Xiao and Jiang *BMC Psychology* (2024) 12:417
https://doi.org/10.1186/s40359-024-01931-2

BMC Psychology

RESEARCH

Open Access

Multiple object tracking training affects the executive function in basketball players: the role of instant feedback

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Abstract

Background The present study aims to investigate the potential impact of eight sessions of Multiple Object Tracking (MOT) training on the executive function in basketball players. The purpose of the study was primarily to observe the effects of MOT training with and without feedback on the executive function of basketball players.

Methods A sample of fifty-eight participants was selected from college students enrolled in a university basketball special selection class. The participants were divided into three equal groups. The first group received MOT training with instant feedback and was called feedback group, the second group received MOT training without instant feedback and was called no feedback group, and the third group did not receive any intervention and was called control group.

Results After eight sessions of MOT training, feedback group demonstrated the best performance in the Go/No-go task and the 3-back task. After eight sessions of MOT training, there was no significant difference in test scores on the Stroop task between the feedback and no feedback groups. There was also no significant difference in test scores between the feedback and no feedback groups on the 2-back task after eight sessions of MOT training. The findings of this study suggest that MOT training can effectively enhance the executive function of basketball players.

Conclusions MOT training was found to enhance the executive function of basketball players, irrespective of whether they received instant feedback. However, the feedback group exhibited superior improvements in the Go/No-go task and the 3-back task.

Keywords Executive function, Basketball, Multiple object Tracking, Instant feedback

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Background

Executive function refers to a set of cognitive processes that enable individuals to manage and regulate their thoughts, actions, and emotions in order to achieve goals effectively. These higher-order mental skills are crucial for tasks requiring planning, problem-solving, decision-making, and self-control [1]. Executive function involves several key components: working memory, inhibitory control and cognitive flexibility. Working memory enables the temporary storage and manipulation of information needed for cognitive tasks. It involves holding information in mind while processing it or using it to guide behavior. Working memory capacity is essential for tasks that require mental calculations, reasoning, and decision-making [2]. Inhibitory control refers to the ability to suppress automatic or impulsive responses in favor of more appropriate actions. It helps individuals regulate their behavior, resist temptations, and make deliberate choices rather than acting impulsively [3]. Cognitive flexibility involves the capacity to adapt to new situations, switch between tasks or mental sets, and consider multiple perspectives. It allows individuals to adjust their thinking and behavior in response to changing demands or goals [4].

Executive function is known to exhibit plasticity [5], meaning that individuals have the ability to optimize and adapt their cognitive processes and behaviors to varying task demands through learning and training during cognitive tasks [6]. In recent years, research into executive function plasticity has gained significant attention in the fields of neuroscience [7], psychology [8], and education [9]. In a study on the role of executive functions in sports, it was highlighted that athletes with better executive functions tend to exhibit superior decision-making skills, faster reaction times, and enhanced performance under pressure [10]. When examining a sample of basketball players, the link between executive functions and the MOT task becomes even more apparent. The ability to track multiple moving objects accurately in a dynamic and fast-paced environment, as required in basketball, relies heavily on executive functions like attentional control and working memory [11]. Moreover, a study emphasized the importance of executive functions in sports performance, stating that athletes with strong executive functions are better equipped to adapt to changing game situations, anticipate opponents' moves, and execute complex motor actions effectively. This is particularly relevant in basketball, where players need to track teammates, opponents, and the ball simultaneously while making split-second decisions [12]. Some studies have demonstrated that targeted training and interventions, like video games [13], cognitive-behavioral therapy [14], and physical exercise [15], can effectively enhance an individual's executive function plasticity. Moreover, individual differences in executive function plasticity have been observed, which may be associated with factors such as an individual's genetic makeup, brain structure, cognitive style, among others [16–18]. Nevertheless, certain studies have raised questions regarding executive function plasticity, proposing that factors such as task complexity, training duration, and age may influence its potential effects, emphasizing the need for further exploration of its practical applications [19–21]. Consequently, executive function plasticity remains a field of great interest, with numerous unanswered questions and challenges. For instance, comparisons and evaluations of different training methods are necessary to determine their effectiveness and applicability. Additionally, thorough investigations into the long-term effects and stability of executive function plasticity are warranted.

The Multiple Object Tracking (MOT) task in psychology and cognitive science involves tracking multiple objects as they move within a visual field. Participants in MOT experiments are typically asked to monitor and keep track of several objects simultaneously, often testing their attentional capacity, working memory, and cognitive processing abilities [22]. In the context of basketball, MOT becomes crucial. For instance, basketball players need to simultaneously track multiple targets, such as keeping an eye on the position of opposing players and the basketball itself. This task closely resembles the challenges encountered in MOT. In MOT, the primary objective is to memorize and track the relevant targets while disregarding irrelevant ones. Consequently, this could have effects on an individual's inhibition—the cognitive process responsible for tasks such as inhibiting irrelevant information and maintaining focus. MOT training is a cognitive training approach that aims to enhance an individual's attention and memory capacity when simultaneously dealing with multiple tasks or goals [23, 24]. The impact of MOT training on executive function remains inconclusive. The connection between MOT and executive functions lies in their shared reliance on cognitive processes that facilitate goal-directed behavior, attentional control, and working memory. MOT tasks require individuals to track multiple moving objects simultaneously while inhibiting distractions and updating spatial information—a complex cognitive challenge that taps into various executive functions. However, several studies have suggested a positive association between MOT training and improvements in executive functioning. For example, one study indicated that MOT training not only enhances executive function but also translates into real life situations, such as improved driving safety [25, 26]. Another study has also demonstrated the benefits of MOT training. For example, one study applied the 360 degrees-MOT task observed improvements in individuals' attention and memory following MOT training [27].

One study using Fruit Ninja as a cognitive training tool showed that cognitive training did not improve executive function in athletes [28]. Consequently, further research is warranted to establish the precise impact of MOT training on executive function. On the other hand, the literature concerning instant feedback in multi-objective training is limited. Some studies suggest that providing instant feedback during MOT training (participants tracked one through four target items among eight total items) can enhance individuals' comprehension of their performance, leading to strategic adjustments and improved overall outcomes [29]. Additional research supports the notion that incorporating instant feedback into a task can enhance task performance [30, 31]. However, it is crucial to consider whether excessive reliance on feedback could have adverse effects, such as impeding focused attention on the task itself. Therefore, exploring the potential benefits of incorporating instant feedback into MOT training, particularly regarding multi-objective training and the executive functioning of basketball players, warrants further discussion.

Based on the theoretical analysis presented above, this study proposes a hypothesis that MOT training can effectively enhance the executive function of basketball players. Furthermore, it is speculated that the inclusion of instant feedback in MOT training can yield even more substantial improvements in the executive function of basketball players. In light of these considerations, the present study was designed to administer MOT training to basketball players, both with and without instant feedback provided, and to assess any resulting changes in their executive function. The aim is to establish a foundation for mental training strategies tailored specifically to basketball players.

Methods

Participants

The sample size for this study was determined using a priori power analysis conducted through G*Power 3.1.9.7. The analysis considered an effect size of 0.35, an alpha level of 0.05, and a desired statistical power of 0.85. Based on these parameters, it was calculated that a minimum of 48 subjects would be required to adequately meet the test requirements. Anticipating a potential attrition rate of 10% during the experiment, a minimum of 53 basketball players were planned to be recruited. In practice, a total of 63 basketball players from a local university were recruited to participate in this experiment. The selection criteria for the participants followed the classification standards of basketball players [32]. Specifically, the recruited players were classified as semi-elite basketball players. Additionally, all recruited basketball players had undergone training for a minimum of 4 years, demonstrating a solid foundation in basketball. It is important to note that all the recruited basketball players were male. The recruitment process adhered to several principles. All subjects were required to be right-handed, have normal or corrected vision, and not have color blindness or color weakness. Furthermore, subjects should not have participated in a similar experiment within the past six months. Prior to the commencement of the experiment, all subjects were asked to provide their informed consent by signing a consent form. After the recruitment phase, the subjects were divided into three groups: the feedback group, the no feedback group, and the control group. Five of the originally recruited semi-elite basketball players dropped out or had personal reasons that prevented them from completing the experiment. As a result, the final number of subjects at the conclusion of the study was 58. For further details about the recruited subjects, please refer to Table 1.

Experimental implementation

The entire experiment spanned a duration of 4 weeks, with 2 training sessions per week. The MOT task utilized a paradigm that involved circle and dot-probe stimuli. Initially, 12 circles of identical size (40 pixels in diameter with a 2-pixel border) appeared at the center of the screen. For the tracking task, four circles were designated, and at the start of the experiment, these four circles were briefly marked with flashes lasting 200 ms. Throughout the experiment, all circles underwent irregular motion, moving at a speed of 140 pixels per second, ensuring that the circles didn't overlap during their movement. During the tracking phase, a red solid circle, with a size of 8 pixels, could appear as a detection stimulus in a blank area. The movement of the circles continued for a duration of 4000 ms. When the circles came to a halt, the subjects were required to identify the previously marked circle and indicate whether they noticed the detection stimulus during the tracking process. If a detection stimulus occurred, they were instructed to press the 'F' key; if not, they were instructed to press the 'K' key. The experiment consisted of a total of 160 trials, with a 2-minute

Table 1 Baseline characteristics of subjects (M ± SD)

Characteristics	Feedback group	No feedback group	Control group	*p*-value
N	18	20	20	—
Age(years)	22.36 ± 3.14	21.65 ± 2.79	21.67 ± 2.77	0.412
Training years	6.94 ± 1.02	6.19 ± 1.76	6.23 ± 1.87	0.703

Note: M, mean; SD, standard deviation

rest period provided for the subjects after 80 trials. The occurrence of the trials was randomized. The performance metrics for the MOT task included the circle tracking accuracy rate and the stimuli detecting rate. The flow of the MOT training with instant feedback is illustrated in Fig. 1.

Measurement of executive function

To assess executive function, the following indicators were measured: working memory, response inhibition, and interference inhibition.

Response inhibition test. The Go/No-go task is a widely used training task for assessing and enhancing response inhibition abilities. In this task, participants view a white number ranging from 1 to 9 on a computer screen. The task commences with the display of a gaze point "+" at the screen's center for 500 milliseconds. Subsequently, a number between 1 and 9 is randomly presented for 1000 milliseconds. Notably, the number 6 appears 25% of the time, while the remaining numbers appear 75% of the time. Participants are instructed to withhold a key press response when the number 6 is shown, but to press a key for all other numbers. The experiment encompasses two procedures: a feedback procedure and a no-feedback procedure. In the feedback procedure, participants promptly receive feedback in the form of accuracy and reaction time after each trial. The primary metrics employed to evaluate performance in the Go trials are response time and accuracy. These metrics provide valuable insights into how efficiently and accurately participants refrain from responding when the number 6 is presented. By comparing response times and accuracy across trials, researchers can assess participants' capacity to inhibit prepotent responses and enhance their response inhibition skills over time.

Interference inhibition test. Interference inhibition was assessed using the Stroop test, which utilized words of different colors (red, yellow, blue, and green) as stimuli. The computer screen initially displayed a white gaze point for 500 ms, followed by random color words presented for 1000 ms. Participants were instructed to identify the color of the words using the abbreviations R for red, G for green, Y for yellow, and B for blue. The Stroop test consisted of two types of trials: color-word congruent

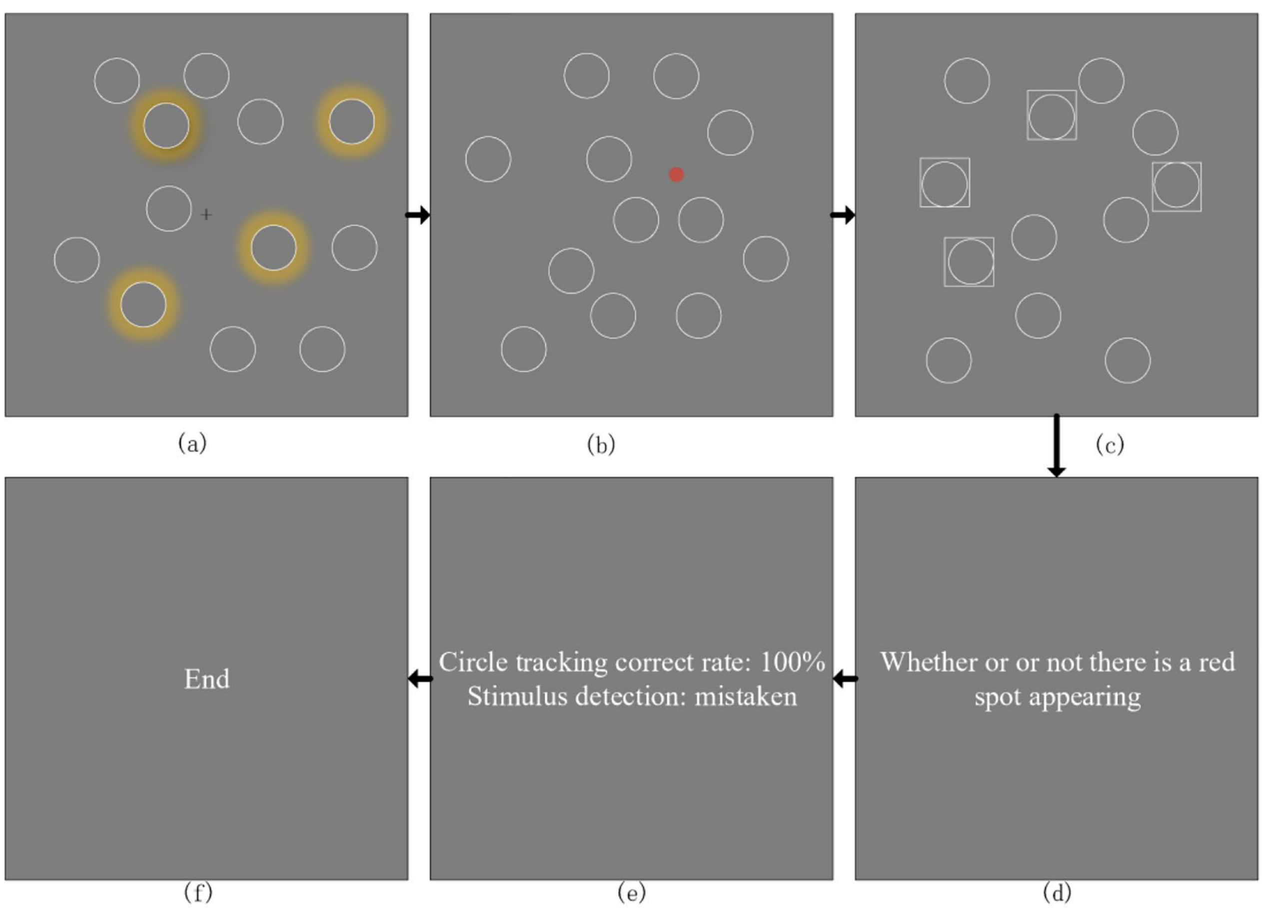

Fig. 1 MOT training with instant feedback (**a**: mark targets; **b**: stimulus detection; **c**: selection of targets; **d**: judgment detection stimulus; **e**: instant feedback; **f**: end)

and incongruent. In the congruent trials, the words matched both their lexical meaning and color, while in the incongruent trials, the words differed in lexical meaning and color. The congruent trials accounted for 75% of the total number of trials, whereas the incongruent trials made up the remaining 25%. The experiment comprised three blocks, with each block containing 10 practice trials and 50 experimental trials. The performance of interference inhibition was measured using the Stroop effect, calculated as the difference between the reaction time for inconsistent trials and the reaction time for consistent trials.

Working memory test. The N-back task was selected as the working memory test. The stimuli for this task comprised uppercase English letters from A to Z. The task started with a 500 ms presentation of a gaze point "+" in the center of the screen. Following this, a random English letter was displayed, and participants were instructed to judge and respond to the current letter based on the previous letter. In a consistent trial, if the currently presented letter matched the letter presented "n" steps ago, participants were instructed to press the "F" key. Conversely, if the currently presented letter was different, participants were instructed to press the "J" key. The task consisted of two blocks: 2-back and 3-back. Each block included 20 practice trials and 100 experimental trials. Performance on the task was evaluated based on accuracy, indicating the accuracy of participants' responses.

Instrumentation

The tasks were displayed on a computer using a 23.8-inch LCD monitor with a screen resolution of 1920×1080 and a refresh rate of 120 Hz. The experiment took place in a laboratory environment that maintained moderate brightness and a quiet atmosphere.

Statistical analysis

Data analysis was conducted using SPSS 26.0. Repeated measures analyses were used to analyze the Multiple Object Tracking training and executive function. Means and standard deviations were standardized for the study, and significance was indicated by p-values. The normal distribution of the data was assessed using the Shapiro-Wilk test, and the homogeneity of variance was examined using Levene's test. Effect sizes for significant main effects and interactions were calculated using Eta squared (η^2). *p*-values for multiple comparisons is a crucial step in statistical analysis to reduce the likelihood of false positives and control the overall Type I error rate. When conducting multiple tests or comparisons, the probability of obtaining significant results by chance increases, necessitating adjustments to account for this inflation in statistical significance. We used the Bonferroni correction method to correct the results in our results. The Bonferroni correction is a conservative method that adjusts the significance threshold by dividing the desired alpha level by the number of comparisons being made. For each individual test, the significance threshold is set at α / m, where m is the number of comparisons. When interpreting the results of statistical tests with multiple comparisons, we consider the correction method applied to the *p*-values. Correcting for multiple comparisons helps maintain the overall Type I error rate at the desired level and reduces the risk of reporting false positives.

Results

MOT training results

The metrics chosen to evaluate Multiple Object Tracking (MOT) were the accuracy of circle tracking and the rate of detecting stimuli. A repeated measures ANOVA was conducted using an 8 (number of training sessions) × 2 (group) design. The results revealed a significant main effect for training sessions on both circle tracking accuracy (F (1,37) = 203.45, p<.001, η^2=0.72) and stimuli detection rate (F (1,37) = 198.43, p<.001, η^2=0.53), suggesting that both the accuracy of circle tracking and awareness of detection stimuli increased with an increase in the number of training sessions. Additionally, there was a significant interaction between the number of training sessions and the group for both circle tracking accuracy (F (1,37) = 99.32, p < .001, η^2 = 0.31) and stimuli detection rate (F (1,37) = 89.23, p < .001, η^2 = 0.30), indicating that the changes observed in the different groups varied across the training phases. Specifically, during the 1st-3rd training sessions, there was no significant difference in performance between the experimental group with feedback and the experimental group without feedback. However, in the 4th-8th training sessions, the two groups showed significant differences. The group with feedback demonstrated better performance in both circle tracking and stimuli detection compared to the group without feedback (Table 2; Fig. 2).

Executive function

Repeated measures ANOVA was performed for response inhibition, interference inhibition, and working memory for executive functioning 2 (measurement time: pre/post) × 3 (group: feedback group/no feedback group/control group), respectively. Table 3 shows the results of the pre-test and post-tests of executive function.

Response inhibition task

A repeated measures ANOVA was conducted to analyze reaction time and accuracy in the Go/No-go task. Regarding the analysis of response time, there was a significant main effect of measurement time (F (1,55) = 139.48, p < .001, η^2 = 0.32). Post-hoc comparisons revealed that reaction times in the post-test phase (319.12±6.13) were

Table 2 Circle tracking accuracy and stimuli detection rate in the feedback group and the no feedback group(M ± SD)

Number of trainings	Feedback group		No feedback group	
	Circle tracking accuracy (%)	Stimuli detection rate (%)	Circle tracking accuracy (%)	Stimuli detection rate (%)
D1	90.35 ± 2.13	70.15 ± 4.25	90.89 ± 1.78	70.39 ± 3.85
D2	91.87 ± 1.78	72.34 ± 3.19	90.67 ± 2.04	71.48 ± 4.58
D3	92.34 ± 1.93	80.23 ± 4.25	91.87 ± 2.58	72.35 ± 4.21
D4	94.56 ± 2.05	81.55 ± 4.96	92.35 ± 2.79	73.17 ± 3.99
D5	95.64 ± 1.74	83.48 ± 4.24	93.43 ± 2.13	72.16 ± 4.04
D6	95.88 ± 1.98	84.12 ± 3.87	93.76 ± 1.95	73.82 ± 4.17
D7	96.72 ± 2.21	85.18 ± 4.42	93.16 ± 2.05	73.10 ± 4.15
D8	96.56 ± 1.86	85.19 ± 4.11	92.97 ± 1.95	72.97 ± 4.26

Note: M: mean; SD: standard deviations; D: Number of trainings

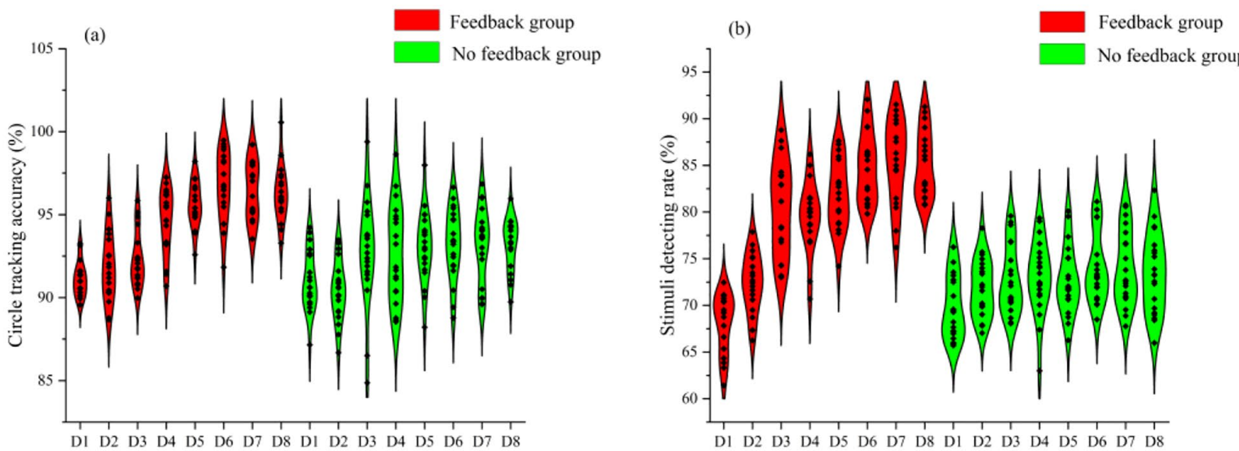

Fig. 2 Changes in circle tracking accuracy and stimuli detection rate in basketball players (**a**: circle tracking accuracy; **b**: stimuli detection rate; **D**: Number of trainings)

Table 3 Descriptive statistics for the pre-test and post-test of each task (M ± SD)

Test	Time	Feedback group	No feedback group	Control group
Go/No-go reaction time (ms)	Pre-test	332.15 ± 5.98	330.13 ± 5.25	333.49 ± 6.43
	Post-test	307.06 ± 6.43	318.12 ± 5.59	332.18 ± 6.32
Go/No-go accuracy (%)	Pre-test	84.13 ± 3.18	85.73 ± 3.32	87.17 ± 3.62
	Post-test	97.35 ± 3.51	96.14 ± 3.63	86.79 ± 3.82
Stroop effect (ms)	Pre-test	34.12 ± 4.58	33.13 ± 4.81	33.24 ± 4.93
	Post-test	30.19 ± 5.10	31.29 ± 4.59	32.97 ± 5.01
2-Back accuracy (%)	Pre-test	75.65 ± 1.73	73.53 ± 2.48	75.49 ± 2.33
	Post-test	88.19 ± 2.26	89.32 ± 1.76	74.34 ± 2.02
3-Back accuracy (%)	Pre-test	62.67 ± 2.07	61.35 ± 1.77	61.56 ± 2.06
	Post-test	69.37 ± 2.71	65.98 ± 2.54	62.11 ± 2.33

Note: M: mean; SD: standard deviations

shorter compared to the pre-test phase (331.92±6.21). Furthermore, a significant interaction between measurement time and group was found (F (2,55) = 28.49, p < .001, η^2 = 0.62). A simple comparative analysis indicated that reaction times decreased in both the feedback group and the no feedback group, while remaining unchanged in the control group. Post-hoc test found that the feedback group's post-test (307.06±6.43) were significantly higher than their pre-test (332.15±5.98). No-feedback group also had significantly higher post-test (318.12±5.59) than pre-test (330.13±5.25) (Table 3; Fig. 3a).

Accuracy: The analysis showed a significant main effect of measurement time, F (1,55) = 115.22, p < .001, η^2 = 0.43. Post-hoc comparisons revealed that accuracy in the post-test (93.43±3.77) were higher compared to the pre-test (85.68±3.52). The interaction of measurement time with

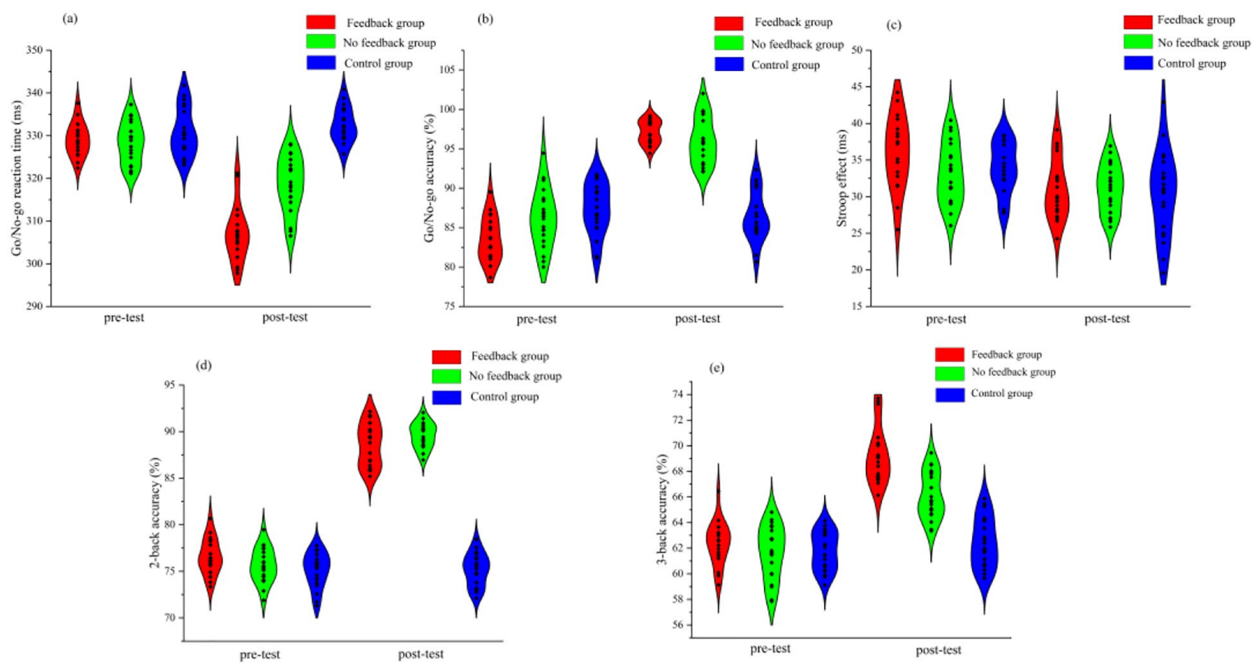

Fig. 3 Changes in executive function in basketball players (**a**: Go/No-go reaction time; **b**: Go/No-go accuracy; **c**: Stroop effect; **d**: 2-Back accuracy; **e**: 3-Back accuracy)

group was significant, F (2,55) = 14.74, $p < .001$, $\eta^2 = 0.58$. Additional simple analyses indicated that the post-test performance was better than the pre-test for both the feedback group and the no feedback group, except for the control group. Post-hoc test found that the feedback group's post-test (97.35 ± 3.51) were significantly higher than their pre-test (84.13 ± 3.18). No-feedback group also had significantly higher post-test (96.14 ± 3.63) than pre-test (85.73 ± 3.32) (Table 3; Fig. 3b).

Interference inhibition task

The Stroop effect, a repeated measures ANOVA was conducted to analyze the effects of time of measurement and group on interference inhibition. The main effect of time of measurement was found to be non-significant (F (1,55) = 47.87, $p = .121$, $\eta^2 = 0.03$), indicating that there was no significant difference in interference inhibition between different time points of measurement. The interaction between time of measurement and group was also non-significant (F (2,55) = 5.98, $p = .302$, $\eta^2 = 0.05$). This suggests that the relationship between time of measurement and group did not have a significant impact on interference inhibition. In contrast, neither the pre-test nor the post-test measurements of the no feedback group and the feedback group showed a significant difference. These findings suggest that MOT training, with or without immediate feedback, is not effective in improving subjects' ability to suppress interference. (Table 3; Fig. 3c).

Working memory task

A repeated measures ANOVA was conducted to examine the effects of measurement time and group on accuracy in the 2-back and 3-back tasks. For the 2-back task, the main effect of measurement time was found to be significant (F (1,55) = 179.39, $p < .001$, $\eta^2 = 0.63$). Post-hoc comparisons revealed that accuracy in the post-test (83.95 ± 2.01) were higher compared to the pre-test (74.89 ± 2.12). The interaction between measurement time and group was also significant (F (2,55) = 48.78, $p < .001$, $\eta^2 = 0.66$). Further analysis revealed that both the feedback group and the no feedback group exhibited a higher rate of accuracy in the post-test compared to the pre-test. Post-hoc test found that the feedback group's post-test (88.19 ± 2.26) were significantly higher than their pre-test (75.65 ± 1.73). No-feedback group also had significantly higher post-test (89.32 ± 1.76) than pre-test (73.53 ± 2.48). These results indicate that both the feedback and no feedback groups improved their accuracy in the 2-back task, whereas the control group did not show any change (Table 3; Fig. 3d).

For the 3-back task, the main effect of measurement time was significant (F (1,55) = 177.45, $p < .001$, $\eta^2 = 0.59$). Post-hoc comparisons revealed that accuracy in the post-test (65.82 ± 2.32) were higher compared to the pre-test

(61.86±2.06) (Table 3; Fig. 3e). In contrast to the 3-back task, the interaction between measurement time and group was not significant (F (2,55)=48.38, p=.412, η^2 = 0.19).

Discussion

Following eight training sessions of MOT training, notable improvements were observed in the accuracy of circle tracking and the detection rate of stimuli among the subjects, irrespective of the availability of instant feedback. However, a comparative analysis revealed that the group that received feedback exhibited higher accuracy in circle tracking and stimuli detection rate compared to the group that did not receive feedback. These findings indicate that the inclusion of instant feedback can effectively enhance both the accuracy of circle tracking and the detection rate of stimuli among the subjects.

The MOT training served as the complex task employed in this study. Participants were tasked with tracking four labeled targets out of a randomly moving set of twelve targets. In order to maintain effective tracking of the labeled targets, participants had to inhibit their attention towards non-targets, which highlights the process of inhibitory control involved in MOT training. Furthermore, simultaneous tracking of multiple targets also requires a certain level of memory ability, making MOT a task that enhances subjects' memory [33]. Additionally, to assess participants' ability to detect non-targets while tracking targets, point detection stimuli were introduced during the MOT training. As for the study on basketball players' executive functions, the present research utilized the Go/No-go task, Stroop task, and n-back task to examine the impact of MOT training on response inhibition, inhibitory control, and working memory, respectively. The findings of this study indicate that MOT training effectively improves the executive function of basketball players. It is worth noting that tasks involving MOT with instant feedback demonstrate superior effectiveness in enhancing the executive function of basketball players. Therefore, incorporating instant feedback into MOT training is recommended as it can effectively improve the executive function of basketball players. Nevertheless, the study also reveals that the MOT training of basketball players shows improvement even without instant feedback, resulting in enhanced executive function. This can be explained by participants' gradual adaptation to the core aspects of MOT training through exposure to MOT training, ultimately resulting in improved performance [34].

Inhibition ability plays a crucial role in tasks involving MOT. Particularly, in situations where the target is occluded, appears distracted, or is in a complex background, inhibition ability aids individuals in ignoring irrelevant information, thereby improving their ability to track the target [35]. The findings of the present study support the effectiveness of MOT training in enhancing subjects' response inhibition. The MOT process involves responding to emergent point-detecting stimuli, akin to the Go/No-go task, where responses are required for the emergent stimuli. Hence, an increase in stimuli detection rate in a MOT training is likely to result in higher accuracy of response inhibition and reduced reaction time. In this study, the feedback group outperformed the no feedback group in terms of the accuracy of response inhibition and response time. Gou demonstrated that basketball players with strong MOT ability exhibited better decision-making skills in sports contexts [36]. Similarly, Harenberg's study demonstrated that multi-objective training had a positive impact on decision-making abilities in soccer players [37]. Previous research has shown that MOT training not only enhances attention and memory but also has an effect on inhibition [38]. Additionally, MOT has been found to be closely linked to visual inhibition, and the effects of MOT training on response inhibition can vary among individuals. Therefore, MOT training may serve as an effective intervention for individuals seeking improvement in response inhibition [39, 40]. Moreover, regarding inhibitory control, this study revealed that MOT training can effectively enhance subjects' interference inhibition. During MOT training, subjects were required to track four labeled circles while inhibiting the other eight interfering circles. The prolonged training period contributed to the subjects' improved resistance to interference. On the other hand, the Stroop task also necessitates subjects to respond to both consistent and inconsistent stimuli, consequently invoking interference inhibition. This phenomenon can be explained by the emergence of a transfer effect in the present study, where inhibitory control acquired through MOT training was transferred to the Stroop task [41]. Three studies have examined the effects of MOT training on interference inhibition, utilizing various experimental paradigms and assessment methods to compare the performance of a MOT training group to that of a control group in terms of interference inhibition. The collective findings suggest that MOT training significantly enhances interference inhibition, leading to improved performance in the trained group in terms of ignoring distractions and selective attention [42–44]. However, in contrast to these findings, the present study did not observe a significant difference in the Stroop task performance between the feedback group and the no feedback group.

MOT training has been shown to effectively enhance working memory in subjects [45]. During MOT training, participants are required to consistently remember the four labeled targets, which demands a certain level of memory capacity. Additionally, the n-back task, which involves remembering whether the first n letters are the same as the current letters, shares similarities with MOT training. Research findings indicate that there was no significant difference in performance between the groups that received accuracy feedback and those that did not, in the 2-back task. However, in the 3-back task, the group that received accuracy feedback demonstrated a significantly higher accuracy rate compared to the group that did not. This highlights the advantage of having instant feedback in more complex working memory tasks during MOT training. Recent studies have examined the effects of MOT training on working memory utilizing diverse experimental paradigms and assessment methods. Comparisons between a MOT training group and a control group led to the discovery that MOT training significantly improves the capacity and precision of working memory [46, 47]. The ability of subjects' working memory can be effectively enhanced through MOT training. Tasks such as attention allocation, target recognition, and location prediction during MOT training contribute to strengthening working memory [48]. Recent research has explored the mechanisms underlying the effects of MOT training on working memory. One study revealed that MOT training enhances the allocation and control of attention, thereby improving working memory performance [49]. Furthermore, other studies have found that MOT training enhances target recognition and location prediction, both of which are closely associated with working memory [50]. This illustrates that the working memory capacity acquired from MOT training exhibits a transfer effect, meaning that the ability to memorize multiple targets is reflected in the n-back task.

MOT training typically involves tracking multiple moving objects simultaneously, which requires attentional control, working memory, and visual processing skills. Immediate feedback in this context can help individuals adjust their tracking strategies and improve their performance on tasks that involve similar cognitive processes [51]. However, executive functions are multifaceted and involve various cognitive abilities such as inhibition, task switching, and planning [52]. While MOT training with immediate feedback may enhance certain aspects of executive function that are directly related to tracking and attention, it may not have a significant impact on other executive functions that are less directly involved in the tracking task. Therefore, the effectiveness of MOT training with immediate feedback on different aspects of executive function may vary depending on the specific cognitive skills targeted by the training and the extent to which those skills overlap with the demands of the tracking task [53].

This study employed MOT training to provide training for basketball players and demonstrated notable improvements in their executive functions following MOT training. These findings suggest that MOT training has a transfer effect on executive functions, specifically enhancing inhibition and working memory abilities of the subjects. However, there are certain limitations to address in this study. Firstly, the participant sample was limited to basketball players, and no further investigation was conducted to determine whether similar effects can be observed in other sports or activities. Secondly, the age range of the participants was restricted to young individuals, and no consideration was given to different age groups. Lastly, the study exclusively consisted of male participants, thus the existence of gender differences remains an area of future exploration. Despite these limitations, this study provides evidence that the incorporation of instant feedback can enhance the executive functions of basketball players.

Conclusions

MOT training was found to enhance the executive function of basketball players, irrespective of whether they received instant feedback. However, the feedback group exhibited superior improvements in the Go/No-go task and the 3-back task.

Acknowledgements

We would like to thank the basketball players who have contributed to this study.

Author contributions

W.X. was conceptualization for the design of the manuscript. Z.J. was responsible for statistical analysis. W.X. and Z.J. were responsible for the writing of the manuscript. All authors read and approved the final manuscript.

Funding

This research received no funding.

Data availability

The datasets generated and analysed during the current study are not publicly available due to privacy reasons, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Yancheng Institute of Technology (LLA20230401001). Informed consent was obtained from all subjects involved in the study.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Received: 26 January 2024 / Accepted: 29 July 2024
Published online: 31 July 2024

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