Article ▸ # Comparison of Three Types of Vision Therapy Exercises on Visual Skills of Sports Performance

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ABSTRACT

Background: Athletes looking for ways to improve their performance focus primarily on physical training regimens. Sports vision therapy is a small but growing field. It has the potential to impact sports performance by enhancing visual skills used in sports and is becoming an integral component of athlete training. This study examines whether daily exercises can improve three types of visual skills: depth perception, peripheral vision, and visual reaction time.

Methods: Using an IRB-approved protocol, 45 children aged 9-14 participating in sanctioned recreational sports teams were baseline tested by either an optometrist, an optical technician, or an occupational therapist specialized in vision therapy. Testing included the Wayne Saccadic Fixator board for peripheral vision, the Howard Dolman test for depth perception, and the King-Devick test for visual reaction time. Participants were divided randomly into 3 groups, each of which was trained in a single visual skill. Daily 12-minute exercise compliance was overseen by parents who were instructed in exercise performance. After four weeks of daily exercises, all parameters were retested by the same team of professionals.

Results: For each visual skill group, approximately 90% of the participants experienced improvement in the skill in which they were trained. Additionally, 60% of those trained in peripheral vision showed improvement in all three skills, while fewer than 35% of those trained in depth perception or reaction time improved in the other skills.

Conclusion: This high level of improvement validates the choice of the exercises for performance enhancement and supports the efficacy of vision therapy on visual skill level.

Keywords: depth perception, peripheral vision, sports vision, vision therapy, visual reaction time

Introduction

Sports vision therapy is a growing field about which many athletes are insufficiently informed. Although athletes are always looking for ways to improve their performance, most only focus on physical workouts. Eighty-five to ninety percent of sensory information regarding the external environment is obtained visually.[1] Thus, vision therapy can potentially impact the performance of visual skills necessary for sports and subsequently improve sports performance. Seasoned athletes who underwent visual training demonstrated a measurable improvement in performance across a wide spectrum of sports, including collegiate basketball,[2] female varsity soccer,[3] varsity baseball,[4] Olympic field hockey,[5] and collegiate hockey.[6] The effect of visual training on less-experienced athletes has been examined with mixed results. Improvements in visual skills have been documented;[7] however, gains in sports performance are likely to be a combination of better visual performance coupled with acquisition and honing of athletic skills, as the visual component cannot be isolated.

Exercise programs can be customized to meet specific needs for athletes. Basketball demands court vision and awareness to locate teammates and opponents at all times and necessitates quick recognition and reaction to movements of both the ball and players on the court. The key visual skills required for success in basketball are depth perception, peripheral vision, and visual reaction time.

Depth perception depends on binocular vision. Binocularity begins with focusing the individual eyes on an object, yielding information referring to color and shape, which travels in the ventral stream to neurons in the inferior temporal visual association cortex and provides information for object identification.[8] Each eye forms the image at a slightly different angle. When an object is closer, the angles differ more significantly than if the object is more distant, thus it is easier to interpret distance of nearer objects.[9] Additional monocular cues, such as relative size, interposition and linear perspective, and light and shade are detected and can be used for spatial location. This information travels in the dorsal stream to binocular receptive fields found in the parietal association cortex and the superior and middle temporal visual association cortices, which fuse the images to generate a single stereoscopic image.[8] This yields information about the relative distance of that object from the athlete and helps athletes to judge distances between objects such as the ball and the basket. Therapies designed to ramp up handling of binocular input train an athlete's brain to fuse the images more effectively through repetitive muscle-memory exercises.

Table 1. Evaluative Testing Protocols

Parameter Tested/Test Used	Testing Protocol
Peripheral vision WSF test[17]	Subjects were instructed to press buttons arranged at varying distances along 16 equally spaced radiating lines as they lit in a random computer-generated series. Once a button was pressed, another button would light. The number of buttons correctly pressed in 60 seconds was recorded.
Depth perception Howard Dolman test[11,24]	Subjects were asked to manipulate a string to align a moving dowel on a track with a fixed dowel from a distance of 30'. Distance from the correct position of dowels was recorded and reported as an average of two trials.
Visual reaction time King-Devick Test[22]	Subjects read seven lines of five single-digit numbers aloud as quickly and accurately as possible. Score was based on time (in seconds) to complete the trial, with one second added for each mistake made and reported as an average of three trials.

Table 2. Exercises for Peripheral Vision

Exercise/Materials	Directions
Letter grid,[14] metronomeonline.com 30 seconds	Read aloud a letter grid, posted at eye level, from 3 feet away, following the rhythm of the metronome @ metronomeonline.com.
Letter grid, flashlight, sticky notes (targets)[14] 1.25 minutes/hand 2.5 min total	Week 1: 60 bpm, Week 2: 100 bpm, Week 3: 144 bpm, Week 4: 184 bpm
Straws & toothpicks[15] 45 seconds slowly/45 seconds quickly each straw 3 min total	In a dimly lit room, while reading the letters off a letter grid aloud to the rhythm of the metronome (see timing above), shine the flashlight from one of 8 visual targets placed 8 inches away from the grid to any other target. Hold flashlight in right hand then left and change reading direction daily (left to right, bottom to top). Push targets out 3-4 inches farther each week.
1 tennis ball, 1 sticky note (target)[16] 90 seconds each activity 6 min total	Place a target on a wall. While looking at the target, toss a ball up and catch it with the same hand, repeat with other hand. Then toss the ball from one hand to the other and back. Weeks 1 & 3 keep arms close to sides; Weeks 2 & 4 hold arms farther out from sides.
Weeks 1 & 2 keep tosses below head Weeks 3 & 4 toss slightly over head	Bounce the ball off the wall from 3' away and catch with same hand, complete for each hand. Repeat by tossing the ball off the wall from one hand to the other. Weeks 1 & 3 keep tosses inside torso region; Weeks 2 & 4 throw tosses farther outside torso. Repeat tossing the ball against the wall with one hand and catching with the other hand. Week 1: toss ball at wall below head level; Week 2: tosses hit wall slightly above head; Week 3: bounce ball at wall so that rebound stays under head; Week 4: toss ball at wall so rebound is overhead.

One very common depth perception exercise tool is the Brock string.[4] Subjects focus on one of five beads along a three-foot string. The image formed by the right eye shows a string going through the bead at an angle to the left, and the left eye shows an image of the string going at an angle to the right. When both images are used by the brain and fused correctly, the two images seem to form an X in the string with the bead in the center (if fused improperly, the X will not appear to pass through the bead). Untrained brains can ignore one eye's input, resulting in failure to see the X. This suppression essentially eliminates half of the sensory information used to evaluate the distance to the bead. Practice increases accuracy of depth perception, which can be vital to a basketball player's shooting and passing accuracy.

The Howard Dolman test can be used to assess depth perception.[10,11] The apparatus is a box containing a fixed dowel and a moveable dowel attached to a string. The subject, standing 30 feet from the apparatus, pulls the string to align the two rods. The test is scored by measuring the distance between the correct alignment and the subject's attempt.

Daily activities emphasize books, paperwork, and computer screens in the center of the visual field. This over-emphasis on central vision can cause peripheral vision pathways to be less potentiated, resulting in poor peripheral awareness. Peripheral vision therapy exercises work to raise awareness of a person to their surroundings[12] and reinforce neural processing of information relayed from the photoreceptive rods, which serve as color insensitive motion detectors,[13] via Type M retinal ganglion cells, to the magnocellular layers of the lateral geniculate nucleus.[8]

In basketball, peripheral awareness is important for recognition of a clear path to the basket, anticipation of defenders, seeing a ball screen, and throwing effective no-look passes. Peripheral vision training exercises include activities performed with common items like a letter grid, flashlight, straws, toothpicks, and tennis balls,[14-16] in which the athlete focuses on one item while interacting with the others. This forces neural awareness of input from rods.

Assessment of peripheral vision can be performed using a Wayne Saccadic Fixator (WSF), a board of randomly lighting buttons.[17] As a patient improves awareness in their peripheral vision, it takes them less time to identify and to push the lit button, which raises their WSF scores.[18]

Basketball players rely on visual reaction time to deflect a pass, to save a ball from out-of-bounds, or to steal a ball off the dribble. Visual reaction time is predicated on saccades, rapid movements of the eyes from fixation on one point to fixation on another. After initial focus on a moving object, there is a delay period of about 200 msec, during which the distance between initial and final positions of the object is calculated by the brain.[19] This will determine the degree of contraction of eye musculature necessary to focus on the target. Because the eyes don't move until after the computation period, movement of the object during this time requires neural adjustments, which cause a delay in eye movement and therefore a delay in maintaining focus on a moving object.[19] This prolongation of reaction time can decrease speed of player action. Training of the visual pathway for eye movements can decrease visual reaction time, improving performance.

Table 3. Exercises for Depth Perception

Exercise/Materials	Directions
Brock String[17]	Attach one end of the Brock string firmly to maintain a taut string. Insert the tip of your finger through the loop end and bring it to your nose so you can look down the string. Have someone place the bead closest to you at the marked line, and spread the remaining beads out so that the further beads have a greater distance between them. Starting with the bead closest to you, focus on each bead until you perceive an X; repeat for all beads. (Week 1 = 90 secs, Week 2 = 90 secs, Week 3 = 75 secs, Week 4 = 45 secs) Next, turn your head to the right and keep the string to the tip of your nose, looking down the string through the outside of your left eye. Find the X in each bead. Repeat with other eye. (Week 1 = 75 secs per eye, Week 2 = 90 secs per eye, Week 3 = 60 secs per eye, Week 4 = 45 secs per eye) Variations: Repeat using metronome at 60 bpm; every fifth beat of the metronome, shift your focus to the next bead; working your way down and back. 90 secs (Week 1 = standing, Week 2 = sitting on ground, Week 3 = standing on chair, Week 4 = 75 secs standing) Repeat having someone gather all the beads to the end farthest from you, and move the first bead until you can see the X, at which point they will slowly move the bead toward you while you maintain focus until it reaches the top of the string. Repeat for all beads, then repeat moving the beads down the string (start this exercise in Week 2 = 90 secs toward you and 90 secs away, Week 3 = 3 min intervals of moving each bead toward and away, Week 4 = 2 min intervals of moving each bead toward and away)
Ball on a stick speed touch[14]	Have someone hold the ball on a stick in front of you. Touch the side of the ball at the middle with your index finger as fast as you can; repeat as they move the ball to varying distances. (Week 1 = 30 secs each hand x 4 positions, Week 2 = 30 secs each hand x 3 positions, Week 3 = don't do this exercise, Week 4 = 20 secs each hand x 3 positions)
Ball on a stick focus shifting[25]	Hold the ball on a stick in front of you and stand in front of a window. Focus on the ball, and then every ten seconds, shift your focus to objects farther and farther away out the window. Once you've focused on 5 objects, work your way back to the ball. (Begin this exercise in Week 3, Weeks 3 & 4 = 90 secs)
Pen capping[25]	Hold a pen about a foot away from your face and remove the cap. Move the hand holding the cap down to your side and then bring it back up and recap the pen. Move the pen farther and farther from your face and repeat; once you reach arms' length, work your way back again. (Week 1 = 90 secs @ chest level, Week 2 = skip, Week 3 = 90 secs b/t eye and waist, Week 4 = 90 secs overhead to waist)
8 inch straw, 1 toothpick[14]	Have someone hold a straw in front of you at any angle; using one hand, put a toothpick into one end of the straw. Repeat at multiple distances; repeat with your other hand. (Week 1 = 60 secs each hand, Week 2 = don't do this exercise, Weeks 3 & 4 = 45 secs each hand)

Table 4. Exercises for Visual Reaction Time

Exercise/Materials	Directions
Warm up[14] 9 tennis balls (color does not matter)	Have someone toss 9 tennis balls at you in rapid succession in all directions within reasonable catching distance. Repeat. (Weeks 1 & 4 = 1.5 mins catching ball w/ whichever hand is closest, Weeks 2 & 3 = 45 secs of catching w/ each hand)
Self-ball-toss[26] 3 tennis balls (3 different colors)	Arrange one tennis ball of each color into two hands so that you can toss a triangular arrangement of the three balls at a wall. Two of the balls will be supported by your fingers, and the ball at the top of the triangle, closest to the ceiling, will be supported by your thumbs. Throw the balls at the wall (while in the triangular arrangement) and try to catch them before they hit the ground. (Week 1 = 2 min.) Catch a predetermined color with your right hand, a different color with your left hand, and let the other one fall. Then, let the balls hit the ground and catch them off the bounce the same way (Week 2 = 2 min). Don't do this exercise for Weeks 3 & 4.
Tennis ball knockdowns[14] 9 tennis balls	Someone will toss the tennis balls toward you rapidly one at a time and call out "catch," "hit," or "skip" when the ball is about halfway to you. Catch = catch the ball, hit = knock the ball down with one of your hands, skip = dodge the ball. 2 min total (Week 1 = tosses in torso region, Weeks 2 & 4 = tosses outside torso region, Week 3 = don't do this exercise)
Tennis ball recognition[14] 9 tennis balls (3 of each of three colors)	Start with your back toward someone. They will say "go," name a color, and toss some colored balls at you. On "go," turn around and catch only the color they said; let other balls fall. (Week 1 = 1 ball for 1 min and 2 balls for 2 mins; Week 3 = 2 balls 1 min, 3 balls 1 min, 4 balls 1 min; don't do this exercise for weeks 2 & 4)
Overhand or underhand[14] 9 tennis balls (3 of each of three colors)	Start facing someone. They will lightly toss two balls toward you at eye level. Catch one specific color over-handed and another color under-handed. Every other day, switch colors. (Week 1 = 90 secs, Week 2 = 75 secs, don't do this exercise for Weeks 3 & 4)
Tennis ball drop[20] 2 tennis balls	Facing someone, distance yourself so if you both outstretch your arms, your hands overlap. They will stand with arms outstretched, holding one ball in each hand. Start with your hands behind your back, and when they drop one of the balls, catch it before it hits the ground. (Week 2 = 90 secs, Week 4 = 1 min 45 secs, don't do this exercise for Weeks 1 & 3)
Partner off the wall[21] 9 tennis balls (color does not matter)	Have someone stand a few feet behind you while you stand facing a wall. When they toss the ball off the wall in front of you, catch it before it hits the ground. (Don't do this exercise for Week 1, Weeks 2 & 4 = 45 secs per hand and 45 secs two-handed, Week 3 = 1 min catch w/ whatever hand is closest.)
Overhead catch[21] 9 tennis balls (3 of each of three colors)	Weeks 1 & 2 don't do this exercise. Stand with your back to someone and focus on a spot in front of you. They will toss the ball up over your head so it drops in front of you. Then, they will say "go" when they toss the ball, and you will clap behind your back before catching the ball in front of you. (Week 3 = 1 min w/ no clap & 2 min w/ clap, Week 4 = 1 min w/ no clap & 1 min w/ clap)
Wrap up[14] 9 tennis balls (color does not matter), a partner	Repeat the exercise you did for the warm up. (Weeks 1, 2, & 4 = 2 mins, Week 3 = 90 secs, Week 1 = toss all balls, Weeks 2-4 = bounce some and toss some.)

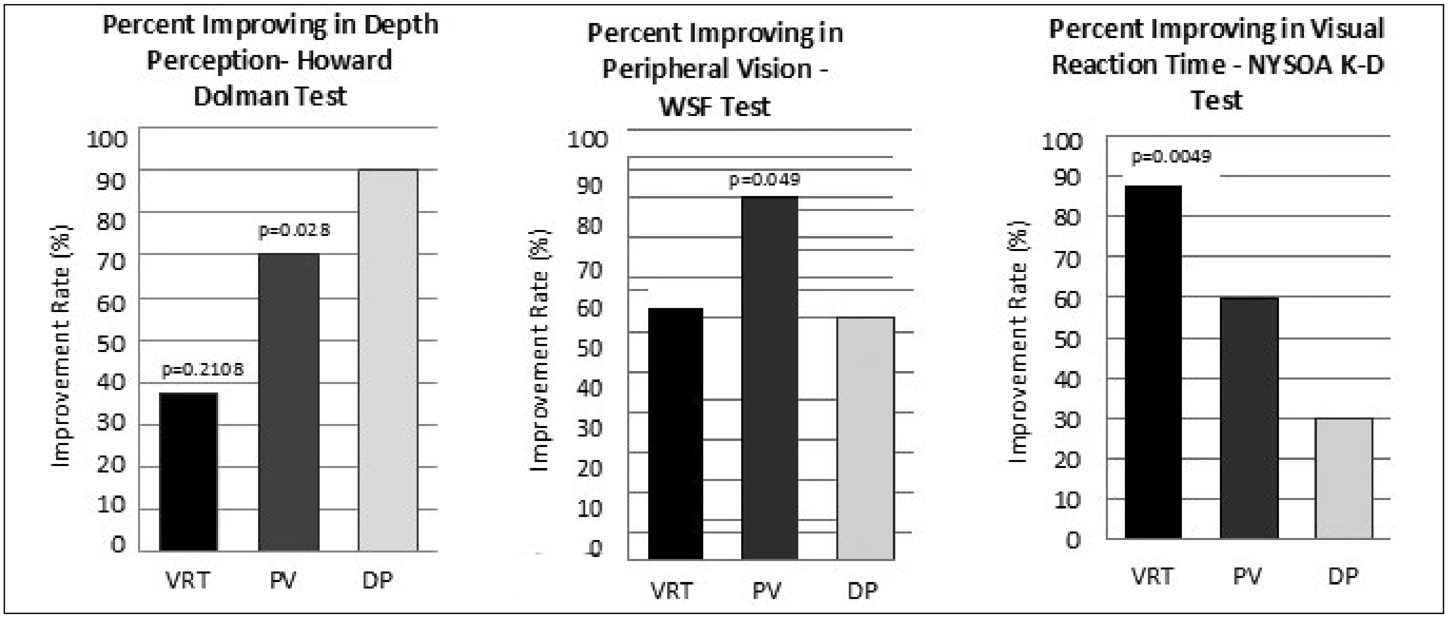

Figure 1. *Percent of participants improving in testing from baseline to post-training exit test. Left: Howard Dolman depth perception testing. Center: Wayne Saccadic Fixator peripheral vision testing. Right: King-Devick reaction time testing. Endcap indicates significance of test improvement by paired t- test.*

Exercises that improve visual reaction time can be performed by tossing and catching tennis balls in specific patterns.[20,21] Visual reaction time is commonly assessed by the New York State Optometric Association King-Devick test,[22] which analyzes tracking ability using a reading exercise at three timed levels. As accurate and efficient tracking is necessary in many sports, including basketball, and is a direct result of visual reaction time, the King-Devick approximates tracking by reading several series of numbers, serving as an approximate examination of reaction time.[23]

This study evaluated the improvement in visual skills of youth athletes following training in one of these three skills, which have been identified as vital to basketball performance. Because the subjects were inexperienced athletes, athletic performance was not evaluated. In consultation with doctors and vision therapists at The Vision Development Team, we developed 12 minutes of daily visual exercises to be performed over a four-week period to determine whether youth athletes could improve visual skill performance.[14] We expected that given a 12-minute daily exercise routine, we could legitimately expect participants to improve in the skill in which they were trained; however, given the short training time of only four weeks of exercises, we did not anticipate appreciable crossover visual improvement.

Methods

We recruited mixed-gender participants aged 9-14 for this Ohio Northern University IRB-approved study by distributing flyers to programs affiliated with a variety of youth sports in the Cleveland area. Expectations were that following baseline testing, subjects would perform the assigned visual exercises for four weeks and return for follow up testing. We assigned each participant a number to protect confidentiality and recorded data only with respect to those numbers.

Entry assessment consisted of a Wayne Saccadic Fixator (WSF) test[17] to analyze peripheral vision, a Howard Dolman test[11,24] to measure depth perception, and the New York State Optometric Association King-Devick test[22] to assess visual reaction time (Table 1). The order of testing was random. Testing was performed by an optometrist, an optometric technician, and multiple vision therapists from The Vision Development Team, North Royalton, Ohio.

After baseline testing, we randomly assigned subjects to train in one of the three visual skills. Peripheral vision exercises, designed to improve and to increase peripheral awareness as opposed to strengthening muscles, included work with letter grids,[14] straws and toothpicks,[15] and tennis balls[16] (Table 2). Depth perception exercises, geared toward improving the visual efficiency of visual pathways directing the eyes to a target, included work with a Brock string,[17] pen capping,[25] ball and stick,[14,25] and straws and toothpicks[14] (Table 3). Visual reaction time exercises, targeted at honing eye movements to follow moving objects, included activities involving tossing and catching tennis balls[14,20,21,26] (Table 4). Exercise materials with written instructions and links to video tutorials were provided, and exercises were demonstrated to participants and their parents. We instructed participants to complete their 12-minute exercise sets once daily for four weeks and to return for post-exercise testing.

At the end of the 4-week vision therapy period, we gave participants/parents an exit survey to ascertain consistency with daily exercises. Then, we repeated the evaluative tests for each visual skill. Thirty-two of the original forty-five volunteer participants completed exercises with fewer than five missed days, finished exit testing, and were included in the data analysis. Differences between baseline tests and post-exercise tests were evaluated. For all tests, the variation in test scores was high. Change in skill level performance for each test was

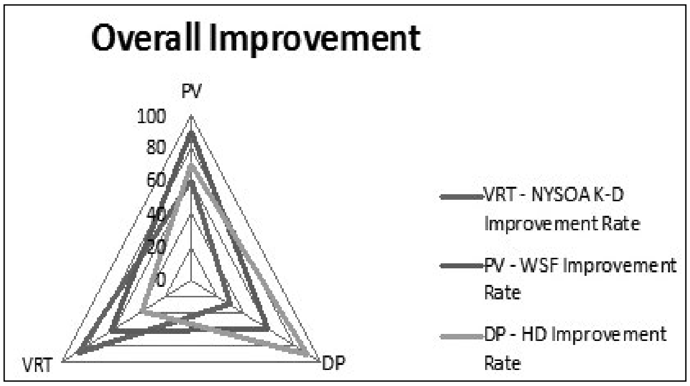

Figure 2. *Relative increase in proficiency showing approximately 90% of participants improving in their area of training, 60% improving in peripheral vision for those trained in the other skills, and 60% improving in other skills for those trained in peripheral vision.*

analyzed by ANOVA with post hoc paired t-tests at a 95% confidence interval.

Results

Post-training peripheral vision test scores improved, regardless of which exercise was performed. Ninety percent of participants (9 out of 10) who were trained in peripheral vision, 60% (6 out of 10) trained in depth perception, and 62.5% (5 out of 8) trained in visual reaction time significantly improved their WSF scores after four weeks of training (by paired t-test p=0.00065; p=0.049; p=0.036, respectively; Figure 1).

Similarly, 90% (9 out of 10) of the depth perception-trained athletes improved their Howard Dolman test scores; however, score improvement was not significant due to wide variation within the test results. A surprising 70% of athletes trained in the peripheral vision group (7 out of 10) significantly improved their depth perception scores (by paired t-test p=0.028), but only 37.5% of visual reaction time-trained athletes (3 out of 8) increased their depth perception scores; again the score improvement was not significant (p=0.21; Figure 1).

Furthermore, 87.5% of athletes trained in visual reaction time (7 out of 8) and 60% trained in peripheral vision (6 out of 10) significantly improved their King-Devick reaction time scores (by paired t-test p=0.0049; p=0.00093), while only 30% of those trained in depth perception (3 out of 10) improved in reaction time, and the change was not significant (Figure 1).

We found that approximately 90% of the participants in each group improved in the area in which they were trained. Additionally, 60% of those trained in peripheral vision showed crossover improvement into the other two visual skills, and 60% of those trained in either depth perception or visual reaction time showed crossover improvement to peripheral vision. However, fewer than 35% of those trained in depth perception or reaction time showed crossover improvement into that other skill (Figure 2).

Discussion

The symmetric data and differential overlap in improvement leads us to conclude that the neurological processing of peripheral vision contributes to processing visual cues for depth perception and visual reaction time more significantly than depth perception and reaction time contribute to each other. While all three modalities are neuromuscular, the motor responses used in depth perception and visual reaction time rely more heavily on central neural processing. The lack of skill-specific motor response in peripheral vision promotes a shift in neural awareness of visual inputs, which may result in the observed crossover improvement. To this end, we conclude that if an athlete were to choose a single type of general visual therapy exercises, peripheral vision training may be the most effective training for athletes to improve multiple visual skills important in competitive play. These general physical therapy exercises are fairly universal; there is evidence to suggest that sport-specific visual training exercises can be designed to improve performance in individual sports.[4]

Conclusion

For each training regimen, approximately 90% of participants who performed daily exercises experienced improvement in the skill for which their exercises were designed. This impressive level of improvement, especially in consideration of only 12 minutes of visual therapy per day, validates the choice of these exercises for performance enhancement and supports the efficacy of vision therapy on visual skill level. Athletes seeking to introduce vision therapy into their general training regimen would benefit most from peripheral vision training.

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