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The Effectiveness of Different Visual Skills Training Programmes on Elite Cricket Players

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ABSTRACT

The effectiveness of visual training interventions for athletes has been questioned over the last few years. Few studies have shown the potential for generic visual skills to improve visual performance in the sport while most interventions seem to be unsuccessful. There is a paucity of studies involving elite performers exposed to visual training programmes, which are becoming popular in the sporting domain. This study aimed to investigate the effect of visual training on visual and cricket skills compared to a control intervention. Twenty-four male county cricket players were pre- and post-tested on 14 visual and 7 cricket tasks. Participants were randomly divided into four groups and underwent a six-week visual training programme consisting of practical drills (P), online training (O), Nintendo Wii games (W), or a control intervention (C). Analysis showed all experimental groups significantly improved from pre- to post-test, whereas the C group showed no significant improvement. The three vision training methods implemented were able to improve visual and cricket skills more than being exposed only to a control intervention. This supports suggestions that visual skills can improve through training. The improvement in cricket skills observed in this study suggests that improvements in visual skills might influence 'on-field' improvements in performance.

Keywords Vision, Visual perception, Cricket, Sports, Athletes, Training.

INTRODUCTION

Visual skills training has recently gained popularity in the sport thanks to the development of novel technological and methodological approaches. However, despite this increase in popularity, there is limited information about the scientific effectiveness of such training. Furthermore, the scientific literature is still lacking consensus on the effectiveness of visual skills training and/or any differences existing between and within athletics groups. A study by Wimshurst, Sowden, and Cardinale (2012) suggested that it is possible to improve the visual skills of Olympic-level athletes by implementing a visual training programme over a period of time. Similar research has shown that field hockey players could significantly improve their choice reaction time and functional field of view through training [1-4], cricketers who carried out visual training showed significant improvements in skills such as peripheral vision, ball skills, concentration, focus flexibility and coordination [5], and soccer, basketball, and handball players have shown improvements in near dissociated phoria and convergence motor fusion following an 8 week training programme [6]

There are relatively few examples of visual skills training interventions; however, the results have been promising. Calder [7] investigated the effectiveness of two types of a training programme on a group of club-level hockey players. One group took part in a dedicated visual skills training programme, while the other group also received 'sport-specific visual awareness coaching'. The performance was measured on a range of visual skills as well as 22 basic hockey skills. The results showed that participants who just received visual skills training improved on two of the basic hockey skills (whereas a control group showed no improvement), but importantly the group who also received 'sport-specific visual awareness coaching' improved on 12 of the 22 basic hockey tests. Similarly, Kofsky and Starfield [8] gave generalized vision training to experienced college level basketball players for 20 sessions over a five-week period. They found that general vision function improved in the experimental group and not the control group but, more interestingly, actual game performance also improved in the experimental group when compared to the control. In contrast, Abernethy and Wood [9] trialed two generalized visual training programmes and compared them to a placebo group and a control group. Their participants were all novices and were pre- and post-tested on both visual skills and tennis-related motor skills. No differences were found between the groups on any of the tasks, and the study concluded that such generalised vision programmes do not appear to provide the improvements in either basic visual function or motor performance that they claim. The main difference between these studies seems to be that Abernethy and Wood used novice participants whereas both Calder, and Kofsky and Starfield used highly experienced athletes who would perhaps be more motivated to improve their performance as they could see the benefits that would come with improved visual skills. To investigate the effects of a vision training programme on novices compared to experts, Quevedo and colleagues (Quevedo & Solé, Quevedo, Solé, Palmi, Planas, & Saona) [10,11] used an unspecified vision training programme on both elite and novice precision shooters. With their elite group (Olympic team members) it was found that both visual function and shooting performance showed statistical improvement as a consequence of the intervention. However, their novice group showed no improvement in shooting performance above that of a control group despite an increase in visual acuity with the same intervention.

The above studies show promise for the use of visual training programmes for the improvement of sport-specific skills, however, there is little consensus or consistency over the methods used. Commonly reported measures to include: practical drills taken from popular sports vision texts books [12-15] non-sport specific eye exercises such as those designed by Revien's [16] 'Eyerobics'; and online sports vision programmes. There is currently a paucity of research which compares different methods of vision training and, for this reason, to date there is no agreement over which types of visual skills training can be beneficial in athletics populations and if such training modalities provide significant improvements in visual abilities and on-pitch performance.

One method of improving vision which has perhaps been overlooked in terms of sports vision training is the use of video games which have been designed for pleasure as opposed to website-style programmes which are specifically designed for sports training. Recent advancements in video games technology require the players to be exposed to a variety of visual stimuli and produce a physical response to them. Green, Bavelier, and colleagues have shown that there are many positive changes that can occur within the visual system as a consequence of playing video games such as improved visual attention, visual tracking spatial resolution selective attention and perceptual templates. Similar studies have also shown that video game players have shorter saccadic reaction times and a larger field of view [16-22] than non-video game players. In terms of a direct link to improvements in sports performance, Frey and Ponserre [23] found a positive transfer of video game playing to actual putting the skill in golf.

Due to the lack of studies comparing methods of vision training or examining the effects of video games on sports performance, this study compared three different methods of vision training and a control intervention in order to assess the effectiveness of visual skills and sports-specific skills training following a six-week intervention period in elite cricket players.

It was hypothesized that athletes undergoing visual training activities would show greater improvement on both visual and cricket tests than those undergoing a control intervention.

MATERIAL and METHODS

Participants

Twenty-four professional male cricketers who were all playing at English county level (mean age of 24.38 ± 3.29 years) voluntarily participated in this experiment. All participants had normal or corrected to normal vision.

The participants were randomly assigned to one of four training groups: practical vision training (mean age 22.00 ± 1.79 years: two bowlers, two batsmen, one wicketkeeper and one all-rounder); computerised vision training (mean age 24.17 ± 1.94 years: one bowler, two batsmen, one wicketkeeper, two all-rounders); Wii vision training (mean age 27.83 ± 3.66 years: one bowler, three batsmen, one wicketkeeper, one all-rounder); and control (mean age, 23.5 ± 2.74 years: five bowlers, one batsman). All participants gave informed consent. Ethical approval was granted by the University of Surrey ethics committee and all procedures complied with British Psychological Society ethical guidelines.

Design

Each participant underwent pre-testing on visual skills and cricketing skills. They then undertook six-weeks of training specific to their randomly assigned group and were then post-tested on the same visual and cricket skills.

Over the course of the six weeks, each player carried out their specified training for three half-hour sessions per week, giving a total of nine hours of visual training per person.

Training protocols – practical training

The training methods for this group were designed according to the suggestions presented in popular sports vision text books [12-14]. Due to the nature and performance demands of cricket, the vision training drills included exercises aimed at improving focusing, eye speed and eye-body co-ordination. All these drills were piloted beforehand on a group of academy-level cricketers to ensure that they could be carried out in the time and space available and that the instructions were clear and easy to understand.

The practical group had four different exercises to work on in weeks 1 to 3. For weeks 4 to 6 they repeated the same exercises but with additional loadings to make the tasks more difficult. These are summarised in Table 1.

Table 1: Practical group training exercises.

Week	Exercise	Description	Training progressions for weeks 4–6
1 and 4	Reaction ball	Throw and catch a reaction ball against a wall as many times as possible in 1 minute. The distance to the wall was varied in each session, as was whether the ball was thrown over- or underarm.	Use only one hand to throw and catch. Vary the hand used in each session.
1 and 4	Juggling	Juggle with three balls for as long as possible.	Try throwing the balls higher in the air. Try adding the fourth ball.
1 and 4	Pencil push-ups	Hold a pencil at arm's length in front of eyes. Look closely at the end of the pencil, make sure the end can always be seen without double vision – if double vision is noticed, move it further away. See how close the pencil can be moved towards the face before vision goes double.	Move the pencil as close as possible and then 'jump' the eyes to look at something far in the distance. Then 'jump' the eyes back to the tip of the pencil and focus as quickly as possible.
1 and 4	Focusing pursuits	A partner holds a small letter chart in front of the participant's eyes. They slowly move the chart around while the participant calls out the letters. The participant must keep the letters in clear focus if they begin to blur the chart should be moved more slowly.	The same exercise but the participant stands on a balance board so they must maintain balance while keeping the letter chart in focus.
2 and 5	Juggling and kick a football	Juggle with three balls while kicking a football against a wall.	Try throwing the balls higher in the air. Try adding a fourth juggling ball.
2 and 5	Number/Letter trace	Number/letter charts were provided with the letters A–J and the numbers 1–10 written on randomly. The task was to time how long it takes to join up all the letters and numbers in order, alternating between numbers and letters. E.g. A – 1 – B – 2 – C – 3 etc. The pen must not be taken off the paper and a complete circle must be drawn around each number/ letter.	Number letter charts went up to T and 20.
2 and 5	Brock string	One end of a brock string (which is a long piece of string with three beads placed along its length) is held to the end of the nose and the other is tied at a distance so the string can be held taut. The first bead should be focused on until the string appears to form a cross at the bead. Hold this gaze and then move the eyes to the second bead and fixate again. Repeat for all the beads several times.	The same but while standing on a balance board.

2 and 5	Carton catch	A 12-hole egg carton is used and each hole is numbered in order from 1–12. A coin is placed in hole one and the task is to flip the coin into all the holes in the correct order.	The holes are numbered in a random order instead of consecutively.
3 and 6	Peripheral catch	A fixation point is marked on the wall and eyes must focus on this at all times. Throw and catch a ball against the wall without moving eyes away from the fixation point.	Same but while standing on a balance board.
3 and 6	Punching Os	A sheet of paper has a number of small letter Os printed on it in a random manner. The task is to put a pen dot inside each O as quickly as possible.	There are more Os on each sheet and they are smaller.
3 and 6	Balancing catch	The participant stands on a balance board while a partner throws a ball for them to catch. As confidence grows the ball should be thrown so it is more difficult to catch – either further away from the participant or thrown harder.	As partner throws the ball in they also call which hand has to be used to catch the ball.
3 and 6	Double brock string	Same as brock string above but with two strings tied to opposite corners of the room and the other ends of both held at the nose of the participant.	The same but while standing on a balance board.

Training protocols – online group training

This training group utilized a bespoke internet based vision training software tool designed for the experimental condition. Each member of the online training group was given access to the programme.

This programme consisted of six different drills, each of which had a total of 30 levels to work through. The athlete could only progress to the next level once they have reached a certain level of attainment at the lower level.

The exercises are summarised in Table 2.

Table 2: Online group training exercises.

Drill	Designed to test:	Task
Speed	The speed of eye movements	A series of arrows move at speed across the screen and the participant has to use the arrows on the keyboard to enter the direction that the arrows are pointing in the correct order.
PA	Peripheral awareness	A target shape flashes up on the screen for a short period of time with four other shapes surrounding it, one above, one below, one left and one right. One of the surrounding shapes matches the target shape and the participant has to identify the matching shape and press the arrow key which corresponds to its position around the target shape.
Flex	The flexibility of eye in changing focus from near to far	In the bottom left of the screen, a target object will appear. Nine other very similar objects will appear on the screen and appear to move from near to far and vice versa. The participant has to identify which of the objects exactly matches the target and press the numerical key that identifies that object.
Track	Ability to track a moving object smoothly	A small green ball appears on the screen and can be moved around using the arrow keys. The participant's task is to move the green ball so that it stays within a larger grey area which is continually moving in an unpredictable manner. There are also small red balls that shoot across the screen and must be avoided.
Jumps	Ability to jump eyes quickly to a point of interest	Nine squares move around the screen in a random fashion. Each square has a number in it to identify it. At some point, one of the squares will flash red. The participant has to identify which square flashes and then quickly enter its number via the numeric key pad.
3D	Ability to use both eyes in combination to view 3D	A stereogram appears on the screen in which is hidden a sequence of numbers or letters. The participant must identify the sequence and enter it via the keyboard.

Training protocols – Wii group training

This group had to play selected games on the Nintendo Wii video game console (Model RVL-001(EUR), Nintendo, Japan). Three different Nintendo Wii games were selected for the training in this study. The games were chosen because of the visual demands and physical responses to visual stimuli required in a short space of time.

Members of the Wii training group were given a different game to play for each of the first three weeks of training. Weeks four to six were a repeat of the first three weeks. The games that the athletes were told to train on are shown in Table 3.

Table 3: Wii group training exercises.

Week	Game	Sub-game	Task
1 and 4	Wii Play	Shooting range	There are various rounds of shooting balloons, targets, ducks, cans etc. Some targets show characters; points are lost if you shoot your own character. Bonus points are awarded for consecutive hits without missing.
1 and 4		Find Mii	Crowds of characters gather on the screen standing, walking, swimming, sitting etc. and the player is given certain details to pick out. The player must select characters that match the objective, for example: finding your own character; finding the odd character out. There are time limits which are extended when the correct character is found.
1 and 4		Table tennis	Much like a normal game of table tennis, the remote control must be moved to the correct position to return a ball which travels faster and faster as the game progresses.
1 and 4		Pose Mii	The player must move their character, using the remote control, into falling bubbles. The player must rotate their character to the correct angle and match the pose of their character to that shown in the bubble.
2 and 5	Mario and Sonic at the Olympic Games	Trampolining	The player has to move the remote control in time to make their character jump on a trampoline. Various instructions appear on the screen that must be performed while the character is in the air. These include pressing buttons in a correct sequence or moving the remote in a certain way. The longer the sequence that can be performed in a short space of time, the higher the score.
2 and 5		Skeet	Involves aiming and shooting at clays which are shot across the screen at various trajectories and at high speeds. The more clays successfully shot, the higher the score.
2 and 5		Rowing	In order to make the boat move forwards, the player has to make a rowing motion with the remote control and press various buttons which are presented on the screen. The more quickly and accurately the buttons are pressed and co-ordinated with the rowing motion, the faster the boat will move.
2 and 5		Archery	The players must use the remote control and the nunchuck attachment to draw back the bow and arrow and aim towards a target which appears to be some distance away. The target must be fixated on, and the aim must take into account differing wind speeds and directions. The closer shots are to the centre of the target, the higher the score.
3 and 6	Wii Fit	Football heading	The player must shift their weight on the balance board to head footballs that are flying towards either side of them. The player must identify some objects that are not footballs and avoid these while heading as many footballs in consecutive order as possible.

3 and 6		Table tilt	Players must shift their balance to move balls around on a table and down a hole, without letting them fall over the edge of the table. Time is gained for successfully getting balls through the holes, but reduced if balls fall off the edge of the table.
3 and 6		Ski slalom	Players must shift their weight to direct their character as they ski at high speed down a slalom track. Body weight must be shifted to make the character go around the slalom markers and to avoid other obstacles.
3 and 6		Bubble balance	The character appears in a bubble, floating in a river. The player must shift their weight to direct their character along the river without bursting the bubble by hitting the sides or any other obstacles.

Training protocols – control intervention group

Members of the C group were also told that they were undergoing visual training. In reality, they were carrying out extra fielding drills, similar to those that they would carry out in normal practice sessions. The exercises they were given to practise can be seen in Table 4. They were designed by the researcher in combination with the cricket coaches to ensure that they were no more visually challenging than the normal fielding drills they regularly undertook, but were different enough that the participants would not doubt that they were part of the experiment. They performed the same exercise every week but had different loadings to increase the difficulty for weeks 3-4 and 5-6.

Table 4: Control intervention group training exercises.

Task	Description	Loading for week 3–4	Loading for week 5–6
Rebound slip catch	Partner hits a tennis ball against the wall with a tennis racquet. Participant has to catch the ball as it rebounds off the wall.	Working player stands closer to the wall.	Player has to call before the ball is hit which hand they are going to catch with.
Rebound net	Player throws a ball against a rebound net and catches it. They must throw the ball back in from wherever they caught it and continue for 30 seconds.	Only use one hand for throwing and catching. Repeat using opposite hand.	As the ball is thrown towards net and partner calls which hand ball has to be caught with.
Intercept and throw	Partner rolls a bouncing ball along the floor towards working player. The player collects the ball and throws towards a target.	The ball is rolled out quicker and with a more difficult bounce.	Target is moved around in between each trial.
Throw to target	Flat throw through a hoop that is 1 meter off the ground.	Throw from a further distance.	The hoop is made smaller and throw is from a greater distance.

Assessment protocols – vision tests

Each player underwent 14 different visual tests. These are summarised in Table 5. Participants were familiarised with each test before they were tested. The familiarisation took place directly before each assessment and involved the participant having the test demonstrated to them and then having one trial of a few seconds or until it was clear they understood the task (this took no longer than 30 seconds for any participant).

Table 5: Visual tests used in assessment.

Visual Test	**What it is testing**	**How it is being tested**
Howard Dolman Test	Test of stereopsis .	Participants sit at a distance of six meters from the apparatus with a piece of string in each hand. Their task is to pull the string to move the right of the white poles until they believe it is level with the stationary left-hand pole. The task is repeated three times and score is the total distance (in millimeters) away from the stationary pole that the moving pole was on all three trials combined.

Rotator board	Tests dynamic visual acuity. Also tests fine hand-eye co-ordination.	A disk with 26 holes, each labeled with a letter from the alphabet, rotates at a speed of 2 seconds per rotation. The participant is instructed to place a golf tee in each hole in alphabetical order while the disk rotates. Participants have 1 minute to work their way as far through the alphabet as possible and the score is the number of letters successfully completed in the time.
Horizontal saccades	Tests saccadic eye movements on the horizontal plane.	Two eye charts (letter size 36 point) are placed side by side on the wall 1 meter apart, at eye level for the participant. Participants are instructed to stand at arm's distance from the wall directly between the charts. The participant's head must remain still and centrally pointed at all times throughout the test. The task is to read alternate letters from each chart for 1 minute. The score is the total number of letters read at the time.
Focus flexibility	Tests vergence and accommodative flexibility.	One eye chart (letters size 36 point) is placed on the wall at eye level and the participant stands 3 meters away with a small eye chart (letters size 12 point) in his hands. Participants have 1 minute to read alternate letters from each chart. The score is the number of letters correctly read in 1 minute.
Crazy Catch	Tests hand-eye co-ordination.	The Crazy Catch is a rebound net designed to return the ball in an unpredictable direction. Participants are timed for 1 minute and the number of times they cleanly catch the ball as it rebounds from the net is counted.
Crucifix Ball Drop	Tests peripheral awareness and physical response to detected movement in the periphery.	The researcher (who is 162cm tall) stands with arms stretched out to the sides, at shoulder level, with a tennis ball held in each hand. The participant is instructed to crouch in front of the researcher with their hands by their sides. The researcher drops one of the tennis balls and the participant has to respond to which ball has been dropped and attempt to catch it before it hits the ground. If the participant makes a clean catch before the ball touches the ground they are given 2 points, if they only manage to get a touch on the ball but not catch it they are given one point. Ten balls are dropped, giving a maximum score of 20 points; the hand they are dropped from is randomised.
Visual Memory	Tests the ability to recognize and recall visual information.	The researcher sits opposite the participant at a table. The researcher makes a sequence of hand motions (either palm flat on the table, a fist, or the side of the hand on the table) and the participant has to copy them back in order. The sequence starts with three actions and if the participant gets them correct then an additional action is added. This continues until the participant fails to get the order correct. The test is done three times with the score being the average of the three trials.
Wayne 9.1	Tests hand-eye co-ordination and reaction time.	The lights on the Wayne saccadic fixator (a wall mounted reaction board) were programmed to illuminate in a random order. The participant has 30 seconds to depress and thus extinguish as many lights as possible. As soon as the light has been pressed, another at a random location will come on. The score is a number of lights responded to in 30 seconds.
Wayne 9.11	Tests hand-eye co-ordination and reaction time.	Again the lights on the Wayne saccadic fixator were programmed to come on randomly – this time, however, each light stays on for 1 second and then turns itself off. If the participant has not touched the illuminated light in that second they have missed it and the next light comes on. The test lasts for 30 seconds with one point scored for each light successfully responded to in time, thus giving a top score of 30.
Wayne 9.21	Tests hand-eye co-ordination and reaction time.	This test combines re-action and pro-action motor measurements. The Wayne saccadic fixator is programmed so that lights will appear, one light per second. The speed of the lights will increase each time the participant touches the light when lit. The test lasts for 30 seconds and the score is the product of the number of correct buttons pushed multiplied by the final speed of the lights.
Wayne 9.62	Tests peripheral awareness.	The Wayne saccadic fixator is programmed so that the central light comes on and once it has been depressed one of the surrounding lights will flash on for 100m/s. Participants have 1.5 seconds to locate and press the light that flashed. If they manage this in the time one point is scored, the central light comes back on and the process is repeated. The test lasts for 1 minute and the score is the number of peripheral lights correctly pressed within the time.
Remote Control Car Test	Tests depth perception.	Participants stand on a marker cone with a remote control car. There is a test cone set 360cm away from them. They are instructed to drive the remote-controlled car in the opposite direction from the test cone until they are happy that the car is the same distance from the marker cone as the test cone is. Once they are happy, the actual distance between the car and the marker cone is measured. The test is repeated with the test cone at

		distances of 480cm and 600cm. Score is the total distance (in centimeters) away from the target the car was on all three trials combined.
Bassin Anticipation Timer	Tests coincidence timing and anticipation.	The test uses the Bassin Anticipation Timer which is a track of 49 lights. The start light comes on and then the lights appear to move along the track at a speed of 7mph. Participants are instructed to press a push button to stop the lights when they believe it will have reached a pre-determined location. Participants are given three test runs and their score is the total amount of time, over the three tests, which they were away from the exact marked location.
Flippers	Tests accommodative flexibility.	Participant needs to focus on a small Snellen chart (letters sized 6/9) through a +2.00 and -2.00 lens (flippers). The participant is instructed to read one letter looking through one side of the flippers, then turns the flippers over, wait until the next letter is in focus and then read that. The score is a number of letters read through alternating sides of the flippers in 1 minute.

Participants were also tested for eye dominance by getting them to line up a target when looking with both eyes open through a gap made by their hands. By then closing one eye at a time it is possible to see which eye the brain aligned to and this is considered the dominant eye [24].

Assessment protocols – cricket-specific assessment

Each player underwent seven different cricket skills-related tests. The tests were designed by the researcher and head cricket coach and then approved by the rest of the coaching staff who agreed that the chosen tests seemed to be valid measures of all-round cricketing skill. As these tests have not been used in previous research their reliability and validity are somewhat subjective but as they were designed by a vision coach and cricket coach they were considered the most suitable option. The tests are summarised in Table 6. All tests were scored on a scale of 0-2. A score of 0 meant that the player failed to adequately perform the required skill. A score of 1 meant that the player performed the skill adequately but not perfectly - for example, they hit the border of the target area or slightly fumbled a catch but did not drop it. A score of 2 meant that the player performed the skill perfectly. Prior to testing, participants underwent familiarisation on each of the tests in an attempt to avoid a learning effect. Scores were given independently by the researcher and two senior members of the coaching staff. Although the researcher knew which training group the participants were in, the coaches did not and were therefore blind in order to try and avoid bias in the scoring. After testing was complete the scores given were compared and all scorers had given the same marks to all players, therefore, giving 100% inter-tester reliability.

Table 6: Tests used to assess cricket skills

Cricket Test	Testing Method
Bat to cover	Bowling machine set at 80mph so that the ball reaches the batter at chest height outside off stump. The task is to hit the ball to 1m-wide area at cover.
Bat to mid	Bowling machine set to 80mph delivering a straight ball. The task is to hit the ball to 1m-wide area straight down the wicket (between mid-off and mid-on).
Bat pull	Bowling machine set to 80mph to deliver a ball just outside off stump. The task is to pull the ball to a 1m-wide area towards backward square leg.
Bowl yorker	Bowling a ball to hit the middle stump. The ball must go underneath a hurdle placed on the line where the batsman would stand.
Diving Catch	Ball fed to either the left or right of a player and they have to make a diving catch.
High catch	The ball is fed high into the air and the player has to move to underneath the ball and make a catch.
Throw to stumps	Player throws the ball from a distance of 20 meters to try and hit the stumps from a sideways angle so only one stump is clearly visible.

Statistical procedures

Data were collected from each participant across the 14 visual tests and seven cricket tests, both pre- and post- the specific training programmes. Descriptive statistics were used to define the outcomes in each group. As several of the tests were scored on different scales the data for each test were first transformed into z scores so that direct comparisons could be made to explore the relative performance on each test across time.

Data were then analyzed using a three-way analysis of variance (three-way ANOVA) with training method (P, O, W, C) as the between-subjects variable and time (pre- or post-) and test (14 visual and 7 cricket tests) as the within-subjects variables.

All main effects and interactions were tested other than the main effect of test, which due to the standardization process (use of z scores) is not meaningful. Statistically significant findings were then investigated further using Tukey HSD post hoc tests.

Prior to the ANOVA, homogeneity of variance was tested and the data were found to violate the assumption of sphericity. Therefore the Greenhouse-Geisser correction was applied. Alpha was set at $p<.05$ level.

RESULTS

The results of the three-way ANOVA found a significant main effect for time, $F(1,20) = 79.60$; $p<.001$; partial $\eta^2 = 0.80$; observed power = 1.0.

There was also a significant interaction effect between time and treatment group, $F(3,20) = 4.99$; $p<.01$; partial $\eta^2 = 0.43$; observed power = 0.85.

Tukey post hoc analysis on this interaction showed that all experimental groups significantly improved from pre- to post-test, whereas the C group showed no significant improvement (P, $p<.001$; O, $p<.01$; W, $p<.005$; C $p=.67$).

However, no significant differences were shown between any of the different training groups (see Figure 1).

No main effect was found for group, $F(3,20) = 0.355$; $p=.786$; partial $\eta^2 = 0.051$; observed power = 0.107.

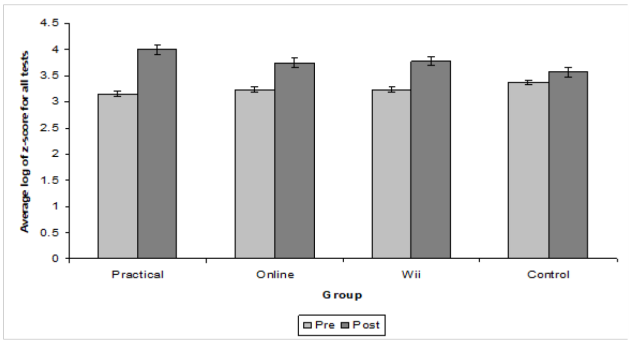

Figure 1: Interaction between time and treatment group (* signifies significant improvement).

A significant interaction was found between time and test, $F(20,400) = 1.721$; $p<.05$; partial $\eta^2 = 0.08$; observed power = 0.97. Raw data can be seen in Table 7.

Table 7: Raw scores on each test at pre-test and post-test averaged across all participants. A ^ indicates that a low score on this test signifies better performance.

Test	Pre-test score	Post-test score
Howard Dolman Test ^	31.17	21.83
Rotator board	10.42	13.29
Horizontal saccades	55.38	64.91
Focus flexibility	61.71	68.29
Crazy Catch	44.67	50.71
Crucifix Ball Drop	9.63	13.13
Visual Memory	3.19	3.83
Wayne 9.1	37.38	45.58

Wayne 9.11	27.71	29.08
Wayne 9.21	2575.75	3285.38
Wayne 9.62	41.63	45.21
Remote Control Car Test ^	127.79	92.29
Bassin Anticipation Timer ^	0.219	0.190
Flippers	24.67	28.21
Bat to cover	6.92	8.25
Bat to mid	5.63	7.54
Bat pull	8.67	8.38
Bowl yorker	2.71	3.92
Diving Catch	7.83	8.54
High catch	8.58	9.58
Throw to stumps	3.96	6.75

Tukey post hoc analysis showed that performance on all tests improved from pre- to post-test with the exception of bat pull. When the more stringent Bonferroni post hoc test was used eight of the 21 tests still showed a significant pre- to post-test improvement. These were rotator board ($p<.005$), crazy catch ($p<.001$), Wayne 9.1 ($p<.001$), Wayne 9.21 ($p<.005$), crucifix ($p<.05$), horizontal saccades ($p<.01$), bat to mid ($p<.05$), and throw to stumps ($p<.001$). A significant three-way interaction between test, time and group was also found, $F(60,400) = 1.547$; $p<.01$; partial $\eta^2 = 0.19$; observed power = 1.

As this three-way significance was found, further analysis was carried out by performing a one-way ANOVA on each test to find if there was a main effect for group on any of the individual tests. In order to carry out the one-way ANOVA, pre-test results were first subtracted from post-test results in order to give an improvement score for each person per test. Significant results were found on four of the visual tests and two of the cricket tests. For the rotator board test there was a significant difference between groups, $F(3,20) = 5.26$; $p<.01$; partial $\eta^2 = 0.44$; observed power = 0.87. Tukey post hoc showed that the difference lay between the P group and the C group with the P group improving significantly more than the C ($p<.01$). The Howard Dolman test also showed a significant difference between groups, $F(3,20) = 3.44$; $p<.05$; partial $\eta^2 = 0.34$; observed power = 0.68.

Tukey testing showed that the W group improved significantly more than the O group. A significant effect of group was also found for the horizontal saccades test, $F(3,20) = 5.36$; $p<.01$; partial $\eta^2 = 0.45$; observed power = 0.88, with all experimental groups performing better than the C group (P, $p<.01$; O, $p<.05$; W, $p<.05$). The final visual test to show a significant difference between groups was the flippers test, $F(3,20) = 9.71$; $p<.001$; partial $\eta^2 = 0.45$; observed power = 0.99. Tukey post hoc testing showed that the W group improved more than all others (P $p<.005$; O, $p<.001$; C, $p<.005$).

The two cricket tests that showed a main effect of group were batting to cover, $F(3,20) = 4.17$; $p<.05$; partial $\eta^2 = 0.38$; observed power = 0.77, and batting to mid, $F(3,20) = 0.07$; $p<.01$; partial $\eta^2 = 0.46$; observed power = 0.9. Post hoc analysis on these results showed that at batting to cover the P group improved more than the W group ($p<.05$) and on the batting to mid-test the P group improved more than either the O group ($p<.05$) or the C group ($p<.005$).

DISCUSSION

The original hypothesis which proposed that the three experimental groups would perform better than the control group was proved correct. All three experimental groups improved significantly from pre- to post-test whereas the C group showed no significant improvement. This shows that any of the three forms of vision training used in this study were able to improve some aspects of both visual and cricket skills more than just training on cricket skills alone. This improvement in visual skills supports previous studies, which showed that basic visual skills can be improved through many repetitions of training [25,26].

Although there were no significant differences between the improvements shown for the three experimental groups, Fig 1 does show that the two computers based groups (W and O) improved a similar amount with the P group showing the greatest level of improvement. The fact that some of the basic cricket skills also improved significantly in the experimental groups supports the suggestion of Wilson and Falkel [14] that improvements in visual skills will carry over and create improvements in performance on the field of play.

Wood and Abernethy [27] criticised many visual training studies as participants undergo the same drills in training as they get tested on. In this study the training for all three experimental groups was completely different from the testing, therefore, the results strongly suggest that various forms of visual training can bring about genuine improvements that are not related to testing familiarity.

Although the C group did show some improvement from pre- to post-test, this improvement was non-significant whereas all three experimental groups showed a statistically significant improvement, therefore, suggesting that the results were not simply affected by learning from pre- to post-testing; otherwise the C group would also have shown a significant improvement, due solely to familiarisation.

Previous research looking at the effects of visual training programmes has shown mixed results. Abernethy and Wood [9] found no improvements after a generalized programme on visual skills or tennis skills but their participants were all novices and had little or no tennis experience. In contrast, the results of the present study are in agreement with the findings of Kofsky and Starfield [8] and Quevedo et al. [10,11] who all used experienced athletes in their training programmes and found improvements in both visual skills and sport-specific ability. It, therefore, seems feasible to suggest that, at the novice level, visual abilities are not the limiting factor in preventing good sports performance, but once an athlete has a level of experience then visual skills training can aid improvement and possibly produce a competitive edge.

The failure of previous studies to suitably describe the training methods used makes it difficult to compare the differing improvements found between training groups in this study with past research. The fact that the Nintendo Wii training group showed the same level of improvement as a specific online visual training programme is somewhat surprising. The Nintendo Wii games have been designed with the primary function of entertainment.

The games used in this study were specifically chosen for the visual and associated motor demands placed on the player, and it is not suggested that all Wii games could provide a similar result. However, the fact that entertainment based computer games can produce improvements in visual skills is an important finding as they could be used for integrative training programmes and interventions for injured athletes. Previous studies have shown that video game players are faster at detecting a visual target [28] and have a larger field of view [22] than non-video game players. Further, Frey and Ponserre [23] found the positive transfer of golf video game playing to actual putting skill.

The present study shows that this positive transfer can also occur in cricket. However, it seems clear that further studies are needed not only to verify the effectiveness of such approaches in other sports but also to elucidate the neurophysiological mechanisms involved in the improvements seen.

To conclude, our results suggest that any of the three methods of vision training used in this study produced greater improvement in some of the tests of both visual and cricket skills than the control intervention group. It would be interesting for future research to consider whether different cricket positions respond differently to vision training, as previous studies [29,30] have shown that players of different positions respond differently to different training and tasks. Further, studies are needed to investigate whether the same visual training has a similar effect on players from other sports and/or if other forms of visual skills training can provide increased benefits.

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