

The Effect of Attention Cues Training on Saccadic Eye Movement and Learning Open Motor Skills in Novice: Quasi-Experimental Study

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Original Article

Abstract

Introduction: The cues of the focus of attention, specifically the external focus of attention affect motor performance and improve motor learning. Researches in this field has mainly investigated closed motor skills in novices. Thus generalization of the findings to unpredictable tasks that require response adaptation to external stimuli (Open Skills) needs further investigation. The purpose of this study was to investigate the effect of practicing attention cues on the eye saccade movement and learning the skill of receiving and sending volleyball service as an open skill in novices.

Materials and Methods: The statistical sample of the current research was 20 novice female students with an age range of 10-12 years old, who were selected through convenient sampling and randomly organized into two groups (10 people) of technical and attention cues training. After the pre-test, the participants took part in 9 training sessions. The first and second retention tests were taken 48 hours and 4 weeks later, respectively. Data in the performance variable were analysed using 3x2 mixed analysis of variance and in the saccade variable with the Mann-Whitney U test.

Results: The performance of the attention cues training group significantly increased compared to the technical training group from the pre-test to the first retention and the second retention ($P = 0.007$). The results of the Mann-Whitney U test in the saccade variable was not significant different between the groups at the first retention ($P = 0.105$) and the second retention ($P = 0.089$) phase.

Conclusion: Apparently, the training of attention cues is a suitable method for teaching open skills to novices in sports.

Keywords: Attention cues; Saccade; Motor skills

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Introduction

Physical exercise can be classified as open-skill or closed-skill practice. Open-skill activities, such as table tennis, team sports, and martial arts, take place in dynamic, externally paced, and relatively

unpredictable environments. Participants must respond to dynamic, unpredictable changes and adapt their responses to external stimuli. In contrast, closed-skill activities, such as swimming, running, and cycling, occur in relatively stable, self-regulated, self-paced,

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and more predictable environments, where movements follow repetitive, predetermined patterns (1, 2).

Attentional focus is an instructional manipulation that has been extensively investigated in sports instruction and practice over recent decades. A learner's attentional focus influences motor performance and learning and can be manipulated through instruction. Specifically, an external focus of attention, in which performers direct their attention toward the effects of their actions on the environment, is superior to an internal focus, in which attention is directed toward the body (3). Instructions incorporating external attentional focus cues benefit athletes' motor skill performance more than instructions incorporating internal focus cues (4, 5). External attentional cues facilitate learning across numerous sports skills, including balance tasks (6), golf (7), swimming (8), and basketball free throws (9).

According to the constrained action hypothesis, an internal focus of attention encourages individuals to consciously control their movements, thereby disrupting automatic motor control processes. Conversely, an external focus facilitates automatic movement processing (10). Although the effects of different attentional focus instructions have been investigated in closed-skill tasks, such as golf (11) and darts (12), their influence on open motor skill performance remains less well understood (13). Nevertheless, findings from closed-skill research provide insights into how attentional focus may affect open motor skills. Research on open motor tasks, such as volleyball serve reception (14) and table tennis (15), indicates that skilled performers adopt specific gaze patterns that allow them to perceive important task-related information during an object's flight.

Gaze behavior comprises four components: fixation, saccades, tracking, and quiet eye (16). A saccade is a ballistic eye movement that brings an object's image onto the fovea, the retinal region of highest visual acuity, enabling clear vision. During saccades, visual information acquisition is suppressed, while information retained in memory contributes to a stable perception of the scene (16). Accordingly, the relationship between gaze behavior and performance in skills requiring adjustments in visuomotor coordination has attracted motor behavior researchers' attention (17).

From an instructional perspective, children are taught specialized motor skills in physical education classes after early childhood and after acquiring fundamental motor skills (18). Understanding how attentional cues influence motor skill learning and performance during this developmental period is

therefore valuable (19). Attentional focus cue instruction appears to improve children's performance in gymnastics (20) and balance tasks (21).

Open-skill training has been shown to offer advantages over closed-skill training for improving cognitive performance in elementary school children (22). Eye movements are also important for acquiring sufficient visual information in complex sports situations that require rapid responses and actions. Furthermore, athletes' gaze behavior reflects perception-based decision-making and the execution of motor responses in dynamic sporting environments (23). In light of these considerations, the present study examined the effects of attentional focus cue training on open motor skill performance and saccadic eye movements during volleyball serve reception and the subsequent directed pass to the setter.

If effective, this approach could provide a practical strategy for coaches and physical education teachers to teach open motor skills. By disregarding irrelevant cues and focusing on essential task-related information, learners may coordinate their movements with visual input and learn and perform these skills more effectively across sports.

Materials and Methods

Study Design and Participants: This quasi-experimental study included 20 female students aged 10–12 years from the volleyball training center of Education District 1 in Shiraz, Iran. Participants were selected through convenience sampling from volunteers who responded to a recruitment announcement at the center.

Inclusion criteria were 20/20 visual acuity (normal vision), a pretest volleyball serve-receive score below 40%, age 10–12 years, and a signed parental consent form. Failure to attend training sessions regularly was considered an exclusion criterion. All participants had previously received instruction in overhead and forearm passing but were novices in receiving volleyball serves using a forearm pass.

Eligible participants were randomly assigned by drawing lots to two groups of 10: attentional cue training and technical training. The sample size was determined using the optimal sample size calculation parameters ($f = 0.25$, $1 - \beta = 0.90$, and $\alpha = 0.05$) reported in the study by Klostermann et al. (24).

Ethical Considerations: The study procedures were approved by the Physical Education and Sport Sciences Research Institute, affiliated with the Iranian Ministry of Science, Research and Technology. All eligible participants were allowed to indicate their willingness to participate. The study details, including

its purpose and testing procedures, were explained to volunteers, and written informed consent was obtained from those willing to participate.

Measurement Instruments

Visual acuity was assessed using a Snellen chart. Volleyball serve-reception accuracy was assessed at the pretest and both retention tests using a forearm serve-reception test conducted in three areas of a mini-volleyball court. In this study, a saccade was defined as a rapid eye movement by the receiver toward the setter's area during serve reception.

The forearm serve-reception test comprised 20 volleyball serve receptions—10 underhand and 10 overhand serves—in three designated court areas (1, 3, and 4), followed by a pass to the setter. Each successful reception and pass to the setter's area was awarded one point. An unsuccessful reception or failure to direct the ball to the setter's area was scored as zero for that trial.

The test reliability was assessed using a test-retest procedure ($n = 10$, $r = 0.71$, $p < 0.05$) and its validity was evaluated by comparing advanced and novice groups ($t = 5.81$, $df = 18$, $p = 0.001$).

Gaze behavior, specifically saccadic eye movements toward the setter's area during reception and passing, was recorded using a Dikablis Professional Wireless eye-tracking system manufactured by Ergoneers (Germany). The system records gaze position at a sampling frequency of 60 Hz and comprises camera-equipped glasses and a portable recording unit. Eye movements and gaze changes were recorded using D-LAB software (version 3.52) on the data-processing system (Ergoneers, Germany).

Testing and Training Procedures

Participants first completed a physical warm-up, then were fitted with the eye-tracking device. Video data were transmitted wirelessly to a compatible computer and processed using D-LAB software to record eye movements and gaze changes. A motor control specialist familiar with the eye-tracking system performed this procedure.

A motor learning specialist administered the pretest, which comprised 20 volleyball serve receptions. Saccadic eye movements toward the setter's area during reception and passing were recorded.

Participants were assigned to the attentional cue training and technical training groups, each comprising 10 participants. Both groups were taught the forearm serve-reception skill through a video demonstration by a skilled performer, accompanied by verbal instructions from the coach.

Both groups completed nine training sessions, held three times per week. The groups trained separately in two afternoon time slots at the sports hall of Education

District 1 in Shiraz. During each session, every participant completed five blocks of 10 serve-reception and passing trials, with a two-minute rest interval after each block.

The technical training group practiced receiving serves delivered from different directions and distances from the net, both near and far, on the opposite side of the court, and passing the ball to the setter. Practice initially started with blocked serves and then became variable by changing distance and court location.

The attentional cue training group also practiced serve reception and passing to the setter. These exercises were designed to enhance visual attention, early recognition and detection, and the control of saccadic eye movements toward the setter's area during serve reception and directed passing. Practice was initially blocked and subsequently became variable by changing distance and court location. The exercises were adapted from visual attention training procedures (14) and comprised the following:

1. Receiving a Tennis Ball Thrown from Behind

The receiver stood two meters from a wall while the coach threw a tennis ball from behind the receiver toward the wall. After the ball rebounded, the receiver used a forearm pass to return it to the wall. Tracking a smaller ball was intended to enhance visual attention and concentration.

2. Tracking and Identifying a Mini-Volleyball

The receiver tracked a served mini-volleyball marked with numbers, read the numbers aloud, and received the ball using a forearm pass. The exercise began with serves delivered from two meters from the net, then from four and six meters.

3. Tracking and Identifying Numbers on a Volleyball Served from Behind a Visual Barrier

The ball was served from four and six meters, with the latter positioned behind the service line and behind a barrier that obstructed the receiver's view. The receiver tracked the ball from three reception areas of the mini-volleyball court, read the numbers on the ball aloud during its flight, and received it using a forearm pass.

4. Tracking and Identifying a Volleyball after a Full Turn

The receiver stood on a line four or six meters from the net, with their back to the court. At the coach's whistle, the server served, and the receiver turned 90°, identified and tracked the ball, read the number on it, and received it.

5. Identifying, Tracking, Receiving, and Passing a Mini-Volleyball to the Setter's Area

The server served from behind the service line. The receiver tracked the numbered ball during its flight and

read the number aloud as soon as it became visible. The receiver then moved into the appropriate position and ready stance, received the ball using a forearm pass, and directed it to the setter.

Following the final training session, both groups completed the first retention test after 48 hours and a long-term retention test four weeks after the first retention test.

Statistical Analysis: Descriptive statistics, including means, standard deviations, and measures of data dispersion, were used to summarize the data. The Shapiro–Wilk test was used to assess the distribution of the data, and Levene’s test was used to examine the homogeneity of variances.

Serve-receive and passing performance across the pretest, first retention test, and second retention test were analyzed using a 2×3 mixed-design analysis of variance, with Bonferroni-adjusted post hoc comparisons. Saccade data were analyzed using the Mann–Whitney U test. All analyses were performed using SPSS software, version 23. The significance level was set at 0.05.

Results

All participants completed every stage of the study; therefore, the attrition rate was zero in both groups. Table 1 presents the demographic characteristics of the 20 participants in the technical training and attentional cue training groups.

The Shapiro–Wilk test confirmed that volleyball serve-reception performance data were normally distributed in both groups ($p > 0.05$). Levene’s test also indicated that the assumption of homogeneity of variances was satisfied ($p > 0.05$).

For the 2×3 mixed-design ANOVA of volleyball serve-reception performance, Mauchly’s test indicated that the assumption of sphericity was met ($p = 0.582$). There was a significant main effect of assessment time ($F_{(2, 36)} = 56.27$, $p = 0.001$, $\eta^2 = 0.758$). The between-group analysis also revealed a significant difference in serve-reception performance between the attentional cue training and technical training groups ($F_{(1, 18)} = 9.359$, $p = 0.007$, $\eta^2 = 0.342$). In addition, the group $\times$ assessment time interaction was significant ($F_{(2, 36)} = 3.658$, $p = 0.036$, $\eta^2 = 0.169$).

Given the significant interaction ($p = 0.036$), between-group differences at each assessment were examined using one-way ANOVA. Serve-reception

and passing performance differed significantly between the groups at both the first retention test ($F = 7.550$, $p = 0.013$) and the second retention test ($F = 9.598$, $p = 0.006$).

Bonferroni-adjusted pairwise comparisons indicated significant improvements from the pretest to the first retention test in both the technical training group ($p = 0.007$) and the attentional cue training group ($p = 0.001$). Significant improvements from the pretest to the second retention test were also observed in the technical training group ($p = 0.006$) and the attentional cue training group ($p = 0.001$). However, no significant differences were observed between the first and second retention tests in either the technical training group ($p = 1.000$) or the attentional cue training group ($p = 0.612$). Table 2 presents performance comparisons.

The Shapiro–Wilk test indicated that saccade data were not normally distributed ($p < 0.05$). Therefore, the Friedman test was used to examine within-group differences across assessments. Significant differences were observed in both the attentional cue training group ($\chi^2 = 17.882$, $p = 0.001$) and the technical training group ($\chi^2 = 16.270$, $p = 0.001$).

Bonferroni-adjusted pairwise comparisons showed significant increases from the pretest to the first retention test in the attentional cue training group ($p = 0.001$) and the technical training group ($p = 0.002$). The attentional cue training group also showed significant increases from pretest to the second retention test ($p = 0.005$), and the technical training group did as well ($p = 0.004$). However, neither group showed a significant difference between the first and second retention tests ($p = 1.000$).

The Mann–Whitney U test revealed no significant between-group differences in saccades toward the setter’s area following serve reception at the pretest ($U = 42$, $p = 0.579$), first retention test ($U = 28.500$, $p = 0.105$), or second retention test ($U = 27$, $p = 0.089$). Table 3 presents comparisons of saccades toward the setter’s area during serve reception.

Discussion

This study compared the effects of attentional cue training and technical training on saccadic eye movements toward the setter’s area during volleyball serve reception and directed passing, as well as on long-term learning of serve-reception performance in novice girls aged 10–12 years.

Table 1. Demographic characteristics of the participants

Group	n	Age (years)	Height (cm)	Weight (kg)
Technical training	10	12.10 $\pm$ 0.568	154 $\pm$ 8.219	46.40 $\pm$ 7.905
Attentional cue training	10	12.10 $\pm$ 0.876	156.5 $\pm$ 7.764	51.50 $\pm$ 9.396

Values are presented as mean $\pm$ standard deviation.

Table 2. Comparison of volleyball serve-reception performance between the technical training and attentional cue training groups

Training group	Pretest (mean $\pm$ SD)	Between-group comparison at pretest	First retention test (mean $\pm$ SD)	Between-group comparison at first retention test	Second retention test (mean $\pm$ SD)	Between-group comparison at second retention test
Attentional cue training	4.30 $\pm$ 1.76	p = 0.914; F = 0.012	11.00 $\pm$ 1.76	p = 0.013; F = 7.550	12.00 $\pm$ 2.00	p = 0.006; F = 9.598
Technical training	4.20 $\pm$ 2.30		8.50 $\pm$ 2.27		8.60 $\pm$ 2.83	

SD: standard deviation. Statistical significance was set at $p < 0.05$.

The results indicated improvements in both groups from the pretest to the first and second retention tests. Neither group showed a significant difference in performance between the two retention tests. In accordance with the traditional motor learning perspective, which associates practice-related improvements with learning (25), these findings suggest that both attentional cue training and technical training led to motor learning.

Serve-reception performance was significantly better in the attentional cue training group than in the technical training group at both retention tests. This finding is consistent with research demonstrating that cues directing attention externally facilitate motor learning (12). It also aligns with evidence indicating that, in open motor skills, an external focus of attention produces more effective performance and technique than an internal focus during skilled task execution (26).

The most widely adopted explanation for these effects is the constrained action hypothesis. This hypothesis proposes that an internal focus encourages conscious movement control and disrupts processes that would otherwise become automatic, whereas an external focus facilitates automatic motor control (10). An external focus appears to create conditions that allow self-organizing processes to regulate implicit learning within the human motor system (27).

The present findings also agree with research demonstrating that attentional focus cues positively affect children's motor performance and that instructing children to focus externally enhances their object-control performance (19). Given previous

evidence supporting the benefits of external attention training in children (3, 28), and the age range examined in this study, comprehensible, task-relevant external focus instructions that emphasize visual cues appear particularly effective for children's motor learning (29). For novices, external attentional cues during the initial stage of learning may also reduce working memory load and thereby enhance performance (28).

The second aim of this study was to examine changes in the receiver's saccadic eye movements toward the setter's area during serve reception and directed passing. The number of saccadic eye movements increased significantly from the pretest to both retention tests in the attentional cue training and technical training groups. Neither group showed a significant difference between the first and second retention tests. Nevertheless, no significant between-group differences in saccadic eye movements toward the setter's area were observed at any of the three assessments.

The findings for the technical training group are consistent with research indicating that sports practice can improve visuomotor performance in children aged 9–12 years (30). Certain visual skills improve through participation in sports activities (31), and comparisons between athletes and non-athletes have revealed significant differences in saccadic eye movements (32). The findings for the attentional cue training group also align with a study reporting that visual attention training significantly increased all measured components of gaze behavior, including saccades, during volleyball serve reception in near-expert athletes (14).

Table 3. Comparison of saccades toward the setter's area during serve reception between the technical training and attentional cue training groups

Training group	Pretest (mean $\pm$ SD)	Between-group comparison at pretest	First retention test (mean $\pm$ SD)	Between-group comparison at first retention test	Second retention test (mean $\pm$ SD)	Between-group comparison at second retention test
Attentional cue training	6.40 $\pm$ 0.966	p = 0.579; U = 42	18.80 $\pm$ 0.919	p = 0.105; U = 28.500	18.60 $\pm$ 0.84	p = 0.089; U = 27
Technical training	6.90 $\pm$ 1.10		19.50 $\pm$ 0.707		19.30 $\pm$ 0.675	

SD: standard deviation. Statistical significance was set at $p < 0.05$.

Visual training may promote the development of brain regions involved in visual functions, including visual memory, figure-ground perception, and spatial orientation. Acquiring these abilities may help athletes apply them effectively in their sports (33). The absence of significant differences in saccadic eye movements between the two groups in the present study may be attributable to the specific visual demands of receiving a volleyball serve and passing the ball to the setter's area.

This finding supports the specificity hypothesis, which proposes that the extent of athletes' visual involvement depends on environmental demands and the nature of their sport. In other words, different sports and different sports skills require distinct visual abilities (34).

Given the significantly greater learning and long-term retention of volleyball serve reception in the attentional cue training group, structured perceptual-cognitive practice incorporating attentional cues may improve the conditions for learning open skills. These skills involve changing environmental regulatory conditions, gaze behaviors such as tracking, fixation, and saccades, and specific visual abilities, including eye-hand coordination, saccadic control, visual acuity, and object tracking. Thus, from an instructional and learning perspective, the findings suggest that incorporating attentional cues into open motor skill instruction can substantially enhance long-term motor skill learning.

Limitations

The study was limited by the participants' skill level and sex, as all participants were novice girls.

Recommendations

Future studies should include participants at different skill levels, particularly intermediate and near-expert performers, as well as male participants.

Conclusion

External attentional cues appear to promote motor skill learning in children more effectively than technical training alone. Overall, however, gaze behavior improves through the practice of sports skills that inherently require gaze-related processes.

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Authors' Contribution

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Funding acquisition: Fatemeh Sharafiyani and Shahzad Tahmasebi Boroujeni.

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Provision of equipment and recruitment of study participants: Fatemeh Sharafiyani and Yaaghoob Moaamer Ghaleh Khalil.

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Conflict of Interest

The authors did not have a conflict of interest.

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