Possible Stereopsis Enhancement in Collegiate Baseball Players with Vision Training

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Abstract.

Introduction. Vision training is rapidly becoming a component of sports enhancement but quantifiable and validated improvement in visual performance has not been clearly demonstrated in high caliber and / or collegiate athletes. We have performed vision training for the last three seasons on the University of Cincinnati Baseball team's hitters. The goal for the work was for performance enhancement and for monitoring purposes, we measured stereopsis pre and post vision training.

Methods. From the preseason (January) 2011 through to the end of the season (May) 2013 all hitters in the University of Cincinnati baseball team underwent regular vision training. Out of season training was 20 minutes twice a week and in season was 20 minutes once per week. Traditional stereopsis (stereo fly) was performed and recorded. Vision training typically consisted of: Dynavision light board, Brock string, Strobe Glasses, Eyeport, saccades and near far.

The players consistently come into the season with stereopsis 23.7 +1.0 mm and six weeks of training increases this stereopsis to and improve to 36.9 + 0.49 mm ($P<0.0001$).

Discussion. There was a consistent and significant improvement in stereopsis measured by stereo fly with the baseball team after 6 weeks of vision training. Equally the stereopsis returned to baseline out of season. Temporal benefits seemed to continue post 6 weeks of vision training. We conclude that in a population of healthy and high caliber athletes that stereopsis can improve with training and suffer from detraining effects as well. We suggest that vision training for sports that require good stereo acuity be considered.

Introduction

Baseball is a vision intensive sport with batting being one of the most visually demanding activities [1, 2] . The ball can depart the pitchers hand at greater than 90 miles per hour leaving only about 0.4s seconds, or so, before it crosses the plate [3-9]. That means the batter needs to see the ball, recognize, process and decide on the swing in a fraction of a second. The mechanics of the swing takes up much of that 0.2s seconds, which means less than 0.2 seconds is needed for the visual and cognitive systems to provide information for making a swing decision [5].

An important component of the assessment of the pitch is speed, which is in part determined by using the depth perception to determine how fast the ball is coming at the batter [10]. The change in distance divided by unit time determines speed [11]. The brain does this calculation subconsciously. We felt that improving visual skills, including depth perception, may be way to improve batting [12]. We previously published results on how vision training improved performance [5] and in the current paper we investigated whether vision training had demonstrable changes in a visual parameter such as depth perception [13]. Depth Perception can be defined as the visual ability to perceive the world in three dimensions and the distance of an object. Depth Perception arises from a variety of depth cues. These are both Monocular and Binocular. Binocular cues include stereopsis, the others are convergence and shadow stereopsis. This is information derived from the different projection of objects onto each retina to judge depth. Using two images of the same scene obtained from lightly different angles, makes it possible to triangulate the distance to an object with a high degree of accuracy. This will be true whether at 16 inches or 60 feet. The premise is that vision training will improve stereopsis and that depth perception improvement will be quantifiable using the stereo-fly. We report on significant improvements in depth perception with vision training and a detraining effect out of season.

Methods

Human Subjects. The vision training was performed as part of the pre-season and regular season practices. All batters were included in the training, which was twice a week pre-season for six weeks and once or twice a week during the season as the schedule allowed. Baseline stereopsis was obtained at pre-season, beginning of the season, end of season. The testing and training was a team wide (hitter wide) activity. The activity has been reviewed by the University of Cincinnati Institutional Review Board and is compliant with all human subjects rules. A total of 16 players were examined and reported here.

Participants: At the beginning of the vision training session, sixteen members of the University of Cincinnati Intercollegiate Baseball Team participated in this study. The 16 participants were between the age of 18 – 22. They were all hitters and field position players as per the mandate from the coach.

All participants were refracted prior to the start of the fall baseball season to ensure the participants had appropriate acuity and binocular vision. Each player was refracted at 20 feet which is a standard testing measure for binocular vision and they were measured at 60 feet.

Baseline stereopsis measurements were obtained in August prior to the beginning the fall baseball season and the beginning of the fall vision training session. The second measurement was taken in January at the beginning of pre-season baseball conditioning and training and prior to start of the pre-season vision training session. The third measurement was taken in February at the end of the baseball pre-season conditioning and training sessions and the beginning of the intercollegiate baseball season and the end of the pre-season vision training session.

Each player was tested for stereopsis using the Stereo Fly Test [Stereo Optical Company, Inc Chicago, Il]. The Stereo Fly was fixed on the wall with each player positioned sitting on a stool 16 inches from the Stereo Fly and at eye level of the Stereo

Fly. During each testing session each player was given a practice session where they got comfortable with the test. The second attempt was measured and reported.

During each vision training session all exercises/skills were conducted in a circuit training method with two repetitions of each exercise/skill at one minute each repetition of each exercise/skill. A 30 second rest was given in between each exercise/skill. Basic visual skill development was initiated during the first 3 weeks of the fall and pre-season training sessions. The purpose was to re-develop oculomotor strength and convergence and divergence movement of the eyes. The remaining weeks of the training sessions escalated in additional cognitive function and visual training skill as it relates to baseball skill.

The Vision Training Program Design, Tools and Equipment

Three vision training sessions were conduct in which all sixteen participants were involved in the training sessions. The sixteen participants were divided into 4 groups of 4 with all groups receiving the same training on the same days. The first session was during fall baseball (5 weeks) with two 25 minute training sessions per week per group. The second training session consisted of the pre-season (7 weeks) with two 25 minute training sessions per week per group. The third training session was conducted during the competitive baseball season (12 weeks) averaging one 25 minute training session per week per group. The vision training sessions were designed and implemented using the following equipment: Eyeport Vision Training System, Brock String, Rotation Trainer, Saccadic Eye Charts, Near/Far Saccadic Eye Charts, Accommodative Flippers, and Nike Strobe Glasses.

Brock String.

The Brock string used consisted of a white string 12 feet in length with 5 small wooden beads of different colors [5, 9, 14]. It is used to develop skills of convergence as well as to disrupt suppression of one of the eyes. It is a valuable procedure for developing accurate fixation skills under binocular conditions.

During the training session the one end of the Brock string is held on the tip of the nose while the other end is tied to a fixed point. The five colored beads are spaced on a length of string at least 12 inch long. The patient is instructed to alternate fixation and focus from one bead to the next while noting the visual input of each eye and sensation of convergence. The patient can use variable techniques to make easier or more difficult by bringing the beads closer\further to the nose.

A the beginning of the second half of (4-7 week) A variation of this exercise was placing the fixed end of the string to the floor or to the ceiling while the patient was standing. Also, the string was shortened to six feet with the player touching the bead with his index finger and return to the side of the leg. They alternated using the right hand and left hand. A wand with tape the color of the ball on the Brock string was also used. The tape was spaced 3 inches apart. When implementing the exercise, the player would have to match the color of the tape on the wand to the color of the ball calling out each color as he matched ball to tape. The athlete would progress from the nearest ball to the furthest ball on the string and repeat [15].

Eyeport

Eyeport Vision Training System: The Eyeport Vision Training System (Exercise Your Eyes, Dove Canyon, CA) is designed to improve visual performance by training the speed, accuracy, and efficiency of the eyes [16]. This electronic device uses alternating red and blue lights. Since viewing red and blue light creates opposing effects in the eyes, alternately looking at these colors creates a rocking action that stimulates and relaxes the eye's aiming and focusing mechanisms. The Eyeport has 10 different speed settings and changeable speed options. The Eyeport was placed in two different positions during each training session; vertical, horizontal, and diagonal eye movement. A progression of low speed to high was utilized in the program. The player was progressed in speed on an individual basis throughout the training session [5]. Each player performed two repetitions of this device at each session.

Rotary

The rotation trainer (Bernell Corporation of Mishawaka, IN) is a piece of equipment to test and enhance eye/hand coordination, perceptual and space awareness, dynamic visual acuity and dynamic fusional training. This piece of equipment includes 20-1/2" diameter plastic disc with a two colored geometric design with drilled holes and an attachment hub and heavy-duty base. It is powered by an electronic control unit with reversible and variable speeds (5-32 RPM). Letters of the alphabet and numbers 1-10 that were constructed of plastic 1x1 inch squares were placed randomly on the plastic disc with velcro. Each player was positioned 8 feet from the disk. The player held a laser light at the tip of their nose and had to identify the letters of the alphabet in order with the light as well as verbally identify the letter. The progression started at 5 RPM and improved up to 24 RPM as they achieved 50 percent of identifying the letters in the alphabet. Each training session alternated the disc in moving clockwise or counterclockwise.

Accommodative Flippers.

Accommodative Flippers were used to enhance the reflex action of the eye. The accommodation reflex is a reflex action of the eye, in response to focusing on a near object, then looking at distant object (and vice versa), comprising coordinated changes in vergence, lens shape and pupil size (accommodation). Utilizing +/- flippers gives the effect of stretching the muscles of accommodation and convergence, much the same as we do before physical exercise. This stretching can help reduce/prevent increases in myopia as well as prolonging presbyopia. The accommodative flippers were used in the preseason training session in 50% of the weekly training sessions. The flippers were implemented in the progression of starting with the .50 and progressing to 3.00 based upon individual ability.

Strobe Glasses

The Nike SPARQ Vapor Strobe are glasses in which liquid-crystal lenses flash between transparent and opaque at a rate set by the user. The purpose of these glasses assists in Visual alignment to have both eyes work together to focus on one object; Hand/eye coordination to assist with reaction time; Visual memory to assist your eyes

and brain communicate more efficiently. The Nike SPARQ Vapor Strobe Goggles work by slowing down movement with a constant flicker in the lens. This effect helps to improve coordination and the ability to process visual information and the timing of movements.

Strobe glasses were used to train two different skills appropriate for this population. The occlusion of vision acts as an interruption of visual information and is somewhat analogous to a base-runner running in front of the subjects' visual field. With practice the athletes learn to focus on the task at hand are may be less likely to be distracted. Also, the relatively rapid interruption of visual input is thought to train the visual systems to take in and process more information when available. So it is thought vision processing improves with strobe glasses training.

Dynavision

The Dynavision is a eye-hand coordination device that tests and improves visual motor skills [9, 17]. We typically perform two one minute sessions on the athletes. The reason for doing multiple sessions is to demonstrate consistency and improvement with the tests. The staged and progressive nature of the tests also helps keep the athletes engaged.

The off the shelf, *A training session is an established Dynavision protocol [5, 17]. It uses traditional eye-hand reaction training to assess visual fields and improve reaction times. This training drill takes one minute. The result is a number of hits in one minute as well as the average reaction time for each hit. Targeted programs were written to improve the perception of the strike zone, and eye hand performance and precision.

Saccades

Saccadic Eye Movement Training: A saccadic eye chart is used to develop the fast movement of the eyes [5, 7, 14]. This saccadic eye exercise emulates a quick simultaneous movement of both eyes in the same direction. This exercise serves as a mechanism for scanning, fixation, and rapid eye movement.

Each player was positioned 8 feet away from the saccadic eye chart and centered between two saccadic charts, which were positioned about five feet from the center line. Prior to beginning the exercise each player had to have full range of the eye motion in order to see all letters on the saccadic chart. The distance from the charts was adjusted accordingly to gain full vision of the chart. Each saccadic chart is constructed on an 81/2 x 11 inch sheet of paper. Each chart has 10 letters with a 36 point font per vertical line with 10 vertical lines on the chart.

This exercise was performed reading the horizontal and vertical charts for one minute each. The player kept their head still with only moving their eyes. The player was asked to read the first letter on the first line on the first chart and then alternated to the second chart to read the first letter of the first line. This completed one cycle. The athlete then would scan the eyes to read the second letter of the left chart followed by the second letter of the right chart. This completed another cycle. The player would alternate between charts and letters progressing across the line horizontally. As they completed the first line on both charts, they moved to the next line etc for one minute.

The horizontal charts were placed at eye level and the vertical charts were distanced 6 feet apart. A progression of this exercises included using unstable surfaces and varying placement of the charts to enhance eye speed and visual focus.

Near Far Training

Near/Far Eye Movements: Near/far eye movements change focus quickly and accurately from a near point to a far point [5, 7, 14]. The two charts utilized for this exercise are a large chart and a smaller chart. The saccadic eye chart was used for the large chart and the small chart was constructed on a 3 1/2 x 2 1/2 inch sheet of paper. Each small chart has 10 letters with a 12 point font per vertical line with 10 vertical lines on the chart.

The far chart was fixed at eye level with the player positioned 10 feet from the chart. The player held the near chart with one hand approximately 4 – 6 inches from the nose. This allowed the player to see over the near chart to see the far chart. The player was instructed to keep their head still with only moving their eyes. The player was asked to read the first letter on the first line of the far chart and then alternate to the near chart to

read the first letter of the first line. This completed one cycle. The athlete then would scan the eyes to read the second letter of the far chart followed by the second letter of the near chart. This completed another cycle. The player would alternate between charts and letters progressing across the line horizontally. As they completed the first line on both charts, they moved to the next line until the time expired for the one minute session. The player was instructed to be sure that both eyes came into focus on the near target as well as the far target when they were alternating from chart to chart.

Stereopsis Measurement

In this observational study the dependent variable whose changes we measured based on the vision training is stereopsis Vision training, above, is the independent variable. We measured depth perception with the stereo fly at intervals before, during and after training. Measurement of Stereopsis was accomplished with the Stereo Fly (Stereo Optical Company, Inc. Chicago, IL). This Stereo Fly test is designed for the evaluation of both gross stereopsis and fine depth perception. The Stereo Fly test is used as a standard in stereo testing. The test only works with the use of the stereo glasses.

Polarizing glasses were placed on the subject and asked if "the fly's wings appeared to be standing up at them and in three dimensions?" Subjects were instructed to observe the Fly at a distance of 14 inches from their nose. If the response was positive, they were instructed to "reach out and pinch the fly's right wing tip with their thumb and forefinger and to hold that position." The distance between the photo and the center of the pinch was recorded with a millimeter ruler. The higher the number, in mm is indicative of better stereopsis when measured on the Stereo Fly. Randot testing measures increasingly smaller increments of stereopsis. So there is a change in stereo fly results in mm. This method is considered to be accurate within + 1-2 mm (personal communication James Ellis).

The Vision Training Procedure.

Three distinct training sessions were conduct during the calendar year. The first session was the fall season (5 weeks) with two 25 minute training sessions per week. The

second training session consisted of the pre-season (7 weeks) with two 25 minute training sessions per week. The third training session was conducted during the competitive season (12 weeks) averaging one 25 minute training session per week. During each session all vision training skills were conducted in a circuit training with two repetitions at one minute each repetition.

Basic visual skill development was initiated during the first 3 weeks of the fall and pre season training sessions. The purpose was to develop oculomotor strength and convergence and divergence movement of the eyes. The remaining weeks of the training sessions escalated in additional cognitive function and visual training skill as it relates to baseball skill.

The stereopsis testing was completed five times during the three baseball training sessions. This included the pre and post fall baseball season (5 weeks), preseason and post preseason (seven weeks), and at the completion of the competitive season (12 weeks).

During each vision training session an average of 5 vision exercises were performed. All exercises were conducted in a circuit training method with two repetitions of each exercise at one minute each repetition. A 30 second rest was given in between each vision exercise. Basic visual skill development was initiated during the first 3 weeks of the fall and pre-season training sessions. The purpose was to re-develop oculomotor strength and convergence and divergence movement of the eyes. The remaining weeks of the training sessions escalated in additional cognitive functional and visual training skill as it relates to baseball. The competitive season training sessions were designed to maintain the oculomotor control that was developed during the preseason session.

During the first three weeks of the fall and preseason training sessions the exercises performed were the horizontal/vertical saccadic eye chart, near/far saccadic eye chart, brock string, eyeport, and the rotary trainer. The exercises were performed at an introductory level on a stable surface. A variation of unstable surfaces such as a dyna disc and half foam roll were added to escalate the difficulty in performing the respective exercise.

During the remaining weeks of the fall and preseason training sessions the exercises were progressed to increase variation and difficulty. This included a progression to unstable surfaces in performing the exercises as well as adding accommodative flippers and Nike Strobe glasses. Nike Strobe glasses were utilized with vision exercises and functional hand eye coordination with a ball and bat.

Statistics.

Paired, two tailed, student T-Test was used go compare the changes in stereopsis for the players. Statistical significance is $P<0.05$.

Results.

Table 1 summarizes the average and standard deviation (SD) for the stereopsis measurements in mm for the University of Cincinnati baseball team as measured through the three years of vision training. Statistical significance is reported as $P<0.05$.

Table 1 Stereopsis Measurements of University of Cincinnati Baseball Players

	Pre-Season	Start of Season
2010		
Average	22.7	36.5
SD	10.6	15.7
T-Test	0.00004	
2012		
Average	23.6	36.7
SD	12.8	12.9
t-Test	0.01	
2013		
Average	24.7	44.2
SD	12.9	8.6
t-Test	0.01	

The players consistently present with stereopsis ranging from 22 to 25 mm at the beginning of training. As a team they go back to this level consistently between seasons. Training increases this stereopsis effect. We consistently reached the 45 to 50 mm levels with the players during the season, data not shown.

Discussion

Depth Perception. Depth Perception in humans is achieved in two main ways. **1.** By assessing the size of an object and estimating its distance based on the size observed. This is how the military trains snipers to estimate distances; based on how big a person was in their sights. It takes training and practice and can be done consciously or subconsciously. Baseball players, especially fielders, will need this skill to estimate where a fly ball will land after the hit. This is done by estimating the change in distance with time and trajectory of the ball [18]. With experience and practice high caliber players can better estimate where a ball will land shortly after being hit. **2.** Depth perception can also be done by a form of triangulation where the vergence of the eyes produces an angle that converges on the target. So if the eyes are looking parallel, there is no vergence and the triangulation estimate is infinity. But as the eyes start to "cross" the angle of the crossing indicates distance. The distance between the eyes forms the base of the triangle, for the triangulation calculation, and the angle of the eyes to vergence gives the brain information concerning distance. Along with the triangulation there is some assistance in depth perception with focus. But this is lost when distances are greater than the hyperfocal length. The focusing method requires eye muscle tone so for this paper it is considered a subcomponent of triangulation. Distance is therefore determined by individuals with a cognitive component concerning size estimations and motor component concerning the eyes' vergence. Together these provide the individual with depth information and speed of the ball is inferred by the change in depth and change in time.

Larsen reported improved depth perception using fusing training in combination with a form of cover test training [13]. This report had a small sample size and the details concerning duration of training, frequency, and intensity of the training was not clear. Notwithstanding, the inference from this work and others [9, 19] strongly supports the concept for improving depth perception. However this is a novel systematic study of a group of high caliber athletes showing consistent and reproducible improvement in stereopsis.

To perceive the distance of an object, or its depth of field, the brain uses the eye's (vergence angles) and size information to determine distances. This information, for a baseball player, is important for determining speed and trajectory of a ball; weather a pitch, throw or hit. The stereo fly tends to assess the depth perception skill of the vergence. Vision training improved this depth perception measure and by extension may help a player improve their ability to assess the characteristics of the ball in flight. Baseball players use and need depth perception at distance (fielders etc) as well as up close (hitters and infielders) to maintain field awareness and optimal performance. Improved depth perception for a batter might mean being less likely to be fooled by a change up pitch [20, 21, 22].

Training. If we assume that the vision training has a causal effect concerning the stereopsis changes observed it begs the question why might this occur. We believe that the vision training, which included ocular motor and neuro visual conditioning led to an improvement in the control and fidelity of the extra ocular and intra ocular muscles of the eyes. This likely included an improvement in proprioception. The eyes were able to more precisely "focus" on a point, remain there and give the brain better information concerning vergence. Hence the brain improves its depth perception. To an extent in the players this may help increase awareness of where that point is in physical space. It is highly likely that the stereo fly results were improved because the ability to detect the angles for the triangulation were better. This could occur with an improved proprioception of the extraocular muscles and / or improved precision as to the position of the eyes. The timing of the improvements are consistent with a muscle training effect coupled. As mentioned in the results, the players consistently come into the season with stereopsis 23.7 +1.0 mm and six weeks of training increases this stereopsis to and improve to 36.9 + 0.49 mm ($P<0.0001$). The players return from the off season, and after not doing vision training for 6 plus months with stereopsis numbers similar to their baselines. This suggests that there is a detraining affect in the absence of vision training.

We kept to a minimum the number of times that the subjects did the stereo fly to prevent the athletes from subjectively improving their performance. The time between stereo fly tests was typically six weeks. It is felt that the pre-season values and the consistent return to similar pre-season values enforces this goal. The reproducible improvement in depth perception with vision training is striking and we believe that the vision training has a causal effect on the stereo fly results. This is, somewhat, reinforced by the observed detraining in the off season with a return to a lower stereo fly results at the beginning of each season along with a relatively consistent improvement in depth perception. We believe that improved neurovisual processing coupled with the ocular motor proprioception leads to improved stereo depth perception [11, 23]. This improvement is lost during the off season, which is consistent with a detraining effect. At this time, however, we are unable to definitely say if the apparent detraining post season vision training is because of incomplete or plateau of the ocular performance or detraining. Either way, the vision training has apparent positive benefits. Continued or regular vision training can regain and/ or maintain these improvements.

We believe that this is a unique report on the improved depth perception of high caliber athletes following vision training. Our previous paper suggested improved performance with vision training [5], and the current results reinforce vision training for performance enhancement. We also believe that depth perception and vision training can continue to improve concerning performance enhancement as well as injury prevention. For example we did not address the "size recognition" component of depth perception. There are methods for training this and they may improve the ability to track and predict the trajectory of a fly ball. Nor did we address the possibility that the subjects were concentrating better from the training.

The weaknesses of a study like ours are that the players changed drastically over the 3 years of the study. Only 4 players were present throughout the 3 years. So all the data presented are a population of the team year by year. No individual or small group performance data are used in this study

In comparison to statistics from the 2011-2012 vision training sessions we determined the post vision training depth perception was reproducible in 2 consecutive years. The team's responses were reproducible in that the pre-season stereopsis was 22.7+10.6 vs 23.6+12.7 mm. After 6 weeks of vision training the stereopsis was 36.6+15.7 and 36.7+12.9 over two consecutive years.

The 66 foot distance we used is important to measure for the batters as this is the distance between home plate and the pitcher's mound. It is important for the hitter to spot the pitcher's finger position on the ball prior to its release [21,22,24]. Coaching strategy indicates for the batter to watch the ball from the bottom of the wind-up position of the pitcher during the throwing motion.

Limitations. We used stereopsis as an indicator of vision training progress. In this paper we have utilized standard stereopsis measure of stereo fly in a non-standard way to observe apparent stereopsis change caused by vision training. While the data clearly show significant changes in the "pinch height" on the stereo fly the method has not yet been directly correlated to the standard method for quantifying stereopsis. Future studies validating the "pinch height" to standard stereopsis methods are warranted. Notwithstanding the data demonstrate that this stereo fly method produces apparently quantifiable results that may be helpful for monitoring ando / or quantifying the effects of vision training. Also, it is not clear, based on our data, what the time course and time to peak is for stereopsis. Nor can we say how long the training lasts or the best dose (frequency and duration of sessions) is for the vision training. There does appear to be some detraining late in the season as the sessions become less frequent.

Further, such vision training methods may improve field and situational awareness, which we believe may prevent injuries. Therefore vision training may be an aid to injury prevention as well; but future studies are needed to investigate this thesis.

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