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Playing videogames or using social media applications on smartphones causes mental fatigue and impairs decision-making performance in amateur boxers

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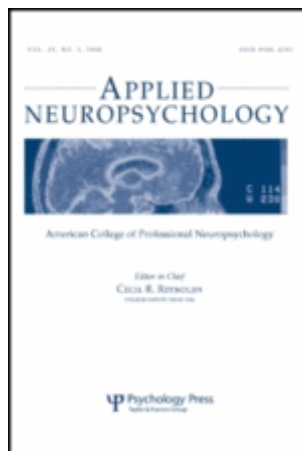
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1 Playing videogames or using social media applications on smartphones causes mental fatigue
2 and impairs decision-making performance in amateur boxers

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Abstract

This study aimed to analyze the effect of playing videogames and using social media applications on smartphones on decision-making and countermovement jump (CMJ) performance in amateur boxers. Twenty boxers were enrolled in the study and were randomly assigned to all three experimental conditions [smartphone (30SMA), videogame (30VID), and control (CON)]. CMJ was measured before and 30-min after each experimental condition. The athletes ran simulated combat recorded for decision-making analysis. The boxers watched coaching videos (CON), used social media applications on smartphones (30SMA), and played video games (30VID) for 30 minutes just before the combat simulation. Both attack and defense decision-making performance were worse in both 30SMA and 30VID conditions compared to the CON condition ($p = 0.001$). Regarding CMJ, despite no condition effect ($p = 0.96$) been obtained, a time effect ($p = 0.001$) was observed; So, it was found a decrease in CMJ performance after all experimental conditions ($p = 0.001$), with no difference between them. Using social media applications on smartphones and playing video game impairs decision-making performance in amateur boxers, with no harms for CMJ performance.

Keywords: cognition, fatigue, media, performance, psychology.

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3 21 Playing videogames or using social media applications on smartphones causes mental fatigue
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5 22 and impairs decision-making performance in amateur boxers
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10 24 Boxing is an Olympic sport in which pugilists' aims to hit a greater number of
11
12 25 punches in their opponents (San Juan et al., 2019). Basic punches such as the jab, direct,
13
14 26 cross (left and right), uppercut (left and right), and hook (left and right) are the most common
15
16
17 27 in the sport (Lenetski et al., 2019). Regarding the defense movements, the footwork, bobbing,
18
19 28 and blocking might be highlighted. In Olympic boxing, each combat consists of four rounds,
20
21 29 and the winner is the one that sums higher scores up (based on punches) later the last round
22
23
24 30 or knocks out the opponent throughout the combat (López-Laval, Sitko, Muñoz-Pardos, Cirer-
25
26 31 Sastre, & Calleja-González). The boxing performance depends on several factors such as
27
28 32 physical, technical, tactical, and cognitive abilities (Loturco et al., 2019), and the decision-
29
30 33 making performance and power output might determine the winner in combat (Stiller et al.,
31
32
33 34 2014).

35 35 Attack and defense decision-making in boxing is vital because a good attack approach
36
37 36 (i.e., jab, uppercut, right cross, or hook) may reach a score or even a knockout; still, a good
38
39 37 defense technique (i.e., slip, block, or duck) may lead to an avoidance score or knockout.
40
41 38 Decision-making refers to the human's ability to perceive relevant information from the
42
43 39 environment, correctly interpret it, and then select the appropriate motor response (Baker,
44
45 40 Coté, & Abernethy, 2003), which is considered essential for a good performance in
46
47 41 unpredictable sports (Fortes, Nascimento-Júnior, Mortatti, Lima-Júnior, & Ferreira, 2018;
48
49 42 Smith et al., 2016).

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53 43 Ecological approaches to assess decision-making performance might be performed
54
55 44 using informational variables that sustain emergent functional behaviors (Travassos et al.,
56
57 45 2012a). Thereby, it has been observed that athletes couple their actions in both space and
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3 46 time, looking for the best way to comprehend the environment and task restrictions during the
4
5 47 performance (Travassos, Duarte, Vilar, Davids, & Arajo, 2012b). To get decision-making
6
7 48 performance better, the athletes need to enhance perception-action couplings able to increase
8
9 49 the attention to perceptual variables, making clear which actions are (or are not) possible to
10
11 50 perform according to their capabilities (Travassos et al., 2012). It is essential to highlight that
12
13 51 perceptual-cognitive ability and executive functions such as perception, attention,
14
15 52 anticipation, inhibitory control, working memory, and cognitive flexibility are related to
16
17 53 decision-making performance (Araújo et al., 2015; Vestberg, Gustafson, Maurex, Ingvar, &
18
19 54 Petrovic, 2012).

20
21
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23
24 55 It is well-documented that an increase in cognitive demand for a prolonged period
25
26 56 may impair those perceptual-cognitive abilities (e.g., perception and decision-making) and
27
28 57 executive functions (e.g., attention and inhibitory control) previously mentioned in athletes
29
30 58 (Fortes et al., 2019a Gantois et al., 2019; Van-Cutsem et al., 2017). Once the harms in
31
32 59 perceptual-cognitive abilities and executive functions seems to impair the decision-making
33
34 60 performance, it is imperative to run studies analyzing these variables in combat sports
35
36 61 athletes.

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39
40 62 The impairment of executive functions based on the psychobiological state that
41
42 63 induces tiredness and lack of energy following long periods of cognitive demand has been
43
44 64 called mental fatigue (MF) (Russel, Jenkins, Rynne, Halson, & Kelly, 2019; Smith et al.,
45
46 65 2018). These periods must last at least 30-min (Fortes et al., 2019a Gantois et al., 2019) and
47
48 66 present a detrimental effect on physical performance (McMorris, Barwood, Hale, Dicks, &
49
50 67 Corbett, 2018; Van-Cutsem et al., 2017), mainly on endurance (Marcora, Staiano, &
51
52 68 Manning, 2009; Martin, Meeusen, Thompson, Keegan, & Rattray, 2018; Pageaux et al.,
53
54 69 2013; Penna et al., 2018), which includes combat sports athletes (Campos et al., 2019).
55
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57
58 70 However, it seems that MF does not affect all-out performance ran for 10 seconds or less
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3 71 (Rozand, Pageaux, Marcora, Papaxanthis, & Lepers, 2014; Silva-Cavalcante et al., 2018), for
4
5 72 example, the countermovement jump (CMJ). The CMJ is considered a good measure for
6
7 73 neuromuscular status (Wilson et al., 2013) and shows a strong relationship with power output
8
9 74 in combat sports athletes (Loturco et al., 2019). So, the present study also analyzed the effect
10
11 75 of MF on CMJ because these findings may reveal if MF can affect the power output in
12
13 76 combat sports athletes.
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15

16
17 77 Regarding perceptual-cognitive ability performance, previous findings demonstrated
18
19 78 that MF impaired decision-making performance in soccer athletes (Gantois et al., 2019;
20
21 79 Smith et al., 2016). However, it is noteworthy that the literature still lacks studies analyzing
22
23 80 the effect of MF on decision-making performance in combat sports athletes (e.g., Olympic
24
25 81 boxing); so, these studies seem to be essential once reduced decision-making might define a
26
27 82 combat result. Also, previous studies have adopted low-ecological validity cognitive tasks
28
29 83 (e.g., Stroop task) to induce MF before training sessions and simulated games (Gantois et al.,
30
31 84 2019; Smith et al., 2016). As it is known, cognitive tasks that require inhibition response and
32
33 85 sustained vigilance (e.g., Stroop task and driving) for a prolonged time might induce MF
34
35 86 (Smith et al., 2018; Ting, Hwang, Doong, & Jeng, 2008; Zhao, Zhao, Liu, & Zheng, 2012).
36
37 87 However, performing Stroop task for more than 30-min before training and competitions is
38
39 88 unusual. A limitation of the Stroop task is that it may not be representative of how MF is
40
41 89 experienced in real-life settings (Thompson et al., 2020). Indeed, this task seems to be
42
43 90 relevant in a laboratory setting to create a transient state of MF. Still, an athlete would not
44
45 91 complete a Stroop task before a competition, which makes the practical validity of using a
46
47 92 Stroop task questionable in some of the sports science fields. The repetitive nature of
48
49 93 continually solving the same task problem may become monotonous and evoke lower levels
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51 94 of contextual interference than real-life tasks such as sports.
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3 95 Thus, some of the studies regarding MF and decision-making performance presents
4
5 96 low ecological validity in sports conditions (Gantois et al., 2019; Smith et al., 2016). In real-
6
7 97 world context, Thompson et al. (2020) showed that ~10% and ~60% of English academy
8
9 98 soccer players reported playing videogame or social media using as a pre-match activity.
10
11 99 Commonly, amateurs' athletes use social media on smartphones (e.g., Facebook®,
12
13 100 WhatsApp®, and Instagram®) or play video games (e.g., combat games), especially before
14
15 101 training sessions or official competitions (Diaz-Brage et al., 2018; Wu et al., 2012). The
16
17 102 sport-based videogame (e.g., Fight Night) presents demand with high amount of visual search
18
19 103 in short time, because the games are characterized by changes of scenery constantly, which
20
21 104 requires high attention sustained, cognitive inhibition and cognitive flexibility. It could be
22
23 105 therefore speculated that the sport-based videogame per prolonged period immediately prior
24
25 106 training session or match would causes mental fatigue and impair the perceptual-cognitive
26
27 107 ability performance. Regarding social media on smartphone, seems to be increasing among
28
29 108 athletes (Thompson, Noon et al., 2020). The social media use on smartphones can be harmful
30
31 109 for athletes when utilized per prolonged period before training sessions or official
32
33 110 competition (Durand-Bush & DesClouds, 2018). Neuroimaging studies of social behaviors
34
35 111 have demonstrated that social media use recruits brain network regions, including the
36
37 112 prefrontal cortex (PFC), dorsomedial PFC (DMPFC), ventromedial PFC (VMPFC), bilateral
38
39 113 temporoparietal junction (TPJ), anterior temporal lobes (ATL), inferior frontal gyri (IFG),
40
41 114 and posterior cingulate cortex/precuneus (PCC) (Schurz et al., 2014; Wolf et al., 2010). It is
42
43 115 essential to highlight that the PFC and VMPFC are responsible for attention, processing
44
45 116 information, and decision-making during physical effort, respectively. Once fatigued
46
47 117 mentally by prolonged use of social media on a smartphone, it might impair the decision-
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49 118 making skill.
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3 119 Recently, real-world studies showed that using social network apps on smartphones
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5 120 (Fortes et al., 2019a; Fortes, De Lima-Júnior, Gantois, Nascimento-Júnior, & Fonseca, 2020)
6
7
8 121 or playing video games (Fortes et al., 2019b) for a prolonged period may cause MF. The
9
10 122 excessive use of these cognitive tasks may cause MF, impairing decision-making
11
12 123 performance that is considered a key-point in combat sports.

14 124 From a practical standpoint, the effect of social media use on smartphones or playing
15
16 125 video games on decision-making, and CMJ performance in box athletes might indicate new
17
18 126 protocols, including avoiding those tasks before the combat. Thus, this study aimed to
19
20 127 analyze the effect of social media use on smartphones and playing video games on decision-
21
22 128 making and CMJ performance in amateurs boxing athletes. Also, we developed two
23
24 129 hypotheses as follows: a) exposure to social media on smartphones or playing video games
25
26 130 (30-min) impair decision-making performance in amateurs boxing athletes; and b) exposure
27
28 131 to social media on smartphones (30-min), playing video games, or watching TV does not
29
30 132 affect CMJ performance in amateurs boxing athletes.

31 133

32 134 **Materials and methods**33 135 ***Participants***

34 136 The sample size was calculated using an equation ($n = 8e^2/d^2$; n, e, and d denote the
35
36 137 required sample size, coefficient of variation, and magnitude of the treatment, respectively),
37
38 138 and we assumed a coefficient of variation of 3.5 % for decision-making performance ran by
39
40 139 martial arts athletes (Fortes et al., 2017; Franchini, Artioli, & Brito, 2013) and a conservative
41
42 140 d value of 1.0 %, which result in ~ 16 participants. However, considering eventual sample
43
44 141 losses, eight female and 12 male amateur boxers (7 amateurs of national level and 13
45
46 142 amateurs of regional level; means and SDs of 23.33 ± 3.46 years; 1.73 ± 0.07 m; 68.14 ± 5.15
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48 143 kg), totalizing 20 boxers of half-medium (until 69 kg) and weight-medium (until 75 kg)
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144 categories volunteered and were enrolled in the study. They had a training frequency of $4.6 \pm$
145 0.4 sessions/week (10.5 ± 1.3 h/week) and training experience of ~ 8.9 years (national and
146 regional tournaments). The participants were non-smokers and presented no cardiovascular,
147 visual, auditory, and cognitive disorders. They were instructed to avoid consumption of
148 stimulants (coffee, energy drink, and so on) and alcoholic beverages, as well as perform
149 vigorous exercise previous the 48-h preceding the sessions. Experimental procedures, risks,
150 and benefits were explained before collecting their written consent form signature. The
151 procedures were previously approved by a local Ethics Committee and performed according
152 to the Declaration of Helsinki. Written informed consent was obtained from each participant
153 before participation.

154

155 *Experimental design*

156 This is a randomized, crossover, and single-blind investigation that adopted three
157 experimental conditions and a one-week washout interval, performed in amateur boxing
158 athletes of both sexes.

159 The participants underwent five visits in which two of them were baseline visits for
160 the reproducibility measure [i.e., CMJ, Stroop task (accuracy and response time), and boxing
161 decision-making performance (simulated combat)], and three of them were for the
162 experimental conditions. Each baseline visit lasted about 30-min and the test order was
163 always the same for all the participants (i.e., Stroop task, CMJ, and decision-making
164 performance during simulated combat). The participants were familiarized with all measures
165 (see details in “measures”) before the investigation began.

166 The three experimental conditions order were randomized, which made the
167 participants performed the smartphone (30SMA), videogame (30VID), and control (CON)
168 conditions in a random order separated by a one-week washout (Figure 1). Simple

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3 169 randomization was carried out for the three experimental conditions (CON, 30SMA, and
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5 170 30VID). A random number table was generated on www.randomizer.org site. The athletes
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7
8 171 were submitted to the same procedure's settings throughout each experimental condition in
9
10 172 this study. Two boxers were assessed per session, and the boxers were always paired (CON,
11
12 173 30SMA, and 30VID) with the same opponent, as used in other studies about mental fatigue
13
14 174 and sport performance (Gantois et al., 2019; Penna et al., 2018). It's important statement that
15
16
17 175 boxers didn't train with their opponents. Until the end of the experiment, the participants were
18
19 176 not aware the experimental question and the issue that was under investigation.

21 177 The Stroop task (~90-s of duration) assessed the MF level before and after the three
22
23 178 sessions: social media use on smartphones, playing video game, and watching TV
24
25 179 (documentary about the Olympic Games). Then, the participants warmed-up for 5-min in a
26
27 180 ring (the same warm-up was adopted in the three experimental conditions). Next, a 5-min
28
29 181 interval was given between the warm-up and the beginning of the simulated combat,
30
31 182 considering the post-activation potential phenomenon (Wilson et al., 2013). Finally, the
32
33 183 athletes participated in simulated combat (four rounds of 2-min with 1-min interval),
34
35 184 adopting the official boxing rules. All combats (four rounds) were filmed using a CANON®
36
37 185 camera (SX60 model, Yokohama, Japan) for further analysis of boxing decision-making
38
39 186 performance using the Game Performance Analysis Instrument (Memmert & Harvey, 2008).

44 187 Perceived recovery was measured before the experiment, and CMJ performance was
45
46 188 obtained before and 30-min after each experimental session. Rating of perceived exertion
47
48 189 (RPE) was measured immediately after the combat simulation. All experimental procedures
49
50 190 are illustrated in Figure 1.

51 191

52 192

*****Figure 1 insert here*****

53 193

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194 ***Experimental Interventions***

195 *CON, 30SMA, and 30VID*. We recommended the athletes to ingest fluid ad libitum up to 2 h
196 before each experimental session. Smartphone use was forbidden 2 h before each
197 experimental session. The CON consisted of watching coaching video about Olympic Games
198 for 30-min on an 84-inch screen (smartphone free room). The emotionally neutral videos
199 were used and did not involve watching boxing matches. This same video was used during
200 CON condition in other studies about mental fatigue and sport performance (Fortes et al.,
201 2020a; 2020b). Studies related to mental fatigue and human performance have long used
202 these emotionally neutral videos in control conditions (Marcora et al., 2009; Gantois et al.,
203 2019) because neither cognitive performance nor underlying brain mechanisms of mental
204 fatigue were found to be altered (Franco-Alvarenga et al., 2019). The 30SMA condition
205 consisted of using social media apps (WhatsApp[®], Facebook[®], and Instagram[®]) during 30-
206 min just before the combat simulation. The smartphone use was supervised to ensure the
207 athletes would only use social media apps. The 30VID condition was composed of playing
208 video games in the first person (Fight Night Round 3, EA Sports[®], EUA) lasting 30-min
209 duration on an 84-inch screen. All participants remained in the same room while using their
210 smartphone, playing video games, or watching a documentary. The participants were
211 prohibited from speaking amongst themselves.

212

213 ***Measures***

214 *Boxing decision making-performance*. The decision-making was evaluated during simulated
215 combats. The participants fought four rounds of 2-min with 1-min interval, adopting the
216 official rules of boxing. The opponents were of the same weight category and the same
217 competitive level to ensure similar technical skills between them. The entire combat was
218 recorded with a CANON[®] camera (SX60 model, Yokohama, Japan). Participants were

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3 219 oriented to “try to score as many points as possible”. The analysis and categorization of
4
5 220 actions were run based on the GPAI (Memmert & Harvey, 2008). Memmert and Harvey
6
7 221 (2008) highlighted that the GPAI evaluates the appropriate decisions. The boxing coaches
8
9 222 used scales that were structured and anchored with specific descriptions. The attack (i.e., jab,
10
11 223 uppercut, right cross, or hook) and defense (i.e., slip, block, or duck) decision-making
12
13 224 components were adopted. The appropriate decision-making was considered when the
14
15 225 attempted attack was directed to a vulnerable region of the opponent (head or trunk) that
16
17 226 could result in a score, or the attempted defense was correctly directed to inhibit or prevent
18
19 227 the opponent’s attack. Any other boxing decision-making different from those indicated
20
21 228 above was classified as inappropriate. The different decisions between the coaches were not
22
23 229 encoded and were not analyzed. The obtained data (videos) were analyzed using open-license
24
25 230 video analysis software (Kinovea 0.8.15 for Windows) for, when necessary, visualize the
26
27 231 actions of boxers in slow motion.

28
29 232 The decision-making index (DMI) was calculated according to the formula below,
30
31 233 following the modifications suggested by Memmert and Harvey (2008). Two experienced
32
33 234 boxing coaches analyzed the combat actions (they oversaw the videos on an 84-inch tv
34
35 235 screen) and categorized it as appropriate or inappropriate. The investigators who reviewed the
36
37 236 video footage and categorized decision-making actions were blinded to the experimental
38
39 237 treatments [30SMA vs. 30VID vs. CON] to attenuate bias risk. The acceptable coefficient of
40
41 238 agreement for the DMI (attack: kappa = 0.93, p = 0.001; defense: kappa = 0.91, p = 0.001)
42
43 239 was calculated by the main researcher for the scores of the two boxing coaches. The
44
45 240 intraclass coefficient correlation (ICC) was used to determine the reliability of attack (ICC =
46
47 241 0.82, CI_{95%} = 0.75 to 0.88) and defense decision-making (ICC = 0.79, CI_{95%} = 0.72 to 0.86).

$$\text{DMI} = \frac{Aa}{Aa + Ia} \times 100$$

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51 243 Aa = appropriate actions

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3 244 Ia = inappropriate actions
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8 246 *Countermovement jump (CMJ)*. An electronic contact jump mat (Hidrofit®, Jump System,
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10 247 Belo Horizonte, Brazil) was used to analyze the CMJ height. Each participant performed
11

12 248 three attempts with 30-s interval among trials, and the best attempt was analyzed. The
13

14 249 participants completed the CMJ with hands on the waist and no restrictions on the knee angle
15

16 250 during the eccentric phase of the jump. Also, the participants were instructed to maintain the
17

18 251 legs in a straight position during the flight and land phases at the take-off point. The
19

20 252 participants were familiarized with the test prior to each experimental condition. In the
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22 253 present study, the ICC was 0.98 ($IC_{95\%} = 0.94$ to 0.99) for CMJ, indicating good
23

24 254 reproducibility of the test.
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30
31 256 *Recovery perceived*. The Total Quality Recovery (TQR) scale proposed by Kenttä and
32

33 257 Hassmén (1998) and validated to the Brazilian culture by Osieck, Osiecki, Burigo, Coelho,
34

35 258 and Malfatti (2015) was used before each experimental condition to assess the level of
36

37 259 perceived recovery. The TQR is a scale that ranges from six (nothing recovered) to 20 (fully
38

39 260 recovered). That is, the higher the value, the higher the level of perceived recovery. The ICC
40

41 261 and coefficient of variation (CV) determined the reliability of the level of perceived recovery
42

43 262 (ICC = 0.85, CV = 9.3%). The results revealed no difference for recovery perceived between
44

45 263 experimental conditions ($F_{(3, 17)} = 1.47$; $p = 0.82$).
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51 265 *Subjective Rating of Mental Fatigue*. The subjective rating of MF was assessed using the 100
52

53 266 mm Visual Analogue Scale (VAS)'s as previously adopted (Franco-Alvarenga et al., 2019).
54

55 267 This scale has two extremities anchored from 0 (none at all) to 100 (maximal). No other
56

57 268 descriptor was presented in the VAS. The participants were required to answer, "How
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3 269 mentally fatigued you feel now?”. Participants were oriented to point throughout the 100mm-
4
5 270 horizontal line-scale their perceived status. To quantify the values, we measured the
6
7
8 271 millimeter distance from the 0 to the end of the line indicated by the participant.
9

10 272
11
12 273 *Stroop task.* The Stroop task (Graf, Uttl, & Tuokko, 1995) assessed inhibitory control and
13
14 274 selective attention, both considered components of the cognitive function. Two assessments
15
16 275 were performed pre and post-each experimental conditions. Considering scientific evidence
17
18 276 has shown impaired accuracy or response time in Stroop task in athletes mentally fatigued
19
20 277 (Marcora et al., 2009; Penna et al., 2018; Smith et al., 2016), it was decided to use this test to
21
22 278 measure mental fatigue, as method has already used in other investigations (Fortes et al.,
23
24 279 2020a; Gantois et al., 2019). The participants answered the word color or according to its
25
26 280 name, since the color of the words might be different from what is typed (e.g., the word
27
28 281 “blue” might show up in “red” color, the word “green” in “blue”, and so on). A stimulus of
29
30 282 30 words with 200 ms of the interval was provided between the response and a new stimulus.
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35 283 Moreover, the stimulus did not fade from the screen until any response was given.
36
37 284 Stimuli vary between congruent (word and color have the same meaning), incongruent (word
38
39 285 and color have a different meaning), and control (colored rectangle with one of the colors of
40
41 286 the test: red, green, blue, and black). The keys D (red), F (green), J (blue), and K (black) were
42
43 287 pressed to answer the questions. The stimulus disappeared when the answer was correct, and
44
45 288 then a new one was set. An “X” letter was showed up on the screen in case of incorrect
46
47 289 answers, and a new stimulus was displayed. The accuracy of the correct answers and
48
49 290 response time were collected at the end of the test, and the evaluator was blind for the
50
51 291 assessments and had previous training for the test. The tests were performed on a full-HD
52
53 292 screen (1800 × 1260 pixels) laptop (MacBook Pro, A1502 model, USA). The ICC and CV
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293 were used to determine the reliability of accuracy (ICC = 0.84, CV = 5.6%) and response
294 time (ICC = 0.96, CV = 7.2%).

295
296 *RPE*. The RPE was measured immediately after the simulated combat in each of the
297 experimental conditions (CON, 30SMA, and 30VID). The athletes answered the following
298 question: "How intense was the combat?". The athlete was asked to demonstrate the intensity
299 perception of the simulated combat from the 10-point Borg scale (0 = nothing at all to 10 =
300 extremely strong). Noteworthy, the athletes were familiar with the 10-point Borg scale for 30
301 days before the beginning of the investigation.

302

303 *Statistical analysis*

304 The Shapiro Wilk test was conducted to evaluate data distribution. The Levene test
305 assessed homoscedasticity. Repeated measures ANOVA was used to compare the perceived
306 recovery level and intensity perception of the simulated combat between the treatments
307 (CON, 30SMA, and 30VID). The Bonferroni post hoc test was used to identify statistical
308 differences. The two-way Anova was used to analyze condition (CON, 30SMA, and 30VID)
309 vs. time (pre-vs post-experimental conditions) interaction for Stroop Task performance
310 (accuracy and response time) and VAS. The same test was used to analyze condition (CON
311 vs. 30SMA vs. 30VID) vs. time (pre-experiment vs. post-experiment) interaction for CMJ.
312 The 3x3 Mixed Model's analysis was conducted to analyze condition (CON vs. 30SMA vs.
313 30VID) vs. time (baseline vs. 1st + 2nd rounds vs. 3rd + 4th rounds) interaction for boxing
314 decision-making performance (attack and defense). Post-hoc pairwise comparisons were
315 conducted using Bonferroni's test when appropriate. Partial eta squared (η^2) effect size (ES)
316 were determined and interpreted using the following cutoff's (Cohen, 1992): small effect, η^2
317 < 0.03 ; moderate effect, $0.03 \leq \eta^2 < 0.10$; large effect, $.10 \leq \eta^2 < 0.20$; very large effect,

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318 $\eta^2 \geq .020$. Data were processed in the Statistical Package for Social Sciences Version 21.0
319 (IBM Corp., Armonk, NY, USA) and GraphPad Prism 8 (San Diego, CA, USA) with a
320 significance level of 5%.

Results

Mental Fatigue

324 *Subjective Rating of perceived MF.* The results showed a condition effect [$F_{(3, 17)} = 103.72$; p
325 $= 0.001$ ($CI_{95\%} = 0.001$ to 0.02); $\eta^2 = 0.08$ ($CI_{95\%} = 0.04$ to 0.99); medium ES] for
326 subjective rating of perceived MF. Also, a time effect for the subjective rating of perceived
327 MF was found [$F_{(2, 18)} = 419.90$; $p = 0.001$ ($CI_{95\%} = 0.001$ to 0.01); $\eta^2 = 0.14$ ($CI_{95\%} = 0.10$
328 to 0.17); large ES]. It was revealed a condition x time interaction for the subjective rating of
329 perceived MF [$F_{(6, 14)} = 103.52$; $p = 0.001$ ($CI_{95\%} = 0.001$ to 0.004); $\eta^2 = 0.12$ ($CI_{95\%} = 0.10$
330 to 0.15); medium ES; CON: 2.95 ± 1.22 mm and 3.23 ± 5.46 mm for pre and post-TV,
331 respectively; 30SMA: 3.23 ± 5.48 mm and 69.66 ± 19.85 mm for pre and post-smartphone,
332 respectively; 30VID: 2.80 ± 4.58 mm and 70.04 ± 20.11 mm for pre and post-videogame,
333 respectively]. The 30SMA and 30VID conditions presented higher subjective rating of
334 perceived MF than CON condition (Figure 2; $p = 0.001$). No difference was observed
335 between 30SMA and 30VID for the subjective rating of perceived MF ($p = 0.84$).

336
337 *Stroop task.* The findings showed no condition [$F_{(3, 17)} = 0.54$; $p = 0.58$ ($CI_{95\%} = 0.40$ to
338 0.62); $\eta^2 = 0.02$ ($CI_{95\%} = 0.005$ to 0.03); small ES] and time effect [$F_{(2, 18)} = 2.78$; $p = 0.10$
339 ($CI_{95\%} = 0.08$ to 0.23); $\eta^2 = 0.01$ ($CI_{95\%} = 0.006$ to 0.02); small ES] for accuracy in the
340 Stroop task (Figure 3). Also, no interaction effect was found for accuracy [$F_{(6, 14)} = 0.52$; $p =$
341 0.59 ($CI_{95\%} = 0.52$ to 0.75); $\eta^2 = 0.02$ ($CI_{95\%} = 0.001$ to 0.03); small ES; CON: 90.95 ± 5.61
342 % and 92.85 ± 5.14 % for pre and post-TV, respectively; 30SMA: 92.38 ± 4.96 % and 92.45

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343 ± 5.80 % for pre and post-smartphone, respectively; 30VID: 93.10 ± 5.41 % and 92.53 ± 4.19
344 % for pre and post-videogame, respectively].

345 However, the results showed condition [$F_{(3, 17)} = 3.42$; $p = 0.04$ ($CI_{95\%} = 0.01$ to 0.06);
346 $\eta^2 = 0.03$ ($CI_{95\%} = 0.02$ to 0.05); moderate ES) and time effects [$F_{(2, 18)} = 41.22$; $p = 0.001$
347 ($CI_{95\%} = 0.001$ to 0.003); $\eta^2 = 0.07$ ($CI_{95\%} = 0.05$ to 0.10); medium ES] for response time.

348 Also, it was found a condition x time interaction regarding response time [$F_{(6, 14)} = 7.53$; $p =$
349 0.001 ($CI_{95\%} = 0.001$ to 0.03); $\eta^2 = 0.05$ ($CI_{95\%} = 0.04$ to 0.09); moderate ES; CON: 637.14
350 ± 136.35 ms and 641.28 ± 150.98 ms for pre and post-TV; 30SMA: 645.23 ± 131.65 ms and
351 713.33 ± 145.23 ms for pre and post-smartphone; 30VID: 660.05 ± 128.70 ms and $721.46 \pm$
352 150.62 ms for pre and post-videogame]. The 30SMA and 30VID conditions showed higher
353 response time in comparison to CON condition (Figure 3; $p = 0.001$). No difference was
354 found between 30SMA and 30VID for response time in the Stroop task ($p = 0.75$).

355

356 *****Figure 2 insert here*****

357

358 *****Figure 3 insert here*****

359

360 ***Boxing decision-making performance***

361 *Attack decision-making.* The findings showed a condition [$F_{(3, 17)} = 7.75$; $p = 0.001$ ($CI_{95\%} =$
362 0.001 to 0.02); $\eta^2 = 0.08$ ($CI_{95\%} = 0.06$ to 0.11); moderate ES] and time effects ($F_{(2, 18)} =$
363 10.70 ; $p = 0.001$ ($CI_{95\%} = 0.001$ to 0.004); $\eta^2 = 0.07$ ($CI_{95\%} = 0.05$ to 0.08); moderate ES]
364 for attack decision-making performance. It was also found a condition x time interaction for
365 attack decision-making performance [Figure 4; $F_{(6, 14)} = 2.79$; $p = 0.01$ ($CI_{95\%} = 0.002$ to
366 0.03); $\eta^2 = 0.04$ ($CI_{95\%} = 0.02$ to 0.06); moderate ES]. The attack decision-making
367 performance in the 1st + 2nd rounds was lower in the 30SMA and 30VID conditions than

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3 368 CON condition ($p = 0.001$). The attack decision-making performance in the 3rd + 4th rounds
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5 369 was impaired in both 30SMA ($p = 0.01$) and 30VID ($p = 0.04$) compared to CON condition.
6
7
8 370 There was no difference in attack decision-making performance between 30SMA and 30VID
9
10 371 in the 1st + 2nd rounds ($p = 0.94$) and 3rd + 4th rounds ($p = 0.86$). The attack decision-making
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12 372 performance was attenuated in 30SMA and 30VID conditions in 1st + 2nd rounds ($p = 0.001$)
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14 373 and 3rd + 4th rounds ($p = 0.001$) compared to baseline.

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19 375 *Defense decision-making.* It was shown a condition [$F_{(3, 17)} = 10.27$; $p = 0.001$ ($CI_{95\%} = 0.001$
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21 376 to 0.03); $\eta^2 = 0.08$ ($CI_{95\%} = 0.06$ to 0.10); moderate ES] and time effects [$F_{(2, 18)} = 26.50$; p
22
23 377 = 0.001 ($CI_{95\%} = 0.001$ to 0.02); $\eta^2 = 0.11$ ($CI_{95\%} = 0.09$ to 0.13); large ES] for defense
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25 378 decision-making performance. Still, it was revealed a condition x time interaction for defense
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28 379 decision-making performance [Figure 5; $F_{(6, 14)} = 3.63$; $p = 0.002$ ($CI_{95\%} = 0.001$ to 0.03); η^2
29
30 380 = 0.05 ($CI_{95\%} = 0.05$ to 0.08); moderate ES]. The defense decision-making performance in
31
32 381 the 1st + 2nd rounds was worse in 30SMA and 30VID than CON experimental condition ($p =$
33
34 382 0.001). The defense decision-making performance in the 3rd + 4th rounds was impaired in
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36 383 30SMA ($p = 0.003$) and 30VID ($p = 0.007$) compared to CON condition. There was no
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38 384 difference in defense decision-making performance between 30SMA and 30VID in the 1st +
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40 385 2nd rounds ($p = 0.81$) and 3rd + 4th rounds ($p = 0.90$). The defense decision-making
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42 386 performance was lower in both 30SMA and 30VID experimental conditions in 1st + 2nd
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44 387 rounds ($p = 0.001$) and 3rd + 4th rounds ($p = 0.001$) compared to baseline.

388

389 ***Figure 4 insert here***

390

391 ***Figure 5 insert here***

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MENTAL FATIGUE AND BOXING

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394 **CMJ**

395 The findings showed no condition effect [$F_{(3, 17)} = 0.04$; $p = 0.96$ ($CI_{95\%} = 0.87$ to
396 0.99); $\eta^2 = 0.01$ ($CI_{95\%} = 0.002$ to 0.04); small ES] for CMJ, despite the time effect
397 observed [$F_{(2, 18)} = 176.31$; $p = 0.001$ ($CI_{95\%} = 0.001$ to 0.01); $\eta^2 = 0.16$ ($CI_{95\%} = 0.12$ to
398 0.18); large ES]. It was found a decrease in the CMJ in post-experiment (30-min) for all
399 conditions compared to baseline measure ($p = 0.001$; CON: 38.38 ± 4.27 cm and 34.61 ± 4.09
400 cm for pre and post-TV, respectively; 30SMA: 38.75 ± 3.96 cm and 35.02 ± 4.38 cm for pre
401 and post-smartphone, respectively; 30VID: 38.40 ± 4.13 cm and 34.87 ± 4.61 cm for pre and
402 post-videogame, respectively), with no difference between conditions.

403

404 **RPE**

405 The results demonstrated significant difference for RPE between experimental
406 conditions [$F_{(3, 17)} = 10.86$; $p = 0.001$ ($CI_{95\%} = 0.001$ to 0.02); $\eta^2 = 0.09$ ($CI_{95\%} = 0.06$ to
407 0.10); moderate ES; CON: 8.1 ± 1.3 u.a.; 30SMA: 8.9 ± 1.0 u.a.; 30VID: 9.0 ± 0.8 u.a.].
408 Specifically, higher RPE was found for 30SMA and 30VID in comparison to CON condition
409 (Figure 2; $p = 0.001$).

410

411 **Discussion**

412 The objective of this study was to analyze the acute effects of social media use on
413 smartphones and playing video games on decision-making (attack and defense) and CMJ
414 performances in amateur boxing athletes. The main findings showed that both smartphone
415 use and video game experimental conditions impaired boxing decision-making performance
416 (attack and defense) compared to control one (i.e., watching TV), but CMJ performance was

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3 417 not changed by the social media use on smartphones or playing video games, which, indeed,
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5 418 confirms the hypotheses of the study.

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8 419 The findings indicated that social media use on smartphones (30SMA) and playing
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10 420 video games (30VID) for 30-min induced MF. The subjective rating of MF and response time
11
12 421 in the Stroop task were greater in both 30SMA and 30VID conditions. These findings
13
14 422 corroborate with recent previous studies (Fortes et al., 2019a; Fortes et al., 2019b). Durand-
15
16 423 Bush and DesClouds (2018) indicated drawbacks for cognitive performance (e.g., disrupt
17
18 424 attention, concentration, memory, and executive function) when athletes use electronic
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20 425 devices (e.g., videogames), mainly social media on smartphones. Social media use on
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22 426 smartphones and playing videogames for a prolonged period requires high cognitive
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24 427 inhibition and sustained attention (Durand-Bush & DesClouds, 2018). So, the use of social
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26 428 media on smartphones and playing videogame for a prolonged period might carry out MF
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28 429 (Fortes et al., 2019; Fortes et al., 2020a).

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31 430 MF induced impaired decision-making performance (attack and defense) in amateur
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33 431 boxers. Our results are supported by other literature findings, although performed with soccer
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35 432 athletes (Fortes et al., 2019a; Gantois et al., 2019; Smith et al., 2016). It was previously
36
37 433 reported that MF reduces attention, focus, reaction time, visual cue interpretation, and also
38
39 434 motor control, which consequently affect performance (Boksem, Meijman, & Lorist, 2005;
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41 435 Lorist, Boksem, & Ridderinkhof, 2005; Jacquet, Poulin-Charronnat, Bard, & Leppers, 2021).
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43 436 The adverse effect of MF on attack decision-making has important implications for boxing
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45 437 athletes, once hitting the opponent is the main aim during the combat and may determine the
46
47 438 winner. The boxing athlete mentally fatigued might misinterpret or delay the right moments
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49 439 to perform the appropriate attacks (e.g., jab, direct, hook, so on) or defense movements,
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51 440 which may impair performance. Also, combat athletes with compromised decision-making
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53 441 performance are more vulnerable to knockouts (Fortes et al., 2017; Franchini et al., 2013).
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3 442 It might happen due to a failure in the brain information in the environment
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6 443 processing (Smith et al., 2018; Thompson et al., 2018), that is, the athlete mentally fatigued
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8 444 presents impaired executive functions (e.g., attention, inhibitory control, memory work, and
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10 445 cognitive flexibility) (Fortes et al., 2019a; Smith et al., 2016). It is important to highlight that
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12 446 the results of this study also revealed that inhibitory control performance is impaired in
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14 447 mentally fatigued boxing athletes (Stroop task). In boxing, the athletes perform rapid actions
15
16 448 because the time to avoid the opponent's punch is short. The duration of ballistic movements,
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18 449 such as the punch, is usually lower than 200-ms. So, MF seems to be harmful to cognitive
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20 450 performance in boxing athletes. Still, new experimental studies to confirm these cognitive
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22 451 mechanisms are needed.

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26 452 No effect of MF was found for CMJ performance. The results indicated that the CMJ
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28 453 performance was attenuated after the simulated combat in all three conditions, with no
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30 454 differences between them. These findings corroborate Rozand et al. (2014) and Silva-
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32 455 Cavalcante et al. (2018), which has demonstrated that high-intensity and short-duration
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34 456 physical efforts are not affected by MF. It might happen because the mechanisms that
35
36 457 regulate high-intensity physical exercise are peripherals (Silva-Cavalcante et al., 2018), while
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38 458 the MF mechanisms are brain-related (Franco-Alvarenga et al., 2019; Pires et al., 2019). It is
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40 459 essential to highlight the relationship between CMJ performance and punch power output in
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42 460 boxing athletes (Loturco et al., 2019). In this sense, although the punch's power output might
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44 461 remain unaltered by MF, once the decision-making performance is reduced, the appropriate
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46 462 moment to perform the punch may be impaired.

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51 463 Concerning the RPE, both 30SMA and 30VID conditions presented higher values
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53 464 than the CON condition. Previous studies indicated that the MF increases RPE in athletes
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55 465 (Marcora et al., 2009; Penna et al., 2018) once it is regulated by the inhibitory control
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3 466 (Marcora, 2008), more specifically, in the anterior cingulate cortex, which might explain the
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5 467 results of RPE in the present study.

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8 468 Although the study presented novel and significant findings, some limitations must be
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10 469 mentioned. The motivation was not measured before and after cognitive manipulation (CON,
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12 470 30SMA, and 30VID). Also, the psychomotor vigilance task (PVT) was not used to measure
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14 471 mental fatigue before and after cognitive manipulation. The theta (Franco-Alvarenga et al.,
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16 472 2019; Pires et al., 2019) and alpha (Jacquet et al., 2021) waves in the electroencephalogram
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18 473 (EEG), a mental fatigue indicator, were not measured as well as decision-making
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20 474 performance using the eye-tracking system. The screen size was different between cognitive
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22 475 manipulation (e.g., CON, 30SMA, and 30VID) and it may have affected the level of mental
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24 476 fatigue, because the level of cognitive effort can be different. On the other hand, the present
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26 477 study demonstrates strong points that should be highlighted. The experimental design shows
27
28 478 high ecological validity, once MF was induced by social media on smartphones and playing
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30 479 video games. Furthermore, the decision-making performance was analyzed in simulated
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32 480 combat, adopting the official boxing rules.

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37 481 From a practical standpoint, the present findings demonstrated that a prolonged time
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39 482 using (more than 30-min) social media on smartphones (WhatsApp®, Instagram®, or
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41 483 Facebook®) or playing video games must be avoided before combat or training session for
42
43 484 amateur boxing athletes; Also, CMJ performance is not impaired by MF. Finally, it is
44
45 485 essential to mention that high-internal training load induced by prolonged use of social media
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47 486 on smartphones or playing video games might make athletes vulnerable to non-functional
48
49 487 overreaching. Future study could investigate the repeated effect of social media network or
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51 488 sport-based videogame immediately before the training sessions on perceptual-cognitive skill
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53 489 (e.g., decision-making) and non-functional overreaching (e.g., cumulated internal training
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55 490 load) in combat sport athletes.
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Conclusion

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Our results showed the MF impaired the attack and defense decision-making

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performance in amateur boxers, with no harms for CMJ performance. It seems that the MF

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caused by the use of social media on smartphones or playing video games also increase RPE

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in simulated combat. The present finding may guide coaches in how to manage the athlete's

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leisure time right before training sessions and competition combats.

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References

500

Araújo, D., Davids, K., Diniz, A., Rocha, L., Santos, J. C., Dias, C., et al. (2015). Ecological

501

dynamics of continuous and categorical decision-making: The regatta start in sailing.

502

European Journal of Sport Science, 15(3), 195–202. doi: 10.1080/

503

17461391.2014.928749

504

Baker, J., Cote, J., & Abernethy, B. (2003). Sport-specific practice and the development of

505

expert decision-making in team ball sports. *Journal of Applied Sport Psychology*,

506

15(1), 12–25. [https:// doi.org/10.1080/10413200305400](https://doi.org/10.1080/10413200305400)

507

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on

508

attention: an ERP study. *Cognitive Brain Research*. 25(1), 107-16.

509

Campos, B. T., Penna, E. M., Rodrigues, G. S., Mendes, T. T., Maia-Lima, A., Nakamura, F.

510

Y., Vieira, E. M., Wanner, S. P., & Prado, L. S. (2019). Influence of mental fatigue on

511

physical performance, and physiological and perceptual responses of judokas

512

submitted to the Special Judo Fitness Test. *Journal of Strength and Conditioning*

513

Research, ahead of print. doi: 10.1519/JSC.0000000000003453

514

Cohen, J. (1992). Quantitative methods in psychology: a power primer. *Psychological*

515

Bulletin, 112(1), 155-159.

MENTAL FATIGUE AND BOXING

2

- 1
2
3 516 Diaz-Brage, P., Fernandez-del-Olmo, M., Ling, L., Rio-Rodriguez, D., & Fogelson, N.
4
5 517 (2018). Athletes versus video game players: A predictive contextual processing study.
6
7 518 *Neuroscience Letters*, 684, 156-163. doi: 10.1016/j.neulet.2018.08.014
9
10 519 Durand-Bush, N., & DesCloudes, P. (2018). How can mental performance consultants help
11
12 520 athletes and coaches leverage their use to generate more benefits than drawbacks?
13
14 521 *Journal of Psychology Psychology in Action*, 9(4), 227-238. doi:
15
16 522 10.1080/21520704.2018.1496211
18
19 523 Duru, A. D., & Assem, M. (2018). Investigating neural efficiency of elite karate athletes
20
21 524 during a mental arithmetic task using EEG. *Cognitive Neurodynamics*, 12(1), 95-102.
22
23 525 doi: 10.1007/s11571-017-9464-y
25
26 526 Fink, A., Bay, J. U., Koschutnig, K., Prettenthaler, K., Rominger, C., Benedek, M., Papousek,
27
28 527 I., Weiss, E. M., Seidel, A., & Memmert, D. (2019). Brain and soccer: Functional
29
30 528 patterns of brain activity during the generation of creative moves in real soccer
31
32 529 decision-making situations. *Human Brain Mapping*, 40(3), 755-764. doi:
33
34 530 10.1002/hbm.24408
36
37 531 Fortes, L. S., Costa, B. D. V., Paes, P. P., Cyrino, E. S., Vianna, J. M., & Franchini, E.
38
39 532 (2017). Effect of rapid weight loss on physical performance in judo athletes: is rapid
40
41 533 weight loss a help for judokas with weight problems? *International Journal of*
42
43 534 *Performance Analysis in Sport*, 17(5), 763-773. doi:
44
45 535 10.1080/24748668.2017.1399323
47
48 536 Fortes, L. S., De Lima-Junior, D., Gantois, P., Junior, J. R. A. do N., & Fonseca, F. S.
49
50 537 (2020a). Smartphone use among high level swimmers is associated with mental
51
52 538 fatigue and slower 100- and 200- but not 50-meter freestyle racing. *Perceptual and*
53
54 539 *Motor Skills (Ahead of Print)*. doi: 10.1177/0031512520952915
55
56
57
58
59
60

MENTAL FATIGUE AND BOXING

2

- 1
2
3 540 Fortes, L. S., De Lima-Junior, D., Fiorese, L., Nascimento-Júnior, J. R. A., Mortatti, A. L., &
4
5 541 Ferreira, M. E. C. (2019b). The effect of smartphones and playing video games on
6
7 542 decision-making in soccer players: a crossover and randomized study. *Journal of*
8
9 543 *Sports Sciences, ahead of print*. doi: 10.1080/17461391.2019.1656781
10
11
12 544 Fortes, L. S., Lima-Junior, D., Nascimento-Júnior, J. R. A., Costa, E. C., Matta, M. O., &
13
14 545 Ferreira, M. E. C. (2019a). Effect of exposure time to smartphone apps on passing
15
16 546 decision-making in male soccer athletes. *Psychology of Sport and Exercise, 44*, 35-41.
17
18 547 doi: 10.1016/j.psychsport.2019.05.001
19
20
21 548 Fortes, L. S., Nascimento-Júnior, J. R. A., Mortatti, A. L., Lima- Júnior, D. R. A. A. d., &
22
23 549 Ferreira, M. E. C. (2018). Effect of dehydration on passing decision making in soccer
24
25 550 athletes. *Research Quarterly for Exercise and Sport, 89*(3), 1–8. doi: 10.
26
27 551 1080/02701367.2018.1488026
28
29
30 552 Fortes, L. S., Nakamura, F. Y., Lima-Junior, D., Ferreira, M. E. C., & Fonseca, F. S. (2020b).
31
32 553 Does social media use on smartphones influence endurance, power, and swimming
33
34 554 performance in high-level swimmers? *Research Quarterly for Exercise and Sport, 91*,
35
36 555 1–10. <https://doi.org/10.1080/02701367.2020.1810848>
37
38
39 556 Franchini, E., Artioli, G. G., & Brito, C. J. (2013). Judo combat: Time-motion analysis and
40
41 557 physiology. *International Journal of Performance Analysis in Sport, 13*(4), 624–641.
42
43
44 558 Franco-Alvarenga, P. E., Brietzke, C., Canestri, R., Goethel, M. F., Hettinga, F., Santos, T.
45
46 559 M., & Pires, F. O. (2019). Caffeine improved cycling trial performance in mentally
47
48 560 fatigued cyclists, despite unchanged prefrontal cortex activation. *Physiology &*
49
50 561 *Behavior, ahead of print*. doi: 10.1016/j.physbeh.2019.02.009
51
52
53 562 Gantois, P., Ferreira, M. E. C., Lima-Junior, D., Nakamura, F. Y., Batista, G. R., Fonseca, F.
54
55 563 S., & Fortes, L. S. (2019): Effects of mental fatigue on passing decision-making
56
57
58
59
60

MENTAL FATIGUE AND BOXING

2

- 1
2
3 564 performance in professional soccer athletes, *European Journal of Sport Science*,
4
5 565 *ahead of print*. doi: 10.1080/17461391.2019.1656781
6
7
8 566 Graf, P., Uttl, B., & Tuokko, H. (1995). Color- and picture-word stroop tests: Performance
9
10 567 changes in old age. *Journal of Clinical and Experimental Neuropsychology*, *17*, 390–
11
12 568 415.
13
14
15 569 Jacquet, T., Poulin-Charronnat, B., Bard, P., & Lepers, R. (2021). Persistence of mental
16
17 570 fatigue on motor control. *Frontiers in Psychology*, *11*, e588253.
18
19 571 doi: 10.3389/fpsyg.2020.588253.
20
21
22 572 Kenttä, G., & Hassmén, P. (1998). Overtraining and recovery. A conceptual model. *Sports*
23
24 573 *Medicine*, *26*(1), 1–16.
25
26 574 Lenetsky, S., Brughelli, M., Nates, R. J., Neville, J. G., Cross, M. R., Lormier, A. V. (2019).
27
28 575 Defining the phases of boxing punches: A mixed-method approach. *Journal of*
29
30 576 *Strength and Conditioning Research*, *ahead of print*. doi:
31
32 577 10.1519/JSC.0000000000002895
33
34
35 578 López-Laval, I., Sitko, S., Muñoz-Pardos, B., Cirer-Sastre, R., & Calleja-González, J. (2019).
36
37 579 Relationship between bench press strength and punch performance in male
38
39 580 professional boxers. *Journal of Strength and Conditioning Research*, *ahead of print*.
40
41 581 doi: 10.1519/JSC.0000000000003362
42
43
44 582 Loturco, I., Pereira, L. A., Kobal, R., Fernandes, V., Reis, V. P., Romano, F., Alves, M.,
45
46 583 Freitas, T. T., & McGuigan, M. (2019). Transference effect of short-term optimum
47
48 584 power load training on the punching impact of elite boxers. *Journal of Strength and*
49
50 585 *Conditioning Research*, *ahead of print*. doi: 10.1519/JSC.0000000000003165
51
52
53 586 Lorist, M. M., Boksem, M. A., & Ridderinkhof, K. R. (2005). Impaired cognitive control and
54
55 587 reduced cingulate activity during mental fatigue. *Cognitive Brain Research*, *24*(2),
56
57 588 199-205.
58
59
60

MENTAL FATIGUE AND BOXING

2

- 1
2
3 589 Marcora, S.M. (2008). Do we really need a central governor to explain brain regulation of
4
5 590 exercise performance? *European Journal Applied Physiology*, *104*(5), 929-31. doi:
6
7 591 10.1007/s00421-008-0818-3
8
9
10 592 Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical
11
12 593 performance in humans. *Journal of Applied Physiology*, *106*(3), 857–864. doi:
13
14 594 10.1152/jappphysiol.91324.2008
15
16
17 595 Martin, K. Meeusen, R. Thompson, K. G., Keegan, R., & Rattray, B. (2018). Mental fatigue
18
19 596 impairs endurance performance: A physiological explanation. *Sports Medicine*, *48*(9),
20
21 597 2041-2051. doi: 10.1007/s40279-018-0946-9
22
23
24 598 McMorris, T. (2020). Cognitive fatigue effects on physical performance: The role of
25
26 599 interoception. *Sports Medicine, (Ahead of Print)*. doi: 10.1007/s40279-020-01320-w
27
28 600 McMorris, T., Barwood, M., Hale, B. J., Dicks, M., & Corbett, J. (2018). Cognitive fatigue
29
30 601 effects on physical performance: A systematic review and meta-analysis. *Physiology*
31
32 602 *& Behavior, a head of print*. doi: 10.1016/j.physbeh.2018.01.029
33
34
35 603 Memmert, D., & Harvey, S. (2008). The Game Performance Assessment Instrument (GPAI):
36
37 604 some concerns and solutions for further development. *Journal of Teaching in*
38
39 605 *Physical Education*, *27*(2), 220–240. doi:10.1123/jtpe.27.2.220
40
41
42 606 Osiecki, R., Osiecki, T., Burigo, T., Coelho, R. L., & Malfatti, C. R. M. (2015). The total
43
44 607 quality recovery scale (TQR) as a proxy for determining athletes? Recovery state after
45
46 608 a professional soccer match. *Journal of Exercise Physiology Online*, *18*(3), 27–32.
47
48
49 609 Pageaux, B., Marcora, S. M., & Lepers, R. (2013). Prolonged mental exertion does not alter
50
51 610 neuromuscular function of the knee extensors. *Medicine & Science in Sports &*
52
53 611 *Exercise*, *45*(12), 2254–2264. doi: 10.1249/MSS.0b013e31829b504a
54
55
56
57
58
59
60

MENTAL FATIGUE AND BOXING

2

- 1
2
3 612 Penna, E. M., Filho, E., Wanner, S. P., Campos, B. T., Quinan, G. R., Mendes, T. T. Smith,
4
5 613 M. R., & Prado, L. S. (2018). Mental fatigue impairs physical performance in young
6
7 614 swimmers. *Pediatric Exercise Science*, *30*(2), 208-215. doi: 10.1123/pes.2017-0128
8
9
10 615 Pires, F. O., Silva-Júnior, F. L., Brietzke, C., Franco-Alvarenga, P. E., Pinheiro, F. A.,
11
12 616 França, N. M., & Santos, T. M. (2018). Mental fatigue alters cortical activation and
13
14 617 psychological responses, impairing performance in a distance-based cycling trial.
15
16 618 *Frontiers in Physiology*, *9*, 1–9. doi:10.3389/fphys.2018.00227
17
18
19 619 Rozand, V., Pageaux, B., Marcora, S. M., Papaxanthis, C., & Lepers, R. (2014). Does mental
20
21 620 exertion alter maximal muscle activation? *Frontiers in Human Neuroscience*, *8*, 1-10.
22
23 621 doi: 10.3389/fnhum.2014.00755
24
25
26 622 Russell, S., Jenkins, D., Rynne, S., Halson, S., & Kelly, V. (2019). What is mental fatigue in
27
28 623 elite sport? Perceptions from athletes and staff. *European Journal of Sport Science*,
29
30 624 *ahead of print*. doi: 10.1080/17461391.2019.1618397
31
32
33 625 San Juan, A. F., López-Samanes, Á., Jodra, P., Valenzuela, P. L., Rueda, J., Veiga-Herreros,
34
35 626 P., Pérez-López, A., & Domínguez, R. (2019). Caffeine supplementation improves
36
37 627 anaerobic performance and neuromuscular efficiency and fatigue in olympic-level
38
39 628 boxers. *Nutrients*, *11*(9), e2120. doi: 10.3390/nu11092120
40
41
42 629 Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of
43
44 630 mind: A meta-analysis of functional brain imaging studies. *Neuroscience &*
45
46 631 *Biobehavioral Reviews*, *42*, 9–34. <https://doi.org/10.1016/j.neubiorev.2014.01.009>
47
48
49 632 Smith, M. R., Zeuwts, L., Lenoir, M., Hens, N., De Jong, L. M. S., & Coutts, A. J. (2016).
50
51 633 Mental fatigue impairs soccer-specific decision-making skill. *Journal of Sports*
52
53 634 *Sciences*, *34*(14), 1297–1304. doi:10.1080/02640414.2016.1156241
54
55
56
57
58
59
60

MENTAL FATIGUE AND BOXING

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- 1
2
3 635 Smith, M. R., Thompson, C., Marcora, S. M., Skorski, S., Meyer, T., & Coutts, A. J. (2018).
4
5 636 Mental fatigue and soccer: Current knowledge and future directions. *Sports Medicine,*
6
7 637 *a head of print*. doi:10.1007/s40279-018-0908-2
8
9
10 638 Stiller, J. W., Yu, S. S., Brenner, L. A., Langenberg, P., Scrofani, P., Pannella, P., Hsu, E. B.,
11
12 639 Roberts, D. W., Monsell, R. M., Binks, S. W., Guzman, A., & Postolache, T. T.
13
14 640 (2014). Sparring and neurological function in professional boxers. *Frontiers Public*
15
16 641 *Health, 21(2)2*: 1-6. doi: 10.3389/fpubh.2014.00069
17
18
19 642 Thompson, C., Fransen, J., Beavan, A., Skorski, S., Coutts, A., & Meyer, T. (2020).
20
21 643 Understanding the influence of a cognitively demanding task on motor response times
22
23 644 and subjective mental fatigue/boredom. *Brazilian Journal of Motor Behavior, 14(1),*
24
25 645 33- 45. doi: 10.20338/bjmb.v14i01.167
26
27
28 646 Thompson, C. J., Fransen, J., Skorski, S., Smith, M. R., Meyer, T., Barrett, S., & Coutts, A. J.
29
30 647 (2019). Mental fatigue in football: Is it time to shift the goalposts? An evaluation of
31
32 648 the current methodology. *Sports Medicine, 49(2)*, 177–183. doi:10. 1007/s40279-018-
33
34 649 1016-z
35
36
37 650 Thompson, C. J., Noon, M., Towlson, C., Perry, J., Coutts, A. J., Harper, L. D., Skorski, S.,
38
39 651 Smith, M. R., Barrett, S., & Meyer, T. (2020). Understanding the presence of mental
40
41 652 fatigue in English academy soccer players. *Journal of Sports Sciences, 38(13)*, 1524–
42
43 653 1530. <https://doi.org/10.1080/02640414.2020.1746597>
44
45
46
47 654 Ting, P., Hwang, J., Doong, J., & Jeng, M. C. (2008). Driver fatigue and high- way driving: a
48
49 655 simulator study. *Physiology and Behavior, 94*, 448–53. doi:
50
51 656 10.1016/j.physbeh.2008.02.015
52
53
54 657 Travassos, B., Araújo, D., Davids, K., Vilar, L., Esteves, P., & Vanda, C. (2012a).
55
56 658 Informational constraints shape emergent functional behaviours during performance
57
58
59
60

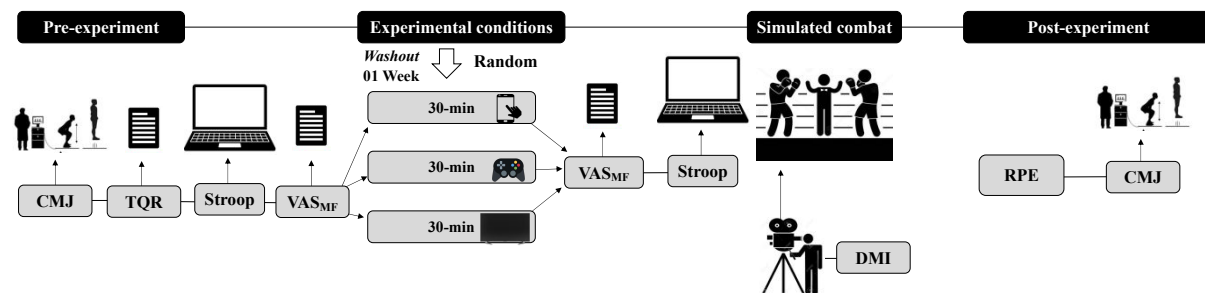
MENTAL FATIGUE AND BOXING

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- 1
2
3 659 of interceptive actions in team sports. *Psychology of Sport and Exercise*, 13, 216–223.
4
5 660 doi: 10.1016/j.psychsport.2011.11.009
6
7
8 661 Travassos, B., Duarte, R., Vilar, L., Davids, K., & Arajo, D. (2012b). Practice task design in
9
10 662 team sports: Representativeness enhanced by increasing opportunities for action.
11
12 663 *Journal of Sports Sciences*, 30(13), 1447–1454. [https://doi.org/10.1080/02640414.](https://doi.org/10.1080/02640414.2012.712716)
13
14 664 2012.712716.
15
16
17 665 Van Cutsem, J., Marcora, S., De Pauw, K., Bailey, S., Meeusen, R., & Roelands, B. (2017).
18
19 666 The effects of mental fatigue on physical performance: A systematic review. *Sports*
20
21 667 *Medicine*, 47(8), 1569–1588. doi:10.1007/s40279-016-0672-0
22
23
24 668 Vestberg, T., Gustafson, R., Maurex, L., Ingvar, M., & Petrovic, P. (2012). Executive
25
26 669 functions predict the success of top-soccer players. *PLoS One*, 7(4), e34731. doi:
27
28 670 10.1371/journal.pone.0034731
29
30
31 671 Wilson, J. M., Duncan, N. M., Marin, P. J., Brown, L. E., Loenneke, J. P., Wilson, S. M. C.,
32
33 672 Jo, E., Lowery, R. P., & Ugrinowitsch, C. (2013). Meta-analysis of postactivation
34
35 673 potentiation and power: effects of conditioning activity volume, gender, rest periods,
36
37 674 and training status. *Journal of Strength and Conditioning Research*, 27(3), 854-859.
38
39 675 doi: 10.1519/JSC.0b013e31825c2bdb
40
41
42 676 Wolf, I., Dziobek, I., & Heekeren, H. R. (2010). Neural correlates of social cognition in
43
44 677 naturalistic settings: A model-free analysis approach. *NeuroImage*, 49(1), 894–904.
45
46 678 <https://doi.org/10.1016/j.neuroimage.2009.08.060>
47
48
49 679 Wu, S., Cheng, C.K., Feng, J., D'angelo, L., Alain, C., & Spence, I. (2012). Playing a first-
50
51 680 person shooter video game induces neuroplastic change. *Journal of Cognitive*
52
53 681 *Neuroscience*, 24, 1286–1293. doi: 10.1162/jocn_a_00192
54
55
56
57
58
59
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MENTAL FATIGUE AND BOXING

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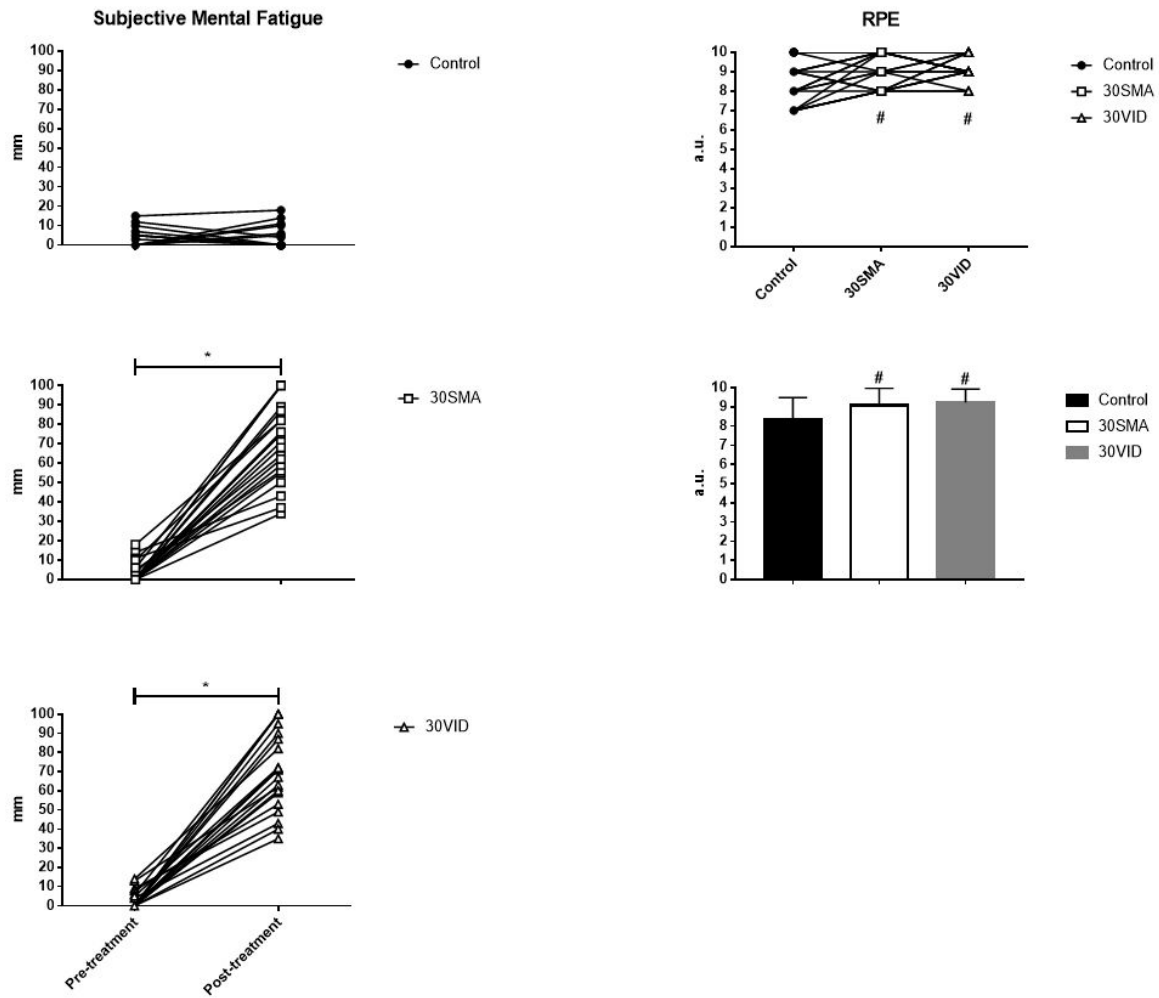


682
 683 Figure 1
 684 *Experimental design*
 685 Note. CMJ = countermovement jump; TQR = total quality recovery; VAS_{MF} = Mental Fatigue Visual Analogue Scale; DMI
 686 = decision-making index.

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MENTAL FATIGUE AND BOXING

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688 Figure 2

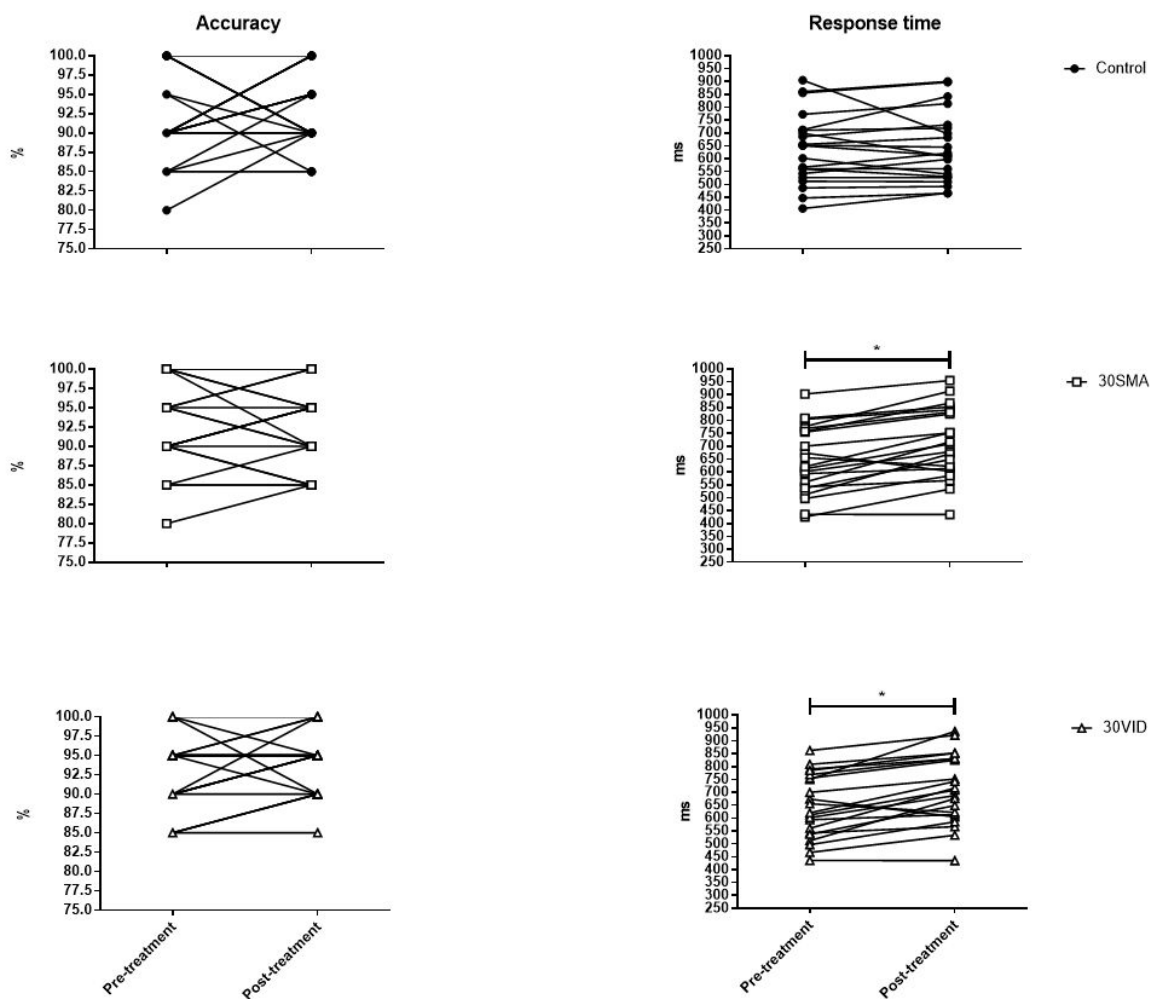
689 *Subjective mental fatigue and rated perceived exertion according to experimental condition (CON vs. 30SMA vs.*
 690 *30VID) in boxing amateurs' athletes.*

691 *Note.* CON = control; 30SMA = smartphone; 30VID = 30-min videogame; * $p > 0.05$ pre-treatment different to post-treatment;

692 $\#p < 0.05$ 30SMA and 30VID different of Control.

MENTAL FATIGUE AND BOXING

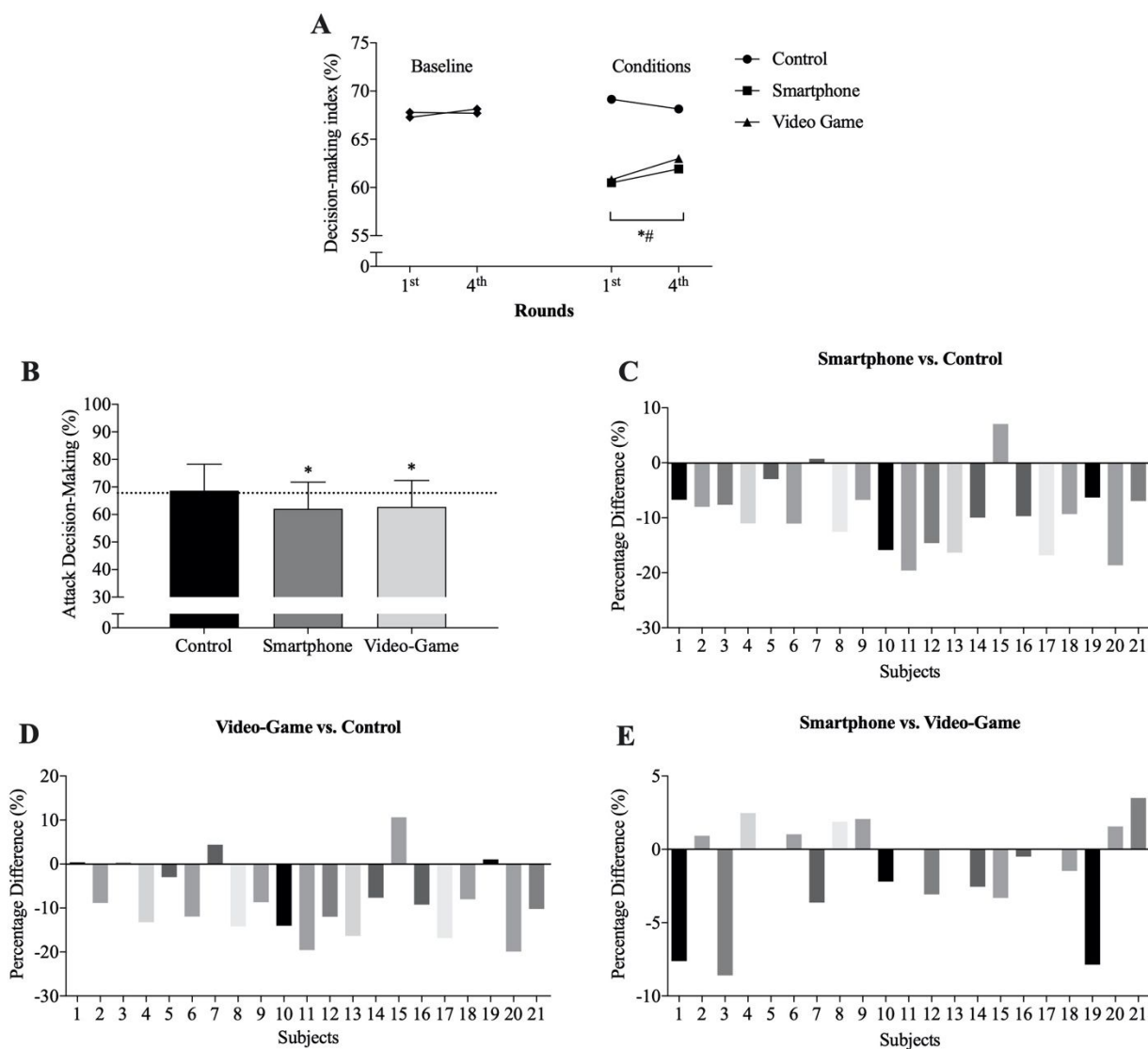
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 694 Figure 3
 695 Stroop task (accuracy and response time) according to experimental condition (CON vs. 30SMA vs. 30VID) in
 696 boxing amateurs' athletes.
 697 Note. CON = control; 30SMA = smartphone; 30VID = 30-min videogame; *p>0.05 pre-treatment different to post-treatment.

MENTAL FATIGUE AND BOXING

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699 Figure 4

700 *Boxing attack decision-making performance according to experimental condition (CON vs. 30SMA vs. 30VID) in*

701 *boxing amateurs' athletes.*

702 *Note. Attack decision-making index of 1st vs. 4th rounds according to experimental condition (A); Attack decision-making index*

703 *(rounds average) according to experimental conditions (B); Individual percentage differences of attack decision-making between*

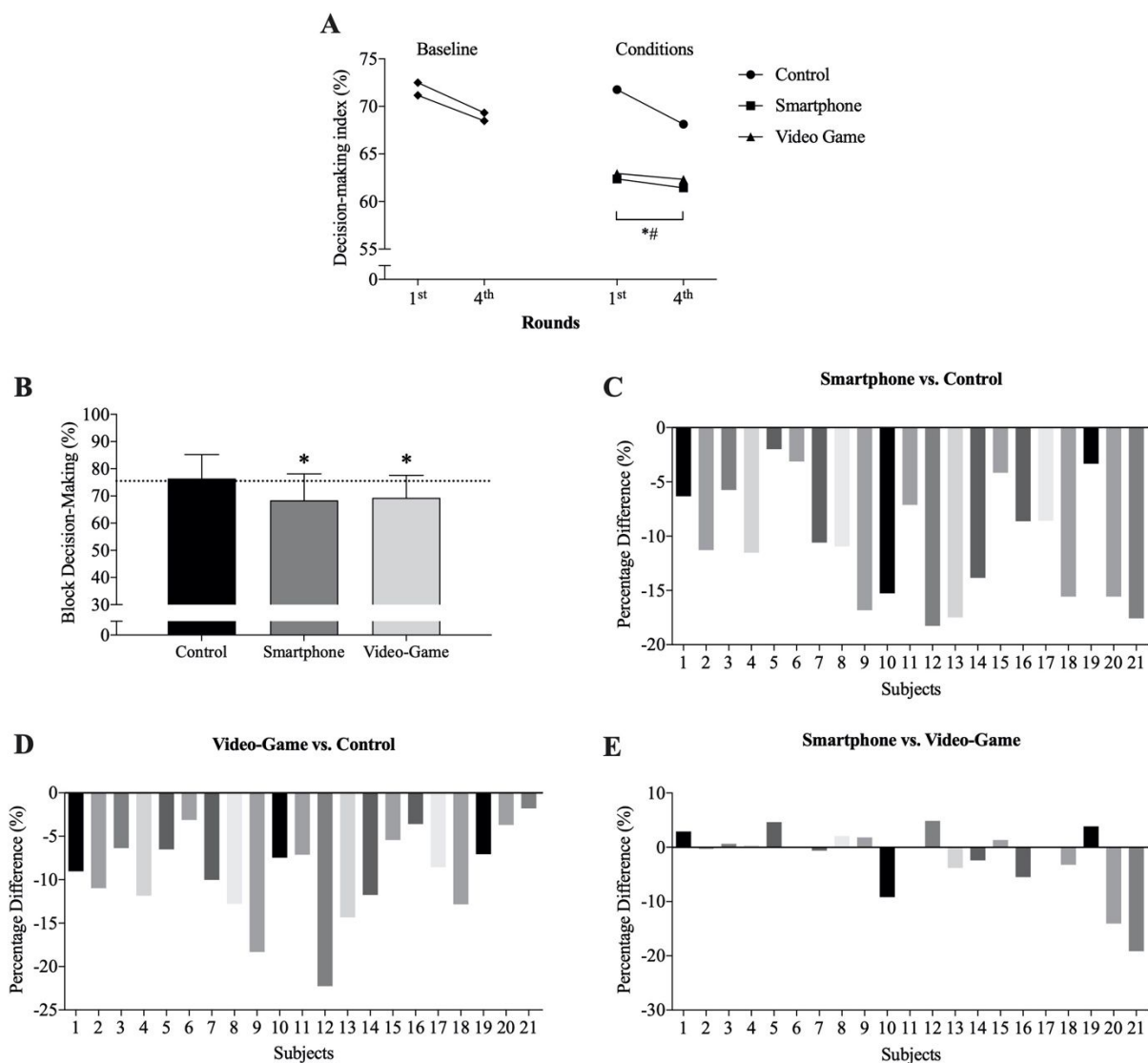
704 *30SMA and CON (C); Individual percentage differences of attack decision-making between 30VID and CON (D); Individual*

705 *percentage differences of attack decision-making between 30SMA and 30VID (E); *Smartphone and Video Game different from*

706 *Control; #Smartphone and Video Game different from Baseline.*

MENTAL FATIGUE AND BOXING

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707
 708 **Figure 5**
 709 *Boxing defense decision-making performance according to experimental condition (CON vs. 30SMA vs. 30VID) in*
 710 *boxing amateurs' athletes.*
 711 *Note. Defense decision-making index of 1st vs. 4th rounds according to experimental condition (A); Defense decision-making index*
 712 *(rounds average) according to experimental conditions (B); Individual percentage differences of defense decision-making between*
 713 *30SMA and CON (C); Individual percentage differences of defense decision-making between 30VID and CON (D); ; Individual*
 714 *percentage differences of defense decision-making between 30SMA and 30VID (E);*Smartphone and Video Game different from*
 715 *Control; #Smartphone and Video Game different from Baseline.*