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BRIEF REPORT

No Effect of Expectancy on Visuospatial Attention in Brief Cognitive Training with Action Video Games

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Abstract

This study evaluated whether the expectation of cognitive improvement due to short-session practice with action games could affect visuospatial attention. All the 140 participants underwent a pre- and post-testing, or just a post-testing, of the Useful Field of View (UFoV) task in a single experimental session. Prior to the post-test, Placebo Group 1 watched a video inducing expectation of game-related effects on cognition, while Control Group 1 watched a control video, both followed by a 10-minute session of a virtual reality action video game. Placebo Group 2 and Control Group 2 underwent the same procedures, except for the pre-test (i.e., Solomon four-group experimental design). Although experimental manipulation induced expectation in Placebo Group 1 compared to Control Group 1, there were no differences of performance in the UFoV task. A comparison of Placebo Group 2 and Control Group 2 assessed an expectancy effect in the absence of a pre-test, and the results showed that the manipulation did not induce expectation, which was not observed in performance as well. A comparison among all experimental conditions in the post-test evidenced a carry-over effect caused by practice and suggests that performance in the placebo group may be benefited or intensified by a pre-testing. In summary, our results do not support previous investigations in the literature claiming that an expectancy effect may account for attentional gains in cognitive training studies.

Keywords Expectancy effects · Placebo effect · Attention · Action video games · Cognitive training

Introduction

Video games demand complex motor movements, a high cognitive load, and information filtering by its players (Bavelier & Green, 2019; Bediou et al., 2018; Latham et al., 2013; Oei & Patterson, 2013; Reynaldo et al., 2021; Stanmore et al., 2017). Particularly, video games require intricate perceptual (Bediou et al., 2018; Bejjanki et al., 2014; Sajan et al., 2017) and attentional processing (Bavelier and Green 2019; Bediou et al. 2018; Föcker et al. 2019; Green and Bavelier 2003, 2006a, b; Oei and Patterson 2013), in addition to recruiting working memory (Ballesteros et al. 2017; Colzato et al. 2013; Green and Bavelier 2006a, b; Toril et al. 2016), reasoning, and decision-making abilities (Curcio & Peracchia, 2019), among other functions compiled in reviews and meta-analyzes over the last decade (e.g., Anguera & Gazzaley, 2015; Bavelier & Green, 2019; Bediou et al., 2018; Boot et al., 2011; Dale et al., 2020; Latham et al., 2013; Stanmore et al., 2017). These findings are in line with prior research on the effects of action video games on neuroplasticity (Bavelier et al., 2012; Bavelier & Green, 2019; Colzato et al., 2013; Föcker et al., 2019; Palaus et al., 2020; Reynaldo et al., 2021; Wu et al., 2012).

Among the cognitive processes involved in video game playing, attention is a crucial skill when playing action video games. Action games are characterized by constantly changing scenarios that present visual and auditory stimuli in rapid sequences that demand fast responses for optimal performance (Bavelier and Green 2019; Bediou et al. 2018; Green and Seitz 2015; Green and Bavelier 2006a, b; Oei and Patterson 2013).

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Considering the very nature these games, research has focused on investigating how the practice of action video games influence attentional processes, and showed positive training effects on players' visual attention (Ballesteros et al., 2017; Bashiri et al., 2017; Bavelier et al., 2012; Bavelier & Green, 2019; Boot et al., 2011; Gonçalves & Castilho, 2024; Latham et al., 2013; Oei & Patterson, 2013). Of interest to this study, attentional gains associated with action video games have been observed in the Useful Field of View task (UFoV; Belchior et al. 2013; Green and Bavelier 2003, 2006a, b; Feng et al. 2018). The UFoV task was developed by Ball et al. (1988) to evaluate the distribution of selective attention across a wide visual field, and to assess limitations in attentional coverage in the visual space.

However, although some studies demonstrate cognitive gains resulting from action video game practice in terms of agility and improvement in attentional tasks and other cognitive functions (e.g., Bediou et al., 2018; Belchior et al., 2013; Boot et al., 2011; Colzato et al., 2013; Curcio & Peracchia, 2019; Föcker et al., 2019; Latham et al., 2013; Sajan et al., 2017; Stanmore et al., 2017), other studies showed no cognitive gains and even a decrease or depletion of attentional resources (Irons et al., 2011; Murphy & Spencer, 2009; Sala et al., 2018; Unsworth et al., 2015; van Ravenzwaaij et al., 2014). Additionally, issues related to experimental design and various methodological problems, such as the lack of control over participant expectations, have been highlighted in the literature. Review studies and opinion papers suggest that participants' expectations on cognitive gains (i.e., placebo-like effect) influence their performance in cognitive training studies involving video games and action video games (Anguera & Gazzaley, 2015; Bavelier & Green, 2019; Bediou et al., 2018; Boot et al., 2011; Dale et al., 2020; Denkinger et al., 2021; Latham et al., 2013; Masurovsky, 2020; Stanmore et al., 2017). These reviews are being corroborated by a new avenue of research that is gathering results of trials that show evidence of expectancy effects in cognitive training on the one hand (e.g., Edwards et al., 2021; Foroughi et al., 2016; Ng et al., 2020; Parong et al., 2022; Rabipour & Davidson, 2015; Rabipour et al., 2018; Tiraboschi et al., 2019; and Ziv et al., 2022), and others that do not (Ballesteros et al., 2017; Brantley et al., 2021; Schwarz & Büchel, 2015; Tsai et al., 2018; Vodyanyk et al., 2021; Watolla et al., 2020). The study conducted by Tiraboschi et al. (2019) was the first to investigate whether expectation during a brief video game training session modulates performance in visual attention tasks. The researchers conducted an experiment to assess spatial and temporal aspects of visual attention using the Useful Field of View (UFoV) and the Attentional Blink tasks, respectively. These tasks are commonly used in the literature of video game training (e.g., Green and Bavelier 2003, 2006a). All participants completed the UFoV and the Attentional Blink tasks before (i.e., pre-test) and after (i.e., post-test) playing a Sudoku on a tablet. Prior to the pre-test, the placebo group received written instructions that induced expectation by informing them about the benefits of video game playing. In contrast, the control group was told that they would play Sudoku during a break to recover. The results showed an overall performance increase in the UFoV task only for the placebo group, but no differences were found for the Attentional Blink task. The study was the first to show an expectation bias that was induced by a short textual instruction in a brief single video game training session, and therefore ruled out neuroplasticity-related confounding variables. A first conceptual replication of Tiraboschi et al.'s (2019) study was carried out by Joessel et al. (2025), who adopted nearly identical procedures, including expectation induction, pre- and post-tests, a brief session of cognitive training with Sudoku, and control groups. However, they introduced important methodological refinements, such as improved masking of participants and experimenters, enhanced baseline group matching, the addition of a negative-expectation (nocebo) group, and an increased sample size determined by Bayesian criteria. Nevertheless, their findings were not consistent with those of Tiraboschi et al. (2019). Specifically, participants' expectations—whether placebo or nocebo—did not modulate performance in visual attention, thus creating a point of impasse in the literature.

Even with the methodological contributions of Joessel et al. (2025), some aspects can still be improved in the replication of Tiraboschi et al.'s (2019) study. Sudoku, which is often employed as a control, fits well in a placebo intervention since there are no reports of any modulation of this reasoning game in visual attention (Bediou et al., 2018, 2023). However, Sudoku hampers the generalization of the results, as it greatly differs from action video games, which are of central interest in this research area (Bediou et al., 2018, 2023). According to Bediou et al. (2023), action video games are qualitatively defined by features such as fast pace, requirements for responses under severe time constraints, and a high perceptual, motor, and working memory load. Moreover, these games demand constant shifts between focused attention (on specific targets) and distributed attention (to monitor the entire visual field) in environments filled with stimuli and distractions. For the purposes of meta-analyses and cognitive training studies, the term "action video games" typically encompasses first- and third-person shooter games, which has been the dominant definition in the literature. These games are considered the most effective category for training visual attention due to their high interactivity and immersion (Bavelier & Green, 2019; Bediou et al., 2018, 2023; Dale et al., 2020; Dale & Green, 2017; Green and Bavelier 2006a, b). Therefore, for the purpose of replicating the study by Tiraboschi et al. (2019), we propose the use of a first-person shooter action game to ensure greater consistency with the literature.

Furthermore, the induction of expectation prior to the pre-test, as implemented in Tiraboschi et al.'s (2019) study, contrasts with more recent investigations on expectancy effects in the cognitive training literature (Brantley et al., 2021; Edwards et al., 2021; Tsai et al., 2018; Vodyanyk et al., 2021; Watolla et al., 2020; Ziv et al., 2022). Manipulating expectation before the pre-test hinders the establishment of a reliable baseline and may potentially induce a nocebo effect during the pre-test. In addition, the study did not control for individual differences in participants' level of gaming experience (see Boot et al., 2011; Ziv et al., 2022) or in their prior expectations regarding the cognitive benefits of video game practice (see Rabipour et al., 2018). These limitations were highlighted by Joessel et al. (2025) and were addressed in the present study.

Therefore, in the present study, we conducted a conceptual replication of Tiraboschi et al.'s (2019) UFoV task, addressing the aforementioned limitations of the original study and incorporating contributions from subsequent replications, such as Joessel et al. (2025). In addition, expectation induction was delivered in a video format, and participants played a brief action video game, based on a first-person shooter, using a virtual reality headset. The virtual reality environment provides deeper visual and auditory immersion while minimizing distractions and unwanted noise (Bashiri et al., 2017; Bauer & Andringa, 2020; Feng et al., 2018; Wais et al., 2021; Zając-Lamparska et al., 2019). We also implemented the Solomon four-group experimental design (Braver & Braver, 1988) to control for the effects of pre-testing, practice, and fatigue (i.e., carry-over effects). Participants in the Placebo 1 and Control 1 groups underwent both pre- and post-testing, whereas participants in the Placebo 2 and Control 2 groups completed only post-testing of the UFoV task (see Method).

We hypothesized that the placebo groups, following the experimental expectation induction, would demonstrate superior performance in the post-test compared to the control groups. Specifically, Hypothesis 1 predicted that the Placebo 1 group would outperform the Control 1 group; Hypothesis 2 predicted that the Placebo 2 group would outperform the Control 2 group; and Hypothesis 3 predicted that the placebo groups would exhibit better overall performance than the control groups after both the expectation induction and the action video game training.

Materials and Methods

Participants

A sample size of 136 participants ($n = 34$ per group) was estimated based on a priori 2×2 within-between power analysis (pre-/post-testing × control/placebo) using G-Power v. 3.1.9.7 (Faul et al., 2009) as specified in Cohen (1988). We set the effect size at 0.35, the power at 0.80, the significance level at 0.05, and the correlation among repeated measures at 0.50. Although the present study employed a Solomon four-group design, comprising both pretested and non-pretested groups, the sample size estimation was based specifically on the primary comparison of interest: the interaction effect between pre- and post-test scores in the placebo 1 and control 1 conditions. In these groups, the sample size was increased by approximately 48% compared to Tiraboschi et al. (2019) and by 28% compared to Joessel et al. (2025).

A total of 140 participants were recruited and randomly divided into four groups: Placebo 1 ($n = 37$, female = 23, male = 14, age = 18–29 y.o.), Control 1 ($n = 40$, female = 33, male = 6, preferred not to respond = 1, age = 18–35 y.o.), Placebo 2 ($n = 31$, female = 19, male = 11, preferred not to respond = 1, age = 18–27 y.o.), and Control 2 ($n = 32$, female = 21, male = 11, age = 18–31 y.o.). All participants had normal or corrected-to-normal visual acuity and had no history of sensory, motor, psychiatric, or neurological disorder.

Pre- and Post-Test: The Useful Field of View Task (UFoV)

Participants were positioned 30 cm away from a 24-inch monitor (refresh rate set at 144 Hz), and they had to detect the position of the target stimulus (a dark-gray filled triangle within a circle outline) amid distracting stimuli (gray filled squares). Both target and distractor encompassed 1.3º × 1.3º of visual angle (Fig. 1, right).

Each trial started by pressing the spacebar on a start screen displaying the message "press space to start the trial" (i.e., self-paced trials) that triggered a white cross-shaped central fixation point that was displayed for 600 ms. Immediately afterward, the target was flashed for 21 ms at one of three possible eccentricities, at 10º, 20º, or 30º of visual angle, and at one of eight possible radial directions relative to the center of the screen, i.e., 24 possible positions for stimulus presentation. Simultaneously, 23 distractors were displayed in the remaining 23 positions. Then, a visual mask was presented for 750 ms. At the mask offset, the participant used the numerical keyboard keys 1 to 9 to indicate the direction in which the target stimulus was presented. There was no time limit for response, but participants were instructed

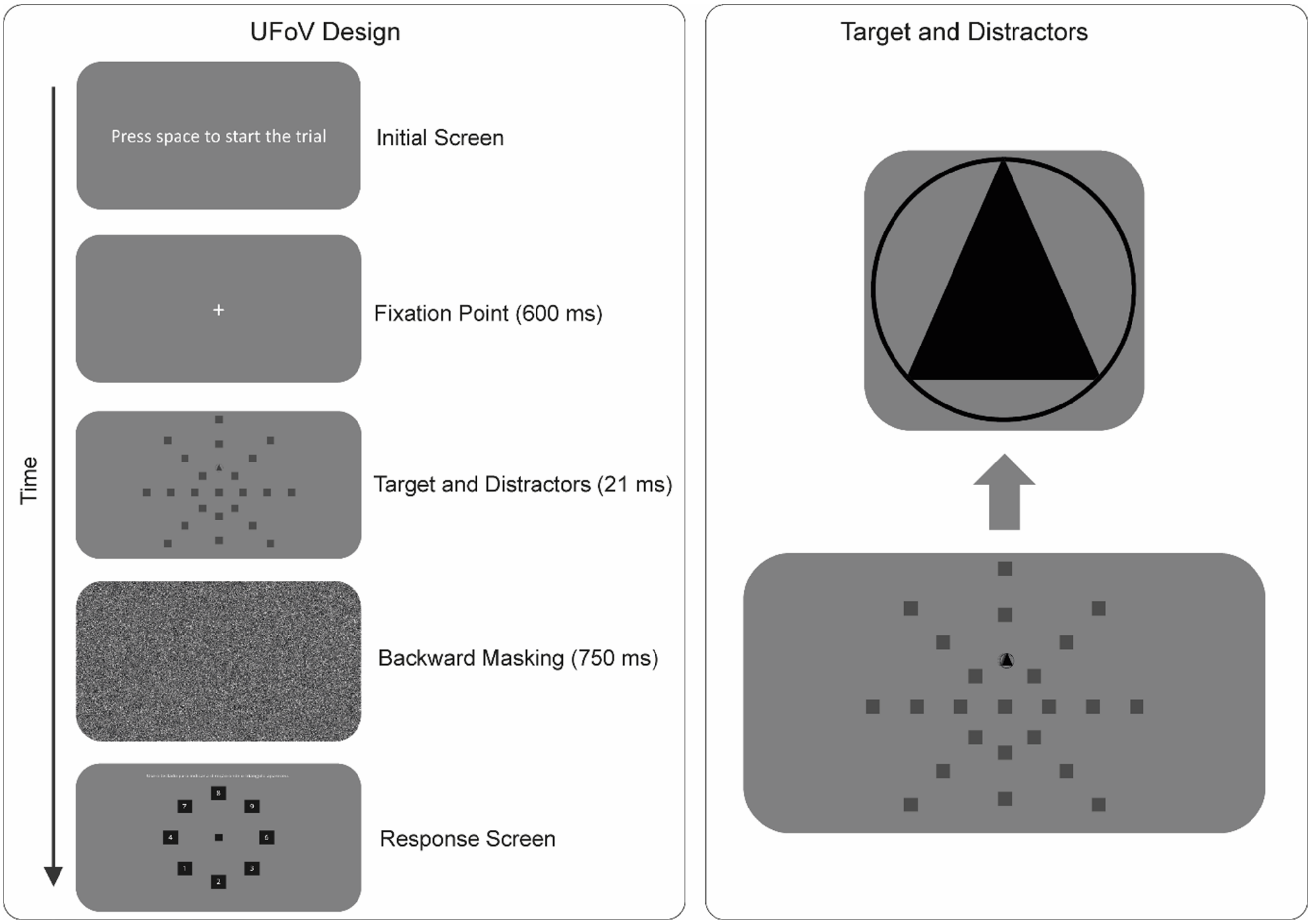


Fig. 1 The Useful Field of View Task (UFoV). The figure illustrates one trial (left) and the spatial layout of the visual stimulation with the target stimulus amid distractors (right)

to respond as quickly as possible. When the response was given, the initial screen was presented again, starting the subsequent trial. Figure 1 (left) illustrates one trial.

Participants completed 24 training trials at the beginning of the task with feedback indicating correct/incorrect responses. After the training phase, participants completed 240 trials with no feedback, consisting of 10 trials for each possible position of the stimulus. The experimental task took approximately 15 min. We used PsychoPy 3 v. 2022.2.4 (Peirce, 2007; Peirce et al., 2022) to present the stimuli and collect data. The code is available in the supplemental material of the Open Science Framework – OSF (https://osf.io/ahx7k/).

Procedures and Induction of Expectation

This study was approved by the Human and Social Sciences Research Ethics Committee of the University of Brasília (CAAE: 62068722.9.0000.5540) and was conducted under the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Participants were invited to a study that aimed to "evaluate visual attention in computerized tests". The study goal and the use of action video games in virtual reality were deliberately withheld to avoid a biased sample. The sample was reached by convenience using social networks and posters fixed on the campus bulletin boards. In the laboratory, the recruited participants read and signed an informed consent approved by the research ethics committee and then underwent a visual acuity assessment test using a Snellen chart (McGraw et al., 1995). After that, they completed a health and socio-demographic form (available in the supplemental material on OSF). Subsequently, eligible participants were randomly assigned to one of the experimental groups. The experiment was single-blind and was conducted in a single session in an adapted room under constant illumination. Participants performed the UFoV task in front of a computer using a chin and forehead rest and wore ear protectors to minimize auditory distractions.

The participants of the groups Placebo 1 and Control 1 performed the pre-test session of the UFoV task, and the participants of the groups Placebo 2 and Control 2 did not.

Then, all participants watched a 1.5-minute video. Participants in the placebo groups watched a video containing instructions aimed at inducing expectations on the cognitive benefits of playing action video games in a virtual reality setup. Control groups watched a video with neutral instructions reporting that participants were going to play a video game in a “brief break to prevent fatigue during the experiment, while keeping attentional resources working”. The videos included narration, subtitles, and copyright-free B-roll footage related to the script. The videos were adapted for each group (e.g., mentioning or not a pre-testing session). Scripts (203–237 words) are available in the Appendix, and the complete videos can be accessed both in the journal's supplemental material and on OSF (https://osf.io/ahx7k/).

Immediately after watching the video, all participants played the game Dead and Buried (Meta, Inc., Menlo Park, USA) using the Oculus GO 32 GB standalone virtual reality headset (Meta, Inc., Menlo Park, USA) for an average of 10 min (SD = 2 min). The duration was based on the original study by Tiraboschi et al. (2019) and its conceptual replication by Joessel et al. (2025), aiming to isolate the effect of expectation and avoid confounding it with the effects of the video game training itself (see Discussion). The game combines elements of the First-Person Shooter and Beat’em Up genres, in which the player controls a gunslinger in a Western setting and shoots at successive waves of zombies. Each wave contained a certain number of enemies to be defeated, and as the player advanced, the game progressively increased in difficulty, introducing stronger and faster enemies. This design required a high level of attention to detect enemies across the visual field. This game meets the criteria defined by Bediou et al. (2018, 2023) for action video games, which are consistently recommended in the literature. Figure 2 illustrates the procedure adopted for each group (top) and images of the action video game played (bottom). Immediately after playing the video game, all participants performed the UFoV post-test.

After the post-test, participants completed two questionnaires. The first questionnaire inquired about participants’ level of expertise in action video games (no experience–very experienced), frequency of gameplay (no frequency – high frequency), and mental states during the research (happy–sad, relaxed–anxious, and rested–fatigued) on a paper-and-pencil visual analogue scale ranging from 0 to 100, in addition to an inquiry about weekly hours dedicated to gaming scaled from 0 to 20 h. The second questionnaire included three questions about participants’ expectations regarding the trained game. Item 1 evaluated the potential effect of pre-testing, and examined participants’ performance perceptions in groups that did not undergo pre-testing. Item 2 assessed how much participants expected their performance to be altered due to action games in virtual reality. And item 3 assessed the expectation of video game effects on people’s attention. Items 1 and 2 were adapted for groups Placebo 2 and Control 2. Participants also responded on a visual analog scale ranging from 0 (strongly disagree) to 100 (highly agree). Full transcripts of the expectancy-related items are found in the Results.

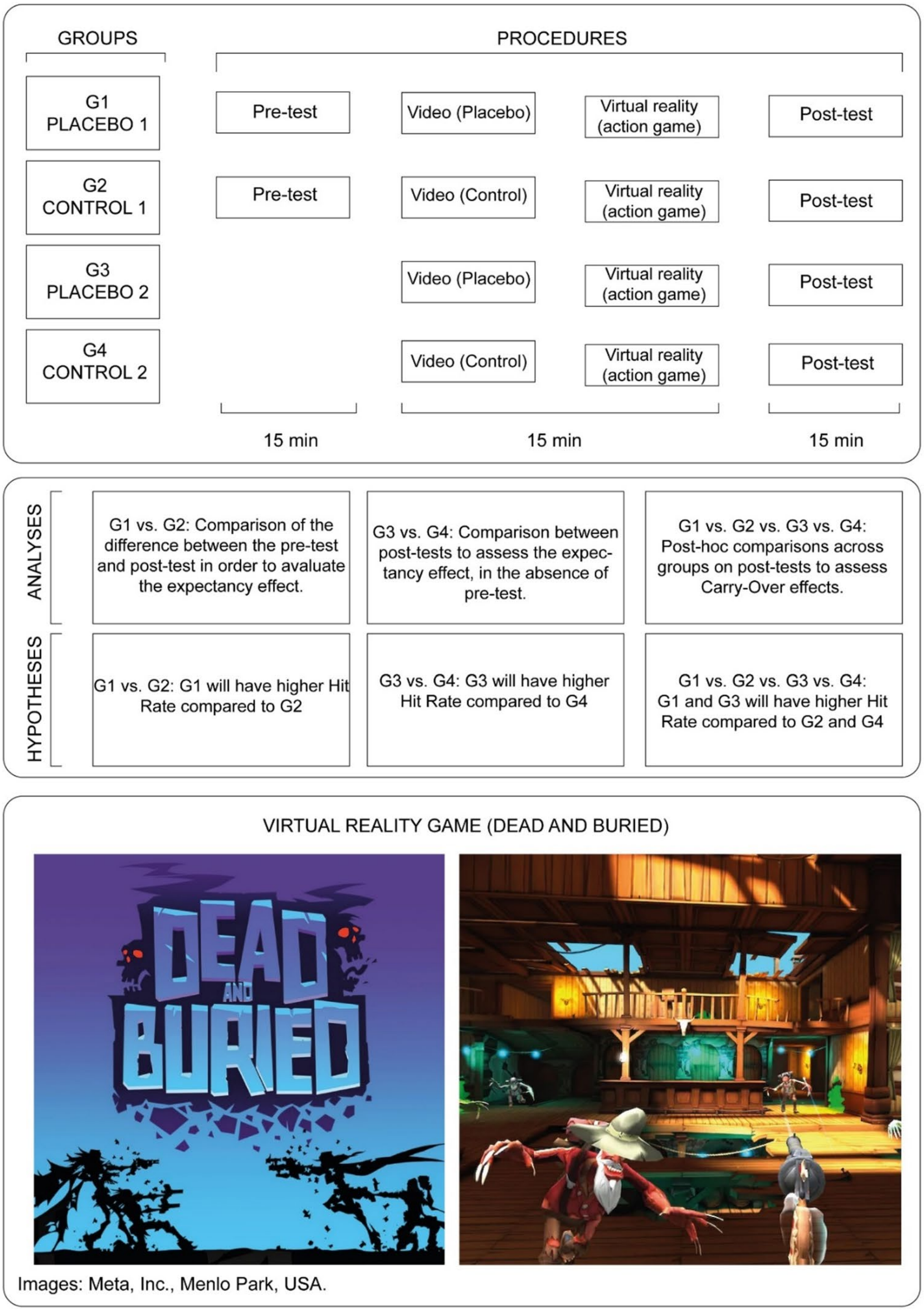
The experimental session took approximately 60 min for groups Placebo 1 and Control 1, and 45 min for groups Placebo 2 and Control 2. This included an average of: 15 min for the UFoV application; 15 min for video presentation and virtual reality training; and additional 15 min for questionnaire and scale administration. The questionnaires, scales, stimuli, and experiment codes used in the study are available as supplemental materials on OSF.

Experimental Design and Data Analysis

The current investigation implemented a Solomon four-group experimental design to control for the effects of pre-testing, practice, and fatigue (Braver & Braver, 1988). Thus, participants were randomly assigned to the groups Placebo 1, Control 1, Placebo 2, or Control 2 (also represented as G1–G4 in Fig. 2, top). We employed a general $2 \times 2 \times 2 \times 3$ experimental design with Pre-testing (present and absent) and Expectation (placebo and control) as between factors, and Session (pre- and post-test) and Eccentricity (10º, 20º, and 30º visual angle) as within factors. The hit rate was assessed as a measure of performance in the UFoV task.

Three different analyses were performed based on appropriate statistical analyses for this experimental design (Braver & Braver, 1988). Although the Pre-Testing factor accounted for the occurrence of a pretest in the Solomon four-group design, it was not included in our main analysis. Instead, we focused on pre- and post-test comparisons within the Placebo 1 and Control 1 groups across all eccentricities, which allowed us to directly examine the presence of an expectancy effect (i.e., primary analysis: Expectation [2] × Session [2] × Eccentricity [3]). Likewise, a comparison between Placebo 2 and Control 2 assessed an expectancy effect for all eccentricities while ruling out pre-test biases (i.e., second analysis: Expectation [2] × Eccentricity [3]). Finally, a comparison of the post-test for all eccentricities among all four groups evaluated the effects of pre-testing, practice, and fatigue, controlling for the occurrence of the Pretesting factor (i.e., third analysis: Pre-testing [2] × Expectation [2] × Eccentricity [3]). Analyses and hypotheses are stated in Fig. 2 (center).

Exploratorily, similar analyses were conducted using individual difference data obtained from the scales as covariates in ANCOVAs. We included measures related to participants’ mental states during the study (happy–sad, relaxed–anxious,



Images: Meta, Inc., Menlo Park, USA.

Fig. 2 Solomon four-group design. The top part presents the Solomon four-group experimental design adopted in the study. The central part presents the study hypotheses. The bottom part illustrates the action video game used in the training session; information and a demo video are found at www.meta.com/experiences/pcvr/1198491230176054/

and rested–fatigued), in addition to an inquiry about weekly hours dedicated to gaming, scaled from 0 to 20 h, and three questions assessing participants' expectations regarding the trained game. Additionally, MANOVAs were conducted with Hit Rate and Reaction Time as dependent variables.

The statistical analyses were conducted using Jamovi v. 1.1.9.0 (The Jamovi Project, 2019). The significance level was set at 5%. Normality was assessed by the Shapiro-Wilk test and density plots. We used Greenhouse-Geisser correction when sphericity was violated. Bonferroni adjustment and Dwass-Stell-Crichlow-Fligner test (nonparametric) were used for post hoc multiple comparisons. In addition to frequentist analyses, given the limited statistical power for detecting triple interactions (analyses 1 and 2), Bayesian repeated-measures ANOVA and post hoc comparisons were conducted to provide a more comprehensive interpretation of the results. The Bayesian framework allowed us to quantify the strength of evidence supporting either the null or alternative hypotheses, offering a more nuanced perspective on the observed effects. Bayes Factors (BF_{10}) were reported to compare the predictive performance of models. To specifically evaluate the interaction effects, Bayes factors were calculated by dividing the BF_{10} of the model that included the interaction by the BF_{10} of the nested model that excluded it (see van den Bergh et al., 2022). According to Lee and Wagenmakers (2013), Bayes factors (BF_{10}) between 1 and 3 were considered anecdotal evidence for the alternative hypothesis, 3 to 10 moderate evidence, 10 to 30 strong evidence, 30 to 100 very strong evidence, and values above 100 extreme evidence. Conversely, BF_{10} values between 1/3 and 1 indicated anecdotal evidence for the null hypothesis, 0.1 to 1/3 moderate evidence, 0.033 to 0.1 strong evidence, 0.01 to 0.033 very strong evidence, and values below 0.01 extreme evidence.

Results

Subjective Perception of Expectation

We initially assessed whether the study successfully induced expectation in participants assigned to the placebo groups. For this purpose, participants rated their expectations using a visual analogue scale at the end of the study (as described in the subsection "Procedures and Induction of Expectation"). The ratings were non-normally distributed for all items.

On Item 1, "I believe that my performance improved from the first session to the second session of the experiment," assessed participants' subjective perception of improvement due to UFoV-task training. Placebo Group 1 had significantly higher ratings than Control Group 1, U=483, p = .009, rank-biserial r = .34, BF_{10} = 5.232. This Bayes Factor indicates moderate evidence in favor of a group difference. For Placebo Group 2 and Control Group 2, the item was adapted to "I believe I performed well during the test." No significant difference in ratings was observed, p = .315, BF_{10} = 0.318, suggesting moderate evidence in favor of the null hypothesis (i.e., no difference between groups; see Fig. 3, left).

Item 2 assessed a subjective perception of expectation in the statement "I believe that my performance improved from the first to the second session due to the virtual reality game", and Placebo Group 1 presented higher rates compared to Control Group 1, U=407, p = .001, rank-biserial r = .45, BF_{10}=20.779. This result provides strong evidence

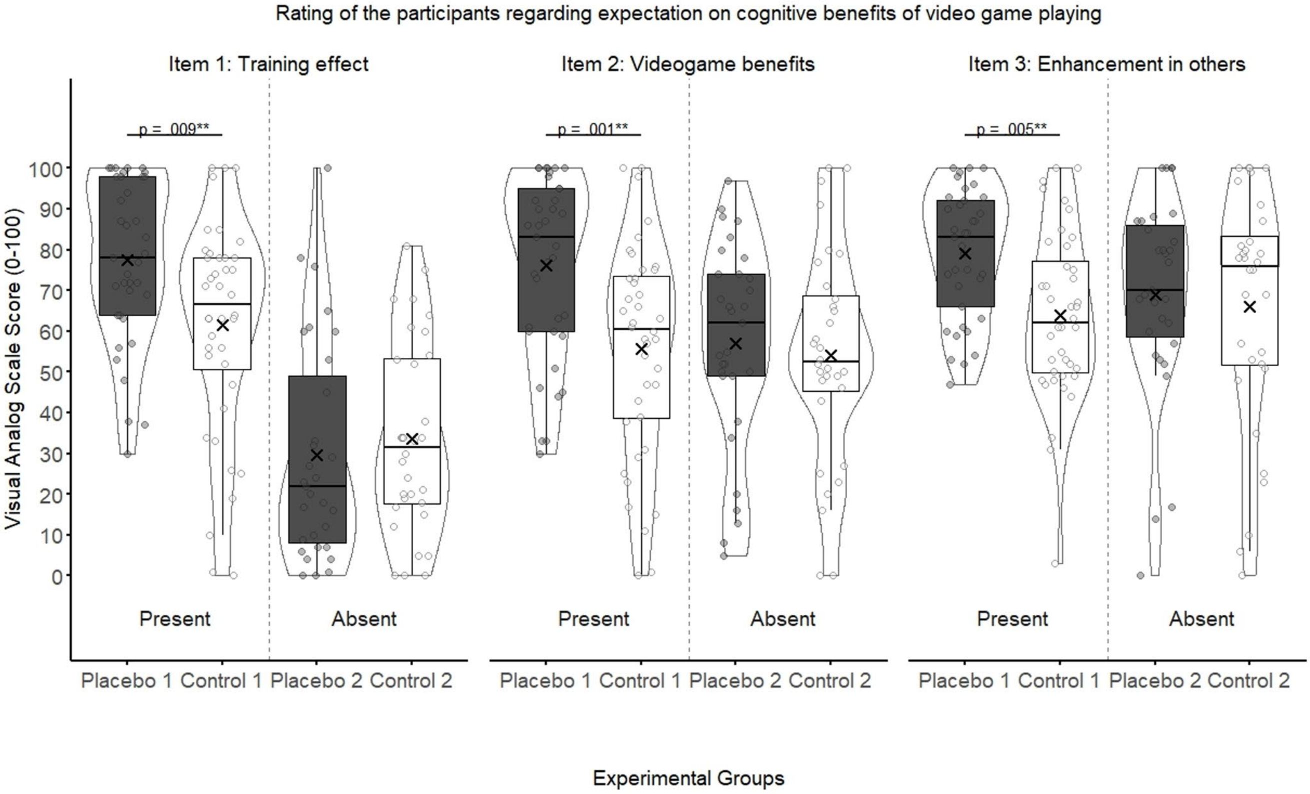


Fig. 3 Rating of the participants regarding expectation on cognitive benefits of video game playing. Ratings of the three expectancy items (full transcript of each item is found in the text). Item 1 (left): Training effect; Item 2 (center): Videogame benefits; Item 3 (right): Enhancement in others ratings are shown for each group: Placebo 1 (dark gray), Control 1 (white), Placebo 2 (dark gray), and Control 2 (white). The cross "×" indicates the mean score for each group; "Present" and "Absent" refers to the presence or absence of the UFoV pre-testing. Ratings ranged from 0 (strongly disagree) to 100 (highly agree)

supporting the presence of an expectancy effect. The adapted item for Placebo 2 and Control 2 was: "I believe that my performance in the test is better when I play the virtual reality game compared to the performance when I do not". No rating differences were observed, p = .518, BF_{10} = 0.286, offering moderate support for the absence of an expectancy effect (Fig. 3, center).

Item 3 assessed a subjective perception of cognitive enhancement due video game in others. The statement "I believe video games improve people's attention" was presented for all groups, which were directly compared (Kruskal-Wallis), X^2 (3) = 10.45, p = .015, ε^2 = 0.07, BF_{10} = 1.73. While the frequentist analysis suggested a significant overall difference, the Bayes Factor indicated inconclusive evidence for the global effect. However, post hoc comparisons clarified the result: Placebo Group 1 reported significantly higher ratings than Control Group 1, p = .005, BF_{10} = 48.301, representing very strong evidence for a group difference. In contrast, no difference was observed between Placebo Group 2 and Control Group 2, p = .988, BF_{10} = 0.279, supporting the null hypothesis (Fig. 3, right).

In summary, subjective ratings of expectation were consistently higher in Placebo Group 1 than in Control Group 1 across all three items, with BF_{10} indicating moderate to strong evidence supporting these effects. Conversely, no differences were observed between Placebo Group 2 and Control Group 2 for any item, with Bayesian analyses consistently favoring the null hypothesis. These findings suggest that expectation was successfully induced only in Placebo Group 1, the group that underwent both pre- and post-testing. The convergence between frequentist and Bayesian results reinforces the reliability of this interpretation.

Attentional Performance

Hypothesis 1: Is there a performance difference between the Placebo 1 and Control 1 groups?

We assessed an expectancy effect by examining changes in mean hit rate between the Placebo 1 and Control 1 groups (see Fig. 4). A three-way mixed ANOVA was conducted with Expectation (placebo vs. control) as the between-subjects factor, and Session (pre- vs. post-test) and Eccentricity (10º, 20º, and 30º) as within-subjects factors. This is the same analysis conducted by Tiraboschi et al. (2019). The ANOVA revealed a main effect of Session, $F(1, 75) = 72.62$, $p < .001$, $\eta_p^2 = 0.49$, $BF_{10} = 4.17 \times 10^5$, indicating strong evidence that hit rate was higher in the post-test. A main effect of Eccentricity was also observed, $F(1, 101) = 139.67$, $p < .001$, $\eta_p^2 = 0.65$, $BF_{10} = 1.34 \times 10^{54}$, indicating strong evidence that target stimuli were better recognized at 10º than at 20º, which in turn were better recognized than at 30º (all with $p <$ .001, $BF_{10} \geq 2.96 \times 10^{19}$). No main effect of Expectation was found, $F(1, 75) = 3.46$, p = .067, $\eta_p^2 = 0.04$, BF_{10} = 0.89, providing anecdotal or insensitive evidence in favor of the null.

Importantly for the study goal, the two-factor interaction Expectation × Session was nonsignificant, $F(1, 75) = 1.79$, p = .188, $\eta_p^2 = 0.02$, BF_{10} = 0.21, providing moderate evidence in favor of the null hypothesis. The three-way interaction including Eccentricity was also nonsignificant, $F(2, 139) = 0.41$, p = .647, $\eta_p^2 < 0.01$, BF_{10} = 0.10, providing strong evidence for the null hypothesis. Therefore, the experimental manipulation of expectation did not modulate attentional performance. The two-factor interaction Expectation × Eccentricity was significant, $F(1, 101) = 4.68$, p = .023, $\eta_p^2 = 0.06$, BF_{10} = 13.10. However, the hit rates of the Placebo 1 and Control 1 groups did not differ when the target stimulus was presented at the same spatial distance from the fixation point, regardless of eccentricity condition, all with $p \geq .076$. The two-factor interaction Eccentricity × Session was also significant, $F(2, 139) = 4.86$, p = .011, $\eta_p^2 = 0.06$, BF_{10} = 0.22, and post hoc analyses revealed strong evidence for an increase in hit rate from pre- to post-test when comparing the same target stimulus eccentricity (all with $p <$ .001).

Hypothesis 2: Is there a Performance Difference Between the Placebo 2 and Control 2 groups?

A second analysis compared the mean hit rate of the Placebo 2 and Control 2 groups to assess an expectancy effect while ruling out pre-test biases (see Fig. 5, right). A two-way mixed ANOVA was then carried out with Expectation and Eccentricity as factors. Similar to the "Placebo 1 vs. Control 1" comparison, a main effect of Eccentricity was found, $F(2,100) = 78.47$, $p <. 001$, $\eta_p^2 = 0.56$, $BF_{10} = 4.92 \times 10^{19}$, providing strong evidence for a higher hit rate for target stimuli presented at 10º, 20º, and 30º, in that order (all pairwise comparisons with $p < .001$, $BF_{10} \geq 2.72 \times 10^{12}$). Importantly for the study goal, no main effect of Expectation was found, $F(1,61) = 2.03$, p = .159, $\eta_p^2 = 0.03$, BF_{10} = 0.71, providing anecdotal evidence in favor of the null. The Expectation × Eccentricity interaction was also nonsignificant, $p < .05$, BF_{10} = 0.10, with moderate evidence in favor of the null hypothesis. These results support our previous analysis, indicating that the expectation of cognitive benefits from video game playing does not modulate visuospatial attention.

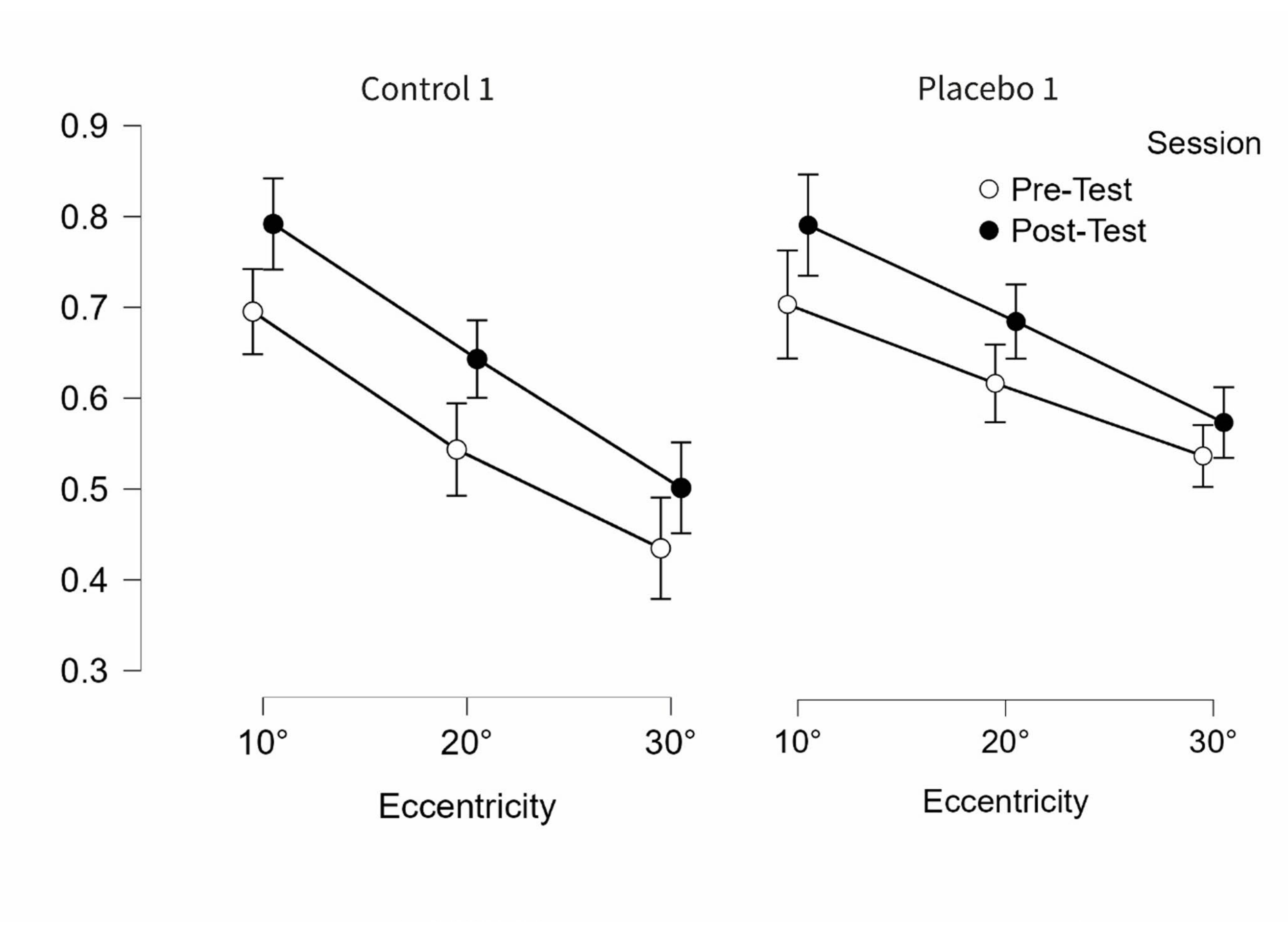


Fig. 4 UFoV performance in the pre- and post-test for the groups Placebo 1 and Control 1. Hit rate as a function of eccentricity for Control 1 (left) and Placebo 1 (right) groups. White circles represent pre-test sessions and black circles represent post-test sessions. Error Bars indicate 95% confidence intervals

Hypothesis 3: Is there a Performance Difference Across all Groups Following Expectation Induction and Training?

Finally, a comparison of the mean post-test hit rate across all experimental groups and eccentricities was conducted to evaluate the effects of pre-testing and carry-over from practice (see Fig. 5). A three-way mixed ANOVA was performed with Pre-testing (present vs. absent) and Expectation (placebo vs. control) as between-subjects factors, and Eccentricity (10º, 20º, and 30º) as a within-subjects factor. The ANOVA revealed a main effect of Pre-testing, $F(1, 136)=8.75, p=.004, \eta_p^2=0.06, BF_{10}=7.44$, providing moderate evidence for a greater hit rate in the post-test for groups that underwent a pre-test. This result suggests a carry-over effect caused by practice. No main effect of Expectation was found, $F(1, 136)=0.20$, p = .655, η_p^2 < 0.01, BF_{10} = 0.19, providing moderate evidence that the induction of expectation did not modulate visuospatial attention in the UFoV task, which supports our previous analysis. A main effect of Eccentricity was found, $F(2, 196)=199.38$, p < .001, η_p^2 = 0.59, BF_{10} = 1.65×10^{51}, and pairwise comparisons supported previous results for this factor (all with p < .001, $BF_{10}\geq1.07\times10^{17}$), providing strong evidence for the effect of eccentricity. The interactions " Expectation × Eccentricity" and "Pre-testing × Expectation × Eccentricity" were nonsignificant, with ps > 0.05, $BF_{10}\leq0.64$. The significant interaction Pre-testing × Eccentricity, $F(2, 196)=4.59$, p = .021, η_p^2 = 0.03, BF_{10} = 3.36, provided moderate evidence that the post-test hit rate of the experimental groups that underwent a pre-test was greater than the groups with no pre-testing, but only when the target stimulus was presented at 10º (p = .010). The effect was marginally significant at 20º (p = .069) and nonsignificant at 30º of eccentricity (p > .999; see Fig. 6, left). The interaction Pre-testing × Expectation was also significant, $F(1, 136)=4.11$, p = .045, η_p^2 = 0.03, BF_{10} = 1.35, providing anecdotal or insensitive evidence for the alternative hypothesis. The only significant comparison showed that the post-test hit rate of the pre-tested placebo group (Placebo Group 1) was higher than the placebo group

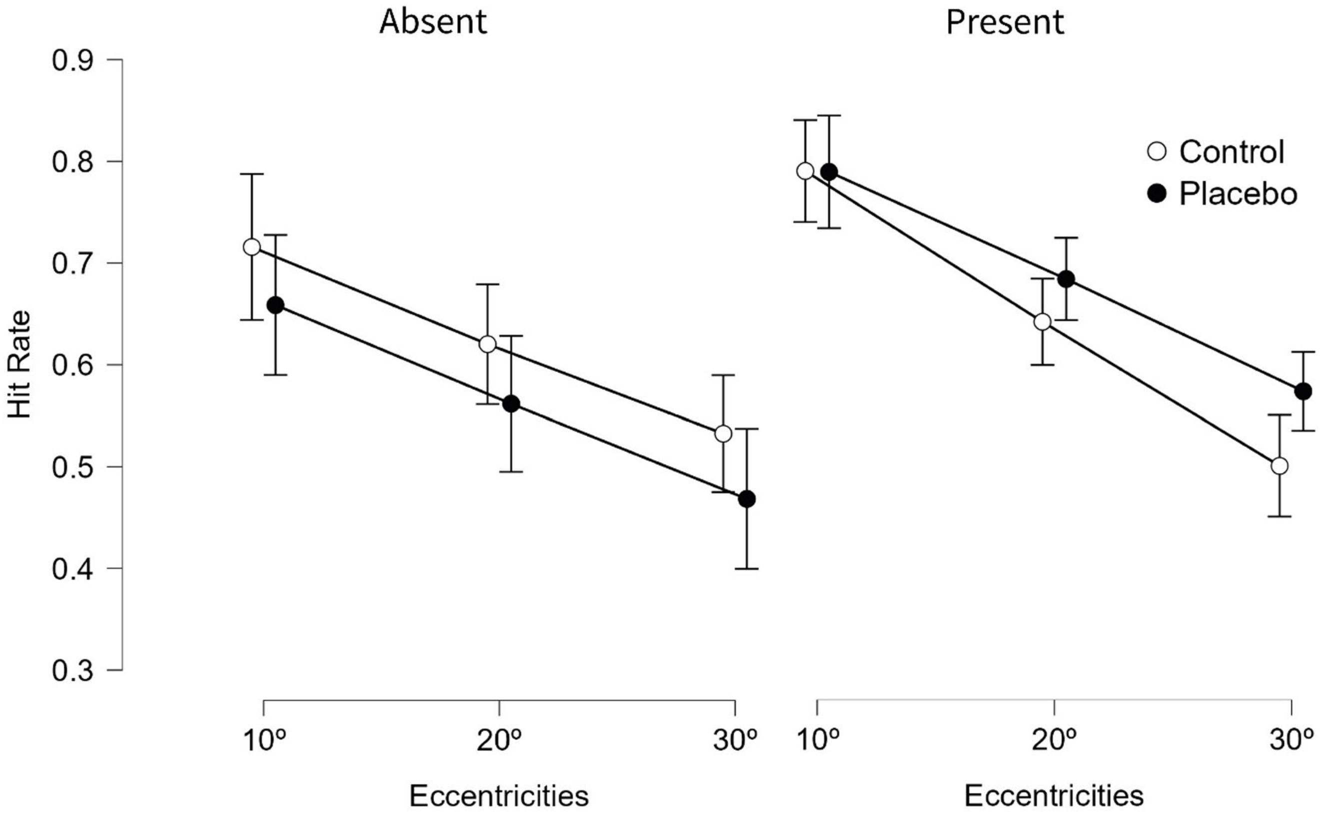


Fig. 5 UFoV Performance in the post-test grouped by pre-testing conditions (present or absent). Hit Rate of the Control 1 and Placebo 1 (pre-test performed [Present]) groups are represented on the right half, and the Control 2 and Placebo 2 (pre-test not performed [Absent]) groups are represented on the left half. The error bars indicate 95% confidence intervals

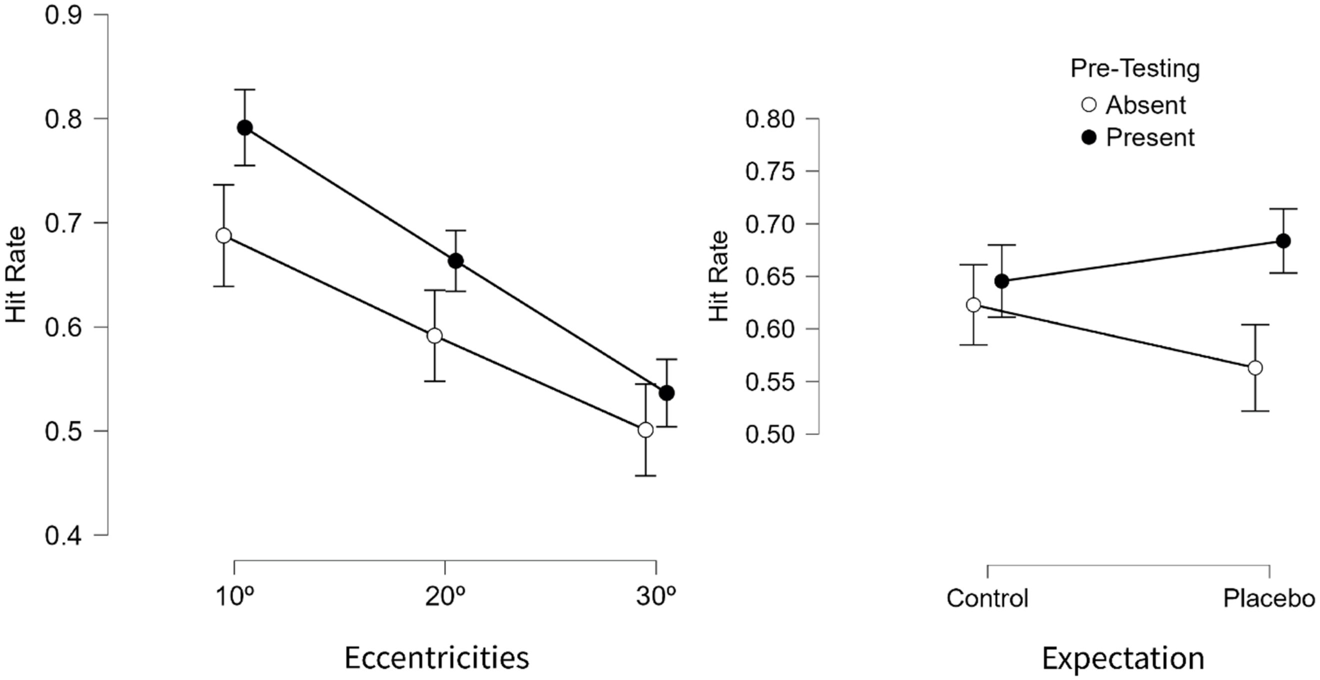


Fig. 6 UFoV Performance in the post-test grouped by pre-testing conditions (present or absent). The accuracy rates for the Control 1 and Placebo 1 groups (pre-test performed) are represented in black, and those for the Control 2 and Placebo 2 groups (pre-test not performed) are represented in white. Error bars indicate 95% confidence intervals

with no pre-testing (Placebo Group 2), p = .004, BF_{10}=49.0 (see Fig. 6, right). This result suggests that placebo interventions may be benefited or intensified by pre-testing.

Exploratory Hypothesis: Are there Covariates that Influence Group Comparisons?

We also ran the same analyses considering the correct response time as the response variable. Data points that fell outside the two standard deviation limits of the mean correct response time for each participant were excluded, with the mean of exclusions being M=0.04, SD=0.01 (≈4%). An expectancy effect was not observed. Complementary to the ANOVAs, we ran ANCOVAs and MANOVAs in many different combinations of response variables and covariates. The hit rate and response time were considered as response variables. The covariates were assessed in the forms that the participants responded at the end of the study regarding expectation (subjective expectancy, training effect, and enhancement in others), video game-related profile (expertise, frequency of gameplay, and weekly hours dedicated to gaming), and mental state during the experiment (happy/sad, relaxed/ anxious, and rested/fatigued). No expectancy effect was observed in any model that was implemented. These additional analyses are not reported in the paper for the sake of brevity. All analyses conducted, assumption checks, post hoc comparisons, and additional graphs are found in the supplemental material's online repository.

Discussion

The present study was based on the assumption that an expectancy effect in brief cognitive training with action games could boost visuospatial attention. We simulated cognitive training with action video games in naïve participants (i.e., those without prior knowledge of the study's objectives or experience with video games and virtual reality) while experimentally manipulating their expectations. Different information regarding the effects of a short training session with an action game in virtual reality was used for the placebo and control groups. It was expected that participants in the placebo groups would perform better in the post-test evaluation of the UFoV compared to the control groups, but this was not observed in any of our analyses. Therefore, our results do not support the findings of previous studies (e.g., Edwards et al., 2021; Foroughi et al., 2016; Ng et al., 2020; Parong et al., 2022; Rabipour & Davidson, 2015; Rabipour et al., 2018; Tiraboschi et al., 2019; Ziv et al., 2022). However, they align with investigations that did not find evidence that expectation could improve participants' performance (e.g., Ballesteros et al., 2017; Brantley et al., 2021; Schwarz & Büchel, 2015; Tsai et al., 2018; Vodyanyk et al., 2021; Watolla et al., 2020).

Our results showed that we successfully induced participants' expectations in Placebo Group 1. This means that these participants had higher expectations of improving their performance after playing an action game in virtual reality compared to participants in Control Group 1 (as described in "Subjective Perception of Expectation" subsection). These results demonstrate that information given to participants can modulate their subjective perception of expectation, which was also demonstrated in the studies conducted by Edwards et al. (2021), Foroughi et al. (2016), Parong et al. (2022), Rabipour et al. (2018), Rabipour and Davidson (2015), and Ziv et al. (2022).

However, our results showed no effect of this subjective perception on attentional performance as measured by the UFoV task, contrary to the results found in Tiraboschi et al. (2019). Differences observed may be associated to differences in the experimental protocol. For example, we used a virtual reality action video game, whereas Tiraboschi et al. (2019) used a Sudoku video game. Given that action video games are known to enhance visual attention and are the most widely used in the literature, our results contribute uniquely to the literature on the effects of expectation in short training sessions with action video games (e.g., Bediou et al., 2018; Latham et al., 2013; Sajan et al., 2017; Stanmore et al., 2017).

However, we cannot rule out the possibility that we may have observed a training effect in the post-test that minimized differences in potential expectation effects. For example, the classic study by Green and Bavelier (2003) demonstrated robust pre- and post-test improvements in the useful field of view among gamers compared to non-gamers across all three eccentricities. If this interpretation holds, expectancy effects in our study—with its brief training period—may have been masked by practice effects with the game itself, although this seems unlikely given the limited exposure time to the game (≈10 min). As argued by Bavelier and Green (2019), longer training durations are typically associated with measurable benefits of action video game practice. This may also indicate that short training protocols are insufficient to elicit strong expectancy effects, as observed in Joessel et al. (2025) and Vodyanyk et al. (2021). In contrast, longer interventions with multiple sessions may foster stronger expectations, and the combined influence of training and expectancy may produce more pronounced performance improvements, as reported by Parong et al. (2022), although their study did not involve action video games.

Hence, as in Tiraboschi et al. (2019) and Joessel et al. (2025), our primary goal was not to directly assess the effects of cognitive training but rather to investigate how expectancies might influence performance on cognitive tasks derived from procedures commonly used to evaluate training outcomes. Accordingly, we maintained the training session duration used in the replicated study (see Tiraboschi et al., 2019), opting for a single, brief session with a virtual reality action video game to minimize potential performance gains attributable to practice (see Bavelier & Green, 2019; Gonçalves and Mendonça, 2024). To date, however, no studies have examined expectancy effects in the context of extended action video game training protocols. Future research may benefit from implementing longer training sessions with action video games, more comparable to those associated with robust cognitive outcomes reported in the literature (e.g., Bavelier and Green 2019; Bediou et al. 2018; Föcker et al. 2019; Green and Bavelier 2003, 2006a, b; Oei and Patterson 2013).

Although we increased the sample size compared to the original study by Tiraboschi et al. (2019; 26 participants per group) and the study by Joessel et al. (2025; 30 participants per group), reaching more than 30 participants per group—including the primary groups Placebo 1 ($n=37$) and Control 1 ($n=40$)—our sample size calculation was based on detecting the interaction between these groups in a 2 × 2 mixed-design ANOVA, with Session (pre- and post-test) as the within-group factor and Expectation (placebo vs. control) as the between-group factor. Consequently, while the performance difference between eccentricities was not central to our analyses, our analyses involving more complex interactions, such as the 2 × 2 × 3 interaction (Expectation × Session × Eccentricity), likely had lower statistical power than initially assumed. This underscores the importance of recruiting larger sample sizes in future studies to ensure adequate power for testing such interactions, or using sequential sampling methods with a Bayes Factor stopping rule, as was done by Joessel et al. (2025). However, to mitigate the low frequentist statistical power, we calculated the Bayes Factors for these interactions, which showed moderate to strong evidence for the null hypothesis and converging evidence to the frequentist analyses.

Other relevant finding regards to the failed attempt to induce expectation in Placebo Group 2. This suggests that manipulating participants' beliefs about their performance may rely on concrete feedback from a pre-test to observe changes in post-test performance. Supporting this idea, the performance results of the placebo groups indicate that pre-testing may play a critical role in shaping expectations. To investigate this formally, our Hypothesis 3 examined whether the presence of a pre-test influenced expectancy; all groups were compared solely on post-test performance, as shown in the analyses for Hypothesis 3. This approach takes advantage of the Solomon four-group design, which enables us to experimentally manipulate pre-test conditions and thereby isolate the effect of expectancy. Unlike Joessel et al. (2025), who statistically controlled for pre-test effects, our design directly accounts for them through experimental manipulation (see Braver & Braver, 1988). By design, performance is expected to change from pre- to post-test, which can act as a confounding variable when evaluating expectation effects. The Solomon four-group design experimentally isolates this pre-test effect, enabling us to assess only the influence of expectancy across participants, representing one of the main contributions of our study. Indeed, only placebo group participants exposed to the pretest performed better on the UFoV task than those who did not undergo a pretest (Fig. 6, left), suggesting a possible influence of pretesting on expectancy; however, this hypothesis requires formal testing.

The successful manipulation of expectation in the pre-tested groups in our study can be explained by how the assessment of subjective perception of expectation was conducted, which is discussed by Denkinger et al. (2021). We opted for the evaluation of a retrospective perception of the participants' expectation (i.e., at the end of the experiment), which can be influenced by both real prospective expectation ("I just played a video game and now I'm going to do well on this test!"), and by the performance they retrospectively perceived ("I did very well in that second phase, so the video game must have worked!"). In other words, participants' ratings on the expectation may be a function of performance, and it is influenced, for example, by transfer effects. Thus, groups Placebo 2 and Control 2 did not have an online parameter of their own performance in a pre-test phase, and therefore may not have believed that their performance could be modulated by the game.

Considering this relationship, Bayesian models help us understand how online experience obtained during tests can modulate retrospective or prospective subjective perception of expectations (see Denkinger et al., 2021). An example of this type of manipulation can be seen in the study conducted by Vodyanyk et al. (2021). Four experiments induced expectation effects regarding cognitive training in domains such as fluid intelligence, attention, and spatial perception. For this purpose, expectation induction was employed in the placebo groups with verbal instruction in addition to manipulation of associative learning during the cognitive tasks. Associative learning consisted of intermediary tasks that provided evidence that the training intervention was improving their cognitive abilities. Although no expectation effect was observed in the performance of any task, the combination of verbal expectation induction and associative learning evidence during the experiments could potentially enhance the effects of prospective expectation.

Another important aspect to understand the results observed in the groups Placebo 2 and Control 2 refers to the adaptation items 1 and 2 of the expectation assessment questionnaires have suffered since there was no pre-test. Modifications to the items were adopted, possibly causing these items not to capture the transfer effect (item 1) and the implication of the gaming session on UFoV performance (item 2), and thus limiting comparability between the four groups. In addition, individual differences, such as different growth mindset profiles, may affect the subjective perception of expectation and consequently its effects on performance. It is recommended that future studies assess profiles regarding growth mindset to increase comparability among experimental groups or to check its effect as a covariate (see Rabipour et al., 2018, Rabipour & Davidson, 2015). Finally, our results are restricted to visuospatial attention. Other cognitive processes may be more prone to an expectation of a boost on cognition, and the Solomon four-group experimental design is useful for disentangling expectancy and the effects of pre-testing, practice, and fatigue.

To demonstrate that individual characteristics (e.g., mood, level of expectation, time dedicated to gaming) did not influence our results, we conducted ANCOVAs including these variables as covariates. This is particularly relevant when compared with studies in the literature on expectancy effects (e.g., Rabipour et al., 2015, 2018). Additional analyses using reaction times and MANOVAs were performed to examine whether latency—a measure known to be affected in the UFoV task—might have been more sensitive to potential expectancy differences among participants (see Kiuru et al., 2020). Taken together with the Bayesian analyses, these results strengthen our findings by showing that expectancy was not sufficient to alter UFoV performance.

In summary, the results of this study do not corroborate the findings of previous research suggesting that expectation could modulate cognitive performance in visuospatial attention. Although the induction of expectation was successful in participants of Placebo Group 1, no improvement in performance in the UFoV task was observed. The results of the Placebo Group 2 suggest that the experience (i.e., pre-testing) may influence the subjective perception of expectation. It is recommended that further research delve into the relationship between the subjective perception of expectation and participants' performance. We also note that the generalizability of these findings to other cognitive domains, such as mental rotation or other measures of top-down attention, remains an open question. For this purpose, researchers may implement procedures like associative learning combined with verbal instructions, biased samples (as utilized by Foroughi et al., 2016), and tasks assessing different mental functions. Furthermore, individual differences, such as growth mindset profiles, may help better understand how expectation affects cognitive performance.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41465-026-00346-8.

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Author contributions E.S. conducted data collection, data tabulation and analysis, created the figures and tables, edited the instructional videos, and programmed the tasks used in the study. R.M. reviewed all stages of the project as the primary supervisorof the research. All authors have made substantial contributions to the conception or design of the work; or theacquisition, analysis, or interpretation of data. Each author has either drafted the article or critically revised it forimportant intellectual content. Furthermore, all authors have approved the version to be published and haveparticipated sufficiently in the work to take public responsibility for appropriate portions of the content.

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Data Availability We made available as supplemental material: (1) the code of the experimental task and the stimuli set, (2) the video to induce expectation and the control video along its scripts, (3) forms and scales used in the study, (4) raw and processed data, and (5) statistical analyzes (access: https://osf.io/ahx7k/).

Declarations

Ethical Approval This study was approved by the Human and Social Sciences Research Ethics Committee of the University of Brasília (CAAE 62068722.9.0000.5540) and was conducted under the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Competing interests The authors declare no competing interests.

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