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Vision and tennis

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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 trainfng? and (2) Can enhanced visual skills be transferred to better performance in tennis? We used two different statistical tests in analyzing the data we gath.ered, 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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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 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.

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I. INTRODUCTION

Current literature in the area of sports visions shows that (1) athletes have better visual abilities than non-athletes,[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11] (2) better athletes have better visual abilities than non-athletes[12, 13, 14, 15, 16, 17, 18, 18, 19] (3) visual abilities can be enhanced through visual training,[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.[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

		V.T. Group									Control Group					
		H.B.	T.B.	J.F.	B.L.	J.L.	R.Q.	B.R.	D.S.	F.Y.	J.H.	C.J.	I.J.	K.M.	D.M.	T.S.
DVA (20/40) @ 10' (sp., rpm x 10)	Pre	5.0	6.2	4.8	7.6	10.0	8.8	6.4	6.8	9.0	7.5	9.0	6.8	5.0	9.2	10.0
	Post	6.5	6.4	8.0	9.0	9.4	7.5	7.8	6.0	6.4	5.6	6.4	5.6	7.2	5.2	9.2
DVA (20/20) @ 10' (sp., rpm x 10)	Pre	5.2	5.6	3.7	5.8	5.9	6.6	4.2	5.0	5.2	4.4	5.4	5.6	3.2	5.8	6.0
	Post	5.4	6.4	4.8	6.5	7.0	6.9	5.5	3.8	6.2	4.2	6.0	5.0	3.7	3.0	6.2
± 2.00 Rock (cycle/min)	Pre	6	18	30	25	34	20	27	27	16	24	34	20	38	25	39
	Post	16	13	26	20	33	20	25	19	14	33	9	21	34	30	20
Haynes Rock (cycle/min)	Pre	20	20	22	20	23	26	27	22	22	24	30	28	20	27	20
	Post	36	26	28	28	30	28	28	29	31	26	26	32	20	25	28
8 Rock (cycle/min)	Pre	18	16	28	20	25	20	19	18	10	17	10	10	51*	26	16
	Post	17	15	20	16	30	10	16	16	6	13	45	25	29	11	17
SFT	Pre	55	45	40	62	62	55	50	53	48	65	75	54	55	60	52
	Post	41	43	39	61	58	69	52	43	50	63	63	53	58	60	73
Pierce (total time in sec)	errors	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0
	Pre	41	45	41	63	53	47	42	52	46	43	47	45	57	61	46
	errors	0	1	0	1	1	0	0	1	6	0	0	0	0	0	1
	Post	38	46	34	52	53	42	39	47	50	39	41	42	41	49	49

* possible suppression

TABLE I (cont.)

		V.T. Group									Control Group					
		H.B.	T.B.	J.F.	B.L.	J.L.	R.Q.	B.R.	D.S.	F.Y.	J.H.	C.J.	I.J.	K.M.	D.M.	T.S.
F.D.	Pre	8e	2x	2e	2e	4x	2x	2x	25e	0	4e	8x	2x	2e	2x	2e
	Range	2x	6x	4x	6e	16x	2e	4e	6e	8x	10e	12x	6e	4x	6x	4x
	Post	4x	0	6e	2e	3e	63	10e	6e	0	2e	6e	2e	2x	4x	6e
	Range	2e	6x	0	2x	6x	4e	6e	2x	4d	4x	2x	16e	4e	8x	0
Randot (arc sec)	Pre	50	20	70	50	20	40	25	20	20	30	30	70	70	70	70
	Post	20	40	10	20	20	20	20	20	20	20	20	20	30	40	30
H.D. (arc sec)	Pre	28.7	9.7	7.3	8.6	14.3	42.6	14.5	11.3	14.6	11.3	10.0	17.7	38.7	40.0	21.2
	Post	10.4	14.3	14.9	12.6	24.7	13.5	8.9	12.8	9.3	12.3	8.2	17.1	98.0	23.2	34.5
Wayne (score) (light 220 apos)	Pre	43	66	46	47	45	59	49	46	57	41	47	53	45	40	42
	Post	59	61	89	77	57	74	75	32	60	42	48	62	58	56	68
Wayne (score) (dark 80 apos)	Pre	63	81	76	68	67	72	74	47	81	73	65	66	60	68	65
	Post	67	78	89	81	71	86	81	60	90	63	56	71	68	72	81

TABLE II

T-Test Results of Visual Skills

	V.T. Group	Control Group
DVA 20/40	not significant	0.10
DVA 20/20	0.025	not significant
± 2.00 Rock	not significant	not significant
Haynes Rock	0.005	not significant
8 Rock	0.05	not significant
SFT	not significant	not significant
Randot	0.10	0.005
H.D.	not significant	not significant
Wayne (L)	0.025	0.025
Wayne (D)	0.005	not significant
Pierce	not significant	0.05

TABLE III

ANOVA Results of Visual Skills

	F Ratio	Significant .05 Level	Significant .01 Level
Howard Dolman	18.26	yes	yes
Randot	5.70	yes	yes
Wayne (L)	4.55	yes	no
Haynes Rock	3.77	yes	no
SFT	3.07	yes	no
Wayne (D)	2.54	no	no
8 Rock	1.98	no	no
± 2.00 Rock	1.72	no	no
DVA 20/20	1.54	no	no
DVA 20/40	.80	no	no
Pierce	.40	no	no

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 IV

Tennis Performance Results

		V.T. Group									Control Group				
		H.B.	T.B.	J.F.	B.L.	J.L.	R.Q.	B.R.	D.S.	F.Y.	J.H.	C.J.	I.J.	K.M.	T.S.
SERVES: (# out of 25)															
Deuce Court:	Pre	16	9	13	8	16	19	17	15	15	14	21	15	15	19
	Post	20	16	18	11	23	18	19	14	22	17	20	16	19	23
Add Court:	Pre	19	15	13	15	15	21	16	14	17	17	17	18	19	20
	Post	22	15	17	13	22	18	19	15	22	20	18	17	19	23
SERVE RETURNS: (# out of 12)															
Deuce Court:															
Backhand	Pre	5	7	6	6	8	9	9	5	7	9	7	6	4	10
	Post	10	8	8	4	5	8	9	1	9	8	7	4	1	8
Forehand	Pre	9	6	7	8	8	10	7	6	10	10	10	6	10	9
	Post	12	8	9	7	10	8	9	5	10	11	5	7	7	10
Add Court:															
Backhand	Pre	8	6	5	5	7	10	9	3	9	3	7	5	6	11
	Post	10	9	10	8	5	9	10	3	11	8	7	7	4	11
Forehand	Pre	9	6	4	6	7	9	6	8	9	7	9	9	9	11
	Post	7	8	10	7	12	9	9	6	9	10	7	5	7	9
COURT DRILLS: (# out of 25)															
Backcourt:	Pre	14	18	12	20	20	21	20	12	19	22	14	14	21	21
	Post	22	20	17	22	20	17	16	18	18	15	16	16	15	14
Net:	Pre	18	23	18	22	21	22	23	24	22	12	19	18	18	23
	Post	19	20	22	15	22	21	18	20	19	18	21	17	18	20

TABLE V

T-Test Results of Tennis Performance

		V.T. Group	Control Group
SERVES:			
Deuce Court:		0.005	0.05
Add Court:		0.10	not significant
SERVE RETURNS:			
Add Court:	Backhand	0.05	not significant
	Forehand	0.10	not significant
Deuce Court:	Backhand	not significant	0.025
	Forehand	not significant	not significant
COURT DRILLS:			
Backcourt:		not significant	not significant
Net:		0.10	not significant

TABLE VI

ANOVA Results for Tennis Performance

	F-Ratio
Serves to the deuce court	2.81
Court drills; net	2.17
Serves to the add court	1.78
Return of serve to the add court; forehand	0.80
Return of serve to the add court; backhand	0.76
Return of serve to the deuce court; forehand	0.51
Return of serve to the deuce court; backhand	0.42

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:

Subject	V.T.; pre		V.T.; post		Cont.; pre		Cont.; post		Subject
	x	x^2	x	x^2	x	x^2	x	x^2	
HB	16	256	20	400	14	196	17	289	JH
TB	9	81	16	256	21	441	20	400	CJ
JF	13	169	18	324	15	225	16	256	IJ
BL	8	64	11	121	15	225	19	361	KM
JL	16	256	23	529	19	361	23	529	TS
RQ	19	361	18	324					
BR	17	289	19	361					
DS	15	225	14	196					
FY	15	225	22	484					
Σ	128	1926	161	2995	84	1448	95	1835	

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

$N = n_1 + n_2 + n_3 + n_4 = 9 + 9 + 5 + 5 = 28$

Within Groups Variance Estimate:

$$\Sigma x^2 = \Sigma x^2 - \frac{(\Sigma x)^2}{n}$$

$$\Sigma x_1^2 = 1926 - \frac{(128)^2}{9} = 1926 - 1820.4\bar{4} = 105.56$$

$$\Sigma x_2^2 = 2995 - \frac{(161)^2}{9} = 2995 - 2880.1\bar{1} = 114.89$$

$$\Sigma x_3^2 = 1448 - \frac{(84)^2}{5} = 1448 - 1411.20 = 36.80$$

$$\Sigma x_4^2 = 1835 - \frac{(95)^2}{5} = 1835 - \frac{(95)^2}{5} = 1835 - 1805.00 = 30.00$$

Pooled sum of squares = 287.25

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

Within groups variance estimate = $S_w^2 = \frac{287.25}{24} = 11.97$

Between Groups Variance Estimate:

$M_1 = 128/9 = 14.2$, $M_2 = 161/9 = 17.9$, $M_3 = 84/5 = 16.8$,

$M_4 = 95/5$, $M = 468/28 = 16.71$

$$n_1 (M_1-M)^2 = 9 (14.2 - 16.71)^2 = 9 (-2.51)^2 = 9 (6.3) = 56.70$$

$$n_2 (M_2-M)^2 = 9 (17.9 - 16.71)^2 = 9 (1.42)^2 = 9 (2.02) = 18.18$$

$$n_3 (M_3-M)^2 = 5 (16.8 - 16.71)^2 = 5 (0.0081)^2 = 5 (.0001) = 0.00$$

$$n_4 (M_4-M)^2 = 5 (19 - 16.71)^2 = 5 (2.29)^2 = 5 (5.24) = 26.20$$

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

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

Between groups variance estimate = $S_B^2 = \frac{101.08}{3} = 33.69$

F Ratio = $F = \frac{S_B^2}{S_w^2} = \frac{33.69}{11.97} = 2.81$

$F_{.05} = 3.01$ $\qquad$ $F_{.01} = 4.72$

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

(studying for finals) near the end of the term when post testing was done. This variable affected some players more than others and we feel a large sample size was needed (i.e. 50 or more) to overcome this confounding variable.

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.

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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

Marsden Ball
Rotoscope
Tachistoscope
Balance Board
Vodnoy Aperature Rule
Stereoscope (hand-held)

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.
3. Kirshner Dynamic Visual Acuity Tester (see Appendix A for description).
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

JF [redacted]

13 April 82

~~30 March 82~~

Examiner:

IN OFFICE

± 2.00 : 2 min

Cine: Bo & BI 10 min

~~Tech:~~

Acetate Rings: 3 min

Tranaglyph: none done

Stereoscope: 3 min

Marsden Ball: 5 min

Wayne: rt hand: 65/min
left hand: 70/min

Aperature Rule: 3 min

Rotoscope: 5 min

Prisms: none done

	dx	nr
Bo	15Δ	15Δ
BI	10Δ	12Δ

HOME VT

Prisms:

	dx	nr
Bo	15Δ	15Δ
BI	10Δ	12Δ

Flippers: ± 2.50

Acetate Rings esp. BI

Patient: JF [redacted]

Doctor: Young & Stine

Date: 16/3 Next Appointment 30/3 12:15

VISUAL TRAINING

Training: Description:	time/day	Monday 22nd	Tuesday 16th	Wednesday 17	Thursday 18	Friday 19	Saturday 20	Sunday 21st
Prisms: (see back)			6	–	4	5	–	–
Flippers:		2	6	3	–	4	–	2
Tranaglyph:		2	5	2	–	2	–	3
~~Aperture Rule~~:		–		–	–	–	–	–
Brock String:		–	3	–	–	–	–	–
Marsden Ball:		–	7	–	–	–	–	–

VISUAL TRAINING WORK SHEET

PATIENT: TB [redacted] CLINICIAN: Paul Tochluk

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 Life Saver Card - able to fuse BO but not BI on next to highest separated rings.

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

③ Rotoscope - Card #26

Static 40^Δ BO
10^Δ BI

Dynamic 30^Δ BO
10^Δ BI

④ Cine Fusion

Film #4 7½ BO – 7½ BI
Fuses to limit on BO, loses fusion near 2nd pl. on BI.

Film #8 3^Δ BO – 12^Δ BI
Fuses BO easily, loses BI at a ½ way pl.

⑤ Wayne Saccadic Fixator

81/min - hard eye

53/min - peripheral

TB

[redacted]

Patient: [redacted]

Doctor: Paul Tachau

Date: 4/15/82 Next Appointment _____

VISUAL TRAINING

Training: Description:	time/day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
① ± 2.50 flipper - work on ⊕ phase & ⊖ phase independently then work with entire rock.	5 min/day							
② Tranaglyph BI ⊂ +2.00 lens on BC52 BO ⊂ ±2.50 on BC54	10 min/day 2 min/day							
③ Prism Rock ⊂ 10^{Δ} BI & 10^{Δ} BO - concentrate on BI	3 min/day							

APPENDIX E

Visual Skills Measures (pre and post)

Pre-Test Results
Visual Enhancement of Athletic Performance

Name [redacted] Date 3-2-82 Age 20

Sport Tennis Position

Visual (Through present habitual correction):

	20 feet		16 inches		Static Snellen Visual Acuity
1.	OD /20	20/20-3	OD /20	20/20	
	OS /20	20/20-4	OS /20	20/20	
	OU /20	20/20-3	OU /20	20/20	

27-20/20 48 20/40

2. ______ Dynamic Visual Acuity __/__ Letter/Size ____ Distance

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

4. 22 Distance-Near Accommodative Rock (Haynes's Method)

5. 40 Stern Fixation Test (Form 2)

6. ______ Pierce Saccadic Test

7. 70 Arc Sec Randot Stereo Test

8. Desc 4/80 Howard-Dolman Depth Perception Test

R-F	F-R
-.8	+.3 3.77
-.8 10.62	+.8
+.4 5.32	+.2 2.66

9. 2eso 4xo Fixation Disparity

10. 28 8 prism BI/BO Rock on Letter chart at 16", number of letters called out correctly, one/flip

11. ______ Wayne Saccadic Fixator, Bright ______ Dim ______ Mode/Setting

12. ______ Other: 46/min 76/min 1/A

13. ______ Other:

Athletic Performance (Through present habitual correction):

1. ______ Task ______

2. ______ Task ______

3. ______ Task ______

4. ______ Task ______

Post
Pre-Test for upon
Visual Enhancement of Athletic Performance

Name [redacted] JF Date 5/6/82 Age _____

Sport Tennis Position _____

Visual (Through present habitual correction):

	20 feet	16 inches	Static Smaller Visual Acuity
1.	OD 20/20^{-3}	OD 20/20	
	OS 20/20^{+1}	OS 20/20	
	OU 20/15^{-2}	OU 20/20	

2. _____ Dynamic Visual Acuity $\frac{20/40}{8.0}$ Letter/Size $\frac{20/20}{4.8}$ Distance

3. 26 cycles/minute ± 2.00 D Rock on letter chart at 16", number of letters called out correctly, on/flip

4. 28 letters/30 sec Distance-Near Accommodative Rock (Haynes's Rether)

5. 39 sec. Stern Fixation Test (Form 2)

6. _____ Pierce Saccadic Test

7. #10 20 arc sec Arc Sec Randot Stereo Test

8. _____ Howard-Dolman Depth Perception Test

IN cm	B → F	F → B
1)	-15 mm 19.7	-20 mm 26.3
2)	-25 mm 33.0	-5 mm 6.7
3)	-2 mm 2.7	0 mm 0

9. 6 sec — ϕ Fixation Disaprity

10. 20 cycles/min 8 prism BI/BO Rock on letter chart at 16", number of letters called out correctly, on/flip

11. _____ Wayne Saccadic Fixator, Dark 89/min Light 89/min on/flip

12. _____ Other:

13. _____ Other:

Athletic Performance (Through present habitual correction):

1. _____ Task _____

2. _____ Task _____

3. _____ Task _____

4. _____ Task _____

Pierce Saccades

	Test 1	Test 2	Test 3
Time →	11 sec	11 sec	12 sec
# of Omissions →	0	0	0
# of Errors →	0	0	0

Notes: slight head movement

Pre-Test Measures
Visual Enhancement of Athletic Performance

Name CJ [redacted] Date 2/24/82 Age 19

Sport Tennis Position

Visual (Through present habitual correction):

	20 feet		16 inches		Static Snellen Visual Acuity
1.	OD	20/20+2	OD	20/20	
	OS	20/20+2	OS	20/20	
	OU	20/15-2	OU	20/20	

2. 5,4 Dynamic Visual Acuity 20/~~20~~ 9,0 Letter/Size 20/40 Distance

3. 34 /minute ± 2.00 D Rock on letter chart at 16", number of letters called out correctly, ~~or~~/flip

4. 30 Distance-Near Accommodative Rock (Haynes's Method)

5. 1min 15sec Stern Fixation Test (Form 2)

6. _____ Pierce Saccadic Test

7. 30 Arc Sec Randot Stereo Test

8. _____ Howard-Dolman Depth Perception Test

F-R	$\bar{x}$=10.0	R-P
+1.2	16.0	4.6 8.0
+.1	1.3	-.5 6.7
-.5	6.7	+1.6 21.4

9. ~~12~~ 8xo-12xo ~~8~~ 8xo Fixation Disaprity

10. 10 8 prism BI/BO Rock on letter chart at 16", number of letters called out correctly, ~~or~~/flip

11. _____ Wayne Saccadic Fixator. Bright 47/min Dim 65/min ~~Int~~/Extr. 1/A

12. _____ Other:

13. _____ Other:

Athletic Performance (Through present habitual correction):

1. _____ Task _____

2. _____ Task _____

3. _____ Task _____

4. _____ Task _____

POST

~~PRE~~-Test Battery

Visual Enhancement of Athletic Performance

Name [redacted] CJ Date 5-4-82

Sport TENNIS Position

Visual (Through present habitual correction):

	20 feet	16 inches	Static Keller Visual Acuity
1.	OD 20/20	OD 20/20	
	OS 20/20	OS 20/20	
	OU 20/15	OU 20/20	20/20 -6.0 20/40 -6.4

2. _____ Dynamic Visual Acuity ___/___ letter/size 10' Distance

3. 9 cycles/minute ± 2.00 D Rock on letter chart at 16", number of letters called out correctly, one/flip

4. 26/30sec Distance-Near Accommodative Rock (Haynes's Method)

5. 63secs Stern Fixation Test (Form 2)

6. _____ Pierce Saccadic Test

7. #10 Arc Sec Randot Stereo Test

8. _____ Howard-Dolman Depth Perception Test

	R-F (cm) x̄=8.2	F-B
	+1.6 21.4	0 0
	+.2 2.7	+.5 6.7
	-.4 5.3	-1.0 13.3

9. 6eso-2xo Fixation Disaprity

10. 4.5 cycles/min 8Δ prism BI/BO Rock on letter chart at 16", number of letters called out correctly, one/flip

11. _____ Wayne Saccadic Fixator, Bright 48/min Dim 56/min 1A Random

12. _____ Other:

13. _____ Other:

Atheletic Performance (Through present habitual correction):

1. _____ Task _____

2. _____ Task _____

3. _____ Task _____

4. _____ Task _____

APPENDIX F

Tennis Performance Measures (pre and post)

PRE-MEASURE

PLAYER HB [redacted]

EXAMINER Paul Tachau

DATE 3/7/82

		DC	AC
1. SERVES	#good	16/25 ✓	19/25 ✓
	#ws	0/25	0/25
2. SERVE RETURNS	#good	bh 5/12 ✓ fh 9/12 ✓	bh 8/12 ✓ fh 9/12 ✓
	#ws	bh 4/12 fh 2/12	bh 2/12 fh 1/12
3. COURT DRILLS			
Backcourt,	#good	14/25	
	#ws	4/25	
net,	#good	18/25	
	#ws	3/25	

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)".

① This Screening was done outside at the high school courts (court #2)
② Not height OK
③ Done after practice
④ Player has had enough sleep
⑤ Hit 3/4 speed on all drills
⑥ @ 4:00 PM, mild temperature
⑦ ~~Player~~ Served & Played on non-sunny side

POST
~~PRE~~-MEASURE H.B

PLAYER [redacted]

EXAMINER Paul Tachau

DATE 4/29/82

		DC		AC	
1. SERVES	#good	20/25		22/25	
	#ws	0/25		0/25	
2. SERVE RETURNS	#good	bh 10/12	fh 12/12	bh 10/12	fh 7/12
	#ws	bh 0/12	fh 0/12	bh 0/12	fh 0/12
3. COURT DRILLS					
Backcourt,	#good	22/25			
	#ws	0/25			
net,	#good	19/25			
	#ws	0/25			

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)".

(1) Net O.K.
(2) Got enough sleep
(3) Ball given at 5/8 speed
(4) 5 minute warm up

PRE-MEASURE CJ

PLAYER [redacted]

EXAMINER Paul Tachau

DATE 2/24/82

		DC	AC
1. SERVES	#good	21/25	17/25
	#ws	0/25	0/25
2. SERVE RETURNS	#good	bh 7/12 fh 10/12	bh 7/12 fh 9/12
	#ws	bh 1/12 fh 4-/12	bh 2/12 fh 2/12
3. COURT DRILLS			
Backcourt,	#good	14/25	
	#ws	5/25	
net,	#good	19/25	
	#ws	3/25	

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 tired? No

(4)

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

POST
[redacted]-MEASURE

PLAYER [redacted] CJ

EXAMINER Paul Tarkan

DATE 4/29/82

		DC	AC
1. SERVES	#good	20/25	18/25
	#ws	0/25	0/25
2. SERVE RETURNS	#good	bh 7/12 fh 5/12	bh 7/12 fh 7/12
	#ws	bh 0/12 fh 0/12	bh 0/12 fh 0/12
3. COURT DRILLS			
Backcourt,	#good	16/25	
	#ws	2/25	
net,	#good	21/25	
	#ws	0/25	

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)".

(1) Net OK
(2) Not enough sleep
(3) 5 minute warm up
(4) Ball 3/4 speed

APPENDIX G

Human Subject Release Forms

Human Subject Release Form

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 effect 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 CJ [redacted]

Signed [redacted] Date [redacted]

Address [redacted] Pacific University Phone [redacted]

Forest Grove Oregon 97116

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