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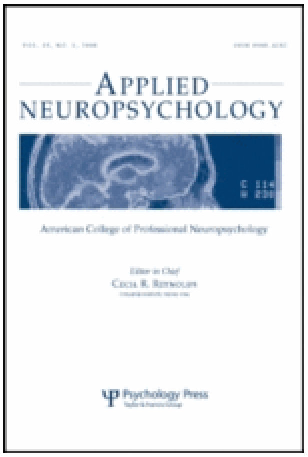

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# Abstract

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.

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

Boxing is an Olympic sport in which pugilists' aims to hit a greater number of punches in their opponents (San Juan et al., 2019). Basic punches such as the jab, direct, cross (left and right), uppercut (left and right), and hook (left and right) are the most common in the sport (Lenetski et al., 2019). Regarding the defense movements, the footwork, bobbing, and blocking might be highlighted. In Olympic boxing, each combat consists of four rounds, and the winner is the one that sums higher scores up (based on punches) later the last round or knocks out the opponent throughout the combat (López-Laval, Sitko, Muñiz-Pardos, Cirer-Sastre, & Calleja-González). The boxing performance depends on several factors such as physical, technical, tactical, and cognitive abilities (Loturco et al., 2019), and the decision-making performance and power output might determine the winner in combat (Stiller et al., 2014).

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

Ecological approaches to assess decision-making performance might be performed using informational variables that sustain emergent functional behaviors (Travassos et al., 2012a). Thereby, it has been observed that athletes couple their actions in both space and time, looking for the best way to comprehend the environment and task restrictions during the performance (Travassos, Duarte, Vilar, Davids, & Arajo, 2012b). To get decision-making performance better, the athletes need to enhance perception-action couplings able to increase the attention to perceptual variables, making clear which actions are (or are not) possible to perform according to their capabilities (Travassos et al., 2012). It is essential to highlight that perceptual-cognitive ability and executive functions such as perception, attention, anticipation, inhibitory control, working memory, and cognitive flexibility are related to decision-making performance (Araújo et al., 2015; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012).

It is well-documented that an increase in cognitive demand for a prolonged period may impair those perceptual-cognitive abilities (e.g., perception and decision-making) and executive functions (e.g., attention and inhibitory control) previously mentioned in athletes (Fortes et al., 2019a Gantois et al., 2019; Van-Cutsem et al., 2017). Once the harms in perceptual-cognitive abilities and executive functions seems to impair the decision-making performance, it is imperative to run studies analyzing these variables in combat sports athletes.

The impairment of executive functions based on the psychobiological state that induces tiredness and lack of energy following long periods of cognitive demand has been called mental fatigue (MF) (Russel, Jenkins, Rynne, Halson, & Kelly, 2019; Smith et al., 2018). These periods must last at least 30-min (Fortes et al., 2019a Gantois et al., 2019) and present a detrimental effect on physical performance (McMorris, Barwood, Hale, Dicks, & Corbett, 2018; Van-Cutsem et al., 2017), mainly on endurance (Marcora, Staiano, & Manning, 2009; Martin, Meeusen, Thompson, Keegan, & Rattray, 2018; Pageaux et al., 2013; Penna et al., 2018), which includes combat sports athletes (Campos et al., 2019). However, it seems that MF does not affect all-out performance ran for 10 seconds or less

(Rozand, Pageaux, Marcora, Papaxanthis, & Lepers, 2014; Silva-Cavalcante et al., 2018), for example, the countermovement jump (CMJ). The CMJ is considered a good measure for neuromuscular status (Wilson et al., 2013) and shows a strong relationship with power output in combat sports athletes (Loturco et al., 2019). So, the present study also analyzed the effect of MF on CMJ because these findings may reveal if MF can affect the power output in combat sports athletes.

Regarding perceptual-cognitive ability performance, previous findings demonstrated that MF impaired decision-making performance in soccer athletes (Gantois et al., 2019; Smith et al., 2016). However, it is noteworthy that the literature still lacks studies analyzing the effect of MF on decision-making performance in combat sports athletes (e.g., Olympic boxing); so, these studies seem to be essential once reduced decision-making might define a combat result. Also, previous studies have adopted low-ecological validity cognitive tasks (e.g., Stroop task) to induce MF before training sessions and simulated games (Gantois et al., 2019; Smith et al., 2016). As it is known, cognitive tasks that require inhibition response and sustained vigilance (e.g., Stroop task and driving) for a prolonged time might induce MF (Smith et al., 2018; Ting, Hwang, Doong, & Jeng, 2008; Zhao, Zhao, Liu, & Zheng, 2012). However, performing Stroop task for more than 30-min before training and competitions is unusual. A limitation of the Stroop task is that it may not be representative of how MF is experienced in real-life settings (Thompson et al., 2020). Indeed, this task seems to be relevant in a laboratory setting to create a transient state of MF. Still, an athlete would not complete a Stroop task before a competition, which makes the practical validity of using a Stroop task questionable in some of the sports science fields. The repetitive nature of continually solving the same task problem may become monotonous and evoke lower levels of contextual interference than real-life tasks such as sports.

Thus, some of the studies regarding MF and decision-making performance presents low ecological validity in sports conditions (Gantois et al., 2019; Smith et al., 2016). In real-world context, Thompson et al. (2020) showed that ~10% and ~60% of English academy soccer players reported playing videogame or social media using as a pre-match activity. Commonly, amateurs' athletes use social media on smartphones (e.g., Facebook®, WhatsApp®, and Instagram®) or play video games (e.g., combat games), especially before training sessions or official competitions (Diaz-Brage et al., 2018; Wu et al., 2012). The sport-based videogame (e.g., Fight Night) presents demand with high amount of visual search in short time, because the games are characterized by changes of scenery constantly, which requires high attention sustained, cognitive inhibition and cognitive flexibility. It could be therefore speculated that the sport-based videogame per prolonged period immediately prior training session or match would causes mental fatigue and impair the perceptual-cognitive ability performance. Regarding social media on smartphone, seems to be increasing among athletes (Thompson, Noon et al., 2020). The social media use on smartphones can be harmful for athletes when utilized per prolonged period before training sessions or official competition (Durand-Bush & DesClouds, 2018). Neuroimaging studies of social behaviors have demonstrated that social media use recruits brain network regions, including the prefrontal cortex (PFC), dorsomedial PFC (DMPFC), ventromedial PFC (VMPFC), bilateral temporoparietal junction (TPJ), anterior temporal lobes (ATL), inferior frontal gyri (IFG), and posterior cingulate cortex/precuneus (PCC) (Schurz et al., 2014; Wolf et al., 2010). It is essential to highlight that the PFC and VMPFC are responsible for attention, processing information, and decision-making during physical effort, respectively. Once fatigued mentally by prolonged use of social media on a smartphone, it might impair the decision-making skill.

Recently, real-world studies showed that using social network apps on smartphones (Fortes et al., 2019a; Fortes, De Lima-Júnior, Gantois, Nascimento-Júnior, & Fonseca, 2020) or playing video games (Fortes et al., 2019b) for a prolonged period may cause MF. The excessive use of these cognitive tasks may cause MF, impairing decision-making performance that is considered a key-point in combat sports.

From a practical standpoint, the effect of social media use on smartphones or playing video games on decision-making, and CMJ performance in box athletes might indicate new protocols, including avoiding those tasks before the combat. Thus, this study aimed to analyze the effect of social media use on smartphones and playing video games on decision-making and CMJ performance in amateurs boxing athletes. Also, we developed two hypotheses as follows: a) exposure to social media on smartphones or playing video games (30-min) impair decision-making performance in amateurs boxing athletes; and b) exposure to social media on smartphones (30-min), playing video games, or watching TV does not affect CMJ performance in amateurs boxing athletes.

## Materials and methods

### *Participants*

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

### *Experimental design*

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

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

The three experimental conditions order were randomized, which made the participants performed the smartphone (30SMA), videogame (30VID), and control (CON) conditions in a random order separated by a one-week washout (Figure 1). Simple randomization was carried out for the three experimental conditions (CON, 30SMA, and 30VID). A random number table was generated on www.randomizer.org site. The athletes were submitted to the same procedure's settings throughout each experimental condition in this study. Two boxers were assessed per session, and the boxers were always paired (CON, 30SMA, and 30VID) with the same opponent, as used in other studies about mental fatigue and sport performance (Gantois et al., 2019; Penna et al., 2018). It's important statement that boxers didn't train with their opponents. Until the end of the experiment, the participants were not aware the experimental question and the issue that was under investigation.

The Stroop task (~90-s of duration) assessed the MF level before and after the three sessions: social media use on smartphones, playing video game, and watching TV (documentary about the Olympic Games). Then, the participants warmed-up for 5-min in a ring (the same warm-up was adopted in the three experimental conditions). Next, a 5-min interval was given between the warm-up and the beginning of the simulated combat, considering the post-activation potential phenomenon (Wilson et al., 2013). Finally, the athletes participated in simulated combat (four rounds of 2-min with 1-min interval), adopting the official boxing rules. All combats (four rounds) were filmed using a CANON® camera (SX60 model, Yokohama, Japan) for further analysis of boxing decision-making performance using the Game Performance Analysis Instrument (Memmert & Harvey, 2008).

Perceived recovery was measured before the experiment, and CMJ performance was obtained before and 30-min after each experimental session. Rating of perceived exertion (RPE) was measured immediately after the combat simulation. All experimental procedures are illustrated in Figure 1.

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

### *Experimental Interventions*

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

### *Measures*

*Boxing decision making-performance.* The decision-making was evaluated during simulated combats. The participants fought four rounds of 2-min with 1-min interval, adopting the official rules of boxing. The opponents were of the same weight category and the same competitive level to ensure similar technical skills between them. The entire combat was recorded with a CANON® camera (SX60 model, Yokohama, Japan). Participants were oriented to “try to score as many points as possible”. The analysis and categorization of actions were run based on the GPAI (Memmert & Harvey, 2008). Memmert and Harvey (2008) highlighted that the GPAI evaluates the appropriate decisions. The boxing coaches used scales that were structured and anchored with specific descriptions. The attack (i.e., jab, uppercut, right cross, or hook) and defense (i.e., slip, block, or duck) decision-making components were adopted. The appropriate decision-making was considered when the attempted attack was directed to a vulnerable region of the opponent (head or trunk) that could result in a score, or the attempted defense was correctly directed to inhibit or prevent the opponent’s attack. Any other boxing decision-making different from those indicated above was classified as inappropriate. The different decisions between the coaches were not encoded and were not analyzed. The obtained data (videos) were analyzed using open-license video analysis software (Kinovea 0.8.15 for Windows) for, when necessary, visualize the actions of boxers in slow motion.

The decision-making index (DMI) was calculated according to the formula below, following the modifications suggested by Memmert and Harvey (2008). Two experienced boxing coaches analyzed the combat actions (they oversaw the videos on an 84-inch tv screen) and categorized it as appropriate or inappropriate. The investigators who reviewed the video footage and categorized decision-making actions were blinded to the experimental treatments [30SMA vs. 30VID vs. CON] to attenuate bias risk. The acceptable coefficient of agreement for the DMI (attack: kappa = 0.93, p = 0.001; defense: kappa = 0.91, p = 0.001) was calculated by the main researcher for the scores of the two boxing coaches. The intraclass coefficient correlation (ICC) was used to determine the reliability of attack (ICC = 0.82, $CI_{95\%}$ = 0.75 to 0.88) and defense decision-making (ICC = 0.79, $CI_{95\%}$ = 0.72 to 0.86).

$$\boxed{\mathrm{DMI} = \frac{Aa}{Aa + Ia} x\ 100}$$

Aa = appropriate actions

Ia = inappropriate actions

*Countermovement jump (CMJ).* An electronic contact jump mat (Hidrofit®, Jump System, Belo Horizonte, Brazil) was used to analyze the CMJ height. Each participant performed three attempts with 30-s interval among trials, and the best attempt was analyzed. The participants completed the CMJ with hands on the waist and no restrictions on the knee angle during the eccentric phase of the jump. Also, the participants were instructed to maintain the legs in a straight position during the flight and land phases at the take-off point. The participants were familiarized with the test prior to each experimental condition. In the present study, the ICC was 0.98 ($IC_{95\%}$ = 0.94 to 0.99) for CMJ, indicating good reproducibility of the test.

*Recovery perceived.* The Total Quality Recovery (TQR) scale proposed by Kenttä and Hassmén (1998) and validated to the Brazilian culture by Osieck, Osiecki, Burigo, Coelho, and Malfatti (2015) was used before each experimental condition to assess the level of perceived recovery. The TQR is a scale that ranges from six (nothing recovered) to 20 (fully recovered). That is, the higher the value, the higher the level of perceived recovery. The ICC and coefficient of variation (CV) determined the reliability of the level of perceived recovery (ICC = 0.85, CV = 9.3%). The results revealed no difference for recovery perceived between experimental conditions ($F_{(3, 17)} = 1.47$; $p = 0.82$).

*Subjective Rating of Mental Fatigue.* The subjective rating of MF was assessed using the 100 mm Visual Analogue Scale (VAS)'s as previously adopted (Franco-Alvarenga et al., 2019). This scale has two extremities anchored from 0 (none at all) to 100 (maximal). No other descriptor was presented in the VAS. The participants were required to answer, "How mentally fatigued you feel now?". Participants were oriented to point throughout the 100mm-horizontal line-scale their perceived status. To quantify the values, we measured the millimeter distance from the 0 to the end of the line indicated by the participant.

*Stroop task.* The Stroop task (Graf, Uttl, & Tuokko, 1995) assessed inhibitory control and selective attention, both considered components of the cognitive function. Two assessments were performed pre and post-each experimental conditions. Considering scientific evidence has shown impaired accuracy or response time in Stroop task in athletes mentally fatigued (Marcora et al., 2009; Penna et al., 2018; Smith et al., 2016), it was decided to use this test to measure mental fatigue, as method has already used in other investigations (Fortes et al., 2020a; Gantois et al., 2019). The participants answered the word color or according to its name, since the color of the words might be different from what is typed (e.g., the word "blue" might show up in "red" color, the word "green" in "blue", and so on). A stimulus of 30 words with 200 ms of the interval was provided between the response and a new stimulus.

Moreover, the stimulus did not fade from the screen until any response was given. Stimuli vary between congruent (word and color have the same meaning), incongruent (word and color have a different meaning), and control (colored rectangle with one of the colors of the test: red, green, blue, and black). The keys D (red), F (green), J (blue), and K (black) were pressed to answer the questions. The stimulus disappeared when the answer was correct, and then a new one was set. An "X" letter was showed up on the screen in case of incorrect answers, and a new stimulus was displayed. The accuracy of the correct answers and response time were collected at the end of the test, and the evaluator was blind for the assessments and had previous training for the test. The tests were performed on a full-HD screen (1800 × 1260 pixels) laptop (MacBook Pro, A1502 model, USA). The ICC and CV were used to determine the reliability of accuracy (ICC = 0.84, CV = 5.6%) and response time (ICC = 0.96, CV = 7.2%).

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

### ***Statistical analysis***

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

$\eta p^2 \geq .020$. 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*

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

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

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

However, the results showed condition [$F_{(3,\ 17)} = 3.42$; $p = 0.04$ ($CI_{95\%} = 0.01$ to $0.06$); $\eta p^2 = 0.03$ ($CI_{95\%} = 0.02$ to $0.05$); moderate ES) and time effects [$F_{(2,\ 18)} = 41.22$; $p = 0.001$ ($CI_{95\%} = 0.001$ to $0.003$); $\eta p^2 = 0.07$ ($CI_{95\%} = 0.05$ to $0.10$); medium ES] for response time. Also, it was found a condition x time interaction regarding response time [$F_{(6,\ 14)} = 7.53$; $p = 0.001$ ($CI_{95\%} = 0.001$ to $0.03$); $\eta p^2 = 0.05$ ($CI_{95\%} = 0.04$ to $0.09$); moderate ES; CON: 637.14 ± 136.35 ms and 641.28 ± 150.98 ms for pre and post-TV; 30SMA: 645.23 ± 131.65 ms and 713.33 ± 145.23 ms for pre and post-smartphone; 30VID: 660.05 ± 128.70 ms and 721.46 ± 150.62 ms for pre and post-videogame]. The 30SMA and 30VID conditions showed higher response time in comparison to CON condition (Figure 3; $p = 0.001$). No difference was found between 30SMA and 30VID for response time in the Stroop task ($p = 0.75$).

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

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

### *Boxing decision-making performance*

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

CON condition ($p = 0.001$). The attack decision-making performance in the 3rd + 4th rounds was impaired in both 30SMA ($p = 0.01$) and 30VID ($p = 0.04$) compared to CON condition. There was no difference in attack decision-making performance between 30SMA and 30VID in the 1st + 2nd rounds ($p = 0.94$) and 3rd + 4th rounds ($p = 0.86$). The attack decision-making performance was attenuated in 30SMA and 30VID conditions in 1st + 2nd rounds ($p = 0.001$) and 3rd + 4th rounds ($p = 0.001$) compared to baseline.

*Defense decision-making.* It was shown a condition [$F_{(3, 17)} = 10.27$; $p = 0.001$ ($CI_{95\%} = 0.001$ to $0.03$); $\eta p^2 = 0.08$ ($CI_{95\%} = 0.06$ to $0.10$); moderate ES] and time effects [$F_{(2, 18)} = 26.50$; $p = 0.001$ ($CI_{95\%} = 0.001$ to $0.02$); $\eta p^2 = 0.11$ ($CI_{95\%} = 0.09$ to $0.13$); large ES] for defense decision-making performance. Still, it was revealed a condition x time interaction for defense decision-making performance [Figure 5; $F_{(6, 14)} = 3.63$; $p = 0.002$ ($CI_{95\%} = 0.001$ to $0.03$); $\eta p^2 = 0.05$ ($CI_{95\%} = 0.05$ to $0.08$); moderate ES]. The defense decision-making performance in the 1st + 2nd rounds was worse in 30SMA and 30VID than CON experimental condition ($p = 0.001$). The defense decision-making performance in the 3rd + 4th rounds was impaired in 30SMA ($p = 0.003$) and 30VID ($p = 0.007$) compared to CON condition. There was no difference in defense decision-making performance between 30SMA and 30VID in the 1st + 2nd rounds ($p = 0.81$) and 3rd + 4th rounds ($p = 0.90$). The defense decision-making performance was lower in both 30SMA and 30VID experimental conditions in 1st + 2nd rounds ($p = 0.001$) and 3rd + 4th rounds ($p = 0.001$) compared to baseline.

*****Figure 4 insert here*****

*****Figure 5 insert here*****

### *CMJ*

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

### *RPE*

The results demonstrated significant difference for RPE between experimental conditions [$F_{(3,\ 17)} = 10.86$; $p = 0.001$ (CI$_{95\%}$ = 0.001 to 0.02); ηp$^2$ = 0.09 (CI$_{95\%}$ = 0.06 to 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.]. Specifically, higher RPE was found for 30SMA and 30VID in comparison to CON condition (Figure 2; $p = 0.001$).

## Discussion

The objective of this study was to analyze the acute effects of social media use on smartphones and playing video games on decision-making (attack and defense) and CMJ performances in amateur boxing athletes. The main findings showed that both smartphone use and video game experimental conditions impaired boxing decision-making performance (attack and defense) compared to control one (i.e., watching TV), but CMJ performance was not changed by the social media use on smartphones or playing video games, which, indeed, confirms the hypotheses of the study.

The findings indicated that social media use on smartphones (30SMA) and playing video games (30VID) for 30-min induced MF. The subjective rating of MF and response time in the Stroop task were greater in both 30SMA and 30VID conditions. These findings corroborate with recent previous studies (Fortes et al., 2019a; Fortes et al., 2019b). Durand-Bush and DesClouds (2018) indicated drawbacks for cognitive performance (e.g., disrupt attention, concentration, memory, and executive function) when athletes use electronic devices (e.g., videogames), mainly social media on smartphones. Social media use on smartphones and playing videogames for a prolonged period requires high cognitive inhibition and sustained attention (Durand-Bush & DesClouds, 2018). So, the use of social media on smartphones and playing videogame for a prolonged period might carry out MF (Fortes et al., 2019; Fortes et al., 2020a).

MF induced impaired decision-making performance (attack and defense) in amateur boxers. Our results are supported by other literature findings, although performed with soccer athletes (Fortes et al., 2019a; Gantois et al., 2019; Smith et al., 2016). It was previously reported that MF reduces attention, focus, reaction time, visual cue interpretation, and also motor control, which consequently affect performance (Boksem, Meijman, & Lorist, 2005; Lorist, Boksem, & Ridderinkhof, 2005; Jacquet, Poulin-Charronnat, Bard, & Leppers, 2021). The adverse effect of MF on attack decision-making has important implications for boxing athletes, once hitting the opponent is the main aim during the combat and may determine the winner. The boxing athlete mentally fatigued might misinterpret or delay the right moments to perform the appropriate attacks (e.g., jab, direct, hook, so on) or defense movements, which may impair performance. Also, combat athletes with compromised decision-making performance are more vulnerable to knockouts (Fortes et al., 2017; Franchini et al., 2013).

It might happen due to a failure in the brain information in the environment processing (Smith et al., 2018; Thompson et al., 2018), that is, the athlete mentally fatigued presents impaired executive functions (e.g., attention, inhibitory control, memory work, and cognitive flexibility) (Fortes et al., 2019a; Smith et al., 2016). It is important to highlight that the results of this study also revealed that inhibitory control performance is impaired in mentally fatigued boxing athletes (Stroop task). In boxing, the athletes perform rapid actions because the time to avoid the opponent's punch is short. The duration of ballistic movements, such as the punch, is usually lower than 200-ms. So, MF seems to be harmful to cognitive performance in boxing athletes. Still, new experimental studies to confirm these cognitive mechanisms are needed.

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

Concerning the RPE, both 30SMA and 30VID conditions presented higher values than the CON condition. Previous studies indicated that the MF increases RPE in athletes (Marcora et al., 2009; Penna et al., 2018) once it is regulated by the inhibitory control

(Marcora, 2008), more specifically, in the anterior cingulate cortex, which might explain the results of RPE in the present study.

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

From a practical standpoint, the present findings demonstrated that a prolonged time using (more than 30-min) social media on smartphones (WhatsApp®, Instagram®, or Facebook®) or playing video games must be avoided before combat or training session for amateur boxing athletes; Also, CMJ performance is not impaired by MF. Finally, it is essential to mention that high-internal training load induced by prolonged use of social media on smartphones or playing video games might make athletes vulnerable to non-functional overreaching. Future study could investigate the repeated effect of social media network or sport-based videogame immediately before the training sessions on perceptual-cognitive skill (e.g., decision-making) and non-functional overreaching (e.g., cumulated internal training load) in combat sport athletes.

## Conclusion

Our results showed the MF impaired the attack and defense decision-making performance in amateur boxers, with no harms for CMJ performance. It seems that the MF caused by the use of social media on smartphones or playing video games also increase RPE in simulated combat. The present finding may guide coaches in how to manage the athlete's leisure time right before training sessions and competition combats.

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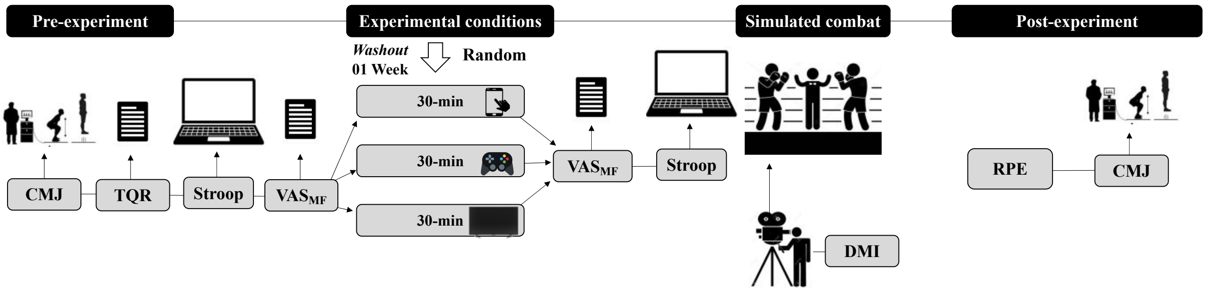

Figure 1

*Experimental design*

*Note.* CMJ = countermovement jump; TQR = total quality recovery; $VAS_{MF}$ = Mental Fatigue Visual Analogue Scale; DMI = decision-making index.

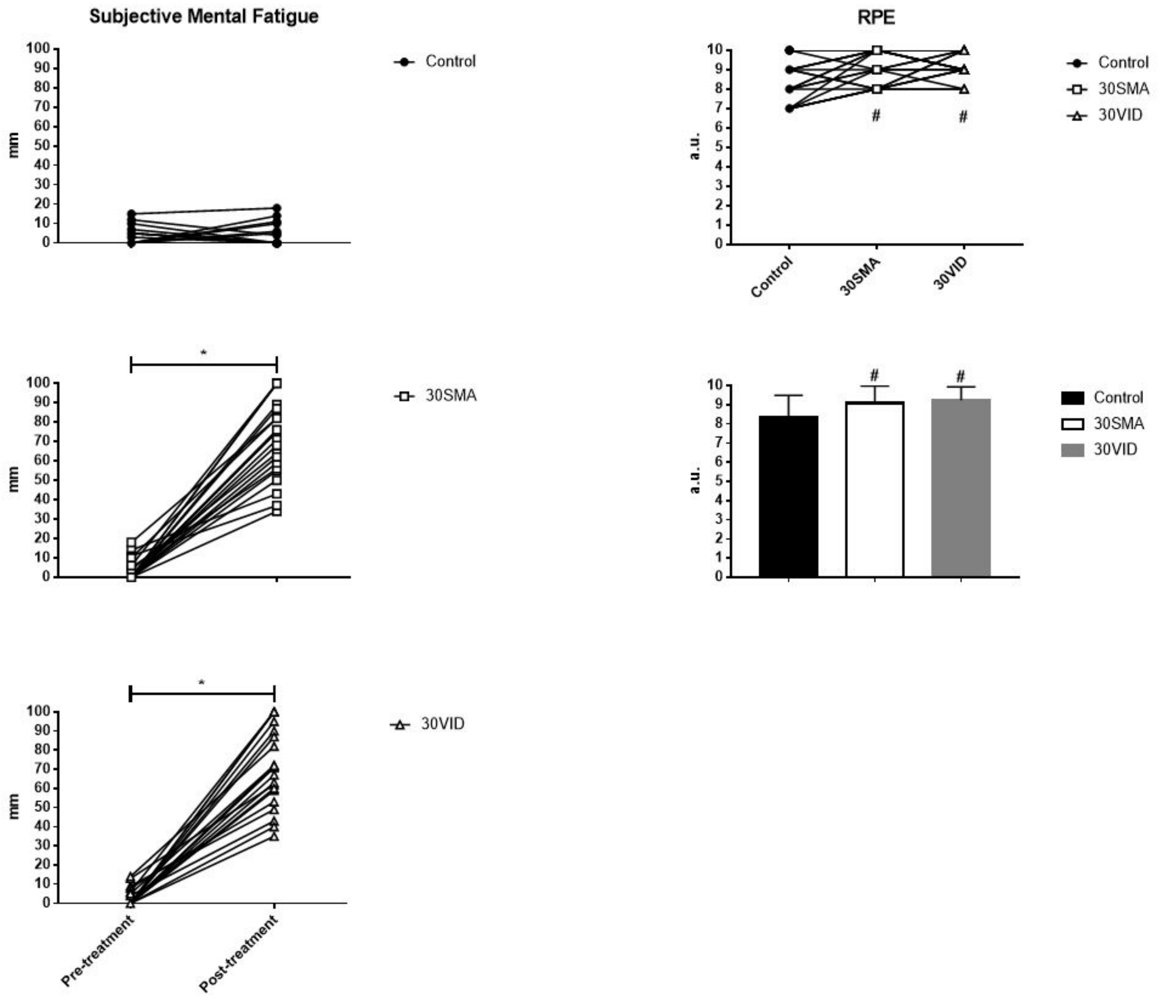

Figure 2

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

*Note.* CON = control; 30SMA = smartphone; 30VID = 30-min videogame; *p>0.05 pre-treatment different to post-treatment; $^{\#}$p<0.05 30SMA and 30VID different of Control.

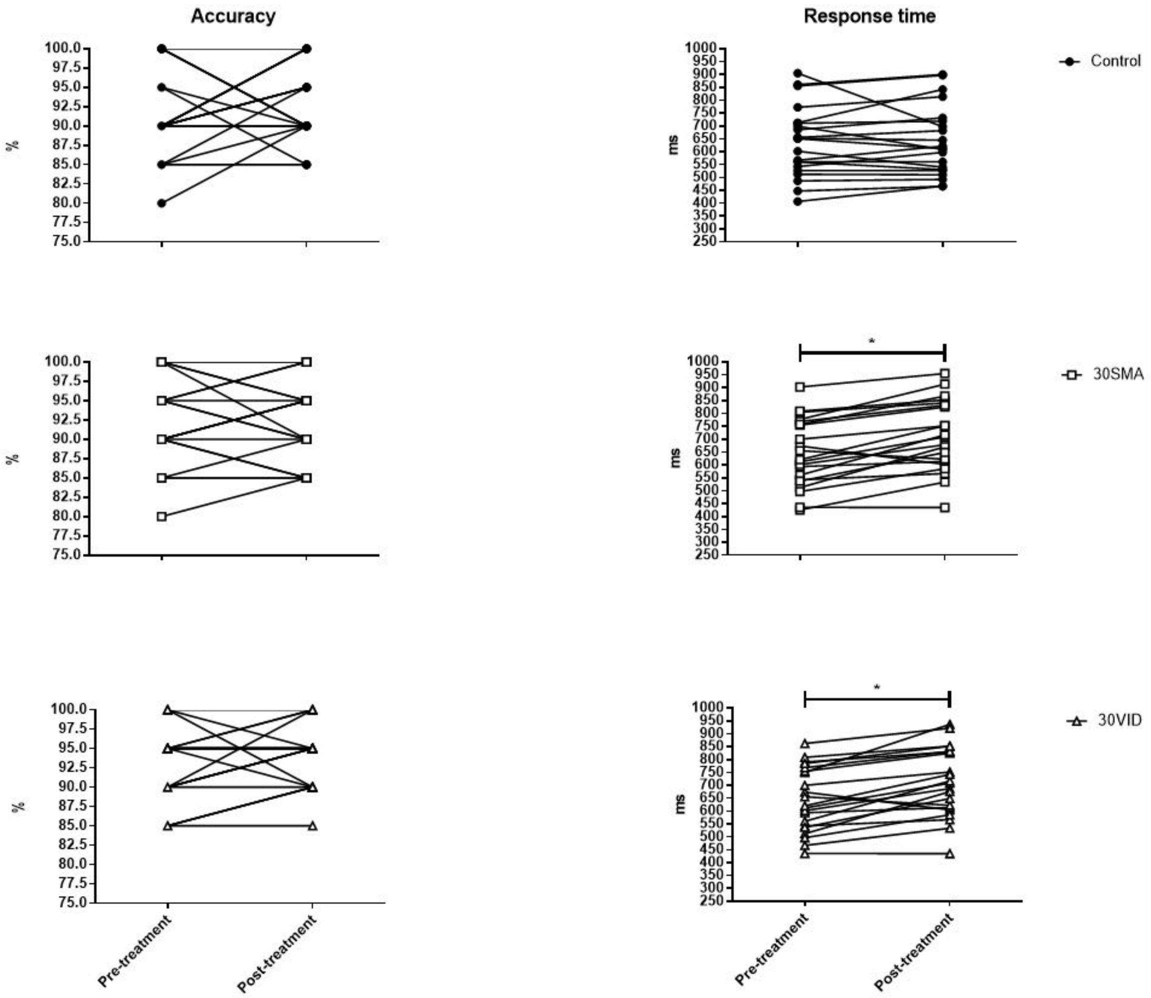

Figure 3

*Stroop task (accuracy and response time) according to experimental condition (CON vs. 30SMA vs. 30VID) in boxing amateurs' athletes.*

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

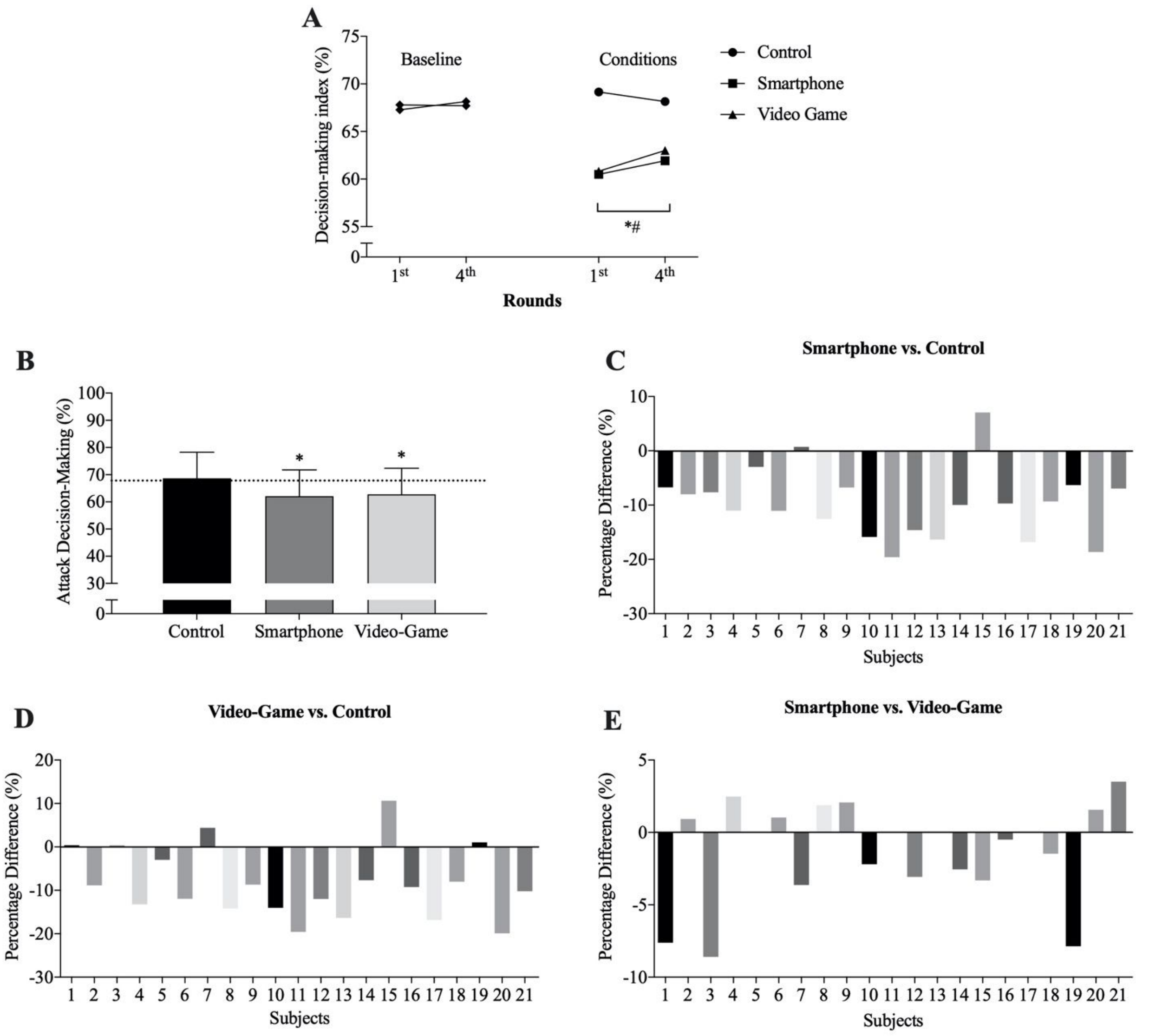

Figure 4

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

*Note. Attack decision-making index of 1st vs. 4th rounds according to experimental condition (A); Attack decision-making index (rounds average) according to experimental conditions (B); Individual percentage differences of attack decision-making between 30SMA and CON (C); Individual percentage differences of attack decision-making between 30VID and CON (D); Individual percentage differences of attack decision-making between 30SMA and 30VID (E);* *Smartphone and Video Game different from Control; #Smartphone and Video Game different from Baseline.

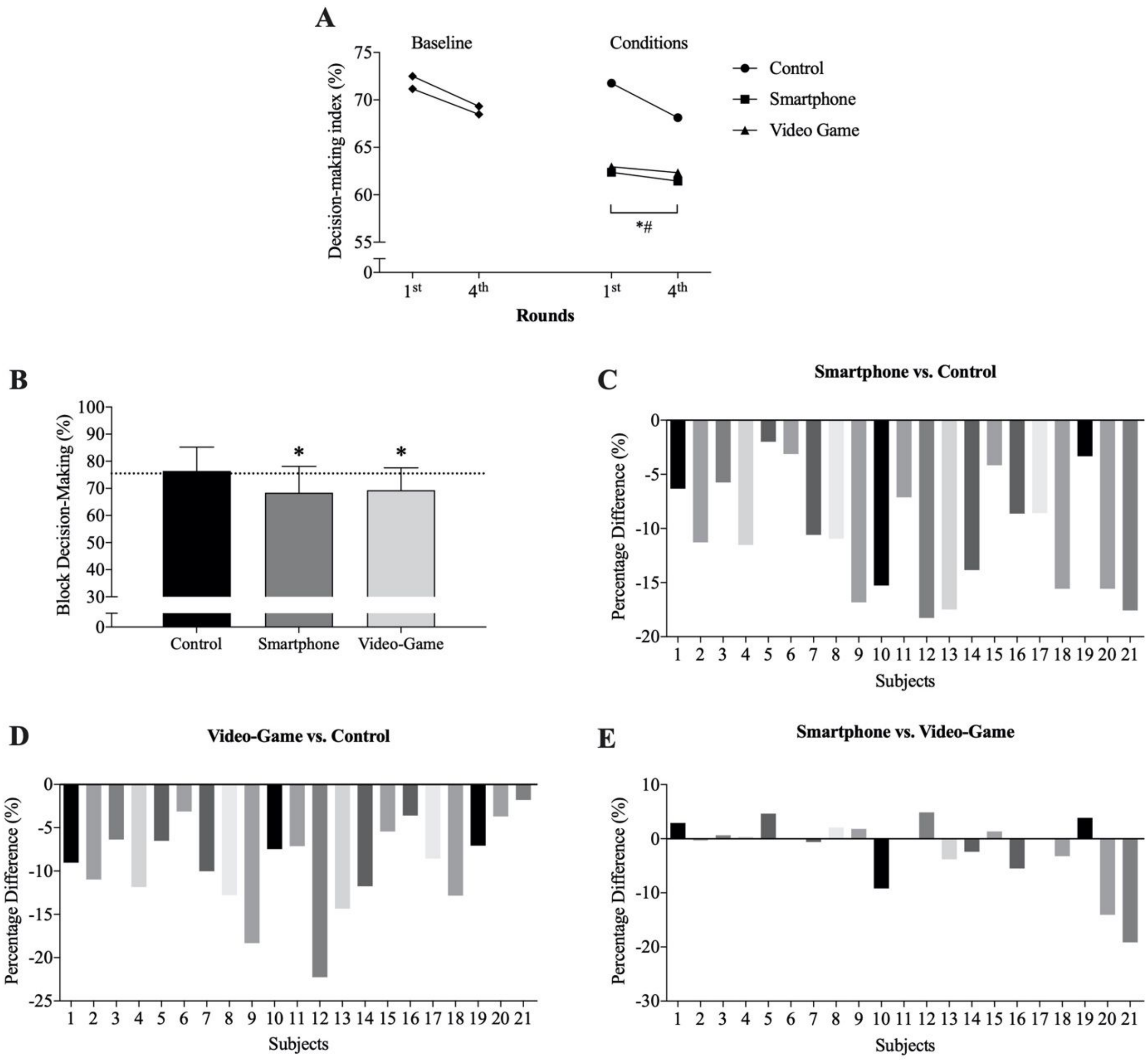

Figure 5

*Boxing defense decision-making performance according to experimental condition (CON vs. 30SMA vs. 30VID) in boxing amateurs' athletes.*

*Note. Defense decision-making index of 1st vs. 4th rounds according to experimental condition (A); Defense decision-making index (rounds average) according to experimental conditions (B); Individual percentage differences of defense decision-making between 30SMA and CON (C); Individual percentage differences of defense decision-making between 30VID and CON (D); ); Individual percentage differences of defense decision-making between 30SMA and 30VID (E);* *Smartphone and Video Game different from Control; #Smartphone and Video Game different from Baseline.