Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes

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Virtual reality promotes greater improvements than video on visual search behavior

Virtual reality promotes greater improvements than video on decision-making

Virtual reality promotes greater improvements than video on inhibitory control

Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes

Abstract

Background: New studies are needed to provide more significant accurate conclusions about the effect of virtual reality (VR) on perceptual-cognitive skills in team sport athletes. **Purpose:** This study aimed to analyze the chronic effect of VR and video-stimulation screen training on passing decision-making, visual search behavior, and inhibitory control performance in young soccer athletes. **Method:** A total of 26 young soccer players underwent an eight-week training protocol after being randomly assigned to the VR (n=13) or video-screen (VID, n=13) group. Passing decision-making, visual search behavior, and inhibitory control performance were measured before and after both interventions. **Results:** A group x time interaction was found for decision-making performance ($p < 0.01$) and visual search behavior ($p < 0.01$). Both groups improved both decision-making performance ($p < 0.01$) and visual search behavior ($p < 0.01$); however, greater improvements were verified in VR ($p < 0.01$). Both VR and VID improved inhibitory control ($p < 0.01$), but no group interaction effect was observed ($p > 0.05$). **Conclusion:** Our results suggest that VR leads to greater improvements in decision-making and visual search behavior in young soccer athletes than VID.

Keywords: Sports psychology, team sports, visual search, brain; cognition.

Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes

Soccer demands frequent bouts of high-intensity activity distributed among prolonged low-intensity periods (Gantois et al., 2019; Smith et al., 2016). In addition, soccer is cognitively demanding as it requires sustained attention to make quick and accurate decisions based on retrieval and information processing from a dynamic environment (Fortes, Lima-Júnior et al., 2020; Smith et al., 2016). These demands suggest that soccer athletes have to improve their perceptual-cognitive skills to avoid the adverse effects of mental fatigue throughout training (i.e. during small-sided games) (Trecroci, Boccolini, Duca, Formenti, & Alberti, 2020) and matches (Gantois et al., 2019) to make winning possible (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007). It is commonly suggested that the better perceptual-cognitive skills such as decision making, visual search behavior, and inhibitory control are, the better the soccer players will perform in competitive matches (Gantois et al., 2019; Roca, Ford, & Memmert, 2019; Vaeyens et al., 2007).

Decision-making skill represents the human brain's ability to extract meaningful contextual information from the visual scene and is essential for high-level performance in sports (Gantois et al., 2019; Smith et al., 2016). Visual search behavior is part of the mechanisms underlying decision-making skill (Vaeyens et al., 2007). It is theoretically assumed that a more efficient visual search strategy is characterized by relatively fewer fixations of long duration (Vaeyens et al., 2007). Some scientific findings also support that team sport athletes with better decision-making skill present greater inhibitory control (Fortes, Lima-Junior et al., 2020; Gantois et al., 2020). Nevertheless, this hypothesis has not always been supported in the literature. It is important to identify interventions or training programs which can improve visual search strategy and consequently potentialize decision-making skill in soccer athletes.

Previous studies have revealed decision-making performance improvements after an imagery training program in team sport athletes (Fortes, Freitas-Júnior et al., 2020; Slimani et al., 2016). Other studies have demonstrated the positive effects of small-sided games (SSG) on visual search behavior (Davids, Araújo, Correia, & Vilar, 2013; Vaeyens et al., 2007). Moreover, video-stimulus training has been shown to improve perceptual-cognitive skills in team sport athletes (Lorains, Ball, & MacMahon, 2013; Pagé, Bernier, & Trempe, 2019). It is essential to highlight that the Modified Perceptual Training Framework (Hadlow, Panchuk, Mann, Portus, & Abernethy, 2018) suggests that transfer gains obtained from perceptual-cognitive training might be predicted based on the similarity degree between the training modality and the targeted skill. While efforts can be made to increase the stimulus correspondence of video simulations compared to what is seen in "real life", a difference in stimulus/visual correspondence between the two modalities (video vs real life) remains inevitable. This difference is probably one of the reasons why video simulations using a TV/computer screen lead to relatively modest levels of immersion in the action (Pagé, Bernier, & Tremp, 2019). According to the Modified Perceptual Training Framework (Hadlow et al. 2018), this dissimilarity would decrease the transferability of video simulation training programs. In this regard, it is noteworthy that "virtual reality" (VR), a visual-based computer simulation of a real or imaginary environment in which the viewer can interact with the simulation (Craig, 2013), can increase visual correspondence of the video simulation and may be able to improve perceptual-cognitive skills, such as passing decision-making, visual search behavior, and inhibitory control performance in team sport athletes.

VR is known as a visual-based computer which simulates a real or imaginary environment in which the viewer can interact with it (Dunkin, Holmberg, & Sperlich, 2018) and increases the action immersion feeling (Pagé et al., 2019). It is essential to highlight that there are different VR types, like those regarding virtual environments (Gray, 2017), and 360 video/360 VR/immersive video (i.e. Pagé et al., 2019, Kittel et al., 2019). In the virtual environment, the subject watches 3D video without any subject-environment interaction changes. There are an additional three other VR types (360 video/360VR/immersive video) allowing subject-environment interaction, in which the subject has control over their actions. Several studies have demonstrated the effectiveness of VR on perceptual-cognitive skill improvements (Gray, 2017; Miles Pop, Watt, Lawrence, & John, 2012; Pagé et al., 2019; Kittel, Larkin, Elsworthy, Lindsay & Spittle, 2020). The most recent studies verified improvements in perceptual-cognitive skills in basketball athletes post four VR experimental sessions (Pagé et al., 2019). Another recent study revealed improvement in decision-making skills in soccer athletes submitted to five experimental sessions with VR (Kittel, Larkin, Elsworthy, Lindsay & Spittle, 2020). Although the VR strategy seems to be promising to improve perceptual-cognitive skills in team sport athletes, the recent studies regarding this field have presented limitations such as: a) a reduced sample size in the experimental group (Pagé et al., 2019) and b) a short-term intervention (Kittel et al., 2020; Panchuk Klusemann, & Hadlow, 2018). These limitations mean that the findings cannot be generalized and new studies are needed to provide more significant accurate conclusions about the effect of VR on perceptual-cognitive skills in team sport athletes.

As a main practical point, this study might indicate if perceptual-cognitive skills (e.g., passing decision-making, visual search behavior, and inhibitory control) are improved when team sport athletes are chronically submitted to a VR or video-stimulation just before the training sessions. Thus, this study aimed to analyze the short-term effect of VR and video-stimulation screen training on passing decision-making, visual search behavior, and inhibitory control performance in young soccer players. Based on previous studies (Dunkin et al., 2018; Pagé et al., 2019), we hypothesize that VR would promote greater improvements in passing decision-making, visual search behavior, and inhibitory control than video-stimulation screen training in young soccer athletes.

Materials and Methods

Participants

We estimated the sample size using the GPower v.3.1 with the power set at 0.80, α = 0.05, and an effect size of 0.50 for passing decision-making performance in the experimental design of parallel groups (Pagé et al., 2019). The results indicated that twenty subjects were necessary for the study. By considering eventual losses and dropouts, 30% more volunteers were added to the first twenty volunteers, which resulted in a total of twenty-six volunteers needed for the study. The non-probabilistic method was adopted for sample recruitment. The recruited volunteers were about 15-16 years old (M = 15.4, SD = 0.3), at the national level, and had been playing soccer on average for 5.0 years (SD =1.2). They were randomly divided into two equal groups, hereafter named as the Virtual reality (VR) and Video screen (VID) groups. All experimental sessions were conducted in-season; therefore, the study was performed throughout the weekly training (i.e. three times per week). This study was approved by the local Ethics committee, the consent form was obtained from the volunteers, and the principles of the Helsinki Declaration were observed throughout the study.

Experimental design

This is an experimental and randomized study with parallel groups. The young male soccer athletes underwent an eight-week intervention (1st week - baseline assessment; 2nd-6th weeks - experimental sessions [three sessions per week]; and 7th week - post-experiment assessment) (Figure 1). Each volunteer performed 18 experimental sessions (VR or VID) plus

30 training sessions which involved physical, technical, and tactical skills. The athletes were pair-matched according to decision-making performance (pass) and randomized into two groups: VR (n = 13) and VID (n = 13).

Passing decision-making, visual search behavior (number of fixations and fixations duration time), and inhibitory control performance (accuracy and response time) were measured before (baseline) and after (post-experiment) the six-week intervention. An interval of 24-48 h was adopted between each test in both baseline and post-experiment measurements.

For the passing decision-making and visual search behavior analyses, the athletes were organized into two small-sided games (SSG) with different setups (5 vs. 5 and 3 vs. 3 with goalkeeper), adopting the official rules of soccer. A CANON® camera (SX60 model, Yokohama, Japan) was used in the passing decision-making analysis, and a head-mounted eye-tracking device was used to analyze visual search behavior.

All experimental procedures are illustrated in Figure 1. The participants were asked to avoid any physical exercise or alcohol ingestion 24-h before testing during the whole eight-week experiment, as well as to refrain from consuming caffeine at least 3-h before each training session.

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

Interventions

VR and VID. Videos for the VR and VID training sessions were custom-made for this study and acquired using a GoPro Hero 3. The GoPro Hero 3 captured 123° horizontal and 94° vertical images. VR group videos were edited on Final Cut Pro (Apple Inc.), while iMovie (Appel Inc.) was used to edit VID group videos. Participants enrolled in the VR group watched the VR videos in a Utopia 360 Head Mounted Display (HMD) equipped with an LG3 smartphone (LG Electronics), while an iMac desktop computer (iMac14.1, 21.5-inch) was used to present the videos from the VID group. The HMD presented the original scene 110° horizontally and 100° vertically (with both components being adjusted in real-time based on the orientation in the participant's head), while the computer screen displayed the entire field of view recorded with the GoPro Hero 3.

Before the training session the participants were asked to watch custom-made videos from a first-person perspective, including nine actors (four as teammates and five as opponents) performing pre-determined variations of two distinct offensive patterns related to a soccer game. Thus, from an observer's point of view, the perspective of the images captured by the camera was identical, and the same players were presented to the participants in both VR and VID groups. The video clips lasted an average of 10.2 seconds (SD = 0.4), and a total of 160 different video clips were recorded.

Participants of the VR and VID groups watched 20 video clips during each experimental session, which represents 60 video clips weekly. From the 160 video clips recorded, 100 were presented three times during the experiment, while 60 video clips were performed only once. The order of these video clips was randomized; however, once the video clip order was chosen, the same video clip was presented for all participants. Individuals from both experimental groups (VR and VID) were placed in different rooms while using the HMD or watching the video. The participants were instructed not to talk to each other during the intervention.

Small-sided games

Passing decision-making and visual search assessments were obtained during standardized SSGs before and after the intervention period. SSGs consisted of a standard 5 vs. 5 and 3 vs. 3 soccer matches on a 40 m x 30 m (for both SSG configurations) interior turf soccer field to avoid weather influence. The teams were composed of five (5vs5) or three (3vs3) players each, including a goalkeeper. Each player took part in four halves of 5 min in matches lasting 20 min; a 3-minute rest interval was adopted between each half in both SSG setups (5 vs 5 and 3 vs 3). Players who were waiting for the next game to start kept themselves warmed up by stretching or practicing with the ball. The SSG was recorded using two video cameras (Canon SX60, Japan). Cameras were positioned in the bleachers of the stadium, approximately 10 m above the playfield, to cover the entire playing area. Jerseys and numbers identified the players, and the video recordings were analyzed using Dartfish Connect v6.0.

Variable measurements

Passing decision making-performance. The passing decision-making ability during SSG was coded using standardized coding criteria adapted from a previous study (Romeas, Guldner, & Faubert, 2016). The decision component involves skill selection (i.e. passing), as well as which teammate received the pass. The quality of each decision was coded as 1 for an appropriate decision and 0 for an inappropriate decision according to the following criteria: 1) for the one-point decision, the player made the right decision when the pass went to a free (i.e. unmarked) teammate and: a) directly or indirectly created a shot attempt; or b) passed the ball to a teammate who was in a better position than himself; 2) for the zero-point decision, the player made a poor decision related to the pass because: a) he passed the ball to a player who was closely guarded or when there was a defensive player positioned in the passing lane; or b) the pass was intercepted or turned over; or c) the pass was directed to an area where no teammate was positioned; or d) he kicked the ball out of the playing field. Decisions which were not appropriate or inappropriate were not coded. Decision-making coding was assessed by two experienced soccer coaches blinded to the experiment and trained to use the instrument for coding. Next, the total score of each player by session was converted to a percentage for analysis. Percentage accuracy values were established for each participant by dividing the number of points awarded by the total amount available and then multiplying by 100. The intraclass coefficient correlation (ICC) was used to determine the reliability of passing decision-making accuracy at baseline (ICC = 0.82, $CI_{95\%}$ = 0.77 to 0.86) and post-experiment (ICC = 0.79, $CI_{95\%}$ = 0.74 to 0.85).

Visual search behavior. The visual search behavior data was measured using a portable Eye Tracking-XG (Applied Science Laboratories, USA) device with a sampling frequency of 60 Hz. A second camera with a frequency of 25 Hz attached to the eye-tracking-XG glasses worked as the footage of the game scenario. Data from both cameras were combined using the Gaze Tracker software program (Applied Science Laboratories, USA). Visual search data were analyzed frame-by-frame using video software (Kinovea open source project, www.kinovea.org). The number and duration of the fixations were obtained to examine visual search behavior during SSGs (5 vs 5 and 3 vs 3). A total of 55,536 trials (28,690 trials for SSG 5 vs. 5 and 26,846 trials for SSG 3 vs. 3) were coded of the maximum 64,400 possible. However, 8,084 trials were not included due to technical difficulties with the eye tracker and/or camera during data collection. Next, the recorded values were averaged across all trials for each participant. A fixation was defined as the time when the individual's gaze remained stationary at a specific location for a minimum of 100 ms or four video frames and within a 3° visual angle (or less). So, the number of fixations was the sum of all fixations during the experiment. In addition, the duration of the fixations was defined as the mean duration of all fixations higher than 100 ms observed during the experiment.

Inhibitory control. The Stroop task (Graf, Uttl, & Tuokko, 1995) was used to assess the inhibitory control and selective attention. Both are considered components of cognitive function. The task requires the participants to read the written color names of the words independently of the typed color (for example, they would have to read red even if the color in the font was blue). However, a mismatch between the name of the color and the printed color is commonly set up, which may cause a delay in the reaction time. A 50-words stimulus was applied, and 200ms-intervals were provided between the response and a new stimulus.

Moreover, the stimulus did not fade out 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 showed up on the screen in case of incorrect answers, and a new stimulus showed up. These same procedures have been used in other studies (Diamond, 2013; Gantois et al., 2019). Furthermore, the partipants of the present study were familiar with these procedures of Stroop Task. 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 intra-class coefficient correlation (ICC) and coefficient of variation (CV) were used to determine the reliability of accuracy (ICC = 0.96, CV = 3.5%) and response time (ICC = 0.93, CV = 5.4%) at baseline and post-experiment [accuracy (ICC = 0.94, CV = 3.2%) and response time (ICC = 0.95, CV = 5.7%)].

Statistical analysis

The Shapiro Wilk test was conducted to evaluate data distribution. The Levene test assessed homoscedasticity. Two-way mixed ANOVA of repeated measures was used to analyze the group (VR vs. VID) vs. time (baseline-vs post-experiment) interaction for passing decision-making, visual search behavior (number of fixations, and fixation duration) and inhibitory control (accuracy and response time) performance. The effect size (ES) was indicated by the partial eta square (ηp^2). Based on Cohen (1992) criteria, the following classifications were adopted: $\eta p^2 < 0.03$ = small; $0.03 \leq \eta p^2 < 0.10$ = moderate; $0.10 \leq \eta p^2 < 0.20$ = large, and $\eta p^2 \geq 0.20$ = very large effect size. Data were processed in the GraphPad Prism Software Version 8.0 program (California Corporation®, USA), and a significance level of 5% was adopted.

Results

Passing decision-making performance

A group x time interaction was found for passing decision-making performance in SSG 5vs5 (Figure 2A; $F_{(1, 24)} = 5.04$; $p = 0.02$ [$CI_{95\%} = 0.01$ to 0.03]; $\eta p^2 = 0.05$ [$CI_{95\%} = 0.03$ to 0.06]; ES moderate). The findings also presented group ($F_{(1, 24)} = 26.68$; $p = 0.001$ [$IC_{95\%} = 0.001$ to 0.01]; $\eta p^2 = 0.03$ [$CI_{95\%} = 0.01$ to 0.04]; ES moderate) and time ($F_{(1, 24)} = 14.75$; $p = 0.001$ [$CI_{95\%} = 0.001$ to 0.02]; $\eta p^2 = 0.02$ [$CI_{95\%} = 0.01$ to 0.04]; ES small) effects, where both groups improved the passing decision-making performance in SSG 5vs5 ($p < 0.05$) with greater improvements observed in the VR group ($p < 0.05$).

A group x time interaction for passing decision-making performance in SSG 3vs3 (Figure 2B; $F_{(1, 24)} = 7.07$; $p = 0.01$ [$CI_{95\%} = 0.003$ to 0.02]; $\eta p^2 = 0.04$ [$CI_{95\%} = 0.02$ to 0.06]; ES moderate). The findings also showed group ($F_{(1, 24)} = 36.86$; $p = 0.001$ [$CI_{95\%} = 0.001$ to 0.02]; $\eta p^2 = 0.03$ [$CI_{95\%} = 0.02$ to 0.05]; ES moderate) and time ($F_{(1, 24)} = 24.19$; $p = 0.001$ [$CI_{95\%} = 0.001$ to 0.03]; $\eta p^2 = 0.02$ [$CI_{95\%} = 0.01$ to 0.04]; ES small) effects. Although improvements were verified in both groups, the passing decision-making performance in SSG 3vs3 ($p < 0.05$) was greater in the VR group ($p < 0.05$).

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

Visual search behavior

Number of fixations. A group x time interaction was verified for the number of fixations in SSG 5vs5 (Figure 3A; $F_{(1, 24)} = 4.26$; $p = 0.04$ [$CI_{95\%} = 0.02$ to 0.05]; $\eta p^2 = 0.05$ [$CI_{95\%} = 0.03$ to 0.07]; ES moderate). The findings also showed group ($F_{(1, 24)} = 55.81$; $p = 0.001$ [$CI_{95\%} =$ 0.001 to 0.03]; $\eta p^2 = 0.02$ [$CI_{95\%} = 0.01$ to 0.04]; ES small) and time ($F_{(1, 24)} = 17.76$; $p =$ 0.001 [$CI_{95\%} = 0.001$ to 0.004]; $\eta p^2 = 0.02$ [$CI_{95\%} = 0.01$ to 0.05]; ES small) effects for the number of fixations in SSG 5vs5. Both groups increased the number of fixations ($p < 0.05$) with a greater increase observed in the VR group ($p < 0.05$).

A group x time interaction was found for number of fixations in SSG 3vs3 (Figure 3B; $F_{(1, 24)} = 7.26$; $p = 0.01$ [$CI_{95\%} = 0.002$ to 0.03]; $\eta p^2 = 0.04$ [$CI_{95\%} = 0.02$ to 0.06]; ES moderate). The findings also revealed group ($F_{(1, 24)} = 62.67$; $p = 0.001$ [$CI_{95\%} = 0.001$ to 0.01]; $\eta p^2 = 0.03$ [$CI_{95\%} = 0.01$ to 0.04]; ES moderate) and time ($F_{(1, 24)} = 29.04$; $p = 0.001$ [$CI_{95\%} = 0.001$ to 0.004]; $\eta p^2 = 0.02$ [$CI_{95\%} = 0.01$ to 0.03]; ES small) effects, where both groups increased the number of fixations ($p < 0.05$) with a greater increase in the VR group ($p < 0.05$).

Fixations duration. A group x time interaction was observed for fixation duration in SSG 5vs5 (Figure 3C; $F_{(1, 24)} = 4.13$; $p = 0.04$ [$CI_{95\%} = 0.03$ to 0.06]; $\eta p^2 = 0.03$ [$CI_{95\%} = 0.01$ to 0.05]; ES moderate). Furthermore, group ($F_{(1, 24)} = 15.10$; $p = 0.01$ [$CI_{95\%} = 0.003$ to 0.02]; $\eta p^2 = 0.02$ [$CI_{95\%} = 0.01$ to 0.04]; ES small) and time ($F_{(1, 24)} = 13.38$; $p = 0.01$ [$CI_{95\%} = 0.004$

to 0.03]; *ηp^2 = 0.03 [$CI_{95\%}$ = 0.02 to 0.06]; ES moderate*) effects were observed for fixation duration in SSG 5vs5. Both groups attenuated the fixation duration in SSG 5vs5 ($p < 0.05$), with a greater reduction in the VR group ($p < 0.05$).

A group x time interaction was found for fixation duration in SSG 3vs3 (Figure 3D; $F_{(1, 24)} = 7.26$; $p = 0.01$ [$CI_{95\%}$ = 0.003 to 0.04]; $\eta p^2 = 0.05$ [$CI_{95\%}$ = 0.02 to 0.07]; ES moderate), followed by group ($F_{(1, 24)} = 67.09$; $p = 0.001$ [$CI_{95\%}$ = 0.001 to 0.003]; $\eta p^2 = 0.03$ [$CI_{95\%}$ = 0.01 to 0.04]; ES moderate) and time ($F_{(1, 24)} = 29.04$; $p = 0.001$ [$CI_{95\%}$ = 0.001 to 0.01]; $\eta p^2 = 0.02$ [$CI_{95\%}$ = 0.01 to 0.04]; ES small) effects for fixation duration in SSG 3vs3. Both groups attenuated the fixation duration in SSG 3vs3 ($p < 0.05$), however, the VR group presented a greater reduction ($p < 0.05$).

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

Inhibitory control

No group x time interaction for accuracy was observed (Figure 4A; $F_{(1, 24)} = 0.23$; $p = 0.63$ [$CI_{95\%}$ = 0.50 to 0.72]; $\eta p^2 = 0.04$ [$CI_{95\%}$ = 0.02 to 0.05]; ES moderate). Although the findings presented no group effect ($F_{(1, 24)} = 0.05$; $p = 0.80$ [$CI_{95\%}$ = 0.61 to 0.84]; $\eta p^2 = 0.01$ [$CI_{95\%}$ = 0.004 to 0.03]; ES small), a time effect was verified for accuracy ($F_{(1, 24)} = 5.76$; $p = 0.02$ [$CI_{95\%}$ = 0.01 to 0.04]; $\eta p^2 = 0.02$ [$CI_{95\%}$ = 0.01 to 0.04]; ES small). Both groups improved the accuracy ($p < 0.05$) with no difference between them ($p > 0.05$).

A group x time interaction was not found for response time (Figure 4B; $F_{(1, 24)} = 2.46$; $p = 0.12$ [$CI_{95\%}$ = 0.07 to 0.18]; $\eta p^2 = 0.03$ [$CI_{95\%}$ = 0.01 to 0.04]; ES moderate). The findings did not present a group effect ($F_{(1, 24)} = 0.83$; $p = 0.86$ [$CI_{95\%}$ = 0.71 to 0.95]; $\eta p^2 = 0.01$ [$CI_{95\%}$ = 0.003 to 0.02]; ES small), despite indicating a time effect ($F_{(1, 24)} = 16.87$; $p = 0.01$ [$CI_{95\%}$ = 0.003 to 0.04]; $\eta p^2 = 0.02$ [$CI_{95\%}$ = 0.01 to 0.04]; ES small) for response time.

Additionally, both groups improved the response time ($p < 0.05$) with no difference between them ($p > 0.05$).

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

Discussion

This study aimed to analyze the short-term effects of VR and video-stimulation screen training on passing decision-making, visual search behavior, and inhibitory control performance in young soccer players. The main findings revealed greater improvements in passing decision-making skill and visual search behavior for athletes submitted to VR than VID, however, no group interaction effect was observed for inhibition control. Our hypothesis was partially confirmed.

Decision-making skill improvements as a result of the video-stimulation training observed in the present study can take place in a real-life context and adds relevant content to previous studies (Broadbent, Causer, Williams, & Ford, 2015; Gray, 2019). The VR group led to greater improvement in passing decision-making performance than the video-stimulation intervention, even watching similar training videos; these findings corroborate a previous study conducted by Kittel et al. (2020) assessing soccer athletes. Interestingly, a recent study assessed basketball players and also verified greater decision-making skills improvements after VR intervention compared to VID stimulation (Pagé et al., 2019); however, it appears that the number of offensive and defensive players may equally affect passing decision-making performance post-VR or post-VID intervention, since the results were similar for 5vs5 and 3vs3 SSG.

The better performance in passing decision-making observed in the VR group compared to VID stimulus is aligned with the Modified Perceptual Training Framework

(Hadlow et al., 2018), which suggests that transfer gains resulting from a perceptual-cognitive training can be predicted based on similarity degree between the training modality and the targeted skill. Both the VID and VR modalities targeted the same perceptual functions (e.g., anticipation and decision-making skills) and involved the same response correspondence in order to compare them. However, the videos presented in the VR headset looked closer to what would be perceived on a real soccer field and were thus more immersive. It seems that the immersion level can be a key factor leading to transferable gains of perceptual-cognitive skills (Brault, Kulpa, Duliscouët, Marin, & Bideau, 2015; Gokeler et al., 2016). It is also noteworthy that videos in the VR group were presented using a head-mounted display which was responsive to the head movements. This adjustment enabled more coupling between the participant's actions and acquiring visual information compared to the VID intervention, which provides the visual flow perception (Gray, 2019). When together, these two elements increased the sport-specificity of the stimulus correspondence (Hadlow et al., 2018).

Regarding visual search behavior, the results revealed an increased fixation number and a reduced fixation duration in both experimental groups. However, the VR group presented a more significant increase and reduced fixation number and duration, respectively, than the VID group. The VR group participants employed a different search strategy comprising a higher number of fixations of shorter duration and directed towards more suitable locations in the environment. The scientific literature has been indicating that more skilled soccer players usually show a higher number of fixations and lower fixation duration (i.e., fixation duration higher 100 ms) when compared to less skilled ones (Roca et al., 2018; Vaeyens et al., 2007). Therefore, although the video-stimulation screen can potentialize visual search behavior in young soccer athletes, it is essential to highlight that the VR showed greater efficiency. Our results suggest that VR can develop attentional focus, which has been shown to facilitate the emergence of skilled decision-making (Roca et al., 2018). Also, the results for visual search behavior data showed that players in the VR group could detect a greater number of teammates in positions which might lead to a goal-scoring opportunity if they received the ball.

In considering inhibitory control, the findings showed improvement in accuracy and response time for both VR and VID groups, without in-between differences. Our results suggest that both training strategies (i.e. video-stimulation screen and VR) were efficient in improving inhibitory control performance in young soccer athletes. Inhibitory control is an executive function which inhibits consistently irrelevant stimulation attention focus (Diamond, 2013). Thus, soccer players with higher inhibitory control performance employ a broader attention focus on more relevant stimuli, which facilitates the emergence of skilled creative behavior (Roca et al., 2018). According to Friedman, Fishbach, Forster, and Werth (2003), cognitive inhibition limits the stimuli number and relevant information which can be acquired and processed, providing game-relevant details to the players.

The present data presents relevant implications for coaches and those involved in developing perceptual training programs. The strengths of the study are the ecological validity (i.e. experimental design close to what happens in sport training centers) and originality (i.e. it is the first study to analyze the chronic effect of VR on visual search behavior in athletes). Although the present study revealed impressive results which might add information to the scientific literature, it presents some limitations such as the impossibility of blinding group allocation and treatment. Also, it was not possible to use an electroencephalogram to analyze brainwaves (i.e. alpha and theta) during VR and VID interventions. Therefore, the results should be interpreted cautiously, and future research should investigate the chronic effects of VR strategy on perceptual-cognitive skills in team sport athletes and measure brain waves.

Conclusion

In conclusion, our results support the effectiveness of using video simulations to improve decision-making skills, visual search behavior, and inhibitory control in athletes and confirm the value of this training modality. In addition, the greater gains obtained post-VR simulation is a very appealing strategy to further optimize the development of percept-cognitive skills in young soccer athletes.

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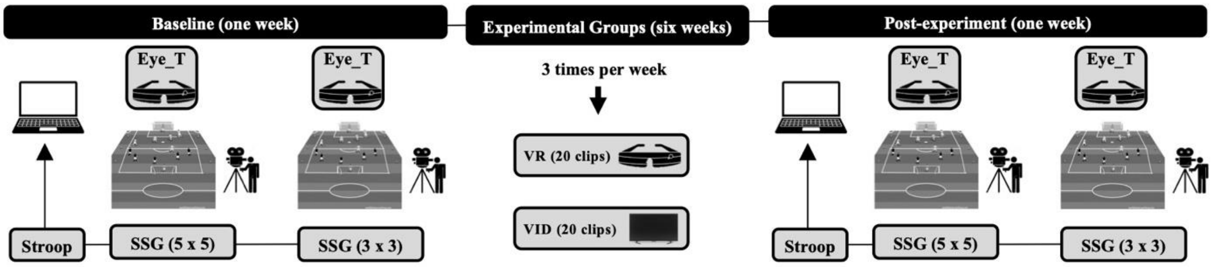

Figure 1

Experimental design of the study

Note. SSG = small-sided game; Eye_T = Eye-tracker; VR = virtual reality; VID = video screen.

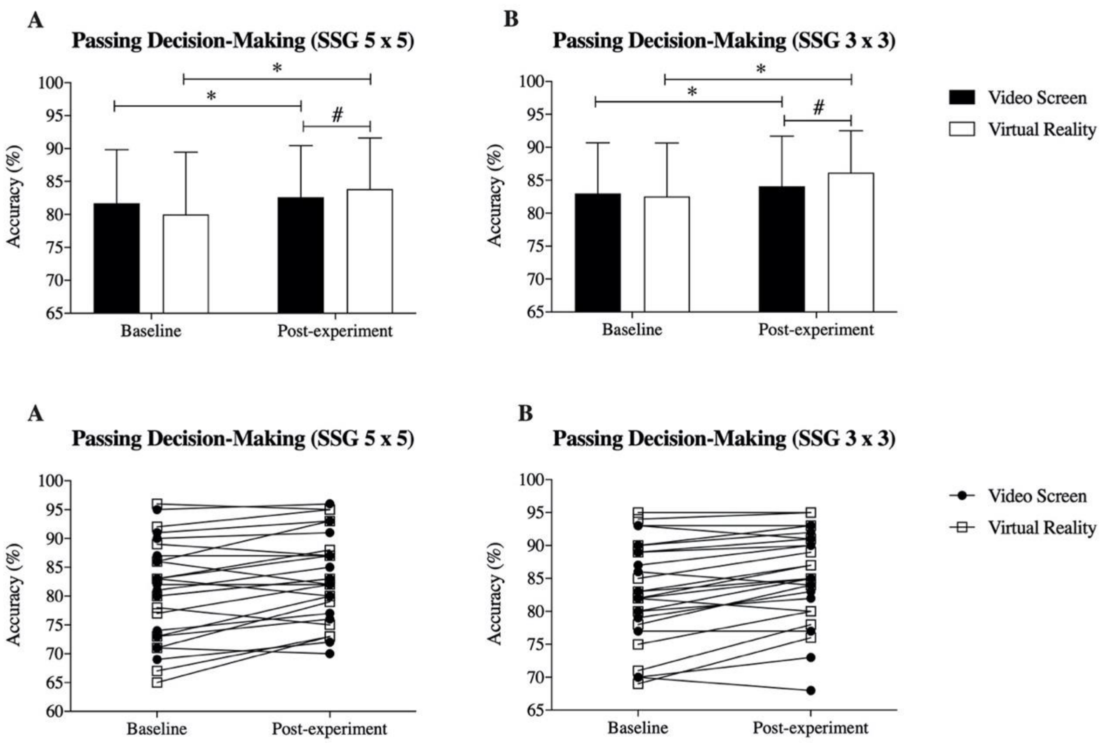

Figure 2

Passing decision-making performance in small-sided game 5vs5 (A) and 3vs3 (B) according to the experimental group (VR and VID) in young soccer athletes.

Note. **difference pre-vs post-experiment intra-group ($p<0.05$); #difference between groups in post-experiment ($p<0.05$).*

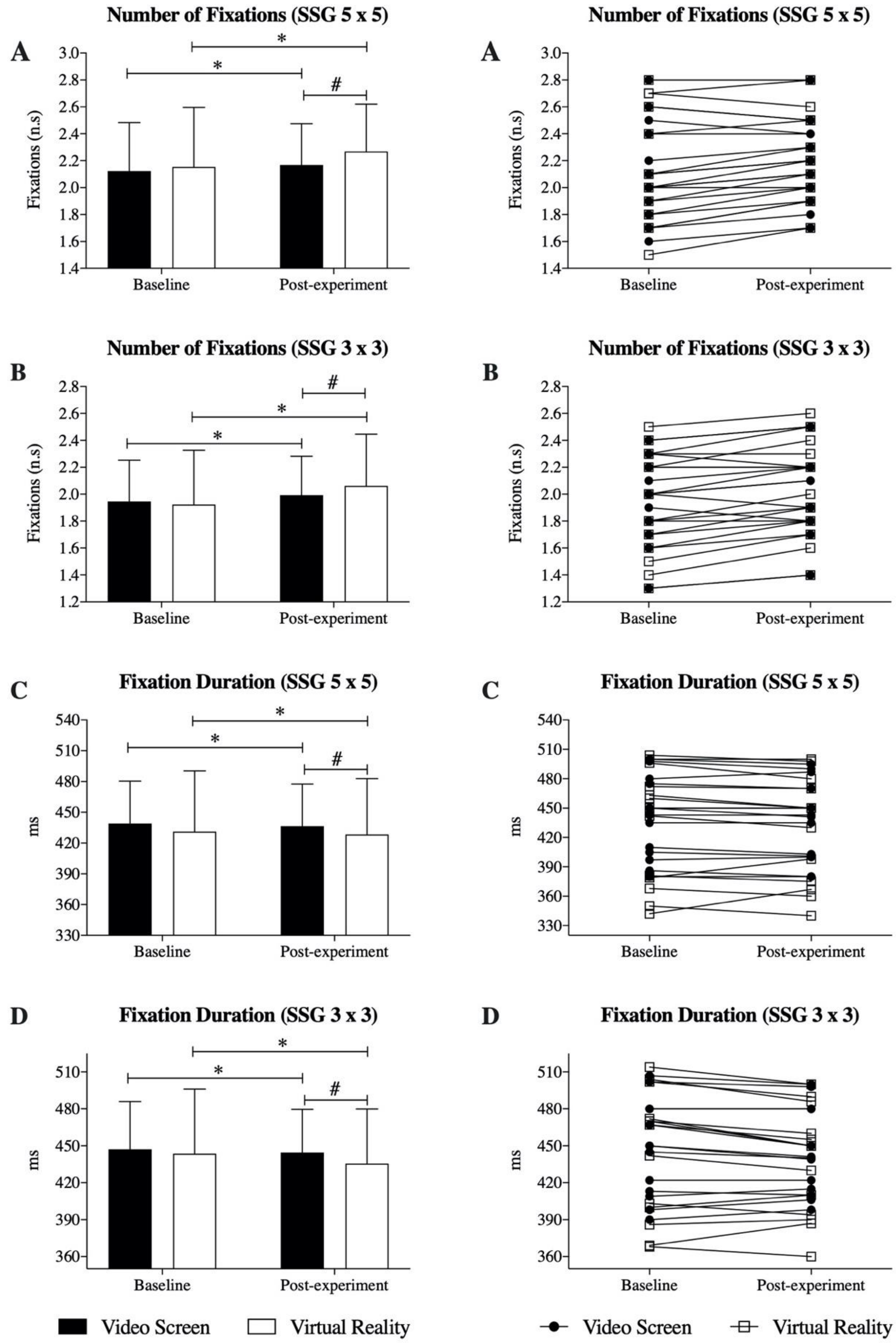

Figure 3

Number of fixations in small-sided game 5vs5 (A) and 3vs3 (B) and fixation duration in small-sided game 5vs5 (C) and 3vs3 (D) according to the experimental group (VR and VID) in young soccer athletes.

*Note. *difference pre-vs post-experiment intra-group (p<0.05); #difference between groups in post-experiment (p<0.05).*

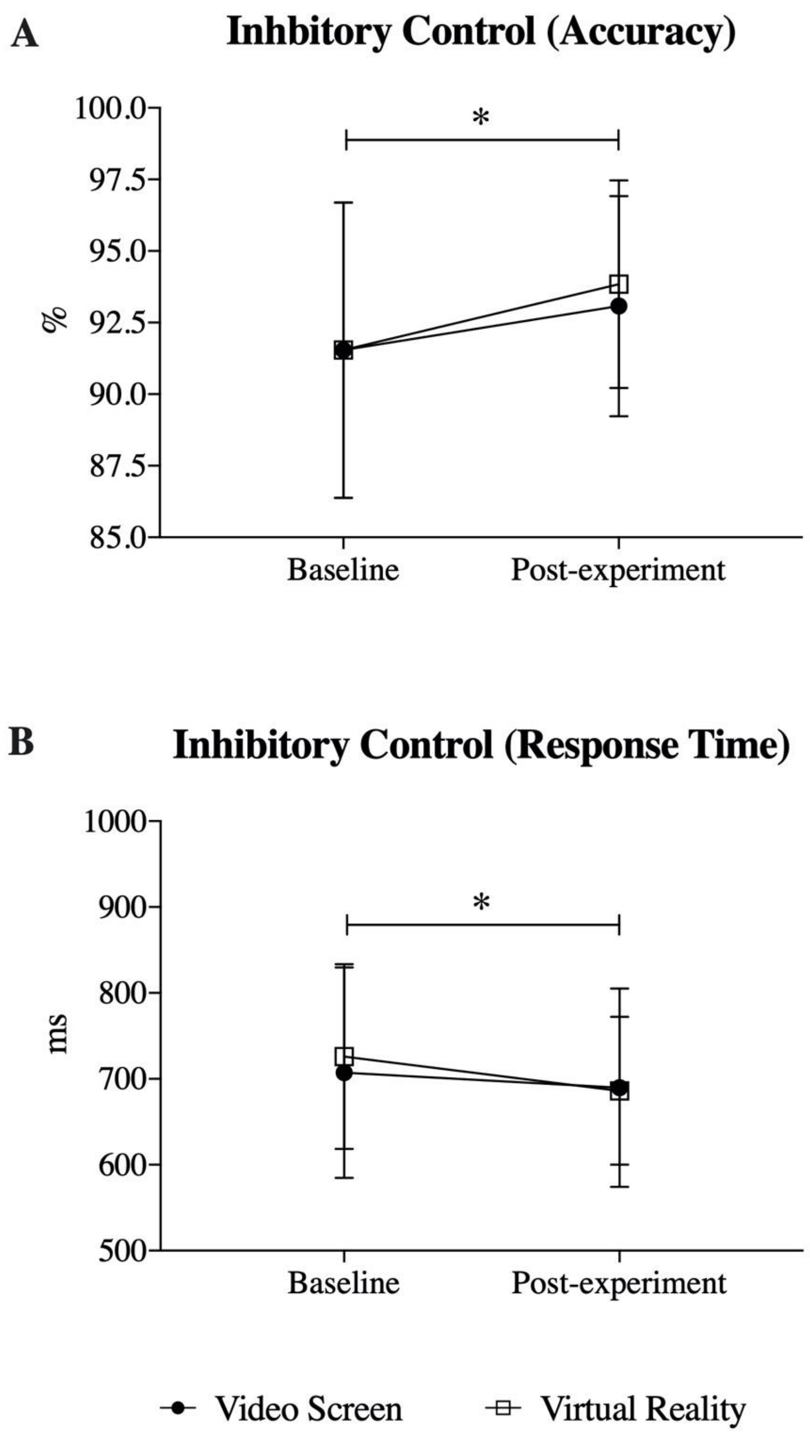

Figure 4

Accuracy (A) and response time (B) of inhibitory control according to the experimental group (VR and VID) in young soccer athletes.

*Note. *difference pre-vs post-experiment intra-group (p<0.05).*

Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes

Conflicts of interest: none