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Sport-based video game causes mental fatigue and impairs visuomotor skill in male basketball players

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Heloiana Faro^a, Leonardo de Sousa Fortesa^a, Dalton de Lima-Junior^a, BrunoTeixeira Barbosa^a, Maria Elisa Caputo Ferreira^b, and Sebastião Sousa Almeida^c

A Associate Graduate Program in Physical Education of Federal University of Paraíba, João Pessoa, Brazil;

B Associate Graduate Program in Physical Education of Federal University of Juiz de Fora, Brazil;

C Graduate Program of Psychology of University of São Paulo, Brazil

CONTACT Heloiana Faro heloianafaro@gmail.com Associate Graduate Program in Physical Education of Federal University of Paraíba, Campus I – Lot. Cidade Universitária, João Pessoa – PB, 58051-900, Brazil

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ABSTRACT

This study verifies the prolonged use effect of a sport-based video game (SB V) on basketball players' visuomotor performance. Fourteen male national-level basketball players (24.3 ± 4.1 years; experience time: 6.5 ± 1.9 years) performed two baseline visits and two experimental conditions in a randomised and counterbalanced crossover study. They completed a baseline visuomotor task with and without a ball and were familiarised with the mental fatigue assessment. The experimental conditions consisted of playing an SB V and watching a documentary as control (CON) lasting 60-min each. Before and after experimental conditions, the participants performed a visuomotor task and response subjective rating of mental fatigue indicator measures (i.e., Visual Analogue Scale [VA S]), Stroop Test (i.e., accuracy and response time), and theta band from electroencephalogram. Accuracy decreased, and response time increased on visuomotor tasks with and without the ball, only for the SB V condition ($p < 0.05$). Subjective rating of mental fatigue (i.e., VA S), the response time on Stroop task, and theta band increased only for the SB V condition ($p < 0.05$). Mental fatigue induced by prolonged use of SBV impairs visuomotor performance in male basketball players, decreasing accuracy and significantly increasing response time.

KEYWORDS

Cognitive fatigue, basketball, video game, brain, team sport

Introduction

Basketball is an open-skill sport with unpredictable actions and constant changes in its dynamic (Wang et al., 2013). This characteristic demands its players' perceptual-cognitive skills, such as anticipation, decision-making, and visuomotor abilities. Visuomotor skill is defined as the capacity to receive, perceive, and interpret visual information and respond to it with a motor action (Hülsmüller et al.,

2016, 2018). This skill is part of the visual skills group and the “sports vision pyramid”, being the transition point between the complex visuo-oculomotor skills and an athlete’s action on its field performance (Gao et al., 2015). Many brain areas are involved in the visuomotor system, such as the supplementary motor area (SMA), the primary motor cortex (M1), posterior parietal cortex (PPC), and primary visual cortex (V1), which seems to exert the main functions (Hülsdünker et al., 2018). Interestingly, the visuomotor skill is strongly linked with cognition, either by the sharing of brain areas working in visual attention, preparatory motor signalling as happening with frontal and parietal, also by the correlation between the cognitive process and the control of movement and regulations of actions during the visuomotor tasks (Formenti et al., 2019; Hülsdünker et al., 2018). Thus, activities that can damage cognitive performance, such as mental fatigue, also might impair visuomotor performance.

Mental fatigue is a psychobiological state of negative sensations such as lack of energy, tiredness, decreased alertness, and slow reaction caused by prolonged exposition to high-demanding cognitive tasks and/or prolonged necessity to exert self-control in cognitive, emotional, or behavioural activities (Brown et al., 2020; Li et al., 2020; Marcora et al., 2009). Previous studies found the negative effects of mental fatigue on technical, physical, and psychomotor performance, including in basketball players (Brown et al., 2020; Cao et al., 2022; Habay, Van Cutsem et al., 2021; McMorris et al., 2018). For instance, Filipas et al. (2021) found impaired free-throw accuracy when athletes were mentally fatigued and/or with sleep restriction. Commonly, the performance in the Stroop task is worsened in mental fatigue conditions, which denotes this task as an indicator of mental fatigue (Smith et al., 2019). In this way, executive function, especially the inhibition responses and attention, seems to be the main cognitive abilities required in tasks that lead to mental fatigue (Pageaux et al., 2014; van der Linden et al., 2003). Not by chance, previous findings suggested that subjects who present high executive function performance could be more successful and more resistant to mental fatigue during sports tasks (Martin et al., 2016; Vestberg et al., 2012). Another reflection of mental fatigue is the increase in perceived effort, perceived fatigue, and failure in self-regulation, mainly in activities that require self-control of rhythm (i.e., self-paced) and motor control (Jacquet et al., 2021; Pageaux, 2016; Pageaux & Lepers, 2018; van der Linden et al., 2003). The perceived fatigue is measured by the visual analog scale (VA S), which has been extensively used as a subjective indicator of mental fatigue (Smith et al., 2019).

Physiologically, mental fatigue increases cerebral adenosine concentration, which inhibits the dopaminergic release on the prefrontal (PFC) and anterior cingulate cortices resulting in a higher perception of effort on subsequent physical tasks (Martin et al., 2018). Moreover, previous studies found an increase in electroencephalography (EEG) theta wave amplitude on the PFC, supporting this band as a neurophysiological marker of mental fatigue (Pires et al., 2018; Wascher et al., 2014). Interestingly, some daily activities with high- cognitive demand might lead to mental fatigue, such as prolonged use of social media on smartphones and playing video games (Fortes et al., 2020, 2021). These types of screen-based activities are frequently reported among team sports athletes in pre-match activities (Thompson et al., 2020), which might induce mental fatigue.

Action video games are characterised by 3D settings, quick movement of targets, intense speed, frequent switch of attention type, necessity to move accurately and fast, and high mental demand to keep focus (Green & Bavelier, 2015; Oei & Patterson, 2013). When the action video game involves sports (i.e., NBA live), the visual’s search and attention need to increase due to the necessity to pay attention to multiple elements, such as the ball, both teammates and opponents’ position, and the scenario changes. Indeed, the sport-based video games genre imposes a high perceptual, cognitive, and motor load (Oei & Patterson, 2013), which might impact its behaviour and brain activity. Recently, Fortes et al. (2020) found that playing a video game for 30 min before a soccer match impaired professional athletes’ passing decision-making performance

because playing video games induces mental fatigue. However, this study has limitations regarding mental fatigue biomarkers, such as the lack of EEG.

Most mental fatigue studies have been using computerised tests (i.e., Stroop test, A X-CPT)(Smith et al., 2019). However, this strategy is low-ecological since it does not reproduce a sport's real-world context (Fortes et al., 2020). Then, sports studies should be designed to replicate or get close to real sports situations. Moreover, although it was already shown that visuomotor skill is impaired by mental fatigue in individual sports (Habay, Proost et al., 2021; Van Cutsem et al., 2019, 2020), this effect in team sports is under-explored. Thus, this study aimed to verify the effect of prolonged use of a sport-based video game on basketball players' visuomotor performance with and without the ball during the task. Considering previous findings of prolonged use of video games (Fortes et al., 2020), we hypothesised that visuomotor skills in both cases (i.e., with and without the ball) are impaired in mentally fatigued basketball players.

Methods

Participants

The sample size was estimated using GPower 3.1 for the two-way A NOVA (i.e., two experimental conditions and repeated measures) with a set power of 0.80, $\alpha = 0.05$, and an effect size of 0.49 for visuomotor skill (Van Cutsem et al., 2019). The results indicated that 14 subjects would be necessary for the study. Participants were 14 male basketball players (Age: 24.3 ± 4.1 years; time of experience: 6.5 ± 1.9 years), playing in the second division of the National League of Brazil. Their training routine is periodized and accompanied by a basketball coach (in the case of technical-tactical sessions) and a strength and conditioning coach (in the physical training sessions). In total, their routine includes five to six sessions throughout 9.74 ± 1.42 h per week, divided as follows: two sessions of technical-tactical training with small-sided games (120 min each; Mondays and Wednesdays), two sessions of physical exercise and perceptual-cognitive training (150 min each; Tuesdays and Thursdays), one session of technical and mental training (150 min each; Fridays), and one simulated or official match (Saturdays). According to the McKay et al.(2022) classification framework, the athletes are classified as a "tier 3" or highly trained/National level. Participants self-reported normal or corrected-to-normal vision. The subjects were informed of the study's purpose, methods, and risks. Written informed consent was obtained from all of them. This study followed all ethical standards set by the Declaration of Helsinki and was approved by the Institutional Ethics Committee (Approved number: 4.622.544).

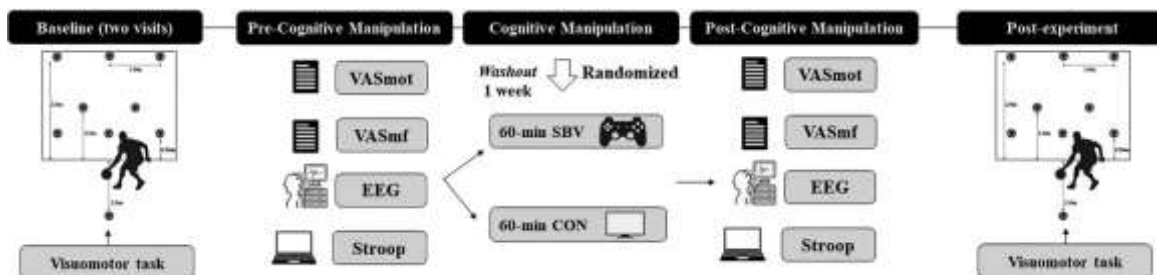
Experimental design

It is a randomised and counterbalanced crossover study, divided into two baseline visits and two experimental conditions, separated by a one-week washout interval, keeping the training routine along. First, the participants were familiarised with the mental fatigue measurements (i.e., subjective, behavioural, and physiological) and the visuomotor task (i.e., accuracy and response time) with and without a ball in the two initial visits. The order of experimental conditions was then randomised (with and without mental fatigue inducement) through a random number table generator (www.randomizer.org). Both experimental conditions comprise visuomotor tasks with and without a ball.

In the experimental conditions (i.e., video game [SB V] and control [con]), the athletes passed by similar procedures in the pre- and post- experiment, but in the SB V condition, the athletes played a video game in the treatment, while in the CON condition they watched a documentary, both cases for an hour (Figure 1). Participants completed the pre-trial checklist before each visit when they needed to answer how many hours slept in the last night, if was ingested alcohol and caffeine in the previous 12 h, how much physical exercise made in the 24 h before, and the cognitive activity in the last three hours (e.g., video game use, time reading, smartphone use). The Visual Analogue Scale (VA S), Stroop task, and the electroencephalogram (E E G) assessed mental fatigue in pre- and post-cognitive manipulation in both experimental conditions. The participants refrained from any physical exercise and alcohol ingestion 48-h before experimental sessions and abstained from caffeine for at least four hours before beginning the sessions. We recommended the participants ingest fluid ad libidum up to two hours before each experimental session. Activities with high-cognitive demand (e.g., social media on a smartphone) were forbidden two hours before each experimental session. All trials lasted about 90 min.

Figure 1.

Experimental design of the study.



Note: VAS = Visual Analogue Scale (mental fatigue [VASmf] and motivation [VASmot]); EEG = electroencephalogram; SBV = sport-based video game; CON = control.

Mental fatigue protocols

Based on previous studies (Marcora et al., 2009; Moreira et al., 2018), it was set 60 min of emotionally neutral documentaries (i.e., coaching videos about the Olympic Games) to be watched by the participants on a 48-inch screen in the CON condition.

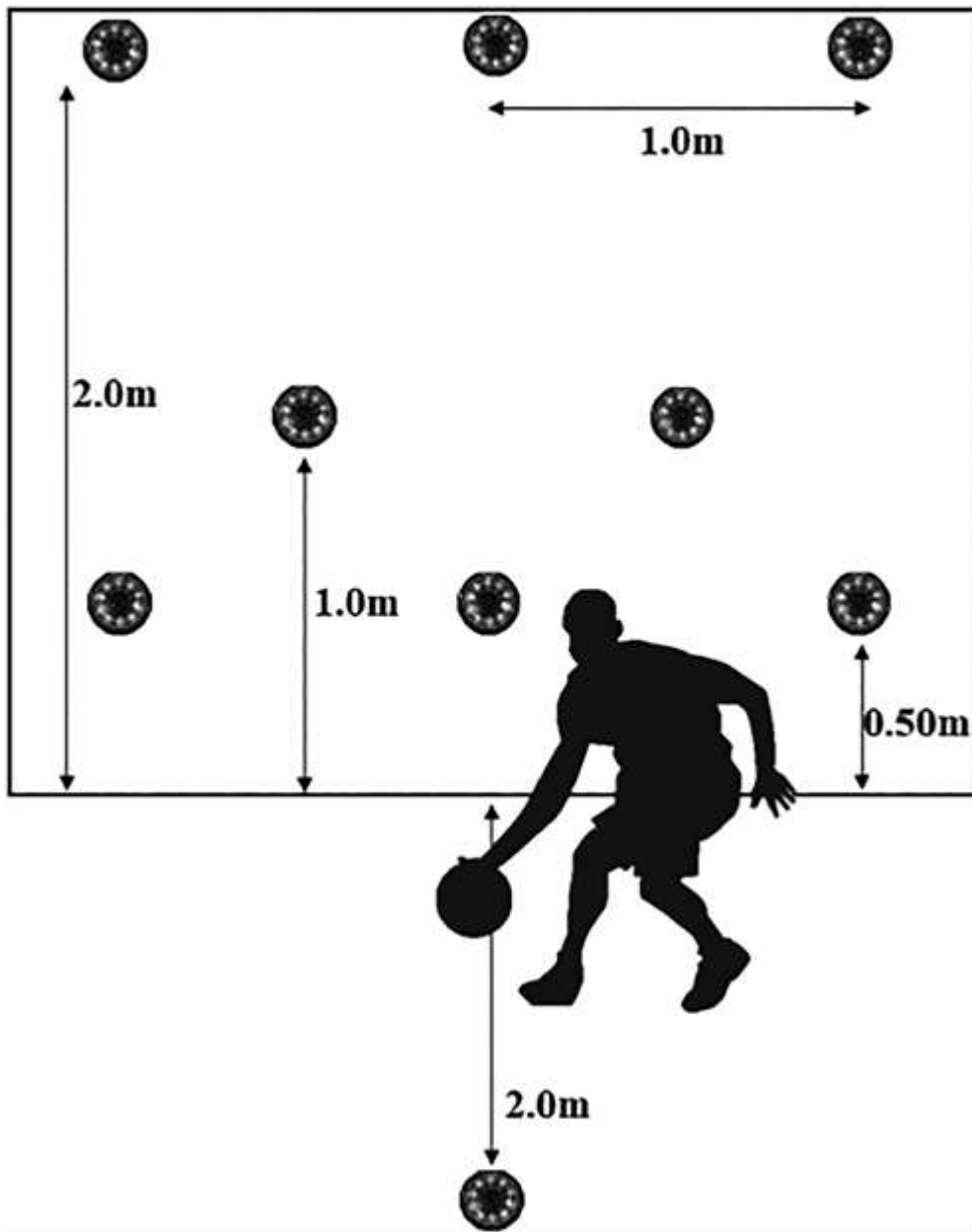
The sport-based video game protocol (SB V) consisted of playing NB A live 19 (E A Sports, E UA) on a video game console (Playstation 4, Sony, Japan) for 60 min. Each video game console was attached to a 48-inch TV. Pairing players were made on baseline visits considering each athlete's performance level at the NBA live 19.

Visuomotor task

The visuomotor performance was assessed using two tasks: with and without a ball. The tasks were developed by Fitlight-hardware (<http://www.fitlighttraining.com/>). Eight LE D lights were fixed on a wall, and one was put on the floor in front of the wall (see Figure 2). The LE D-colored lights presented the same colours used in the Stroop task (i.e., red, blue, green, and yellow), one after the another, in a set sequence. When

the LED light turns blue, green, or yellow, participants should touch or pass the hand to the light on the wall as fast as possible. On the other hand, when the red light shows up on the wall, it must be ignored, and the participant must touch/pass the hand on the LED light on the floor. The test presented 60 stimuli, 15 times each colour. The lights were on for 2 s, and the inter-stimulus time varied between three to five seconds. Each inter-stimulus time was randomly used 15 times. This task design was previously used by Van Cutsem et al. (2020). The total task duration was approximately six minutes for each visuomotor task (with and without basketball), and the task's order was always the same. During the visuomotor task, basketball participants simultaneously perform the visuomotor task and bounce the ball (i.e., simulating what happens at a basketball match). Response times and accuracy were collected to assess visuomotor performance. The intraclass coefficient correlation (ICC) was used to determine the reliability of the visuomotor test using the data from the two baseline visits. The data came from the same athletes that participated in experimental visits. The values found for visuomotor test with the ball were ICC = 0.98 (CI95% = 0.94–0.99) for response time and ICC = 0.71 (CI95% = 0.08–0.90) for accuracy. The values found for visuomotor test without the ball were ICC = 0.97 (CI95% = 0.91–0.99) for response time and ICC = 0.78 (CI95% = 0.32–0.93) for accuracy.

Figure 2. Visuomotor task with LED lights with eight lights fixed on the wall and one on the floor, against the wall.



Manipulation checks

Electroencephalogram (EEG). The EEG signal was continuously measured during three minutes of pre- and post-cognitive manipulation, at 500 Hz sampling frequency, with active electrodes (Ag-AgCl) fixed at the FP1 position according to the 10–20 international system. Conductive gel, adhesive tape, and medical strips were used to fix the electrode on the scalp. The impedance was kept below 5 K Ω . The surface signal was amplified (gain of 1.000) and treated with a notch (60 Hz) and a 1–30 Hz bandpass filter. The EEG data were analyzed in frequency domains through a fast-Fourier transformation. The area under the theta band power spectrum (3–7 Hz) was calculated over a five-second window. Previous EEG studies suggested that theta band is sensitive to distinguishing a mental fatigue state (Pires et al., 2018; Wascher et al., 2014).

Visual analog scale (VAS). The 100 mm VAS was used to measure mental fatigue's subjective rating (Smith et al., 2019). This scale has two extremities anchored from 0 (none at all) to 100 (maximal), without descriptors between them. Participants were required to answer the question: "How mentally fatigued you feel now?". The definition of mental fatigue (e.g., a psychobiological state caused by prolonged periods of demanding cognitive activity) was provided to participants and examples of "none at all" (no feelings of tiredness and lack of energy) and "maximal" (maximum feelings of tiredness and lack of energy) mental fatigue were explained based on tasks of prolonged periods of demanding cognitive activity. Participants were oriented to drawing a single vertical line to reflect mental fatigue throughout the 100 mm scale according to their perceived status. To quantify values, we measured distance in millimetres from 0 to 100, indicated by the participant.

As a manipulation check of motivation rating, we also used a 100-mm VAS anchored by the words "not at all" and "maximal". Participants were required to answer the question: "How motivated are you now for perceptual-cognitive task?" and mark in the line the correspondent to how they felt motivated at that moment. The motivation was defined as the feeling of determination at that moment. Rating of motivation was measured at pre- and post-cognitive manipulation. This measure was also used in studies involving mental fatigue and performance (Queiros et al., 2021; Smith et al., 2016).

Stroop task. The computerised version of the Stroop task (Graf et al., 1995) assessed inhibitory control and selective attention performance before and after cognitive manipulation (i.e., video game and documentary). Forty incongruent stimuli of words, with 500 ms of the interval between response and a new stimulus, were used. The stimulus did not fade from the screen until the participant responded. The tests were carried out on a full-HD screen (1800 \times 1260 pixels) laptop (MacBook Pro, A1502 model, USA). The total time of the Stroop task application was approximately 2.5 min. The mean values of accuracy and response time were recorded for analysis. This response is considered accurate when the participant answered the right colour letter in the stimuli. The response time is the interval between the reception of stimuli and the right motor answer. The ICC calculation considered the values of the Stroop task in pre-cognitive manipulation in both conditions (i.e., CON and SBV). The values found were ICC = 0.99 (CI95% = 0.97–0.99) for response time and ICC = 0.71 (CI95% = 0.11–0.90) for accuracy.

Statistical analysis

The Shapiro–Wilk test evaluated data distribution. The Levene test verified homoscedasticity. The two-way Anova was used to analyze condition (CON versus SBV) \times time (baseline versus post-experiment) interaction for the visuomotor task (accuracy and response time). The same test was used to analyze condition (CON versus SBV) \times time (pre-versus post-cognitive manipulation) interaction for VAS (mental fatigue and

motivation), Stroop task (accuracy and response time), and E E G (theta wave). A Bonferroni posthoc test was used to identify possible statistical differences. Partial eta squared (η^2) effect size (E S) were determined and interpreted using the following cutoffs (Cohen, 1992): small effect, $\eta^2 < 0.03$; moderate effect, $0.03 \leq \eta^2 < 0.10$; large effect, $0.10 \leq \eta^2 < 0.20$; very large effect, $\eta^2 \geq 0.20$.

Data were processed in the Statistical Package for Social Sciences Version 21.0 (IBM Corp., Armonk, NY, USA) and GraphPad Prism 8 (San Diego, CA, USA) with a significance level of 5%.

Results

Mental fatigue

VAS. A condition \times time interaction for subjective rating of mental fatigue [$F(1, 13) = 33.50$; $p = 0.001$ [CI 95% = 0.001–0.003]; $\eta^2 = 0.41$ [CI95% = 0.35–0.48]; E S: very large) was found (Table 1). Subjective rating of mental fatigue only increased ($286.1 \pm 52.5\%$) for the SB V condition ($p = 0.001$). No condition \times time interaction for subjective rating of motivation ($F(1, 13) = 1.53$; $p = 0.46$ [CI 95% = 0.40–0.59]; $\eta^2 = 0.002$ [CI95% = 0.001–0.004]; ES: small) was found.

Table 1. Subjective level of mental fatigue, motivation, theta wave amplitude, and Stroop task performance during the experiment in both conditions and moments. Data presented in mean and standard derivation.

	SVB		CON		Interaction (Condition \times time)				Effect	F	η^2 (CI _{95%})	p	ES
	Pre	Post	Pre	Post	F	η^2 (CI _{95%})	p	ES					
VAS _{MF} (mm)	15.70 \pm 6.41	54.23 \pm 14.75	13.97 \pm 6.08	16.18 \pm 5.59	33.50	0.41 (0.35– 0.48)	0.001	Very large	Condition	31.91	0.37 (0.34– 0.42)	0.001	Very large
									Time	25.49	0.22 (0.18– 0.24)	0.001	Very large
VAS _{MOT} (mm)	92.60 \pm 5.24	94.35 \pm 4.96	90.86 \pm 6.57	92.12 \pm 5.02	1.53	0.002 (0.001– 0.004)	0.46	Small	Condition	1.29	0.002 (0.001– 0.01)	0.61	Small
									Time	0.91	0.003 (0.002– 0.01)	0.79	Small
Theta wave (μV^2)	2.86 \pm 0.34	4.17 \pm 0.84	3.02 \pm 0.37	2.99 \pm 0.36	27.86	0.21 (0.19– 0.28)	0.001	Very large	Condition	9.11	0.19 (0.14– 0.22)	0.001	Large
									Time	28.82	0.25 (0.18– 0.29)	0.001	Very large

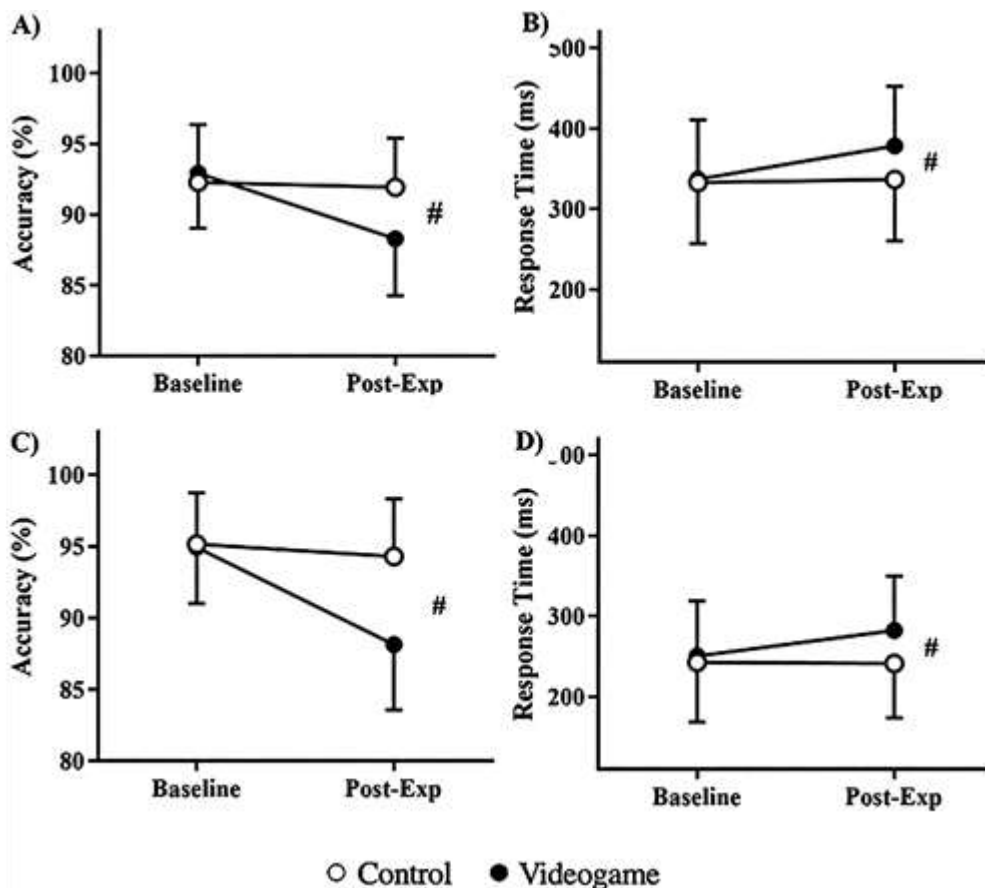
Stroop task

Accuracy (%)	96.61 ± 4.12	95.39 ± 4.72	94.50 ± 4.16	96.30 ± 3.82	1.04	0.003 (0.001–0.01)	0.53	Small	Condition	0.87	0.01 (0.004–0.02)	0.38	Small
									Time	0.54	0.003 (0.002–0.01)	0.61	Small
Response time (ms)	547.62 ± 123.37	623.89 ± 147.01	564.05 ± 129.67	572.55 ± 119.73	14.72	0.11 (0.07–0.14)	0.001	Large	Condition	12.70	0.09 (0.06–0.13)	0.001	Moderate
									Time	10.62	0.07 (0.05–0.10)	0.001	Moderate

Note: SBV = Sport-based video game; CON = control; VASMF = Visual analogue scale for mental fatigue level; VASMOT = Visual analogue scale for motivation; ES = effect size.

EEG. A condition × time interaction for theta wave on Fp1 [Figure 3; ($F(1, 13) = 27.86$; $p = 0.001$ [CI95% = 0.001–0.01]; $\eta^2 = 0.21$ [CI95% = 0.19–0.28]; ES very large) was found (Table 1). The theta wave on Fp1 only increased ($43.2 \pm 14.8\%$) for the SBV condition ($p = 0.001$).

Figure 3. Visuomotor task with (Figures A and B) and without the ball (Figures C and D) according to the experimental condition (Control versus Sport-based video game) and time (baseline versus post-experiment) in male basketball players.



Note: Post-Exp = post-experiment; #p < 0.05 control-vs video game in post-experiment.

Stroop task. There was no condition × time interaction for accuracy ($F(1, 13) = 1.04$; $p = 0.53$ [CI95% = 0.51–0.72]; $\eta^2 = 0.003$ [CI95% = 0.001–0.01]; E S: small) (Table 1). On the other hand, a condition × time interaction for response time [($F(1, 13) = 14.72$; $p = 0.001$ [CI95% = 0.002–0.02]; $\eta^2 = 0.11$ [CI95% = 0.07–0.14]; E S: large) occurred. Response time only increased ($13.5 \pm 4.9\%$) for the SB V condition ($p = 0.001$).

Visuomotor task with ball

Accuracy. A condition × time interaction for accuracy [**Figure 3A**; ($F(1, 13) = 12.53$; $p = 0.001$ [CI95% = 0.001–0.004]; $\eta^2 = 0.09$ [CI95% = 0.06–0.11]; E S: moderate) occurred. A main effect of condition ($F(1, 13) = 18.20$; $p = 0.001$ [CI95% = 0.001–0.01]; $\eta^2 = 0.09$ [CI95% = 0.07–0.12]; E S: moderate) and time effect ($F(1, 13) = 9.15$; $p = 0.01$ [CI95% = 0.004–0.02]; $\eta^2 = 0.07$ [CI95% = 0.05–0.10]; E S: moderate) were found.

Accuracy only decreased ($6.4 \pm 2.5\%$) for the SBV condition ($p = 0.001$).

Response time. A condition × time interaction for response time [**Figure 3B**; ($F(1, 13) = 27.76$; $p = 0.001$ [CI95% = 0.001–0.003]; $\eta^2 = 0.17$ [CI95% = 0.12–0.19]; E S: large) occurred. A main effect of condition ($F(1, 13) = 23.19$; $p = 0.001$ [CI95% = 0.001–0.004]; $\eta^2 = 0.14$ [CI95% = 0.12–0.18]; E S: large) and time effect ($F(1, 13) = 26.98$; $p = 0.001$ [CI95% = 0.001–0.01]; $\eta^2 = 0.12$ [CI95% = 0.10–0.16]; E S: large) were found.

Response time only impaired ($17.2 \pm 5.1\%$) for the SBV condition ($p = 0.001$).

Visuomotor task without the ball

Accuracy. A condition × time interaction for accuracy [**Figure 3C**; ($F(1, 13) = 9.02$; $p = 0.01$ [CI95% = 0.004–0.03]; $\eta^2 = 0.08$ [CI95% = 0.05–0.10]; E S: moderate) occurred. A main effect of condition ($F(1, 13) = 10.40$; $p = 0.004$ [CI95% = 0.003–0.02]; $\eta^2 = 0.09$ [CI95% = 0.06–0.10]; E S: moderate) and time effect ($F(1, 13) = 25.85$; $p = 0.001$ [CI95% = 0.001–0.003]; $\eta^2 = 0.10$ [CI95% = 0.07–0.13]; E S: large) were found. Accuracy only decreased ($7.1 \pm 2.8\%$) for the SBV condition ($p = 0.01$).

Response time. A condition × time interaction for response time [**Figure 3D**; ($F(1, 13) = 24.84$; $p = 0.001$ [CI95% = 0.001–0.003]; $\eta^2 = 0.12$ [CI95% = 0.10–0.15]; E S: large) occurred. A main effect of condition ($F(1, 13) = 11.61$; $p = 0.004$ [CI95% = 0.002–0.01]; $\eta^2 = 0.09$ [CI95% = 0.06–0.12]; E S: moderate) and time effect ($F(1, 13) = 12.62$; $p = 0.003$ [CI95% = 0.001–0.04]; $\eta^2 = 0.08$ [CI95% = 0.05–0.11]; E S: moderate) were found. Response time only impaired ($10.3 \pm 3.5\%$) for the SBV condition ($p = 0.01$).

Discussion

We aimed to verify the effect of prolonged use of sport-based video games on visuomotor performance in basketball players. The main finding was the impairment of visuomotor performance only after video game condition (SB V) since both accuracy and response time were impaired in with and without ball tasks in basketball players. Moreover, perceptual (i.e., VA S), behavioural (i.e., the response time on Stroop Test), and physiological (i.e., theta amplitude) mental fatigue parameters were altered after SB V, showing that the sport-based video game induces mental fatigue state. Considering that mental fatigue was induced in a similar magnitude to the less ecological way (i.e., computerised Stroop task), our results showed that it does

not matter the type of mental exertion, when the executive functions are used for a long time, mental fatigue occurs. These results confirm our initial hypothesis.

Mental fatigue might lead to perceptual, cognitive, and behavioural adverse effects. The present study explores these effects in three ways (i.e., VA S, Stroop task, and E E G) and found negative responses in all of them. The perceptual response to mental fatigue increased by 286.1% after SB V, representing an increase in the athletes' mental load. Previous studies have found an increase in VA S after mental fatigue conditions (Smith et al., 2016; Van Cutsem et al., 2020; Vrijkotte et al., 2017), although its induction has been different in the present study. Indeed, VA S has been indicated as the most practical and sensitive way to assess mental fatigue (Smith et al., 2016, 2019), probably because the main effect of mental fatigue seems to be perceptual (Martin et al., 2018).

Similarly, the Stroop task response time was harmed by mental fatigue, presented by an increase of 13.5% on response time in the SB V condition. This was an expected result since previous findings presented similar motor-cognitive response time effects, regardless of how mental fatigue was induced (Fortes et al., 2020; Gantois et al., 2020; Smith et al., 2019; Van Cutsem et al., 2019). Remarkably, we used a short version of the Stroop task as a manipulation check, contrary to most studies that used it to induce mental fatigue. Taken together with perceptual and physiologic results, the increase in response time shows the Stroop task's sensibility to detect mental fatigue state, but more studies should be performed. Also, the theta band wave presented an increased amplitude by 43.2% post-SB V condition. This result corroborates previous findings (Franco-Alvarenga et al., 2019; Pires et al., 2018) and confirms the high-cognitive demand imposed by video game use. Interestingly, the SB V induced an increase almost 10 times higher on E E G theta band amplitude than Franco-Alvarenga et al.'s study, which found a 4.8% increase after continuous cognitive tasks. Hence, it is possible to speculate that the magnitude of change caused by video game use induced on the brain might be bigger than a computerised task, but more studies should be conducted to test this assumption. Lastly, considering that the time course of the effects of mental fatigue might reach 90 min (Gantois et al., 2019), the coaches and athletes should consider abstaining from the use of video games in the pre-match.

Video game conditions thoroughly impaired the ball's visuomotor performance since the accuracy decreased 6.4% and response time increased 17.2%. These findings follow recent studies investigating mental fatigue's effect on visuomotor performance in non-athletes and athletes from individual sports (Van Cutsem et al., 2019, 2020). For instance, Van Cutsem et al. (2019) found that together with badminton players and healthy controls, their response time on visuomotor tasks increased by 7% after mental fatigue induced by the Stroop task. In a similar condition, Van Cutsem et al. (2020) found a 4.4% increase in response time on visuomotor tasks in non-athletes, even when the participants ingested creatine. However, this is the first study to point out that the prolonged use of sport-based video games can impair visuomotor performance. Moreover, we also found a prejudice on the accuracy of the visuomotor test, different from the previous studies' findings. Additionally, during the visuomotor test, the ball's inclusion makes the experiment closer to basketball drills and match situations since the ability to track multiple elements with the ball is crucial in team sports (Qiu et al., 2018). In sum, computerised cognitive tasks (i.e., Stroop task) and sport-based video games require cognitive effort and might lead to mental fatigue.

Taken together with the E E G results (i.e., increase in theta band on PFC), it is possible to speculate that the SB V changed the activity to the visuomotor system's brain structures once the PFC is linked to parietal and visual brain areas and has a crucial function on visual attention and preparatory motor signalling (Formenti et al., 2019). Consequently, the visual-attentional and motor performance might be compromised, so basketball performance either, since visuomotor performance is essential to the technical-tactical actions of basketball. Future studies should also include more realistic elements of matches (e.g., adversary) to make the experiments more similar to the real world.

Like the ball's task, performance on the visuomotor task without the ball was compromised by 7.1% and 10.3% on accuracy and response time, respectively. As expected, the decreased magnitude was smaller on response time (i.e., with the ball 17.2%), probably due to both hands' freedom to respond to the stimulus. The basketball player stays without the ball most time of the match. In these moments, they must monitor many elements, such as teammates' and opponents' positions, the self-position and movements, and empty spaces on the field (Pagé et al., 2019; Qiu et al., 2018). Hence, a decrease in visuomotor performance might compromise team performance since the self-organisation might be disturbed by excessive mental exertion, compromising team behaviour (Moreira et al., 2018; Passos et al., 2013). For instance, the continuous need to adapt to attack and defense positions requires a fast change in behaviour and adaptability to the rules (Passos et al., 2013), high-level attention (sustained and divided), and the capacity to inhibit irrelevant external stimulus. As shown in our results, these abilities might be compromised if the athlete is mentally fatigued. Following studies should analyze how mental fatigue might impact collective actions (e.g., tactical behaviour).

The main strength of our experiment is the ecological way chosen to induce mental fatigue. Indeed, it was already found that some athletes used video games at least two hours before the match (Thompson et al., 2020). Moreover, previous findings showed that playing action video games might impair decision-making performance in boxing and soccer players (Fortes et al., 2020, 2021). As well as cognitive tasks, sport-based video games require a high level of attention, visual search behaviour, and executive functions. Hence, when athletes play video games for an extended time, they will probably feel mental fatigue. On the other hand, even though this study presents interesting results, some limitations should be mentioned. The EEG measure was not made during the visuomotor task and might limit the interpretation of data. The order of visuomotor tasks applied (i.e., with and without the ball) was not randomised. Also, our experiment did not use eye behaviour (i.e., eye-tracking), which has been indicated as a potential detector of mental fatigue conditions (Yamada & Kobayashi, 2018). Considering that playing video games might be enjoyable for some, we did not measure the enjoyment in our experiment, and this should be measured in future studies with the same line. The lack of a basketball-specific task (i.e., free throw or similar) or match is also important to be mentioned. Lastly, the unchecked whether the athletes ingested alcohol or other nutritional substances 48 h before the experiment is a limitation. Future studies should take more real-world scenarios to identify mental fatigue's impact on basketball performance more precisely.

We conclude that mental fatigue induced by prolonged use of sport-based video games impairs visuomotor performance in male basketball players by decreasing accuracy and significantly increasing response time. Furthermore, the SB V led to increased mental fatigue's perceptual, behavioural, and physiological parameters. Our results have significant implications for male basketball players and coaches since visuomotor performance is crucial to the team, and players commonly play video games; given that, playing video games should be avoided to prevent eventual adverse effects from mental fatigue induction.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Heloiana Faro <http://orcid.org/0000-0003-1801-2328>

Leonardo de Sousa Fortes <http://orcid.org/0000-0002-0778-769X> Dalton de Lima-Junior <http://orcid.org/0000-0003-1542-604X> Bruno Teixeira Barbosa <http://orcid.org/0000-0002-2654-6453>

Maria Elisa Caputo Ferreira <http://orcid.org/0000-0002-3294-7560>

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