

Influence of two sports vision training techniques on visual skills performance of university students

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Abstract

Vision is an essential sense and crucial throughout a student's academic career. Reading and writing during formal studies require a basic level of visual skills. Training of visual skills to students may improve the way visual stimuli are processed, and subsequently lead to visual skill-, motor- and cognitive performance enhancement. The visual system processes information by way of 'hardware'-skills (physical, mechanical properties) and the more trainable 'software'-skills (perceptual, cognitive abilities). Sports vision skills training in athletes indicated faster response to visual information and ultimately improved performance, particularly in fast-ball sports. The efficiency of two sports vision training programmes were tested and compared in undergraduate physiology students of various ethnicities (aged 18-25 years), during a 6-week training period. Three groups were used. One control group and two experimental groups were used. Two programmes were used for the experimental groups (a vision laboratory executed battery of repeated visual skills vs. 'Eyedrills' an available web-based training programme). Both comprised 'hardware' and 'software' skills, and include: visual acuity, focusing, tracking, vergence, sequencing, eye-hand coordination and visualisation. For pre-test/post-test evaluations of all students the repeated laboratory training programme was executed. The control group was only exposed to the pre- and post-test. Individuals trained in the laboratory indicated the highest improvement in all visual skills, except vergence. The 'Eyedrills' group displayed significant improvements in focusing, tracking and eye-hand coordination, with the control group indicating the least improvement in visual skills - ruling out the notion of improvement occurring only due to test familiarity. Visual training was verified an essential method of improving visual skills, and fundamental in the expansion of basic visual abilities of university students for enhanced performance.

Keywords: Visual skills training, student visual perceptual skills, sports vision exercises, visual motor skills.

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Introduction

Visual skills are an important characteristic in the processing of information in all areas of life. The scientific study of visual skills in sports only started in the late 90's (Berman, 1988; Wilson & Falkel, 2004) after sport performance became increasingly more competitive (Ludeke & Ferreira, 2003). Visual skills allow information to be gathered and processed rapidly and correctly. Furthermore they are responsible for quick and accurate reactions (Abernethy & Neal, 1999). Therefore they are an important aspect in sport skills.

Vision and visual screening were initially only routinely assessed in sports to identify visual acuity which could adversely affect athlete participation (Kirschen & Laby, 2011). The possibility of the regular athlete having *good* visual skills vs. the excellent athlete having *superior* visual skills was subsequently questioned by researchers (Ferreira, 2003). Initial research on the differences in visual competency concluded that athletes with superior performance had enhanced visual skills, compared to regular athletes (Berman, 1988; Laby, Kirschen & Pantall, 2011).

The study of visual skills revealed two equally important components: i) '*hardware*'-skills that rely on the physical properties of the eyes, and ii) '*software*'-skills that depend on the cognitive abilities of the visual processing system (Laby et al., 2011). The contrast in visual ability between professional- and non-professional athletes within different sports codes, indicated the professional athlete's dominancy in specific visual skills (Berman, 1988; Ludeke & Ferreira, 2003) and particularly those with a '*software*' type (Abernethy, 1986; Laby et al., 2011). '*Software*' visual skills provide them with an advantage in recognising visual information, recalling visual facts and decision making, which ultimately leads to better sports performance (Ludeke & Ferreira, 2003; McPherson & Vickers, 2004; Mori, Ohtani & Imanaka, 2002). A deficiency in '*hardware*' visual skills, e.g. below normal visual acuity (clearness of vision), may affect the performance of cognitive aspects, that ultimately distinguish the non-professional athlete from the professional athlete (Jackson & Farrow, 2005; Laby et al., 2011).

Neurological brain activity tests using various neuro-physiological and neuro-imaging methods revealed that professional athletes more efficiently manage visual information, and display more structural and physiological brain diversity when compared to non-professional athletes (Abernethy & Wood, 2001; Nakata, Yoshie, Miura & Kudo, 2010). Brain activation, when exposed to known and unknown motor imagery, indicated superior activation in the frontal lobe in professional athletes (Yarrow, Brown & Krakauer, 2009). Better cognitive processing of visual information with superior activation of the parahippocampus was also seen. Although most of these skills are often noticed in professional athletes, one must remember that this could be attributed to the long hours of training that the athletes undergo (Abernethy & Wood, 2001).

Although the importance of visual skills in different sporting disciplines were realised, the ability to improve these skills in professional athletes by introducing sports vision exercises in training regimes, were questioned by some researchers (Laby et al., 2011; Wei & Luo, 2010). Despite the doubt that was expressed in these exercises, sports vision skills training became popular with the possibility of professional athletes responding faster to visual information, ultimately adding to their advantage in performance particularly in fast ball sports and games with time limits (Kida, Oda & Matsumura, 2005; Wood & Abernethy, 1997). The research in sports vision instigated the development of commercially available visual training programmes. However, the limited knowledge the designers of early training programmes had of vision science, raised concerns of its validity to improve performance (Laby et al., 2011; Williams & Ericsson, 2005). Early research study designs and training programmes delivered inconclusive results limited to: i) test familiarity (Wei & Luo, 2010); ii) applying a syllabus mainly designed for people with visual defects or deficiencies, to training athletes; iii) the training of *'hardware'* skills and vision (Jackson & Farrow, 2005; Wei & Luo, 2010) rather than the more teachable *'software'* visual skills (Barrett, 2009; Laby et al., 2011); iv) small sample sizes and; v) limited training periods.

The dominance of *'software'* visual skills in professional athletes compared to non-professional implied the skill could more readily be adapted and improved with training programmes. Specific *'software'* sports vision testing and training exercises suitable to the environment and the needs of athletes were developed (Du Toit, Krüger, Fowler, Govender & Clark, 2010; Du Toit, Krüger & Neves, 2007b; Farrow & Abernethy, 2002). It involved four different eye-hand coordination exercises, exclusively designed to improve the control of eye movement with hand movement. Following visual training rugby players showed significant improvement in eye-hand coordination, visual concentration, visual memory and reaction time (Du Toit et al., 2010; Du Toit, Krüger, Joubert and Lunskey, 2007a).

The improvement of specific visual skills required by university students using sports vision exercises were explored in a recent study conducted by Du Toit et al. (2007a). Although results indicated a significant improvement in eye-hand coordination and sequencing skills, no substantial improvements were seen in other visual skills. It may be reasoned that sports vision exercises primarily focus on eye-hand coordination and sequencing skills, rather than effectively improving eye movement skills, more essential to students reading intensely. Granting the fairly large sample size used in this study, the training period was relatively short, casting doubt if the training exercises have imparted long-term improvement in visual skills (Du Toit et al., 2010; Du Toit et al., 2007b; Farrow & Abernethy, 2002).

The current study expands on past research (Du Toit et al., 2007a) to determine if the visual skills of university students can be significantly improved through different training methods over a longer study period. The aim of this study was to compare the efficiency of two sports vision training methods: i) a vision laboratory implemented battery of visual trained skills (Du Toit et al., 2011) vs. ii) ‘*Eyedrills*’ an available web-based training programme, (Eyedrills Website, 2011) over a 6-week period.

Methodology

Four hundred and sixty male and female undergraduate physiology students of various ethnicities, aged 18-25 years, registered at the University of Pretoria, South Africa, participated voluntarily in the study. The study was approved by the research ethics committees of the Faculties of Health Science and Humanities (Protocol nr. S60/2012). All subjects attended an information session regarding the procedures of the study, and signed an informed consent form. The exclusion criteria included: medical illnesses, cardiovascular diseases, Parkinson’s disease, untreated hyper/hypotension, visual deficiencies (e.g. colour deficiency), the use of medication that could affect the central nervous system, and those diagnosed with a learning disability or mental illness. Participants were randomly divided between three groups, namely a Control group, a Lab-based group and an ‘*Eyedrills*’ group. Subject numbers were assigned to ensure the confidentiality and privacy of students. Training methods implemented were non-invasive and imposed no discomfort, harm or danger to the participants. The methodology that was applied has well-known scientific validity, is reproducible, inexpensive and easy to implement.

Data collection

The study was conducted over a period of 8 weeks. During week one the physical measures of the participants were obtained and the initial pre-intervention evaluation were performed. The participants were then exposed to a

6-week period of different methods of training depending on the group they were allocated to. Group 1 (Control group), underwent no visual skills training, group 2 underwent a battery of visual trained skills executed in a vision laboratory (Lab-based), and group 3 underwent internet-based ('*Eyedrills*') visual skills training. The post-intervention evaluation was completed in week 8. Incomplete participation or poor training attendance excluded the participants from the study.

Research design

A pre- and post-test, within and between subjects design was used. The battery of visual skills pre- and post-tested and trained comprised both '*hardware*' and '*software*' skills (Adler, 2008; Atkinson, Anker, Rae, Hughes & Braddick, 2002). The battery consisted of: visual acuity, focusing, tracking, vergence, sequencing, eye-hand coordination and visualisation (Du Toit et al., 2011). The combination of simple and complex skills include: eye movement, visual concentration, eye-hand coordination, visual memory and visual sequencing. Skills trained and tested matched the visual needs of students: essentially skills required to read fast and accurate, to study via visual techniques and skills required for everyday activities in order to enhance learning ability (Aglioti, Cesari, Romani & Urgesi, 2008; Jackson & Farrow, 2005; Wei & Luo, 2010). The training underwent by the Lab-based group (Training Method A) and the 'Eye Drills' group (Training Method B) are presented in Table 1.

Table 1: Training Method A and Training Method B

Training Method A:	Training Method B:
Vision laboratory based visual skills training	Web-based visual skills training
<i>A repetitive training programme (Du Toit et al., 2011), performed in a sports vision laboratory (Lab-based).</i>	<i>A commercially available internet-based training and intervention programme, 'Eyedrills' (Eyedrills Website, 2011).</i>
<ul style="list-style-type: none"> • Laboratory based training • Battery of 7 tests, repetitive training sessions • A 15 minute session, twice per week • Over a period of 6-weeks • Interchangeable testing and training drills (Du Toit et al., 2011) • Visual skills trained include '<i>hardware</i>' and '<i>software</i>' skills ⁽²⁸⁾ • Inexpensive, easy and quick to implement. • Suitable for large sample sizes. • The repetitive training programme (Method A) was used as pre- and post- visual skill performance testing method for both Method A and Method B. 	<ul style="list-style-type: none"> • Internet-based training • 6 different drills, 100 testing levels • Sessions controlled by online coach • Over a period of 6-weeks • Training performed anywhere • Tests designed by sports vision specialists • Stimulating and competitive. • Each level more challenging than the previous. • Suitable for large sample sizes.

These two training methods are essential in the sense that they are conducted in the environments that the subjects are accustomed to. University students are related to a younger age category, and may thus be more suitable to improve and

develop visual ability and generally under excessive visual skills demand. The accepted time-period for skills improvement through training was found to be 3-6 weeks (Adler, 2008), therefore the planned programme follows a 6-week training period (Abrahamse & Noordzij, 2011; Dayan & Cohen, 2011). A large sample size and control group were used to ensure the validity of the study-design.

Visual Skill Training Methods

Participants that had corrected visual acuity were required to wear their prescription glasses /contact lenses throughout both the visual skills testing processes to ensure improvements in visual skills were due to skill enhancement, and not merely to visual deficiency correction (Jackson & Farrow, 2005). Vision laboratory tests were completed under supervision of trained assistants to ensure participants understood the tests and to not warrant any influence by peers/friends. Participants were requested not to eat, drink or participate in any strenuous exercise or sport one hour prior to testing to ensure that no immediate physiological responses influence the results.

- ***Training Method A: Group 2 (Vision laboratory based visual skills training):*** During each training session participants repeated all the visual skill tests as listed below. These tests were also used in the pre-test/post-test evaluations of all three groups. Visual skills tested comprised of (Du Toit et al., 2011):

- a) ***Visual acuity:-*** The ability to clearly see detail of a stationary object consisting of different sizes at a specific distance. A universal standard Snellen Chart with rows of alphabet, each containing different sizes of letters, was placed on a wall 6 meter (m) away. Participants read each row of letters monocularly and binocularly from the top. Visual acuity was recorded as a fraction indicating the point on the chart to where the participant could read accurately.

Participants that did not have normal/ corrected to normal visual acuity were excluded from the study at this point, as performance of other visual skills would be hampered.

- b) ***Focusing and eye movements:-*** The ability to see and focus clearly at different distances. A large letter chart was placed on a wall. Participants stood at the furthest distance they could see all letters clearly. A small letter chart was held by the participant at nose level ~10cm from their face. Starting with the small letter chart, participants read one letter from the small letter chart and one letter from the large letter chart, alternating between the charts for 1 minute or until providing an incorrect response. The number of letters correctly read was recorded to assess speed and accuracy of focusing ability of the eyes.

- c) **Tracking:-** The eye's ability to make quick saccadic jumps from one point to another. Two strips of letters were placed on a wall at eye level, 1m apart. Participants stood 1m away from the wall. Without moving the head they read one letter from each strip, starting on the left. Number of letters read correctly in 1min or until an incorrect response had been given, was recorded.
 - d) **Vergence:-** The ability to cross and uncross eyes and maintain single vision. A pencil is held at arm's length and in line with the nose. Focusing on the tip, the pencil is slowly moved closer to the nose. At the point that the eyes are no longer able to converge, a double image is seen. Pencil movement is stopped; the distance from the tip of the participants' nose to the tip of the pencil is recorded in centimetres (cm). If no double image was seen, the distance was recorded as 0cm.
 - e) **Sequencing:-** The ability to organise and structure visual information. A sequence of hand movements is shown. The first sequence started with three movements of either P=palm face down, S=side of hand and F=fist. The amount of movements in a sequence increased each time. The sequence and the number of sequences correctly repeated were recorded.
 - f) **Visualisation:-** The ability to form a mental image. The test uses seven playing cards, from Ace to seven, placed on a table in a random order. The cards and the sequence have to be memorised. All the cards are then flipped face down and in the quickest possible time turned over in order from Ace to seven. The time it took to complete this test, from the time the cards were observed, until the last card was turned over, was recorded in seconds (sec).
 - g) **Eye-hand coordination:-** The ability to respond to visual stimuli in a coordinated manner via the central nervous system. An ice-cube tray is marked from 1 to 12 sequentially, with 1 being in the upper left corner, 2 in the lower left corner, and so on. A coin is placed in the cube numbered 1, and flipped from cube to cube in the order 1 to 12. Should the coin fall out or a number is skipped the test is continued from the last correct number. The time taken to flip the coin in the correct order was recorded in seconds (sec).
- **Training Method B: Group 3 ('Eyedrills' web-based visual skills training):** Participants accessed the website for the 'Eyedrills VTS Drill Skin' (Eyedrills Website, 2011) training and intervention programme. Drills and rules pertaining to training are explained on the website. Each level is completed once a target score is reached. Visual skill elements tested were:
 - a) **Avoiding:-** Blue and red balls moves randomly on the screen. The respondent needs to control the movement of the blue ball with a

computer mouse to avoid contact with the red balls. If contact with a red ball is made, points are deducted.

- b) **Bouncing ball:-** A bouncing soccer ball is displayed on the screen. The respondent must continuously click on the ball to keep it in the air.
- c) **Moving arrows:-** Three arrows (black, red and green) are displayed on the screen. They move in either a *left-right*, *right-left*, *top-bottom* or *bottom-top* manner. Keyboard arrows are pressed in correspondence with the black arrow only. If the incorrect direction is pressed, points are deducted.
- d) **Peripheral awareness:-** Five pictures are displayed on the screen, one in the middle, and the other pictures to the left, right, top and bottom of the middle picture. Focusing on the middle picture, and by using peripheral vision, respondents must select from the other pictures the one that matches the middle picture, using the keyboard arrows.
- e) **Rotating arrows:-** Three arrows (black, red and green) are rotating forming circles at a certain speed. In a certain time limit, the direction of the black arrow has to be indicated while focusing on the inner circle. Indicating the wrong direction will result in a reduction in the score.
- f) **3D Stereograms:-** A set of 3D images with possible answers are displayed at the bottom of the image. Using a computer mouse, the respondent must click on the correct answer.

Health assessments

- a) Family and personal medical history were collected to ascertain medical or psychological conditions that may affect results.
- b) Anthropometric measurements (Adams, 1998): Body mass index (BMI) was calculated using: $\text{weight}(\text{kg})/\text{height}(\text{m}^2)$. Respondents were categorised into: low risk ($\leq 24.9 \text{ kg/m}^2$), moderate risk ($\geq 25 - \leq 29.9 \text{ kg/m}^2$) and high risk ($\geq 30 \text{ kg/m}^2$) groups. Waist to hip ratio (WHR) was calculated using: $\text{waist}(\text{cm})/\text{hip}(\text{cm})$. Body fat percentages (Body Fat %) were determined by performing skinfold tests using a standard calliper.
- c) Cardiac health assessments (Phillips, Der, Shipton & Benzeval, 2011; Seery, 2011): Resting blood pressure (BP; mmHg) was taken using a certified standard electronic BP device. Cardio stress index (CSI; %) and heart rate (HR; beats/minute) were determined in privacy, with a Viport™ (Energy-Lab Technologies GmbH) device (Energy-Lab Technologies, 2005; Von Borrell et al., 2007). Using conducting gel on all three electrodes, the Viport™ was placed on the left side of the respondents' chest. All tests were executed with the respondent in a seated position, refraining from conversing during the 2 minutes of measuring. Measurements were categorised as follows:

- i. **CSI %:** low risk ($\leq 25\%$), moderate risk ($\geq 26 - \leq 49\%$) and high risk ($\geq 50\%$)
- ii. **HR:** low risk ($\leq 80\text{bpm}$), moderate risk ($\geq 80 - \leq 99\text{bpm}$) and high risk ($\geq 100\text{bpm}$)
- iii. **Systolic BP:** low risk ($\leq 139\text{mmHg}$), moderate risk ($\geq 140 - \leq 159\text{mmHg}$) and high risk ($\geq 160\text{mmHg}$)
- iv. **Diastolic BP:** low risk ($\leq 89\text{mmHg}$), moderate risk ($\geq 90 - \leq 99\text{mmHg}$) and high risk ($\geq 100\text{mmHg}$)

Analysis

Data analysis consisted of univariate frequency tables, t-tests and repeated measures ANOVA's. All data was collected during week 1 and 8 and statistical analysis was done by means of the statistical package IBM SPSS Statistics 19. Results were compared to determine if visual skills were affected by the two different approaches of training. A repeated measures MANOVA (Multivariate Analysis of Variance) was used to statistically analyse the results to protect against an inflated type 1 error. Post-hoc analyses consisted of paired t-tests for pairwise comparisons of the data. Evaluations involved 'between group comparisons', and 'within group comparisons'.

Results

The performance of visual skills at pre- and post-testing, after the 6-week training period, is displayed in Table 2. Performance of vergence ($p < 0.008$) and visualisation ($p < 0.001$) improved significantly in the Control group.

Table 2: Descriptive statistics of visual skill performance at pre- and post-testing in the Control, Lab-based and 'Eyedrills' training groups

Visual Skills	Control group		Lab-based group		'Eyedrills' group	
	Pre-test Mean (SD) n=112	Post-test Mean (SD) n=112	Pre-test Mean (SD) n=162	Post-test Mean (SD) n=162	Pre-test Mean (SD) n=186	Post-test Mean (SD) n=186
Focusing (letters/min)	48.95 (± 22.12)	53.95 (± 21.25)	42.52 (± 18.81)	52.97 (± 18.74) $p < 0.001$	46.22 (± 21.89)	53.60 (± 19.84) $p < 0.001$
Tracking (letters/min)	34.34 (± 21.80)	40.40 (± 21.45)	55.97 (± 17.58)	62.48 (± 18.23) $p < 0.001$	46.35 (± 22.90)	51.79 (± 22.15) $p < 0.004$
Vergence (cm)	3.58 (± 3.27)	2.66 (± 2.44) $p < 0.008$	4.41 (± 3.60)	4.41 (± 4.02)	1.86 (± 2.22)	2.22 (± 2.22)
Sequencing (#correct)	2.01 (± 1.03)	2.33 (± 1.05)	2.03 (± 0.96)	2.38 (± 1.14) $p < 0.001$	1.96 (± 1.01)	2.03 (± 0.94)
Visualisation (sec)	47.03 (± 21.79)	37.23 (± 18.65) $p < 0.001$	52.44 (± 25.79)	41.96 (± 19.89) $p < 0.001$	38.66 (± 18.13)	39.36 (± 18.16)
Eye-hand coordination (sec)	43.57 (± 27.11)	38.32 (± 21.92)	47.81 (± 31.95)	30.36 (± 18.37) $p < 0.001$	37.41 (± 20.10)	32.14 (± 19.38) $p < 0.001$

The Lab-based group did not display much difference between the pre- and post-test on vergence. This was, however, the only instance where the Lab-based group did not display any difference since they are the group that displayed the most significant improvement ($p < 0.001$) in the other performances (Table 2). The Lab-based group was also the only group that displayed significant improvement in sequencing ($p < 0.001$).

The ‘Eyedrills’ group only improved significantly on focusing ($p < 0.001$), tracking ($p < 0.004$) and eye-hand coordination ($p < 0.001$). Overall they exhibited less improvement and suffered a slight decline in visualisation performance.

Comparing the two training methods, both training groups experienced significant improvements in skills; however the Lab-based group indicated the highest improvements in focusing, tracking and visualisation, and a vast improvement in eye-hand coordination.

Table 3 represents the mean values and standard deviations of the anthropometric measurements taken at pre- and post-testing conditions in the three groups after the 6-week training period.

Table 3: Descriptive Statistics for the anthropometric measurements at pre- and post-testing in the Control, Lab-based and ‘Eyedrills’ training groups

	Control group		Lab-based group		‘Eyedrills’ group	
	Pre-test Mean (SD) n=112	Post-test Mean (SD) n=112	Pre-test Mean (SD) n=162	Post-test Mean (SD) n=162	Pre-test Mean (SD) n=186	Post-test Mean (SD) n=186
Waist to Hip ratio (WHR)	0.82 (±0.07)	0.80 (±0.09)	0.76 (±0.07)	0.77 (±0.06)	0.82 (±4.11)	0.82 (±7.41)
Body Mass Index (BMI)	23.16 (±4.09)	23.45 (±4.11)	22.99 (±4.13)	23.50 (±4.15) <i>p < 0.001</i>	23.46 (±4.20)	23.47 (±4.11)
Body Fat percentage (%)	19.99 (±8.16)	21.78 (±7.74) <i>p < 0.001</i>	24.31 (±8.16)	22.86 (±7.76) <i>p < 0.001</i>	24.47 (±7.75)	23.55 (±7.41)

Table 3 shows that the Control group experienced a significant ($p < 0.001$) increase in Body Fat % over the 6-week training period.

The Lab-based group revealed the highest change in body composition measurements as compared to the other groups, with significant improvements in Body Fat % ($p < 0.001$) and BMI ($p < 0.001$).

There were no significant changes in the anthropometric measurements of the 'Eyedrills' group, although they experienced a slight improvement in Body Fat %. BMI measures remained at low risk with no shift in risk level between the groups. WHR was consistent and experienced little change between the groups.

Table 4 shows the mean values and standard deviations of the cardiac health variables that presented at the pre- and post-testing conditions in the three groups after a 6-week training period.

Table 4: Descriptive statistics for the cardiac health variables at pre- and post- testing in the Control, Lab-based and 'Eyedrills' training groups

	Control group		Lab-based group		'Eyedrills' group	
	Pre-test <u>Mean</u> <u>(SD)</u> n=112	Post-test <u>Mean</u> <u>(SD)</u> n=112	Pre-test <u>Mean</u> <u>(SD)</u> n=162	Post-test <u>Mean</u> <u>(SD)</u> n=162	Pre-test <u>Mean</u> <u>(SD)</u> n=186	Post-test <u>Mean</u> <u>(SD)</u> n=186
Systolic BP (mmHg)	124.24 (±15.11)	128.59 (±13.40)	117.41 (±12.35)	119.45 (±12.43) <i>p</i> <0.039	127.62 (±13.87)	128.72 (±14.20)
Diastolic BP (mmHg)	80.69 (±7.83)	78.45 (±9.30)	72.69 (±9.63)	72.90 (±9.91)	84.52 (±11.61)	86.06 (±9.93) <i>p</i> <0.034
Cardio Stress Index (CSI%)	28.91 (±21.26)	31.51 (±20.90) <i>p</i> <0.001	31.15 (±20.55)	36.02 (±24.06) <i>p</i> <0.017	36.43 (±24.94)	38.15 (±26.31)
Heart Rate (HR) (bpm)	78.26 (±13.27)	81.64 (±12.77) <i>p</i> <0.001	81.4 (±12.95)	83.21 (±14.77)	83.79 (±14.98)	85.71 (±15.85) <i>p</i> <0.034

Although still within normal rates, the diastolic BP in the 'Eyedrills' group increased significantly ($p < 0.034$). Systolic BP increased in all three groups, however only significantly ($p < 0.039$) in the Lab-based group. CSI% increased in all three groups, with a substantial increase in the Control ($p < 0.001$) and Lab-based ($p < 0.017$) groups. HR increased in all three groups, however only significantly in the Control ($p < 0.001$) and 'Eyedrills' ($p < 0.034$) groups. Changes to cardiac health variables across the three groups were quite numerous and varied, however risk levels remained low to moderate.

Discussion

When trained using two different visual skill training programmes, visual skill performance improvement was seen in both the Lab-based and the 'Eyedrills' training groups over a 6-week period. This highlights the efficacy of visual skill training and the need for these training programmes in student populations. Previous research has shown inconclusive results, and the benefit of visual skill training programmes was questioned (Jackson & Farrow, 2005). Wei and Luo

(2010) who, due to insignificant improvements in visual skills tested after training, concluded that visual skills are not trainable and that any improvement after training was a result of test familiarity. The positive results of the current study contradict the findings of these studies.

The results of this study also agree with more recent research (Du Toit et al., 2007b; Farrow & Abernethy, 2002; Venter, 2008) that found significant improvement in visual skills tested after visual skill training. The present results further indicate that not only are visual skills trainable in professional and non-professional athletes, but also in students. Previous research only showed significant improvement with studies mainly conducted on athletes (Du Toit et al., 2007a; Farrow & Abernethy, 2002; Venter, 2008), while studies performed on non-athletes (Jackson & Farrow, 2005; Wei & Luo, 2010) rendered non-significant results. The present study's results also agree with Du Toit et al.'s (2011) findings that showed significant improvement in visual skills after university students had been trained. The concept of visual skills being trainable in students and not only in athletes, is important in the extension of sports vision training to other fields besides the sports field. For students an improvement in visual skills should ideally translate to amelioration in academic results or essentially the ability to cope with visual demands in a university setting. The training methods used was related to the student's environment and natural visual reading distance in which visual progress was expected.

Comparisons between diverse studies that used different training methods are challenging, due to variation in time spent on training, intensity of training and type of skills trained. Therefore, in this study, two different training methods were implemented while keeping all other variables and testing methods constant within the study, posing an ideal approach to compare different training methods.

It is clear that the Lab-based training group experienced a more advanced improvement in visual skills ($p < 0.001$) with the exception of vergence, and distinctly showed a greater enhancement of skills than the 'Eyedrills' training group. This gives credibility to the notion that 'practice makes perfect' as the Lab-based training consisted of a simple repetition of the testing method as a training programme. When using the pre- and post-testing method as training programme for 6-weeks, it raises an evident question: Were visual skills actually learnt or did the mere learning of the test occur? A simple change of the focusing and tracking alphabet charts, or in the sequences of the sequencing test, for example, would have provided a clearer perspective if visual skill improvement actually did occur in the Lab-based training group.

Conversely, the outcomes of the Control group who underwent no visual skill training may shed light on the tests itself being easy to learn. The Control group displayed significant improvement of vergence ($p < 0.008$) and visualisation

($p < 0.001$). Compared to the two training groups that had an even greater improvement, this trend substantiates that mere familiarity and learning of the test cannot be the main reason for visual skill improvement. A study by Du Toit et al. (2007b) used the same visual skill testing methods, but different training methods. Their results only showed a significant improvement in sequencing and eye-hand coordination. The Lab-based and ‘*Eyedrills*’ training groups used different training methods but the same testing method, and yielded a variety of results, indicating that training, and not the simplicity or familiarity of the test, lead to an improvement in visual skill performance.

Arguing that only training improves visual skills does not explain the significant improvement of visualisation and vergence in the Control group. Although it may simply be coincidentally, it poses a limitation to the study design since each test was only performed once during pre-testing, and once during post-testing. If participants did not understand the test during pre-testing and better understood it the second time around, at post-testing, it could translate to significant changes and pose a constraint to the study. However, with the large sample size used and tests explained thoroughly, it is unlikely that such a scenario would significantly affect the group results.

The ‘*Eyedrills*’ group experienced significant improvement in focusing ($p < 0.001$), eye-hand coordination ($p < 0.001$) and tracking ($p < 0.004$) visual skills but to a lesser degree when compared to the Lab-based group. This provides an understanding of the transferability of visual skills learnt during training, since the training method and testing method differed completely in this group, emphasising that the test procedures followed with the ‘*Eyedrills*’ group was relatively the same as that of the Lab-based group. Nevertheless, two major visual skills essential to students, i.e. sequencing and visualisation, did not improve in the ‘*Eyedrills*’ group. It highlights that the specificity of skills tested and trained is important, since previous research has clearly indicated that neglecting specific training may lead to insignificant results (Ferreira, 2003). Furthermore, improvement in the ‘*Eyedrills*’ training group contradict previous research on internet-based visual training programmes that found no significant improvement in visual skill performance (Jackson & Farrow, 2005).

The difference in initial skill levels are very loosely defined by Wilson and Falkel (2004), and could impact on training ability and ultimately the final results. Nakata et al. (2010) and Yarrow et al. (2009) found that the initial skill level is a significant factor in visual skill testing and training, since visual skills are considered to be trainable to a certain extent and then stabilise. Initial visual skill performance levels are not reported in former research, therefore it is unknown whether skills have not improved significantly due to a levelling off in performance or inefficiency of the training programmes. This aspect is a shortcoming, and should be considered in all future research.

There was no visual acuity deficits in the groups since all participants with uncorrected deficient visual acuity were excluded from the study. Many possible reasons exist for the improvement of 'hardware' visual skills in this study and not in previous studies (Jackson & Farrow, 2005; Wei & Luo, 2010). These may include ineffective training programmes, non-suitable training and/or insufficient training duration. 'Hardware' visual skills are extremely important to students during lectures and while reading and studying large volumes of script. The advantage to the students of learning these skills may have led to greater improvement since they could have focussed on those skills that are important to them personally in their study environment. This corresponds with studies that found athletes improved specifically in the skills that were essential to their sport of choice, suggesting that particular sets of visual skills are sports dependent (Ferreira, 2003).

It is imperative to highlight though that the ability to improve eye-hand coordination could be done through training. Numerous studies reported the significant improvement of eye-hand coordination after the introduction of a visual skill training programme. This includes studies involving athletes who require excellent eye-hand coordination especially in ball sports, and also those conducted on students (Du Toit et al., 2007a). Eye-hand coordination is probably one of the most receptive skills to indicate improvement and change.

Stress has been implicated in various conditions such as cardiovascular disease. It has been established that increased stress levels tend to affect performance. However, the results obtained in this study show that even though systolic BP and CSI% increased significantly in the Lab-based group, the values remained within the moderate risk level.

Visual skills tested and trained were specific to the needs of students, and training specifically focussed on the skills that were tested. Training was well controlled, challenging and interesting. Testing environments were realistic and suitable for the type of respondent, and visual skill performance was confirmed to have been trained and also favourably improved. As with previous research the 'software' visual skills, especially eye-hand coordination, was shown as an ability conducive to improvement. The easy, inexpensive and efficient manner of testing and training makes this a study that can easily be repeated and verified.

Limitations involving visual skill testing and training might be due to the training method that was identical to the testing method in the Lab-based training group. However, significant improvements in visual skills were evident and might directly pertain to the training and testing method that relates to normal reading activity and distance when learning and writing occurs. It further shows that the possibility exists that visual skills might be transferred.

Conclusion

The visual skill performance of university students significantly improved with the implementation of visual skill training programmes. Executing the correct training programmes might effectively enhance motor and cognitive learning.

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