Manuscript JoVE52648R2 "Vision Training Methods for Sports Concussion Mitigation and Management"   
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**Editorial comments:**  
  
Changes to be made by the Author(s):  
  
1. Please use the attached document for all manuscript revisions.

**Used the document that was attached.**  
  
2. What quantitative measurement is recorded from step 2.2?

**A measurement is not recorded as this is used as an exercise instead of a test. Clarification has been added to the text.**  
  
3. Are there any measurements taken for sections 3-9?

**Yes – where measurements can be recorded has been noted. When tasks are for exercise and training only is also noted.**  
  
4. References are missing some DOIs

**DOIs when available have been added.**  
  
\* JoVE reference format requires that DOIs are included, when available, for all references listed in the article. This is helpful for readers to locate the included references and obtain more information. Please note that often DOIs are not listed with PubMed abstracts and as such, may not be properly included when citing directly from PubMed. In these cases, please manually include DOIs in reference information.  
  
**Reviewers' comments:**  
  
**Editor’s Note:** Please note that the reviewers raised some significant concerns regarding your method and your manuscript. Please thoroughly address each concern by revising the manuscript or addressing the comment in your rebuttal letter.  
  
**Reviewer #1:**   
*Manuscript Summary:*   
Sentence structure makes many concepts very difficult to comprehend; many confusing phrases presented in sequence, which makes transition between ideas somewhat convoluted. I suggest converting complex sentences into multiple simpler successive sentences, each of which should contain a single main point that is more readily understood by the reader. Specific recommendations for content revisions and queries about unclear text are presented below.  
  
*Major Concerns:*  
Line number(s):  
123-124: The phrase "as they are their own controls" makes more sense as follows: "The 3 concussion tests do not need to be included among the preseason baseline tests, because their differing levels of complexity allow each test result to serve as a reference for the others in the set."

**The recommended sentence above has been inserted into the manuscript.**  
  
149: The word "alternatively" implies that the preceding instructional content could be disregarded. Vertical adjustment of the light board is not an "alternative" consideration to subject positioning; it is an "additional" consideration.

**“Alternatively” has been replaced with “Additionally”**  
  
155-156: The reader may not know that each target button will remain illuminated until hit.

**The following sentence has been added to 1.1.3: “Each light will remain illuminated until hit.”**  
161-162: Is the program typically selected by the "subject" or the "clinician" who is administering the test?

**Sentence has been revised to read as “The clinician will select the \*A program and the subject will hit (deactivate) as many lights as possible in one minute.” An additional sentence has been added, “With experience a subject will become comfortable with the menu for the system and be able to start the \*A without assistance from the clinician, if desired.”**

**In addition section 1.1.5. has been modified to read, “Record the number of hits per minute for each session to track progress along with the average reaction time in seconds for the hits during the one minute test.” This should clarify what is recorded for the reader.**  
  
167-169: The references to "Reaction Test" imply that there is only one test. The content of this section discusses 6 different tests. How many lights sequentially illuminate, and which ones are they?

**Section 1.2.1 has been modified to read, “The Reaction Test Program consists of six different tests, three for the right hand and three for the left hand. Instruct the subject to select the Reaction Test and hit start. The lights for Test 1R (right hand) will light sequentially three times to show the subject which lights they will be hitting. Once the lights are done flashing in sequence, there will be a light to the right that will be lit for the first test. The five horizontal lights to the left of the center ring are utilized for Test 1R and the five to the right of the center are utilized for Test 1L.**

187-189: Does the "linear random target switch" involve a horizontal row of lights? How many? What distance from one end to the other? Which of the concentric rings corresponds to the "unknown targets, which will appear along an arc" for Tests 3 and 4?

**Section 1.2.3. has been modified to clarify that for Tests 1R and 1L there are five horizontal lights used for the test. The first two sentences now read, “1.2.3. Have the subject scan the five horizontal lights that light up during the demonstration sequence. One of the five lights will come on randomly within five seconds. The distance between each light in the horizontal row is 14 inches.”**

**At the end of Section 1.2.4. the following clarifying sentence has been added, “Point out to the subject to disregard the bottom green light during these tests as it is used to change from one test to another but is not one of the lights to be hit.”**

**The Note has been expanded and clarified to read, “Note: Tests 1R and 1L involve a linear random target switch. Tests 2R and 2L are again random, unknown targets, which will appear along an arc in one of eight different planes. It is the middle ring of lights that is used for Test 2R and 2L. Tests 3R and 3L are a simple one light choice using the lights to the right and left of the t-scope.”**

187-189: Apparently, Tests 1-2, 3-4, and 5-6 represent 2-trial sets of 3 different tests. Is this correct? If so, designation of the tests by numbers 1-6 is confusing.

**Have modified to designate them as 1R (for right hand), 1L (for left hand), 2R, 2L, 3R, 3L.**  
218: How much might the fixed point be "elevated or declined" in relation to the tip of the nose?

**The following explanation has been added, “Neutral is straight ahead (horizontal). The up or down angle should not be more than 45° in either direction. Typically the elevation is progressed from 10° to 25° to 45° over a time frame where the tasks are challenging but still comfortable. With some people who have prominent noses or eye brows there may be anatomic limitations that need to be observed.”**  
223: I suggest inclusion of a definition of convergence: "i.e., formation of an image at a single point"

**This definition has been added to Section 2.2.**  
241: Specify "EyePort Vision Training System" with company name, city, and state. Although a web link was provided, an illustration of the system is needed for the reader to understand the content of the "Eye Exercises" section.

**Have added “Exercise Your Eyes, Dove Canyon, CA”.**

**We can include a video or we are okay with this one being referenced - https://www.youtube.com/watch?v=JPN6xTeT9G8**

248: Rotate the linear lights to the left - how far?

**Have added “Rotation is done in stages through 360 degrees. Common stages are 20 degrees at a time providing it is comfortable for the subject.”**

259: An illustration of "Accommodative Flippers" is needed.

**We can add a short video of this method if desired, or reference the following:** [**https://www.youtube.com/watch?v=1htUxVcuZwA**](https://www.youtube.com/watch?v=1htUxVcuZwA)**, but it is not a great video.**  
273: I assume that "Tachistoscope" refers to the Dynavision D2 T-scope. If so, this should be specified.

**This a PowerPoint presentation designed by author J Clark. This has been added to 5.1.**  
289: Are any "pinhole glasses or strobe glasses" acceptable, or do they need to meet specifications? I suggest inclusion of recommended manufacturer/distributor company names and model numbers.

**For pinhole glasses any are acceptable. For strobe we use the Nike Sparq and this has been added.**315: The phrase "the horizontal and vertical charts" implies that there are 2 different charts that are positioned perpendicular to one another. Do you mean "rows and columns" of a single chart? This is very confusing. An illustration is needed to understand the meaning of the terms for chart orientation and spacing of the charts.

**We have modified this section to clarify.**  
357-358: Are any "polarizing glasses" adequate? What is the source of the "Stereo Fly" image? Has the procedure been validated? If so, cite a reference.

**This Stereo Fly test only works with the use of the stereo glasses that come with the kit.** [**http://precision-vision.com/products/stereo-vision-tests/stereo-fly-test.html#.VL2JDUfF-Sp**](http://precision-vision.com/products/stereo-vision-tests/stereo-fly-test.html#.VL2JDUfF-Sp)**.**

**Somers and Hamilton reference has been added.**  
393-396: The phrase in line 394 "compared to the inner three rings" is contradicted by the phrase in line 396 "divided by the mean of the reaction times for the inner two rings."

**These are actually two distinct data points. Have tried to clarify this by modifying it to read as, “The data collected during the \*A session is used to calculate the average reaction time in the outer two rings of the vision board compared to the inner three rings. Each subject’s peripheral vision reaction time ratio from one training session to another is calculated as the ratio of the mean reaction times for the outer two rings divided by the mean of the reaction times for the inner two rings and provides a data point in addition to the average reaction time.”**

473: What is the difference between "functional" and "performance" changes?

**The following has been added, “Functional changes are something changes in the measurement, for example faster reaction times documented during vision training. The goal is to have a change in performance, such as an improved performance change when a snap off the ball is improved.”**  
505-507: What is "strength of eye-hand coordination for linemen"? How is it quantified? How is "precision for a wide receiver" different?

**The following has been added, “Linemen have the task to quickly control the other linemen’s arms which requires great strength and quick hands. This can be trained on the Dynavision with resistance bands on a person’s wrists. Receivers need good eye-hand coordination with very good precision to be able to catch the balls under very dynamic circumstances such as while running down the field.”**  
515: Is there some difference between "functional peripheral vision" and generic peripheral vision?  
**Functional peripheral vision is defined as the peripheral vision reaction time ratio**

534: What exactly is "fidelity" of peripheral vision?

**The following has been added, “Peripheral vision’s ability to discern colors and movement is a component of fidelity of peripheral vision. For the athlete doing vision training the ability to recognize an adversary versus the same team in the peripheral vision better would be considered an improvement in the fidelity of peripheral vison.”**  
543: Because better reaction time is represented by a smaller value, and vice-versa, the phrase "slower times taken to hit the buttons" can be confusing. I suggest replacing the term "slower" with "longer" to emphasize that more time elapses.

**We have changed “slower” to “longer”.**  
550: What is the basis for designation of "70 hits" as normal?

**We have revised and added to now read, “In this age group and based on our experience, a normal test should be 70 hits for the score for the first run on the Dynavision. This is based on our empirical experience of hundreds of college level athletes.”**  
551: Table 2 does not present any information that is relevant to the content of the section of the text.

**We have deleted Table 2.**  
584-585: Why is the term "vergence angles" presented in parentheses? The brain uses the eye's what? Whatever this is supposed to be, shouldn't the plural possessive eyes' be used to describe the process?

**Has been revised – “To perceive the distance of an object, or its depth of field, the brain uses the eyes’ vergence angles and size information to determine distances. The brain uses the eyes’ angles for convergence to estimate distance.”**

596-597: How are "control" and "fidelity" of muscles different?

**These were explained in the sentences before their use.**  
605: What is the muscle training effect "coupled" with?

**The word “coupled” has been deleted.**  
612: Is "stereo depth perception" the same thing as "stereopsis"? If so, why use a different term?

**They are not the same. The sentence has been revised to read “Neurovisual processing coupled with the ocular motor proprioception is believed to improve stereo depth perception, which is the ability to use the convergence angles to perceive depth 8,28.”**  
613-615: This is an example of convoluted sentence structure that makes its mean very hard to readily comprehend.

**Sentence has been revised.**  
  
*Minor Concerns:*  
N/A  
  
  
**Reviewer #2:**   
Overall, you have obviously put a lot of time and effort into this paper. It will make a wonderful video that others will be able to duplicate. The really good things include many points in the discussion section. The concept of monitoring a subject during the recovery process from an injury, the fact that there are improvements in concussion assessment tasks, the results description of Table 2 and the summary of improved functional vision possibly resulting from the improved recognition followed by a wonderful football example. Great troubleshooting paragraph toward the end. And page 14, line 577 "takes approximately eight minutes to complete all five tests." is great, but hidden, buried in your text. That should be prominently positioned.  
  
My major five concerns are:  
1) The concept of injury prevention. By enhancing peripheral awareness through conscious activities, you can eventually have subconscious awareness of surroundings improve and can lessen the amount of injuries, but in any sport, there are always going to be injuries that can not be prevented. In football, hits from behind, in tennis, a misstep, etc. I have a large problem with the wording of "injury prevention" that is used throughout the paper.

**We have chosen to use injury prevention because we have a paper in press with that result in football. Briefly concussion in football decreased 80% consistently for 5 consistent years with the University of Cincinnati football team. That paper is now referenced in the paper when “injury prevention” is mentioned.**  
2) Weak references. Many are reused, others are not peer reviewed, one is a news reporter, and your key reference, the one that "proves" your point is In-Press and not accessible. **The pdf of the paper is attached with publication scheduled for March in Optometry and Visual Performance.**

The retrospective study that is cited says that there was a very small sample size with subjective reporting of concussions after vision training had begun. You mention reference 28 a couple of times in the disclosure and the paper on page 14, but my list only goes up to 26.

**References have been corrected.**

Where is the reference that says that enhancement on a sterofly test of a non-moving target at nearpoint with a seated patient will 100% transfer to enhancement of depth perception of moving targets at a distance with a moving person? **This paper is the companion paper in Optometry and Visual Performance due out in March. A pre-print of this paper is attached.**  
3) Lack of brain processing being included -- the whole article hinged on "neuro-visual processing" yet the brain wasn't mentioned -- just the eyes and eye muscles. Peripheral signals from the retina link with head position centers in the brain as well as spatial coordinate systems, etc.

**The following paragraph is added to address.**

**As we have seen improvements in reaction times and improvements in peripheral vision we ascribe these in part to improvements in brain processing. We believe that improved visual acuity cannot account for such changes as the brain processing is needed to have eye hand coordination speed changes. Regarding the peripheral visual fields the retina’s cones and rods may be functioning but the brain is not processing those signals to the fullest degree. The vision training that results in improved peripheral vision is most likely to occur along with constitutive brain processing changes. Future research to assess the brain’s changes with vision training are needed to better address this.**  
4) Missing alternatives to avoid the loss of abilities. In other words, the paper implies that the peripheral awareness skills were lost if not maintained during downtime. (page 14, line 609) This would be the equivalent of an orthodontist using braces for a year, then removing them without a retainer. The purpose of a retainer is to get the brain to change its habit. Then, it can be removed. There is no discussion of how the brain's (the neuro-visual processing that IS mentioned) shifting of habits (from old to newly acquired) could be achieved. Perhaps a retainer pair of glasses could be worn to continually stimulate the peripheral eyesight? And, although the mention of having a thorough evaluation to check for eye health problems such as double vision or a crossed eye is mentioned, it might be interesting to see if a group of people who received eyeglasses to balance peripheral and central eyesight would either learn the skills more quickly or maintain the skills longer.

**With all due respect to the referee, the vision training is not the same as glasses. So there is no technology or data to suggest that glasses would help maintain the training. Also, the orthodontist analogy is not an appropriate analogy here. A better analogy would be weight lifting. A football player and high caliber athlete who has worked out with weight lifting to improve strength WILL get weaker if they stop weight conditioning. The vision training has benefits when the subject is training and that conditioning is lost when training stops.**

5) Statistical comparisons not seemingly equal. For instance, you mention that the player who have had vision training average 1.4 concussions per 100 player seasons as compared to players who did not receive the vision training which is 9.2 concussions per 100 game exposures; P <0.001). Game exposure is different from player seasons. Then you show that the amount of concussions was done as a retroactive study with no control group where the number was subjectively recalled after the fact.

**It is common to report numbers as per season or per player exposure. This is explained in the attached reprint.**

Minor concerns include:  
1) The wording chosen.   
For instance,  
a) in the list of activities, among the specific list of "tachistoscope, accommodative flippers, saccadic eye movement testing, etc." is simply "eye exercises". Aren't they ALL eye exercises?

**We were using the phrase “eye exercises” to describe EYEPORT training but since it is confusing we have changed it to EYEPORT training in the manuscript.**

b) On page 7, line 267, the word "once" is ambiguous. It is intended to mean "after", but it reads, "the flippers are moved only once" implying only one time. Then it goes on to say read for a minute or until 100 characters are reached. Do the flippers continue to move? It is meant to say that the flippers actually flip back and forth (or up and down) continually while the person's focusing readjusts, but that is not how a layperson would read it.

**Section 4.3 has been changed to read – “Instruct the subject to read from left to right while moving the flippers up and down repeatedly. The flippers are moved only after the subject can focus on and read the saccade card.”**

c) On page 12, line 489 what is "reflex action" of the eye? Pupils? vestibulo-ocular reflex? Optokinetic reflex? Menance reflex? Perhaps it should read focusing action of the eye. But accommodation only occurs after central attention and interest is placed on a target. So, there is a bit of brain function involved also.

**The reflex action is accommodation. Yes, there is brain function on the processing. But the task was to make the accommodative muscles move faster and with precision. Sentence has been modified.**

d) page 13, line 570 states "recent papers" yet the two references refer to papers from 20 years ago. Not recent.

**Have added number citations for newer references.**

e) on page 14, line 580, I don't know what peripheralization is. The term is typically used to classify spinal signal pathways.

**The following has been added, “Peripheralization is generally used by neurologic and related health care workers to describe the general phenomenon where a patient uses one side more than the other. It includes hemiparesis, neglect and conversion disorders.”**

f) page 14, line 597, the word fidelity is an odd choice for an eye muscle.

**Has been changed.**

g) page 15, line 628, diplopia might not be known by the reader.

**This has been changed to “double vision”**

h) on the next line, 629, eye health might be better written as eye health and tolerance ranges, or something like that, because you are discussing exacerbation of symptoms, which is functional not exactly health related.

**This change has been made.**

i) page 12, line 491. Perhaps the word memorable might be better as "salient".

**This change has been made.**  
  
2) The descriptions of the activities.  
a)Lack of figures for the eye exercises testing and accommodative flippers.

**We did not include figures to keep within the requested length of the paper. We can add some if desired.**  
b) The ambiguity of the various testing. Should it be seated, standing, standing with feet apart (wide or narrow stance), standing on an uneven surface? As part of the concussion protocol that was created to assess mental functions, was physical stress, such as an uneven surface, such as a balance board to stand on, while touching the lighted board, a possibility? There are balance boards with sensors that can objectively track center of gravity. After concussions, often people experience visual midline shifts. A balance board could assess this objectively -- currently your paper wrote that observers could see differences in head movement. It would be nice to measure shifts in center of gravity, thus posture and head position.

**We believe that the ambiguity will be diminished with the addition of the demonstration videos.**

c) Clarification on page 13, paragraph beginning with line 536. I was confused regarding the exact task and that it says, and why/how it could conclude with "this is further support..." **Sentence has been deleted.**  
  
3) Discussion additions  
On page 10 line 407, why is it taking 4 years for the sustained benefits to appear?

**In an abundance of caution we wanted to be sure the results were maintained. They were and are in press with preprints supplied.**

Why on page 10, line 428, does it say "data not shown"?

**We have corrected to “in press”.**

On page 12, line 511, it says this paper's methods were validated. Put in by who at that point, even though it is redundant

**Have added the references.**  
  
I don't mean to be picky, but this topic is so controversial, you have to have all your ducks lined up to face the barrage of criticism from adversarial communities who will view this.  
  
  
**Reviewer #3:**  
*Manuscript Summary:*   
The current paper presented the detailed information of conducting vision training on university athletes to improve their eye-hand coordination, reaction time and stereopsis. The detailed information is valuable for sports medicine clinic as well as for civilians who would like to improve their visual functions. But the paper needs to make some changes for better understanding.  
  
*Major Concerns:*  
1) The authors specified three types of vision training: light board, three concussion programs, and vision therapy. The three types training were applied on three different groups according to the description in the paper. But the instruction was read as all subjects did whole three types of training.

**Subjects can do all the types of training. The concussion programs are not training. They are testing. This has been noted in the paper.**2) Were those vision therapy tasks also used as comparison before and after concussion?

**The following has been added to the paper along with reference to the Clark 2015 paper in press. “For the concussion testing The Dynavision A\* and Dynavision Reaction Test can be used for baseline assessments. The three concussion tests are also used for concussion assessment but are generally not done by subjects in advance. The three concussion tests are designed to be multi tasking and executive function tests that the subjects have not seen before.”**  
3) In 1.1 \*A protocol, did the subject do touching by both hands or just one hand? Roughly how large the visual field would be covered in this task?

**1.1.3. has been modified to reflect “using both hands”.**  
4) In 1.3 Concussion 1-3 programs, did the subject run the three programs in a random sequence? If it was always starting from the easiest one, no wonder there was a learning effect.  
**The following has been added to 1.3, “The three programs are designed to be performed in sequence. The learning effect is seen in normal individuals. However, in concussion patients the learning effect is not seen and is considered as diagnostic for concussion.”**

5) In line 227, should "beet" be "bead"?

**Correction has been made.**  
  
6) In line 229, how can the subject touch a bead 6 feet away with the index finger?

**The string is 6 feet and tied off at one end. Many people have a reach from their nose to the tip of their fingers of 4 feet. The farthest bead is placed at the extreme reach of the index finger. Section 2.3 has been modified to read, “Alternatively, use a task where the string is six feet and tied off at one end. Many people have a reach from their nose to the tip of their fingers of 4 feet. The farthest bead is placed at the extreme reach of the index finger. The subject touches the bead with his index finger and returns it to the side of the leg, alternating the right and left hands.”**  
  
7) In Accommodative flippers, what's the power of lens used for flipper?

**Details have been added – “The power of the flipper lenses used is varied to optimize the training effect. The two powers used should be challenging but not onerous to focus on an object as the flippers are alternated.”**  
8) What's the flashing frequency of the Strobe glasses?

**This has been explained in 6.2.**  
9) In Saccadic eye movement training protocol, why did the subject stand 8 feet from the target but not 12 feet used in the light board protocol?

**We have added the following note in case the reader wonders about this. “Note: We believe it is important to change distances to add a dynamic component to the accommodative systems and therefore subjects are asked to stand 8 feet away as opposed to the 12 feet used for light board training. There are vision training programs out there that use only a computer and computer screen and do not exercise the accommodative systems. So we vary the lengths at which the tasks are performed.”**  
10) In stereopsis protocol, what's the upper limit of the distance from the photo to the center of the pinch? In how many arc min?

**We have personal experience of 85 mm. We reference Somers and Hamilton as well as Clark et al., concerning this method. We have added the following sentence plus the Somers and Hamilton reference, “Based on our experience we have found that 85 mm appears to be the upper limit of the distance from the photo to the center of the pinch.”**

11) In the results presented, were those football players participating a maintenance practice of light board practice during the season? Or just at the beginning of each season?

**The following sentence has been added to clarify – “The players participated in training pre-season and weekly during the season for maintenance.”**  
12) In table 4, the authors should consider an interaction effect of position, training times of \*A and the history of concussion, since there is a significant effect of training times and history of concussion. Only report the comparison of positions would overlook the effect from training times and concussion.

**In the future we can examine this. The current paper is on the methods. Other work will examine the mechanisms.**  
  
13) Why the concussed subjects had better results than non-concussed subjects??   
**We do not think it has clinical significance at this time.**

14) I suggested the authors separate the subjects had the history of concussion from the analysis and only use those non-concussion for baseline comparison.

**We would like to include the concussion data.**  
15) Although the authors listed many vision therapy protocols, only the results from stereopsis were reported. It would be better if the authors can report the results in the future

**Results are in press and copies of these papers have been included in this revision submission.**  
16) The statistical analysis looks not appropriate in the paper. The authors should use mixed linear model or repeated ANOVA if the same subjects participated in the study. A simple t test is not suitable for repeated measurement.  
**The results have come from our peer reviewed papers that have been published or are in press and the statistics selected have been accepted.**

*Minor Concerns:*  
1) Are "A\*" and "\*A" the same in the paper?

**It should be “\*A” and we have corrected the places where it was wrong.**  
  
2) In line 98, it sounds like the football players did the three concussion assessment tests. But the results are not reported in the paper. Are they the same as non-player controls?

**This sentence has been removed.**