decision-making scores (Smith et al., 2016a). Since they are mentally fatigued, the athletes require more time to perceive their adversary's and mainly their teammates' movements. Therefore, even though they might anticipate adversary movements, they are unable to focus on their teammates' actions, which represents impairment in decision-making performance.

Despite the present study being innovative and revealing important findings, it shows some limitations that should be mentioned. Only one visit was conducted for each experimental condition, and 'mental load' during smartphone use was not standardized. This is due to lacking an electroencephalogram to analyze the amplitude of brain waves (alpha and theta) during rest and post mental fatigue. Future studies should analyze mental fatigue using objective measures [electroencephalogram and pupil dilation (Eye-tracking system)]. It is important to highlight, in this study, the time from the end of smartphone applications exposure to the kick off has been different from official matches in professional soccer. In the present study, the warm-up was only 5 min, but during official matches the warm-up lasts at least 30 min. In this sense, the time course of mental fatigue in the present study is greater than in official matches, considering that 30 min without smartphone applications exposure might attenuate mental fatigue. In fact, the passing decision-making performance would barely be the same if the official match starts off 30–45 min after smartphone

Table 2
Mean and standard deviation of DMI according to condition (15SMA, 30SMA, 45SMA, and CON).

Variables	15SMA	30SMA	45SMA	CON	Effect	F	*p*
DMI first half (%)	57.5 ± 10.7	52.1 ± 8.2$^{*,\#}$	50.6 ± 9.5$^{*,\#}$	60.3 ± 8.4	Group	32.8	.001
ES (between conditions)	0.7						
DMI seconf half (%)	60.4 ± 11.1	54.3 ± 7.5$^{*,\#}$	52.8 ± 10.9$^{*,\#}$	57.6 ± 9.8	Group	25.3	.01
ES (between conditions)	0.5						
DMI game (%)	59.9 ± 9.9	53.8 ± 8.6$^{*,\#}$	51.4 ± 10.1$^{*,\#}$	58.0 ± 9.2	Group	30.5	.001
ES (between conditions)		0.6					

Note. Values are presented as mean ± standard deviation; DMI = decision-making index; CON = control condition; 15SMA = 15-min smartphone; 30SMA = 30-min smartphone; 45SMA = 45-min smartphone; *p < .05 different from CON; $^{\#}$p < .05 different from 15SMA; ES = effect size.

applications exposure. Thus, our findings should be considered with caution.

Two lines of research are required to assist coaching staff and players on managing mental fatigue. First, researchers should aim to integrate theory and practice, studying mental fatigue and soccer performance with an applied approach. Thereby, it was examined time of smartphone applications exposure, perhaps timing of smartphone applications exposure could be a future research direction. Second, future investigations should attempt to clarify the mechanisms behind the observed mental fatigue effect on soccer-specific performance. Thus, studies that use an electroencephalogram to measure mental fatigue magnitude (alpha and theta waves), the eye-tracking system (pupil dilation) to measure cognitive effort in mental fatigue condition, as well as performing greater dynamic experiment with representative designs are recommended.

4. Conclusion

We conclude that at least 30 min of smartphone app exposure caused mental fatigue (reduction of cognitive performance) and can be responsible for impairment in passing decision-making performance in male soccer athletes. Therefore, the results suggest that coaches should control smartphone time exposure in professional soccer athletes.

Declarations of interest

None.

Conflicts of interest

There is no conflict of interest.

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