Vision and tennis

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Vision and tennis

Abstract
In this sports vision study we made an effort to answer two questions: (1) Can visual abilities (skills) be enhanced through vision training? and (2) Can enhanced visual skills be transferred to better performance in tennis? We used two different statistical tests in analyzing the data we gathered: the students' t-test and analysis of variance (ANOVA). In answering the first question, using the students' t-test, the visual training group improved significantly (0.10 level or better) on 54.5% of the visual skills screening tests and 62.5% of the tennis performance screening tests whereas the control group improved significantly (0.10 level or better) on 27% and 25% respectively. ANOVA analysis showed significant (.05 level or better) improvement on the part of the visual training group as compared with the control group on 45.5% of the visual skills screening measures and on none of the tennis performance measures. We fee 1 that no conclusive statements can be made with regard to the two questions which we attempted to answer mainly because our sample size was so small (n = 15). However, this pilot study serves as a good design with suggestions for future studies in vision and tennis.

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Committee Chair
Alan W. Reichow

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VISION AND TENNIS
VISION AND TENNIS

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the Faculty of the
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in Partial Fulfillment
of the Requirements for the Degree
Doctor of Optometry

by
Paul Tachau
and
Michael Young

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ABSTRACT

In this sports vision study we made an effort to answer two questions: (1) Can visual abilities (skills) be enhanced through vision training? and (2) Can enhanced visual skills be transferred to better performance in tennis? We used two different statistical tests in analyzing the data we gathered, the students' t-test and analysis of variance (ANOVA). In answering the first question, using the students' t-test, the visual training group improved significantly (0.10 level or better) on 54.5% of the visual skills screening tests and 62.5% of the tennis performance screening tests whereas the control group improved significantly (0.10 level or better) on 27% and 25% respectively. ANOVA analysis showed significant (0.05 level or better) improvement on the part of the visual training group as compared with the control group on 45.5% of the visual skills screening measures and on none of the tennis performance measures. We feel that no conclusive statements can be made with regard to the two questions which we attempted to answer mainly because our sample size was so small (n = 15). However, this pilot study serves as a good design with suggestions for future studies in vision and tennis.
## TABLE OF CONTENTS

I. Introduction ................................................. 1  
II. Experimental Design. ....................................... 1  
III. Results. .................................................. 4  
IV. Limitations and Suggestions. ............................... 14  
V. Conclusion .................................................. 16  
VI. Literature Review. ......................................... 18  
VII. Appendices:  

A. Notes on Dynamic Acuity Testing. ...................... 20  
B. Visual Training Regimen. ................................. 20  
C. Visual Screening Equipment ............................... 21  
D. Visual Training Worksheets ...............................  
E. Visual Skills Measures (pre and post). .................  
F. Tennis Performance Measures (pre and post) ..........  
G. Human Subject Release Form ..............................  
I. INTRODUCTION

Current literature in the area of sports vision shows that
(1) athletes have better visual abilities than non-athletes,\textsuperscript{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11} (2) better athletes have better visual
abilities than non-athletes\textsuperscript{12, 13, 14, 15, 16, 17, 18, 18, 19} (3) visual abilities can be enhanced through visual training,\textsuperscript{20, 21, 22, 23, 24, 25} (4) and a few studies have shown that enhanced
visual skills can be transferred to better performance in sports.\textsuperscript{26, 27, 28} We have investigated the later two aspects of sports
vision in a controlled study involving Pacific University's men's
and women's tennis teams. Initial measures will be taken to
quantify the player's visual skills and tennis performance before
and after a six week visual training program. Tennis players in
the visual training program are compared with those players who
were not in the visual training program on both pre and post
measures of visual and tennis performance.

II. EXPERIMENTAL DESIGN

A. Subjects

1. In the visual training group:
   i) four males (ages 18 to 22)
   ii) five females (ages 18 to 20)

2. In the control group:
   i) five males (ages 19 to 25)
   ii) two females (ages 18 to 20)
3. All students at Pacific University and on the tennis team.

4. All subjects in the visual training group were tested and not accepted into the visual training program if they did not meet the following criteria:
   i) no strabismus
   ii) best corrected visual acuity (monocular) better than 20/40 at near and/or far
   iii) stereoacuity better than 500 arc seconds

B. Materials

1. visual training equipment (see Appendix B)
2. visual screening equipment (see Appendix A and C)
3. tennis equipment
   i) indoor tennis courts
   ii) 40 tennis balls
   iii) players own tennis rackets
   iv) tennis clothing

C. Tennis Screening (pre and post visual training measures)

1. service
   i) 25 serves to the forehand court
   ii) 25 serves to the backhand court
   iii) instructions to player, "Get as many serves in as possible."

2. service return
   i) 24 serves returned from the forehand court (12 serves returned from the player's backhand and 12 from the forehand).
   ii) 24 serves returned from the backhand court (12 serves returned from the player's backhand and 12 from the forehand).
   iii) instructions to player, "Get as many serves back within the singles court boundary as possible."

3. net drill: Player is at net position halfway between the net and service line at the center of the court.
   i) 12 shots hit to the player's forehand
   ii) 12 shots hit to the player's backhand
   iii) instructions to player, "Volley as many shorts within the boundaries of the singles court as possible."

4. backcourt drill: Player is at the center of the court just behind the baseline.
i) 13 shots hit to the player's forehand
ii) 12 shots hit to the player's backhand
iii) instructions to player, "Get as many shots back within the bounds of the singles court as possible."

5. The same experimenter tested each player on both pre and post measures on the same indoor court. The number of correct shots versus the number of tries was recorded. Also the number of shots hit on the wood was recorded, the speed of the ball in each drill was controlled by the experimenters and varied depending on the ability of the player. The difficulty was held constant for each player on both pre and post measures. These measures to quantify tennis ability were taken before and after the six week vision therapy program.

D. Vision Screening (pre and post visual training screening tests were performed by third year Optometry students not involved with this study)

1. Static visual acuities, monocular and binocular at both six meter and forty centimeter distances. Aided and unaided visual acuities were recorded.

2. Both the tennis performance and visual skill screenings were administered with best athletic correction worn. The same correction was also worn in sports.

3. Dynamic visual acuity measured at 10 feet with a 20/20 and 20/40 letter (Syn. V.A. tester). See Appendix A for description of instrument design.

4. Accommodative Facility
   i) At 40 cm: $\pm 2.00$ sphere rock. Cycles per minute recorded.
   ii) Distance-near accommodative rock (Haynes' Method).

5. Convergence Facility. 8 prism diopter base-in, base-out rock on a 20/40 letter chart at 40 centimeters.

6. Eye Movements
   i) Stern Fixation Test
   ii) Wayne Saccadic Fixator with sound.
      a. in normal room illumination (220 apostilbs)
      b. in low room illumination (80 apostilbs)

7. Stereoacuity
   i) Howard-Dolman Depth Perception Test at six meters.
   ii) Randot Stereo Test

8. Fixation Disparity
E. Visual Training Program

The eight tennis players involved in the V.T. program met our visual skills criteria, therefore the vision training was geared for enhancement rather than remediation. Some players had a higher level of visual skill than others and we tailored the visual training to fit the skills of each individual. All visual training was done while best athletic correction was worn. Each individual in the visual training received individual attention (one clinician to one athlete) during the in-office training. In-office visits were for one hour each week and home training thirty minutes six days a week. (See Appendix B for weekly visual training program.)

III. RESULTS

A. Visual Skills Performance Results

1. Data was collected on visual skills from all nine subjects in the vision training group and all six subjects in the control group who participated in the pre and post testing.

2. The visual skills performance results on pre and post measures are summarized on Table I.

3. Table II illustrates the data with the student's t-test applied to V.T. and control group data. The t-test results indicate that the V.T. group improved at the 0.10 confidence level or better on 6 of the 11 visual skills tested (54.5%). The control group showed improvement at the 0.10 confidence level or better on 3 of the 11 visual skills tested (27%).

4. The results of the ANOVA statistical analysis are summarized in Table III. Significant improvement on visual skills measures at the 0.05 level or better was found on 5 out of 11, or 45.5% of the visual skills tested. (Stern Fixation Test, Haynes Rock, Wayne (light), Randot, and Howard-Dolman). Two tests (Randot and Howard-Dolman) or 18.2% were significant at the 0.01 level of confidence.
### TABLE I

**VISUAL SKILLS PERFORMANCE RESULTS**

<table>
<thead>
<tr>
<th></th>
<th>V.T. Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DVA (20/40) @ 10'</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>5.0 6.2</td>
<td>4.8 7.6 10.0</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>6.5 6.4</td>
<td>8.0 9.0 9.4</td>
</tr>
<tr>
<td><strong>DVA (20/20) @ 10'</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>5.2 5.6</td>
<td>3.7 5.8 5.9</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>5.4 6.4</td>
<td>4.8 6.5 7.0</td>
</tr>
<tr>
<td><strong>2.00 Rock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>6 18 30</td>
<td>25 34 20 27</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>16 21 26</td>
<td>20 33 20 25</td>
</tr>
<tr>
<td><strong>Haynes Rock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>20 20 22</td>
<td>20 35 23 26</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>35 26 28</td>
<td>28 30 28 28</td>
</tr>
<tr>
<td><strong>8 Rock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>18 16 28</td>
<td>20 25 20 19</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>17 15 20</td>
<td>16 30 19 16</td>
</tr>
<tr>
<td><strong>SFT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>55 45 40</td>
<td>62 62 55 50</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>41 43 39</td>
<td>61 58 69 52</td>
</tr>
<tr>
<td><strong>Pierce</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td>0 2 0 0</td>
<td>0 0 0 0 1 0</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td>41 45 41</td>
<td>63 53 47 42</td>
</tr>
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</table>

* possible suppression
<table>
<thead>
<tr>
<th></th>
<th>V.T. Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Range</td>
<td>8e</td>
<td>2x</td>
</tr>
<tr>
<td>Post Range</td>
<td>2x</td>
<td>6x</td>
</tr>
<tr>
<td>Range</td>
<td>4x</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2e</td>
<td>6x</td>
</tr>
<tr>
<td>Randot (arc sec) Pre</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>Randot (arc sec) Post</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>H.D. (arc sec) Pre</td>
<td>28.7</td>
<td>9.7</td>
</tr>
<tr>
<td>H.D. (arc sec) Post</td>
<td>10.4</td>
<td>14.3</td>
</tr>
<tr>
<td>Wayne (score) Pre</td>
<td>43</td>
<td>66</td>
</tr>
<tr>
<td>Wayne (score) Post</td>
<td>59</td>
<td>61</td>
</tr>
<tr>
<td>Wayne (score) Pre</td>
<td>63</td>
<td>81</td>
</tr>
<tr>
<td>Wayne (score) Post</td>
<td>67</td>
<td>78</td>
</tr>
</tbody>
</table>
### TABLE II
T-Test Results of Visual Skills

<table>
<thead>
<tr>
<th>Test</th>
<th>V.T. Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVA 20/40</td>
<td>not significant</td>
<td>0.10</td>
</tr>
<tr>
<td>DVA 20/20</td>
<td>0.025</td>
<td>not significant</td>
</tr>
<tr>
<td>± 2.00 Rock</td>
<td>not significant</td>
<td>not significant</td>
</tr>
<tr>
<td>Haynes Rock</td>
<td>0.005</td>
<td>not significant</td>
</tr>
<tr>
<td>8 Rock</td>
<td>0.05</td>
<td>not significant</td>
</tr>
<tr>
<td>SFT</td>
<td>not significant</td>
<td>not significant</td>
</tr>
<tr>
<td>Randot</td>
<td>0.10</td>
<td>0.005</td>
</tr>
<tr>
<td>H.D.</td>
<td>not significant</td>
<td>not significant</td>
</tr>
<tr>
<td>Wayne (L)</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>Wayne (D)</td>
<td>0.005</td>
<td>not significant</td>
</tr>
<tr>
<td>Pierce</td>
<td>not significant</td>
<td>0.05</td>
</tr>
</tbody>
</table>
### TABLE III

ANOVA Results of Visual Skills

<table>
<thead>
<tr>
<th></th>
<th>F Ratio</th>
<th>Significant .05 Level</th>
<th>Significant .01 Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Howard Dolman</td>
<td>18.26</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Randot</td>
<td>5.70</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Wayne (L)</td>
<td>4.55</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Haynes Rock</td>
<td>3.77</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>SFT</td>
<td>3.07</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Wayne (D)</td>
<td>2.54</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>8 Rock</td>
<td>1.98</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>± 2.00 Rock</td>
<td>1.72</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>DVA 20/20</td>
<td>1.54</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>DVA 20/40</td>
<td>.80</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Pierce</td>
<td>.40</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>
B. Tennis Performance Results

1. All subjects in the vision training group (nine) participated in the pre and post testing. All but one male in the control group participated in the pre and post testing (absence was due to injury).

2. The tennis performance results on pre and post measures are summarized on Table IV.

3. When the student's t-test was used to compare pre and post tennis performance measures, significant (at the 0.10 level or better) improvement was found for the V.T. group on 5 of the 8 (62.5%) screening tests and on 2 of the 8 (25%) screening tests for the control group (see Table V).

4. The results of the ANOVA statistical analysis including a sample calculation are summarized in Table VI. No significant improvement was found when the V.T. group was compared with the control group on the eight tennis performance measures at the 0.05 and 0.01 confidence levels.
<table>
<thead>
<tr>
<th></th>
<th>V.T. Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SERVES:</strong> (# out of 25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deuce Court:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Post</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Add Court:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>Post</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td><strong>SERVE RETURNS:</strong> (# out of 12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deuce Court:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backhand Pre</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Forehand Pre</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Add Court:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backhand Pre</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Forehand Pre</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td><strong>COURT DRILLS:</strong> (# out of 25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backcourt:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Post</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Net:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>Post</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>
### TABLE V

**T-Test Results of Tennis Performance**

<table>
<thead>
<tr>
<th></th>
<th>V.T. Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SERVES:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deuce Court:</td>
<td>0.005</td>
<td>0.05</td>
</tr>
<tr>
<td>Add Court:</td>
<td>0.10</td>
<td>not significant</td>
</tr>
<tr>
<td><strong>SERVE RETURNS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add Court:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backhand</td>
<td>0.05</td>
<td>not significant</td>
</tr>
<tr>
<td>Forehand</td>
<td>0.10</td>
<td>not significant</td>
</tr>
<tr>
<td>Deuce Court:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backhand</td>
<td>not significant</td>
<td>0.025</td>
</tr>
<tr>
<td>Forehand</td>
<td>not significant</td>
<td>not significant</td>
</tr>
<tr>
<td><strong>COURT DRILLS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backcourt:</td>
<td>not significant</td>
<td>not significant</td>
</tr>
<tr>
<td>Net:</td>
<td>0.10</td>
<td>not significant</td>
</tr>
</tbody>
</table>
TABLE VI

ANOVA Results for Tennis Performance

<table>
<thead>
<tr>
<th></th>
<th>F-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serves to the deuce court</td>
<td>2.81</td>
</tr>
<tr>
<td>Court drills; net</td>
<td>2.17</td>
</tr>
<tr>
<td>Serves to the add court</td>
<td>1.78</td>
</tr>
<tr>
<td>Return of serve to the add court; forehand</td>
<td>0.80</td>
</tr>
<tr>
<td>Return of serve to the add court; backhand</td>
<td>0.76</td>
</tr>
<tr>
<td>Return of serve to the deuce court; forehand</td>
<td>0.51</td>
</tr>
<tr>
<td>Return of serve to the deuce court; backhand</td>
<td>0.42</td>
</tr>
</tbody>
</table>

1. Results are tabulated from largest F-ratio (most significant) to smallest (least significant). None of the results are significant at the 0.05 or 0.01 confidence levels (i.e. $F_{.05} = 3.01$ and $F_{.01} = 4.72$).

2. The following is an example of an ANOVA calculation (one-way analysis of variance with samples of unequal size) as was done on all data in this study. Example: ANOVA for serves to the deuce court:

<table>
<thead>
<tr>
<th>Subject</th>
<th>V.T.; pre</th>
<th>V.T.; post</th>
<th>Cont.; pre</th>
<th>Cont.; post</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x^2$</td>
<td>$x^2$</td>
<td>$x^2$</td>
<td>$x^2$</td>
<td></td>
</tr>
<tr>
<td>HB</td>
<td>16</td>
<td>256</td>
<td>20</td>
<td>400</td>
<td>JH</td>
</tr>
<tr>
<td>TB</td>
<td>9</td>
<td>81</td>
<td>16</td>
<td>256</td>
<td>CJ</td>
</tr>
<tr>
<td>JF</td>
<td>13</td>
<td>169</td>
<td>18</td>
<td>324</td>
<td>IJ</td>
</tr>
<tr>
<td>BL</td>
<td>8</td>
<td>64</td>
<td>11</td>
<td>121</td>
<td>KM</td>
</tr>
<tr>
<td>JL</td>
<td>16</td>
<td>256</td>
<td>23</td>
<td>529</td>
<td>TS</td>
</tr>
<tr>
<td>RQ</td>
<td>19</td>
<td>361</td>
<td>18</td>
<td>324</td>
<td></td>
</tr>
<tr>
<td>BR</td>
<td>17</td>
<td>289</td>
<td>19</td>
<td>361</td>
<td></td>
</tr>
<tr>
<td>DS</td>
<td>15</td>
<td>225</td>
<td>14</td>
<td>196</td>
<td></td>
</tr>
<tr>
<td>FY</td>
<td>15</td>
<td>225</td>
<td>22</td>
<td>484</td>
<td></td>
</tr>
<tr>
<td>$\Sigma$</td>
<td>128</td>
<td>1926</td>
<td>161</td>
<td>2995</td>
<td>84</td>
</tr>
</tbody>
</table>

$\Sigma x = 468$ 
$\Sigma x^2 = 8204$

$N = n_1 + n_2 + n_3 + n_4 = 9 + 9 + 5 + 5 = 28$
Within Groups Variance Estimate:

\[ \sum x^2 = \sum x^2 - \left(\frac{\sum x}{n}\right)^2 \]

\[ \sum x^2_1 = 1926 - \left(\frac{128}{9}\right)^2 = 1926 - 1820.44 = 105.56 \]

\[ \sum x^2_2 = 2995 - \left(\frac{161}{9}\right)^2 = 2995 - 2880.11 = 114.89 \]

\[ \sum x^2_3 = 1448 - \left(\frac{84}{5}\right)^2 = 1448 - 1411.20 = 36.80 \]

\[ \sum x^2_4 = 1835 - \left(\frac{95}{5}\right)^2 = 1835 - 1805.00 = 30.00 \]

Pooled sum of squares = 287.25

Pooled degrees of freedom = 8 + 8 + 4 + 4 = 24

Within groups variance estimate = \[ s^2_w = \frac{287.25}{24} = 11.97 \]

Between Groups Variance Estimate:

\[ M_1 = \frac{128}{9} = 14.2, M_2 = \frac{161}{9} = 17.9, M_3 = \frac{84}{5} = 16.8, \]

\[ M_4 = \frac{95}{5}, M = \frac{468}{28} = 16.71 \]

\[ n_1 (M_1 - M)^2 = 9 \left(14.2 - 16.71\right)^2 = 9 (-2.51)^2 = 9 (6.3) = 56.70 \]

\[ n_2 (M_2 - M)^2 = 9 \left(17.9 - 16.71\right)^2 = 9 (1.42)^2 = 9 (2.02) = 18.18 \]

\[ n_3 (M_3 - M)^2 = 5 \left(16.8 - 16.71\right)^2 = 5 (0.0081) = 5 (0.001) = 0.00 \]

\[ n_4 (M_4 - M)^2 = 5 \left(19 - 16.71\right)^2 = 5 (2.29)^2 = 5 (5.24) = 26.20 \]

\[ \sum_{i=1}^4 n_i (M_i - M)^2 = 56.70 + 18.18 + 0.00 + 26.20 = 101.08 \quad (i = 1) \]

Degrees of freedom = (k-1) = 4 - 1 = 3

Between groups variance estimate = \[ S^2_B = \frac{101.08}{3} = 33.69 \]

\[ F \text{ Ratio} = F = \frac{S^2_B}{S^2_w} = \frac{33.69}{11.97} = 2.81 \]

\[ F_{.05} = 3.01 \quad F_{.01} = 4.72 \]

where \( M_i \) = mean of subgroup
\( M \) = grand mean
\( k \) = number of subgroups
\( s \) = variance
\( x \) = number of serves hit into the deuce service court by each individual player
IV. LIMITATIONS AND SUGGESTIONS

A. Woodshots

Upon preliminary observation of the data gathered on woodshots, it could be seen that this data was of little value in supporting the statement that enhanced visual skills transfer to better performance in tennis. The visual training group performed no better than the control group in any of the areas tested when data on woodshots was gathered.

B. Control Group Activity

Our control group was not able to maintain a regular organized activity to offset the added attention which the V.T. group received during training. This deficiency was due to a lack of motivation despite encouragement from the tennis coaches. Perhaps a reward system would help for future research.

C. Sample Size

We feel that the major limitation in our experiment was the small sample size. A large sample size is needed to make up for:

1. drop-outs and injuries
2. large deviations from the norm
3. confounding variables such as emotional ups and downs, varying amounts of stress on each player at the time of testing, varying degrees of dedication and interest in tennis or visual training.

D. Statistical Analysis

The visual training data should be collected in such a way that it can be statistically analyzed.

E. Experienced Testers

Experimenters should be familiar and experienced with recording data in pre and posting testing skills. For example, an experimenter testing binocular accommodative skills should be able to recognize when a subject is suppressing one eye and be able to control the working distance.

F. Double Blind Experiment

A double blind experiment is preferable to no blind or single blind experiments. Pre and post testers should not be involved with the study in any other capacity. They should have no knowledge of which participants are in either the visual training or control groups. In this experiment, the
visual skills testing was performed under double blind conditions whereas the tennis performance testing was not.

G. Tennis Skill Level

The skill levels of the tennis players in this experiment varied greatly from the top player to lowest player. Unless a very large sample size (50 or more) is used, the players should all be at approximately the same level to eliminate the problem of improving basic skills in some and more advanced skills in others. Also, the room for improvement was much greater for some players. Some players improve quicker due to natural abilities.

H. Testing for Advanced Players

When testing the tennis skills of better players we suggest that participants be required to hit a specific area on the court. This requires greater skill and timing. Also we suggest that ball machines be used in conjunction with requiring the players to hit a specific area on the court. This would make the delivery of ball speed and placement more repeatable. Some drills could be performed with human servers delivering less predictable balls (better similarity to game conditions) and comparing these results with those obtained from the ball machine drills.

I. Scoring Tennis Matches

Some consideration should be given to measuring tennis performance (by scoring errors) in tennis matches played against a neutral player. This player would play each participant for pre and post measures.

J. Round-Robin

Some thought should also be given to measuring tennis performance by having a pre and post V.T. round-robin tournament involving all players in the study.

K. Consistent Home and Office Visual Training

This study ran through spring vacation and many participants abandoned their V.T. efforts for that week causing a set-back in the 2-week experiment. Such interruptions should be avoided.

L. Length of Study

Visual training could be done for periods longer than 6 weeks to check for improvement in visual skills and transference of those skills to tennis.

M. Study Utilizing Students

Some of the players showed decreased performance. In some players this may have been due to increasing near visual stress
V. CONCLUSION

Although there was no statistically significant improvement in overall tennis performance as shown by the ANOVA method of analysis, when the visual training group was compared with the control group using the student t-test the following results were found. The visual training group improved significantly (0.10 confidence level or better) on 62.5% of the screening tests whereas the control group revealed significant improvement (0.10 level or better) on 25% of the screening measures. A larger sample size would help to reduce the impact of decreased performance by some players due to confounding variables such as exams. The ANOVA method of analysis is more sensitive for small sample size such as this study, utilizing two separate analysis systems enabled us to better represent the improvement that was found in tennis performance due to enhanced visual skills. Subjectively the athletes in the V.T. group commented that their tennis performance improved in part due to visual training. This mutual feeling by the V.T. group athletes supports the statement that, "Visual skills can be enhanced and transferred to improved tennis performance."

When each individual is compared on visual screening tests between pre and post testing, the student's t-test reveals that the visual training group improved significantly (0.10 confidence level or better) on 6 of 11, or 54.5% of the visual screening tests and the control group showed significant improvement (0.10 level or
better) on 3 of 11, or 27% of measures. Some results such as accommodative rock using \( \pm 2.00 \) flippers seem to contradict the results of the other test for accommodative facility (Haynes Rock). We feel that our small sample size reflects such differences. The ANOVA method of statistical analysis of visual skills showed favorable results at the 0.05 level of significance in which improvement was found on 5 out of 11, or 45.5% of the categories tested. Two tests showed very significant improvement (0.01 level of confidence). We feel that statistically significant improvement by the ANOVA analysis on 45.5% of the visual skills' measures supports the statement that, "Visual skills can be enhanced through visual training."

There is a tremendous need for research in the area of sports vision. More advanced studies must be run to determine whether improved visual skills from visual training have statistically significant transference to athletic performance. This pilot study of enhancement was needed as guide for future research in the area of sports vision. Future investigators can avoid experimental pitfalls by scrutinizing and considering the contents of this study.
LITERATURE REVIEW


APPENDIX A

Kirshner Dynamic visual acuity tester. A 20/20 to 20/40 letter is projected on a screen with an arc radius of two-and-one-half feet. The rpm's of the letter are reduced until they are recognized. The rpm level is recorded at that point. The meter on the rotator monitors the rpm's at which the letter is moving on the screen.

APPENDIX B

1. First and Second Week:
   a. In office:
      Brock String
      Balance Board
      Marsden Ball
      Wayne Saccadic Fixator
      Accommodative Rock
      Prism Rock (near and far)
      Tranaglyphs
      Vectograph at 6 Meters
      Stereoscope
   b. At home:
      Brock String
      Accommodative Rock
      Prism Rock
      Tranaglyph

2. Third Week:
   a. In office:
      Balance Board
      Vectograph at 6 Meters
      Vodnoy Aperature Rule
      Hand-held Stereoscope
      Tranaglyph
      Accommodative Rock
      Prism Rock (near and far)
      Wayne Saccadic Fixator
      Marsden Ball
   b. At home:
      Vodnoy Aperature Rule
      Hand-held Stereoscope
      Tranaglyph
      Accommodative Rock
      Prism Rock (near and far)

3. Fourth Week:
   a. In office:
      Accommodative Rock
      Tranaglyph
      Prism Rock (near and far)
   b. At home:
      Accommodative Rock
      Tranaglyph
      Prism Rock
4. Fifth Week:
   a. In office:
      Vodnoy Aperature Rule
      Hand-held Stereoscope
      Rotoscope
      Wayne Saccadic Fixator
      Marsden Ball
      Accommodative Rock
      Prism Rock (near and far)
      Tranaglyph
      Cine-Ortho Device

   b. At home:
      Vodnoy Aperature Rule
      Tranaglyph
      Hand-held Stereoscope
      Accommodative Rock
      Prism Rock (near and far)
      Marsden Ball

5. Sixth Week:
   a. In office:
      Life Saver Card
      Tranaglyph
      Hand-held Stereoscope
      Vodnoy Aperature Rule
      Accommodative Rock
      Prism Rock (near and far)
      Marsden Ball

   b. At home:
      Vodnoy Aperature Rule
      Tranaglyph
      Hand-held Stereoscope
      Life Saver Cards
      Prism Rock (near and far)
      Accommodative Rock

APPENDIX C

Visual Screening Equipment:
1. Visual acuity testing chart at 20 feet.
2. Nearpoint card at 40 centimeters.
4. \(\pm 2.00\) D flippers
5. Prism; \(8\)
6. 20/40 letter chart at 40 centimeters.
7. Wayne Saccadic Fixator
8. Disparometer (for testing fixation disparity)
9. Howard-Dolman Depth Perception Apparatus
10. Randot Stereo Test
11. Stern Fixation Test (form 2)
12. Distance-Near Accommodative Rock Chart (20/40 letters at 10 feet and at 40 centimeters)
APPENDIX D

Visual Training Worksheets
IN OFFICE

13 April 82
Examiners:
Cine: Bo & BI 10 min

\[ dx \quad nr \]
\[ Bo \quad 15^\circ \quad 15^\circ \]
\[ BI \quad 10^\circ \quad 12^\circ \]

Acetate Rings: 3 min

Tranaglych: none done
Steroscope: 3 min
Marsden Ball: 5 min
Wayne: rt hand: 65/min
     left hand: 70/min
Aperture Rule: 3 min
Rotoscope: 5 min

HOME

\[ dx \quad nr \]
\[ Bo \quad 15^\circ \quad 15^\circ \]
\[ BI \quad 10^\circ \quad 12^\circ \]

Flippers: ± 2.50

Acetate Rings esp. BI
<table>
<thead>
<tr>
<th>Training:</th>
<th>time/day</th>
<th>Monday 23rd</th>
<th>Tuesday 16th</th>
<th>Wednesday 17th</th>
<th>Thursday 18th</th>
<th>Friday 19th</th>
<th>Saturday 20th</th>
<th>Sunday 21st</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prisms: (see back)</td>
<td>6</td>
<td>-</td>
<td>4</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Flippers:</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Topaglyph:</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Aperature Probe:</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beck String:</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Marsden Ball:</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
VISUAL TRAINING WORK SHEET

PATIENT: T.B.  CLINICIAN: Paul Tarahan

Time of Visual Training: 12:00 Noon  DATE: 4/22/82

Each area to be trained is to be named and underlined. Under each area should be listed the following headings: 1. Equipment to be used 1st and 2nd choices - a. distance, b. targets, c. lens control; 2. Performance desired; 3. Patient's response.

1. Rife Fovea Card - able to fuse BO but not BI on next to highest separated wings.

2. Acetate Rings - easy for BO, has a hard time with BI

3. Retroscope - Card #26
   - Static 40° BO
     10° BI
   - Dynamic 30° BO
     10° BI

4. Ace Fusion
   - Film #4 7½ BO - 7½ BI
     Fuses to limit on BO, loses fusion near 2nd pt. on BI.
   - Film #8 3° BO - 12° BI
     Fuses BO easily, loses BI at a ½ way pt.

5. Wayne Saccadic Fixator
   - 81/minute - Laid eye
     53/minute - Peripheral
<table>
<thead>
<tr>
<th>Training:</th>
<th>Description:</th>
<th>time/day</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.50 flipper</td>
<td>5 min/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>work on phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>phase independently</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>then work with anti</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rock.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T. penaglyol</td>
<td>10 min/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.T = +2.0 on BC 52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.S = ±2.50 on BC 54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freim Rock = 106 BL +</td>
<td>3 min/day</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>106.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>contacts in B.T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Patient: [Redacted]
Doctor: Paul Jackson
Date: 4/15/82
Next Appointment: [Redacted]
APPENDIX E

Visual Skills Measures (pre and post)
Pre-Test Procedure
Visual Entrainment of Attentive Performance
Sport: Tennis
Date: 3-2-82

Visual (through present habitual correction):

<table>
<thead>
<tr>
<th>Task</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>/20/20/3</td>
</tr>
<tr>
<td>OS</td>
<td>/20/20/4</td>
</tr>
<tr>
<td>OU</td>
<td>/20/20/3</td>
</tr>
</tbody>
</table>

Dynamic Visual Acuity: Letter/size

3. 30/minute ± 2.00 D lock on letter chart at 16", number of letters called out correctly, or "flip"

Distance-Near Accommodative Lock (Symmes's Method)

Stern Fixation Test (Form 2)

Pierce Saccadic Test

Arc Sec Randot Stereo Test

Howard-Dolman Depth Perception Test

Fixation Disparity

H prism BI/30 lock on letter chart at 16", number of letters called out correctly, one/flip

Wayne Saccadic Fixator

Bright

Dim

46/min

76/min

17A

Other:

Other:

Athletic Performance (Through present habitual correction):

1. Task

2. Task

3. Task

4. Task
Visual Enhancement of Athlete's Performance

**Name:** [Redacted]
**Date:** 5/6/82
**Age:** [Redacted]
**Sport:** [Redacted]
**Position:** [Redacted]

Visual (Through present habitual correction):

1. **20 feet**
   - **OU 20/20**
   - **OS 20/20**
   - **O3 20/20**
   - **OU 20/25**

2. **Dynamic Visual Acuity**
   - **Letter/Size 20/40**
   - **Distance 20/20**
   - **8.0**

3. **26 cycles/minute**
   - **± 2.00 D**
   - **Hole on letter chart at 16th**
   - **Number of letters called out correctly, no/flip**

4. **20 letters/30 sec**
   - **Distance-Near Accommodative streak**
   - **Boyle's letter**

5. **30 sec**
   - **Sten Fixation Test (Form 2)**

6. **Dissociation Test**

7. **#10 20 arc sec**
   - **Arc Sec Random Stereo Test**

8. **Howard-Dolman Depth Perception Test**
   - 1) 15 mm 12.72 sec
   - 2) 25 mm 22.0
   - 3) 2 mm 27.1

9. **Fixation Disparity**
   - 1) 15 mm 30.0
   - 2) 25 mm 30.0
   - 3) 2 mm 27.1

10. **20 cycles/minute**
    - **Prism BI/BC**
    - **Hole on letter chart at 16th**
    - **Number of letters called out correctly, no/flip**

11. **I-5 Fixator**
    - **Dark**
    - **Light**
    - **87/min**

12. **Other:**
    - **87/min**

13. **Other:**

Athletic Performance (Through present habitual correction):

1. **Task:**
2. **Task:**
3. **Task:**
4. **Task:**

**Pierce Saccades**

<table>
<thead>
<tr>
<th>Test</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>11 sec</td>
<td>11 sec</td>
<td>12 sec</td>
</tr>
<tr>
<td># Omissions</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td># of Error</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Notes:** Light head movement
Visual (Through present habitual correction):

1. **OB**: /20/20
   **OS**: /20/20
   **OU**: /20/20

2. Distance: 20/40

3. **Dynamic Visual Acuity**: 20/20

4. Distance-Near Accommodative Lock (Haynes's Letter)

5. **Stern Fixation Test (Form 2)**

6. **Pierce Saccadic Test**

7. **Arc Sec Handot Stereo Test**

8. **Howard-Dolman Depth Perception Test**

9. **Fixation Discrepancy**

10. **Reference Distance**: 10

11. **Wayne Saccadic Fixator**

12. **Other**

13. **Other**

Athletic Performance (Through present habitual correction):

1. Task

2. Task

3. Task

4. Task
Visual (Through present habitual correction):

1. 20/20 Static Snellen Visual Acuity
2. 20/20 Dynamic Visual Acuity
3. 26/30° Distance-Near Accomodative Read (Wayne's method)
4. 63 sec Stern Fixation Test (Form 2)
5. Pierce Saccadic Test
6. 10°/10 Arc Sec Randot Stereo Test
7. Howard-Dolman Depth Perception Test
8. 60°-2×o Fixation Disparity
9. 30°/30° prism 81/30 rook on letter chart at 75 cm, number of letters called out correctly, one/flip
10. Wayne Saccadic Fixator
11. Other:
12. Other:
13. Other:

Aesthetic Performance (Through present habitual correction):

1. Task
2. Task
3. Task
4. Task
APPENDIX F

Tennis Performance Measures (pre and post)
PRE-MEASURE

PLAyer [Redacted]

EXAMINER Paul Tashaw

DATE 3/7/82

1. SERVES

2. SERVE RETURNS

3. COURT DRILLS

   Backcourt,

   net,

   bh = backhand
   fh = forehand
   dc = deuce court
   ac = add court
   ws = wild shot

Instructions

For 1 Serves - "Get as many in as possible"

For 2 & 3 Serve returns Court drill respectively - "Get as many in as possible (anywhere in the court)".

1. This screening was done outside of high school courts (court #2)
2. Net height OK
3. Serve after practice
4. Player has had enough sleep
5. Hit 34 speed on all drills
6. 4:00 PM, mild temperature
7. Served & played on non-sunny side
1. SERVES

2. SERVE RETURNS

3. COURT DRILLS
   Backcourt,
   net,

<table>
<thead>
<tr>
<th></th>
<th>DC</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>#good</td>
<td>29/25</td>
<td>47/25</td>
</tr>
<tr>
<td>#ws</td>
<td>0/25</td>
<td>0/25</td>
</tr>
<tr>
<td>#good bh10/12</td>
<td>bh1Q/12</td>
<td>bh1Q/12</td>
</tr>
<tr>
<td>#ws bh12/12</td>
<td>fh12/12</td>
<td>fh7/12</td>
</tr>
<tr>
<td>#good bh0/12</td>
<td>fh0/12</td>
<td>bh0/12</td>
</tr>
<tr>
<td>#ws fh12/12</td>
<td>fh0/12</td>
<td>fhQ/12</td>
</tr>
</tbody>
</table>

bh = backhand
fh = forehand
dc = deuce court
ac = ad court
ws = wood shot

Instructions
For 1 Serves - "Get as many in as possible"
For 2 & 3 Serve returns Court drill respectively - "Get as many in as possible (anywhere in the court)"

1. net OK
2. Get enough sleep
3. Ball given at 1/8 speed
4. 5 minutes warm up
1. **SERVES**

2. **SERVE RETURNS**

3. **COURT DRILLS**

   - Backcourt,
   - net,

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<th>DC</th>
<th>AC</th>
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<td>2.1/25</td>
<td>1.7/25</td>
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<tr>
<td>#ws</td>
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<tr>
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<tr>
<td>#ws</td>
<td>5/25</td>
<td>3/25</td>
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</table>

bh = backhand  
fh = forehand  
dc = deuce court  
ac = add court  
ws = wood shot

**Instructions**

For 1 Serves - "Get as many in as possible"
For 2 & 3 Serve returns Court drill respectively - "Get as many in as possible (anywhere in the court)".

**Comments:**

1. Net height ok? Yes
2. Beginning middle end of practice (circle one).
3. Player physically or mentally tried? No

**Note:** I served 3/4 speed to Craig  
I hit the backcourt & net drill at 3/4 pace.
1. SERVES

2. SERVE RETURNS

3. COURT DRILLS

   - Backcourt,
   - net,

   bh = backhand
   fh = forehand
   dc = deuce court
   ac = ad court
   ws = wood shot

Instructions

For 1 Serves - "Get as many in as possible"
For 2 & 3 Serve returns Court drill respectively - "Get as many in as possible (anywhere in the court)".

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<td>8/25</td>
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<tr>
<td>fws</td>
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<tr>
<td>fws</td>
<td>bh 0/12 fh 0/12 bh 0/12 fh 0/12</td>
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</table>

Instructions:

1. Net OK
2. Get enough sleep
3. 5 minute warm up
4. Ball 3/4 speed
APPENDIX G

Human Subject Release Forms
1. **Institution**
   A. **Title of Project:** Visual Enhancement and Tennis Performance  
   B. **Principal Investigators:** Paul Tachau and Michael Young  
   C. **Advisors:** Norman Stern OD., Ph.D. and Doug Stine, OD.  
   D. **Location:** Pacific University College of Optometry, Forest Grove, OR.  
   E. **Date:** 1982

2. **Description of Project**
   This project is designed to determine if superior college tennis players have superior visual abilities as compared to less accomplished players, if these visual abilities are enhanced by visual therapy, and if the enhanced visual abilities will result in improved tennis performance.

3. **Description of Benefits**
   This study will add to the basic understanding of the relationship between visual abilities and athletic performance, and the transfer effect of enhanced visual abilities to athletic performance.

4. **Description of Risks**
   The visual pre and post measures and visual enhancement therapy procedures are normally used optometric techniques and any risks from them are those associated with routinely used techniques. No known routine risks are known for the techniques, but there is always the possibility that the techniques could adversely affect either long or short term athletic performance or cause eyestrain symptoms. The athletic performance measures are routine tasks involved in practice of the sport.

5. **Compensation and Medical Care**
   If you are injured in this experiment it is possible that you will not receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the experiment. All reasonable care will be used to prevent injury however.

6. **Alternatives Advantageous to Subjects**
   Not applicable

7. **Offer to Answer any Inquiries**
   The experimenter will be happy to answer any questions that you may have at any time during the course of this study.

8. **Freedom to Withdraw**
   You are free to withdraw your consent and to discontinue participation in this project or activity at any time without prejudice to you.

I have read and understand the above. I am 18 years of age or over.

Printed Name [Redacted]  
Signed [Redacted]  
Date [Redacted]  
Address [Redacted]  
Phone [Redacted]  

Name and address of a person not living with you who will always know your address [Redacted]