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Abstract

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AEROBIC EXERCISE-INDUCED FATIGUE EFFECTS ON SENSORY ASPECTS OF THE VISUAL SYSTEM

by

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DEVIN J. DAVIS

Devin was born and raised in Riverton, Wyoming, a town centrally located in the state. He attended Riverton High school, graduating in 1984. Devin participated in a variety of sports while in high school. Upon graduation, Devin attended Northwest Community College in Powell, Wyoming where he received his Associate of Science Degree in 1985. From here Devin attended the University of Wyoming for 1 1/2 years before being accepted into Pacific University's College of Optometry. He was awarded his Bachelor of Science in Visual Science in May of 1988 from Pacific. Devin plans to practice in the Rocky Mountain or Midwest Region specializing in vision therapy and pediatric optometry.

BRAD C. PARSONS

Brad grew up in Keosauqua, Iowa a small rural community in the Southeast part of the state. He attended Van Buren Community High School in Keosauqua. He was active in athletics as well as academics. After graduating in 1982 he attended Coe College in Cedar Rapids, Iowa commencing in 1986 with a Bachelor of Arts in Biology. He also participated in football and track. His optometric career began in the Fall of 1987 at Pacific. He plans to practice in Iowa concentrating on performance enhancement, ocular disease, contact lenses and primary care.

ABSTRACT

The purpose of this study was to assess the aerobic exercise-induced fatigue effects upon several aspects of the visual system. Forty subjects participated in this study. Ths subjects were tested pre- and post-fatigue. Fatigue was instituted by having the subject pedal a stationary exercise bicycle at a pre-determined target heart rate for a period of fifteen minutes. The tests performed were; dissociated lateral phoria, static visual acuity, lateral fixation disparity, stereoacuity, contrast sensitivity, reaction/response time, and a perceptual speed task. Statistically significant results ($p<0.05$) were demonstrated in lateral fixation disparity and the perceptual speed task. These results show that physical fatigue does effect certain aspects of the visual system related to sports performance.

KEY WORDS: Aerobic exercise-induced fatigue, Karvonen Method, Target heart rate, Sensory aspects of the visual system

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INTRODUCTION

Sports are performed on a daily basis throughout the world, enjoyed by millions of people in virtually every country. Activities range from a playground game of basketball to the Super Bowl and hundreds of other competitive events in between. One key component to every athlete is his eyes and visual system. The changes that occur to this system when the body becomes physically fatigued is the key question investigated in this study. There has been very little research performed in this specific area.

Throughout the ages man has strived to improve his body to compete at a higher level and to achieve the athletic edge in competition. This has been done by lifting weights, running and practice. To be a better athlete meant to be bigger, faster, in better condition and more skillful in every aspect of the sport. Until recently, little attention has been given to a critical element in the overall competitive equation, the visual system. Without this element, the athlete is very limited in his ability to receive information and react to competition.

Over the past few years, those involved in athletics, from the trainers to the players, have become increasingly interested in the capacity the visual system serves in sports performance. As a result of this, the optometric community has focused attention upon improving knowledge in the area of sports vision. Because of the importance given to this topic, knowledge in this specialized field has expanded greatly. The relationship between vision and sports performance is no longer a mystery in optometric research. Sports vision has developed beyond basic vision care services provided to athletes. It now encompasses such areas as assessment of functional visual abilities, possible enhancement of the athlete's visual performance, and services related to visual-cognitive factors involved in sports performance.

Although it has not been strongly supported by science that such training has more than a neglible effect on sports performance, there continues to be a search to determine the subtle influences vision plays on overall performance. Researchers attempt to isolate factors that may be integral to superior performance in athletics.[1]

Limited research has yielded conflicting results as to what happens to sensory, motor and cognitive abilities when the body becomes fatigued. One study performed on six experienced orienteers in Australia showed that an orienteer's ability to perceive visual information is greatly impaired under the influence of fatigue. This was measured by presenting the subjects slides of orienteering checkpoints at regular intervals followed by a slide showing a set of questions which the subjects had to answer verbally.[2] A study of women volleyball players showed that response speed may actually increase under competitive, stressful situations. When subjects were presented slides depicting both game and nongame situations under both competitive and noncompetitive situations, game information was perceived more quickly than nongame information. Under competitive conditions, all subjects showed decreased perceptual accuracy on the slides.[3] Another study involved adult basketball players and nonplayers. This study showed that the experienced players were much superior to the nonplayers in perceptual recognition tasks as measured by presenting the subjects slides depicting basketball games, half of which contained structured game information (slide represented an offensive play in progress) and the other half which showed unstructured game information (slide represented a turnover or rebound).[4] A similar study was aimed at determining the effects of intense physical exercise on mental performance including verbal, visuospatial and numerical tasks. This study found no impairment on mental performance following physical exercise.[5] This information seemed to support previous studies indicating that physical exertion has no significant effect on symbol substitution tasks, numerical abilities or concentration.[6,7]

However, it did not agree with prior studies showing positive effects of physical activity on mental performance and with studies that have shown an adverse effect of physical fatigue on numerical activity.[8,9,10] Other research has shown that cognitive tasks are disturbed by aerobic exercise but sensory and adaptive behaviors improve upon completion of fatiguing exercise.[11] These several studies and their outcomes are summarized in Table 1.

TABLE 1

AUTHOR	SUBJECTS	EFFECTS ON MENTAL/VISUAL PERFORMANCE	EFFECTS ON VISUAL ONLY PERFORMANCE
Hancock, McNaughton[2]	Orienteers	Impaired	Not tested
Starkes, Allard[3]	Women Volleyball players	Impaired	Not tested
Allard[4]	Basketball players	Experienced players much superior	Not tested
Zervas[5]	Adults	No impairment	Not tested
McAdam, Wang[6]	Adults	No impairment	Not tested
Flynn[7]	Schoolboys	No impairment	Not tested
Lybrand, et al[8]	Adults	Positive effect	Not tested
Burgess, Hokanson[9]	Adults	Positive effect	Not tested
Gutin, DiGennaro[10]	Adults	Adverse effect	Not tested
Fleury, Bard[11]	Adults	Adverse effect on cognitive but positive on sensory and adaptive	Not tested

As can be seen, much work has been done regarding the effects of exercise on cognitive visual tasks, although the results of this work are inconclusive. Little work has been attempted in the area of actual sensory, visual performance following physical fatigue.

We hypothesized that visual performance would be altered negatively by physical fatigue. Due to the exercise fatigue of the entire body, it was hypothesized that more attention would be distributed to maintaining the bodily functions, such as breathing and cardiac function, under physically induced fatigue stress. Therefore, input and processing of visual information would be a subordinate priority.

METHODS

SUBJECTS

Forty Pacific University students, men (n=26) and women (n=14) aged 21 to 28 years old volunteered to be subjects for this experiment. When the subject appeared for the scheduled time slot s/he immediately read and signed an Informed Consent Form releasing them at any time from the study and releasing the experimenters from any liability incurred. Following this, a short questionnaire was verbally presented by the experimenter to the subject asking questions about the subject's present health, immediate family cardiac and respiratory history, and the subject's current exercise habits (See Appendix A).

SCREENING/INCLUSION

The experimenters next performed an entrance screening regimen that included 6 meter monocular and binocular visual acuities, a 6 meter and 40 centimeter cover test, and an assessment of depth perception using disparate circles. The American Optical Vectographic test slide was used with orthogonal polarized filtering spectacles for the depth perception measurement. The demand for the circles were 240, 180, 120, 60 and 30 arc seconds. A resting pulse rate was measured by palpating the radial pulse of the subject for a time interval of 15 seconds and then multiplying this figure by four to determine the one minute rate.

The inclusion criteria for subjects were as follows. In the visual acuity measure, 20/25 monocular and binocular acuities with no correction or best contact lens prescription was required. No presence of a strabismus at far or near was the criterion set for the cover test. In measuring depth perception, the subject had to accurately identify the 240 arc second stimulus within 12 seconds. The requirement for the resting pulse rate was not to exceed 80 beats per minute. Finally, there was to be no subject history of any exercise-induced physical complications or any family history of any uncontrolled cardiovascular, respiratory, or chronic health problems noted during the verbal questionnaire. Any serious eye injuries that had been sustained by the subject or pathological or congenital visual problems noted by the subject also eliminated the subject from the study.

PROCEDURES

The subjects were randomly divided into two groups, Group A and Group B. This was done to control any possible learned effects that might occur. Physical fatigue was induced by requiring the subjects to ride a stationary exercise bicycle for fifteen minutes at a pre-determined target heart rate using the Karvonen method (See Appendix B). Several aerobic exercise texts defined the Karvonen method as being an accurate calculation in determining target heart rate for cardiovascular exercise.[12,13] The stationary bike was chosen as a convenient method of fatiguing the subjects while keeping extraneous testing variables such as excessive head and body movement, variability of exercise level, and changing of testing location to a minimum. It was also noted that cycling produces a higher heart rate than exercise on the treadmill.[14] Seven visual functions considered to be important in sports were measured. For Group B, these tests were performed before the exercise was initiated and then immediately after. Group A completed the exercise and post-testing portion of the experiment at one sitting and returned for the "pre-testing" portion one day later.

Once the subject was deemed qualified for the study they were escorted into the research room. The subject was assisted in adjusting the Monark brand stationary bicycle for maximal comfort and performance. An Amerec-130, Model PM 130 Heart Rate Monitor was attached to the subject's ear lobe to monitor heart rate throughout the testing period. During the pre- and post-testing sessions the subject was asked to maintain a speed of 20-30 revolutions per minute with minimal resistance. During the fifteen minute fatigue portion of the experiment the subject was asked to maintain a heart rate within the 60%-85% range as established by the Karvonen calculation while pedalling at a rate of 30-40 revolutions per minute. The two texts mentioned previously showed that exercise performed above the 60% level to be efficient in producing a significant conditioning effect on the body. These two references also indicated twenty to thirty minutes as being the duration level required to attain the optimal cardiaovascular conditioning effect.[12,13]

However, in order to incorporate all possible fitness levels of the subjects, fifteen minutes was chosen as an acceptable standard to include all levels of cardiovascular conditioning. The resistance of the stationary bicylcle was allowed to be adjusted by the subject but they were asked to keep the speed of the bike between 30-40 revolutions per minute.

The visual factors measured in the experiment were:

1) 6 meter dissociated lateral phoria.
2) 6 meter binocular visual acuity.
3) 6 meter lateral fixation disparity.
4) 6 meter stereoacuity.
5) 3 meter contrast sensitvity.
6) Preferred hand reaction time.
7) 6 meter perceptual form matching task.

The testing order was maintained the same pre- and post- test except for the lateral phoria. It was measured first in the pre-test and last in the post-test. This was done when no pedalling occurred in order to keep head movement to a minimum.

The dissociated lateral phoria was measured using 48 millimeter diameter Risley prisms. They were mounted in a plexiglass holder that enabled the subject to view the target while sitting on the bike. The target was a projected 20/20 "T" on a screen 6 meters away. Standard Von Graefe technique for measuring lateral phoria was employed while changing the prisms at a rate of 1 prism diopter per second (See Appendix C for exact testing protocol).

Visual acuity, fixation disparity, and stereoacuity were measured using the Mentor Binocular Visual Acuity Tester, (the B-VAT), Model II-SG from Mentor O & O, Incorporated of Norwell, Maine. This device employs a cathode ray screen that displays disparate images which change in phase with liquid crystal goggles worn by the subject. This creates a filtering effect similar to using polarized glasses and a polarized target. The subject viewed the screen at a 6 meter distance. Due to the effect created by the B-VAT the subject was in a binocular mode and any pre- or post-test suppression during measurement of all three factors would be readily apparent. The targets were controlled by the experimenters using a hand-held remote control.

Visual acuity was measured in a descending fashion beginning at a 20/60 demand level and progressing downward, ex. 20/50, 20/40, 20/30, 20/25, 20/20, 20/15, until the subject could no longer report 1/2 of a line of letters correctly. Guessing was allowed by the subject. A plus and minus system counting the correct letters called by the subject was used (See Appendix C).

Lateral fixation disparity was also measured using the B-VAT.

The subject was presented a screen that contained a 2, an A, and a 3 with a vertical bar above them. The bar was viewed by the right eye and the 2, A, 3 were viewed by the left eye.

I

2 A 3

The bar was initially moved closer to the "3" creating an uncrossed disparity. The subject was instructed to keep head movements to a minimum. The testing began at 13 arc minutes of exo fixation disparity. The experimenter moved the vertical line by means of the hand-held remote control at a rate of 1 arc minute per second. The subject was asked to report when the bar was directly above the "A". Another trial was performed moving from the "2" towards the "A" coming from the crossed disparity position. The testing was initiated from the 13 arc minutes eso fixation disparity position. The hand-held control automatically reported the fixation disparity value in minutes of arc which was recorded (See Appendix C). Fixation disparity mean and test-retest range were calculated for subsequent analysis.

Depth perception was assessed using the stereopsis test within the B-VAT. The subject was given instructions to report which circle seemed to be floating towards him and to respond as quickly and as accurately as possible. The subject was also asked to keep head movements to a minimum. The rings were displayed in a diamond pattern with only one being presented in crossed disparity.

0

0 0

0

Targets were presented in a descending staircase fashion. The specific target demands were: 240", 180", 120", 60", 30" and 15". The subjects were scored on speed and accuracy of stereopsis. A threshold technique was used to quantify the subject's stereopsis level.

If the subject incorrectly reported the position of a disparate circle the position was changed by the remote control and the subject was asked again to report the position. Elapsed time to correct response was measured for each stimulus level. A correct, instantaneous response was timed as zero seconds. The subject had to successfully identify the position of the disparate circle two out of three times to be awarded that level of stereopsis. Testing was then moved to a target of less disparity. If he was unable to correctly respond two out of three times then the previous level of steropsis was recorded. Time was recorded in seconds at each response level (See Appendix C).

The Nicolet Optronics 2000 Contrast Sensitivity Analyzer was used to measure contrast sensitivity at three spatial frequencies: 15, 18, and 21 cycles per degree. The task was performed at 3 meters. The subject was shown a preview of the spatial frequency being tested at a clearly visible contrast level (20.0) for five seconds. Following this preview, three trials were run at each spatial frequency. The contrast of the grating was gradually increased by the Nicolet from invisible to visible. The contrast was initially set at 0.2 and gradually increased from this level. During each trial, it was emphasized to the subject to be positive of seeing the grating prior to responding (See Appendix C).

Reaction time was measured using the Reaction Plus. This device measures eye-hand reaction and response times. The instrument gave a measurement of reaction time (the amount of time it takes to react to a stimulus) and response time (the reaction time plus the amount of time it takes for a motor movement to terminate the stimulus).

The instrument was placed in front of the subject on an adjustable table at the correct height to allow free movement of the subject's hands. This test was designed to incorporate five measurement trials. The testing was conducted following the protocol noted in the Pacific Sports Visual Performance Profile.[1]

The subject's preferred hand was placed on the instrument with the hand lined up tangent to boundary line with reaction button under flat of hand at base of fingers. The subject's head was aligned vertically over target button. The subject was instructed that the hand was not to cross the boundary line and that the ready light would come on when they had placed their hand on the reaction button. The experimenter would then say 'Ready' and within a short delay the response button would light up. The subject was told to move his hand over and depress the response button as quickly as possible after the delay. For this test the delay was set as 2.5 seconds for the first, third, and fifth trials, 1.7 seconds for the second trial and 3.25 seconds for the fourth trial. The examiner then initiated the stimulus two to four seconds after the 'Ready' command. One practice trial was given during pre-testing with none given before the post-testing measurements (See Appendix C).

A "perceptual speed" task was devised which utilized a set of Structure of Intellect slides.[15] This consisted of 27 form recognition slides containing 6 figures presented one slide at a time. The subject was asked to match a figure on the left side of the slide with its exact match from five spatially rotated examples directly to its right. The subject had 2 minutes to match as many of the slides as possible. The subject was asked to proceed as quickly as possible while holding errors to a minimum. The first slide, a demonstration slide, was shown to familiarize the subject with the task. A score was given for number correct as well as percentage correct determined by using the total number of slides attempted (See Appendix C).

DATA ANALYSIS

Various levels of physical activity for the subject's were ascertained through the verbal questionnaire. For purposes of classification, a grading system of high, moderate and low activity levels was assigned to each subject.

Those participating in some exercise activity five or greater times per week were high level, three to four was moderate and zero to two was a low level grade. The mean resting heart rate was 65.3 beats per minute with a range of 48-76.

Analysis of the data was performed using descriptive statistics, a paired t-test (df=39, $p<0.05$) and a one factor ANOVA (df=39). The t-test comparison measured within group pre- versus post-test differences. The ANOVA was used to investigate differential pre- to post-test change among subjects based upon their habitual exercise level. The subjects were divided into their respective level of activity classification, high (n=10), moderate (n=14), and low (n=16).

RESULTS

Upon reviewing the data a significant post-test change ($p<0.05$) was noted in the perception speed task (Table 2). With increased fatigue, the subjects performed at a higher level, both number and percent correct, than under pre-test conditions. A statistically significant change ($p<0.05$) was also noted in fixation disparity. After aerobic fatigue the subjects moved to a more esophoric posture (Table 2).

Analysis of the other individual variables failed to show a statistically significant change. When comparing between groups by exercise activity level, no differential effect of fatigue was demonstrated on any variable.

DISCUSSION

When an athlete participates in athletics a fatigue element is always in play. This fatigue element can be physical, as in most athletics, mental, or both. This study addressed physical fatigue and its effects upon certain components of the visual system.

We tested seven variables pertaining to the visual system and visual information processing. We expected to see a decline in performance in six of the seven areas, with the cognitive processing ability increasing in performance. We were able to demonstrate a statistically significant result ($p<0.05$) in fixation disparity and the perception speed task.

Fixation disparity, or binocular posture, was expected to become more esophoric. This was shown to occur. This is perhaps the result of stress on the body, induced by aerobic exercise, causing sympathetic activation of the autonomic nervous system. The sympathetic triad, as it relates to vision, causes pupillary dilation, relaxation of the ciliary body allowing accommodation to move toward the farpoint and contraction of the levator muscle widening the palpebral fisssure. When accommodation is in this posture the subject is unable to view the target clearly due to retinal blur. They attempt to overcome this by implementing the parasympathetic triad of pupillary constriction, accommodation and increased convergence. They find it difficult to accommodate and constrict their pupils due to the distance of the target, so convergence is activated causing an increase in the eso fixation posture.[16] This eso posture may cause an athlete to localize targets closer to them than they actually are, therefore causing a reduction in athletic performance. This may result in deleterious effects in sports that require precise spatial localization such as baseball, hockey, and basketball.

Heightened cognitive ability follows in suit with the activation of the sympathetic nervous system. Under stress the body will protect itself by selecting essential elements needed for survival. The triad that occurs in vision as mentioned above, is but one of the processes that is mobilized in a crisis situation. To control the body, an adequate amount of energy must be supplied to the brain to keep the rest of systems in check. This arousal lasts throughout the stressful situation.[17] This higher level of cognitive ability and processing is demonstrated by athletes when they mention that "they are in the groove."

Information processing is more efficient allowing them to make the appropriate action/reaction which is of upmost importance as the competition reaches a level requiring peak visual/mental performance.

We were not able to accept our hypotheses for the five other dependent variables. We attribute this to several causes. The first of which is fatigue level.
We implemented a period of fatigue that we could relate to a wide variety of cardiovascular fitness levels. With some subjects this level proved to be quite sufficient. With others it seemed inadequate. Upon duplicating this study a more defined pool of subjects with a similar fitness level might yield more consistent results. The fitness level would correspondingly give a better estimate of the fatigue level.

The method of fatigue, a stationary bicycle, proved to be the best instrument for testing. It may not have been the best for fatigue. The target heart rate of the subjects was achieved in a fairly brief amount of time in most cases but not in others. Some subjects found it difficult to maintain the target level without increasing the level of resistance of the bike. A more demanding exercise such as running or swimming could be used to induce aerobic fatigue and then maintenance of the heart rate and testing could be done on the stationary bike. This would lead to increased fatigue and testing under a more realistic athletic atmosphere.

Our conclusions are based on a group of non-elite athletes. We are relating these results across a wide variety of sports at all levels. To improve the results and to have a more accurate assessment of fatigue level, future researchers will need to organize specific groups of elite and non-elite level athletes in various sports. The fatigue level will need to match the the specific demands of the particular sports. The specific dependent variables may need to be re-assessed and further defined.

Fatigue is part of every sport. It may be physical, cognitive or both. Information processing, via the visual system, is also a part of every sport. The effects of fatigue can be demonstrated in a controlled setting. Although we were unable to prove statisically significant results with every dependent variable, we were able to show some shifts. As the body of knowledge continues to grow in this area and researchers continue to investigate the visual system and sports performance, better research designs and results may be obtained.

APPENDIX A

QUESTIONNAIRE

NAME________________________________

Please respond to the following questions asked by the experimenters. If yes, please explain.

1. Do you have any congenital or pathological visual problems?

2. Are you currently taking any medications?

3. Do you or anyone in your immediate family (mother or father) have/had any of the following?

YES	NO	Congestive heart failure	YES	NO	Unstable Angina
YES	NO	Uncontrolled hypertension	YES	NO	Heart or related tissue infection(s)
YES	NO	Arrythmias	YES	NO	Marked bradycardia
YES	NO	Severe anemia	YES	NO	Uncontrolled diabetes
YES	NO	Inappropriate blood pressure response to exercise	YES	NO	Asthma

Explain any YES answers:____
____
____
____

4. Have you ever sustained any serious eye injuries?

5. Do you have any known binocularity problems?

6. Do you exercise regularly? If yes, what type and how often?

7. Have you had a recent physical examination? If yes, when and what were the results?

8. What would you consider the condition of your general health? (Fair, Good, Excellent). Explain if problem exists (chronic health problem).

APPENDIX B

KARVONEN TARGET HEART RATE CALCULATION

Target Heart Rate Range

Resting Heart Rate________ 220

\-

(age)________

= ________

\-

(Resting Heart Rate) ________

= ________

*(0.60)_______ *(0.85)_______

\+ +

Resting Heart Rate _______ ________

= =

Target Heart Rate Range _______ to ________

APPENDIX C

PROTOCOLS

Entrance

1) Ask the patients name and age

2) Take the monocular and binocular acuities. Determine if the patient sees better with one eye than the other wearing best distance correction.

"Do you see better with one than the other?"

Begin with the poorer eye viewing the projected Snellen visual acuity chart. "Call out the letters in the lowest line that you can." If the patient calls out 1/2 of the letters then they are awarded the line. Record + and -, as well as the number for higher and lower acuities. The patient must be able to view 20/25 OU or better at 6m using best habitual distance correction.

3) Determine phoric or tropic posture using the 6m and 40cm cover test. Targets to be used will be a projected 20/70 "O" and a near point bead. The patient will be asked to view the "O" first keeping both eyes open and using best distance correction. The standard procedure for the cover test will be followed. The unilateral test will be used first, then the alternating test. Both objective and subjective responses will be recorded. The test will then be repeated at near using a near point fixation bead.

4) An estimate of depth perception will be used implementing the projected A.O. vectographic polarized slide. The subject will be wearing polarized glasses and asked to report as quickly and as accurately which circle appears to look different to them. "You are going to be viewing 5 circles in a line. I would like for you to report as quickly and as accurately which circle appears to look different, if any. Please report the number as if they were numbered from left to right 1-5." If the response is positive then ask the patient to move to the next group of circles.

Record the last correct answer in arc seconds.

5) Determine the patients heart rate by palpating the radial pulse at the wrist.

This will be entered into the equation on the recording sheet to determine the target heart rate range at which the experiment will take place. If the resting pulse exceeds 80 beats per minute the subject will be immediately disqualified.

Testing

1) Three of the seven test procedures will be done on the Mentor Binocular Visual Acuity Tester, model II-SG (the B-VAT). Specific procedures are as follows:

Visual Acuity

E. Visual acuity or sensitivity using the B-VAT .

TD. Test distance is 6m.

IL. Standard room illumination (34-79 foot candles).

P. Sitting upright on the bike looking through the binocular viewer.

CF. Patient is instructed to view the line given and to call out the most letters they are able to.

IS. "View the screen in front of you and call out the lowest line that you can see-guessing is OK.."

R. Record the line if they are able to correctly report 1/2 of the letters. If unable to do so, then record the amount with a + or - and the number of letters within that line.

Contrast Sensitivity

E. Visual contrast sensitivity using the Nicolet Optronics CS 2000.

TD. Test distance is 3m.

IL. Needs to be measured.

P. Sitting upright on the bike looking at the screen of the Nicolet contrast sensitivity tester.

CF. Patient is instructed to fixate on the screen the entire time of testing and to respond when the gratings become visible.

IS. "I would like for you to look at the screen closer to you. You will hear 2 beeps. This indicates that you will see a preview of the grating. This will then disappear and you will hear one beep. Testing will begin at this point. You are to indicate when you begin to see the grating by depressing the black button on the hand control.

YOU WILL ONLY PRESS THE BUTTON WHEN YOU ARE POSITIVE THAT YOU SEE THE GRATING. One practice screen will be given to you so you are familiar with the procedure.

R. Collect and attach the computer printout making sure to note whether pre- or post-test.

Fixation Disparity

E. Horizontal fixation disparity using the B-VAT.

TD. Test distance is 6m.

IL. Standard room illumination.

P. Sitting upright on the bike looking through the binocular viewer.

CF. Occlude each eye to make sure that the subject is viewing the target correctly.

IS. "Look directly at the center of the target. You will notice an "A" with a bar directly over it or to the right or left of it. Please tell me if the bar is closer to the 2 or the 3. Now I am going to move the bar and please tell me when the bar is aligned directly over the center of the target."

R. Record the amount of disparity in arc minutes or seconds displayed on the screen. There will be one trial from each direction-crossed and uncrossed-to calculate a range.

Stereoacuity

E. Stereoacuity in free space at the far point using the B-VAT.

TD. Test distance is 6m.

IL. Standard room illumination.

P. Sitting upright on the bike looking through the binocular viewer.

CF. Instruct the patient to try to minimize head movements so as to reduce lateral parallax.

IS. "You will be shown a series of screens each containing four circles in a diamond pattern. While holding your head as still as possible I would like for you to report as quickly and as accurately if one of them appears to float or is closer to you than the rest. Please respond by saying up, down, left or right. If none of them appear to be different then report by saying none."

R. Three trials will be performed at the stereoacuity demand level where an incorrect response is given. If the subject reports the correct orientation 2 of the 3 times then this level is recorded and the next lowest level is shown to the subject. This defines a threshold measurement. Record the threshold stereoacuity in arc seconds as well as the amount of time it took to give the last correct responses.

Dissociated Phoria

E. Measure the resting heterohoria of the eyes.

TD. Test distance is 6m.

IL. Standard room illumination.

P. Sitting upright on the bike looking through the Risley prisms. The prism amount used was 5Δ base-up OS, and 8Δ base-in OD. The OD prism was adjusted until alignment was acheived.

CF. Occlude each eye to make sure the subject is viewing the target correctly.

IS. "Looking through the prisms how many"E's" do you see? Is one up and to the right? Looking at the upper "E" please tell me when the lower "E" is directly underneath it. Please just say now. There will be 2 trials." One trial will be from base-in and the other from base-out. The average of the two will be used for data analysis.

R. Record the lateral prism value and the direction of the base at the moment of alignment.

Perception Speed Task

E. Quality and speed of central visual information processing on a form recognition and matching task.

TD. Test distance of 6 meters.

IL. Standard room illumination.

P. Subject is sitting upright on the exercise bicycle.

CF. Stimuli consist of 54 form recognition and matching slides, 27 from each form. These slides were obtained from the Structure of Intellect slides, Form A and B, sub-test CFT. There will be one demo slide to demonstrate the task. The testing will last for 2 minutes.

IS. "I'm going to show you a series of shapes located on the left-hand side of the screen.

Once the slide is presented I want you to look at the shape on the left and locate its exact match in the row directly to its right as quickly and accurately as you can. The shapes may be rotated. Once you locate it say the number of shapes it is away from the first. Then we will proceed to the next slide immediately." This is a timed test. You will have two minutes to get as many slides as you can.

R. Record the subject's response for later calculation of number and percent correct.

Reaction/Response Time

E. Visual motor reaction and response time to central visual stimuli based upon visually guided eye-hand motor response (via hand button release and press of lit target button).
Reaction time is measured as the elapsed time between onset of stimulus light and release of depressed "reaction" button. Response time is measured as total elapsed time betweeen onset of stimulus light and press of stimulus ("response") light by subject.

TD. Test distance is an arm-length from the subject at waist level of the seated subject.

IL. Standard room illumination.

P. Sitting relaxed with preferred hand depressing reaction button.
Preferred hand must be lined up tangent to boundary line with reaction button under flat of hand at base of fingers. Subject's head aligned vertically over target button.

CF. Body, head, hand alignment. Control panel and examiner positioned behind and to the side of subject so control panel not visible to subject.

IS. "Which hand is your preferred hand?" Adjust instrument to measure performance using preferred hand. "Place your preferred hand on this button so that your hand lies up against the line without crossing it. The ready light will come on when you have placed your hand on the reaction button. Position yourself with your head directly over the response button.

I will say "Ready" and within one to five seconds the response button will light up. Move your hand over and depress the button as quickly as possible. The reaction button should lie under the base of your hand as I will demonstrate" Examiner will initiate stimulus between two and four seconds after "Ready" command. Subject will be given one practice trial.

R. Record both reaction and response times for each of five trials.

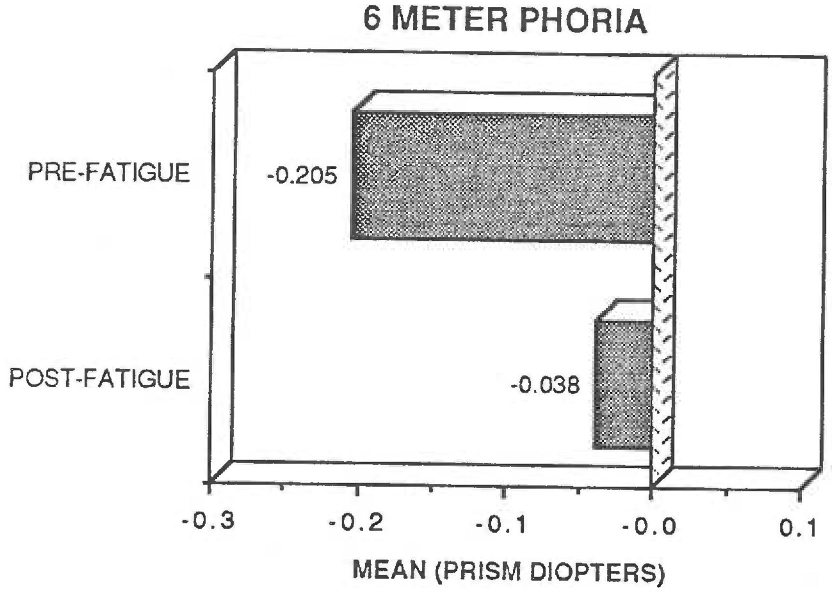

FIGURE 1

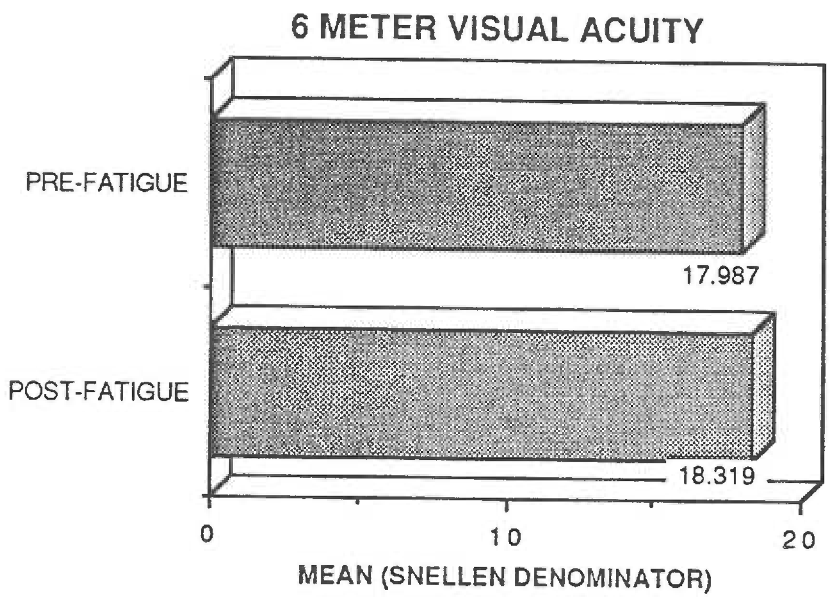

FIGURE 2

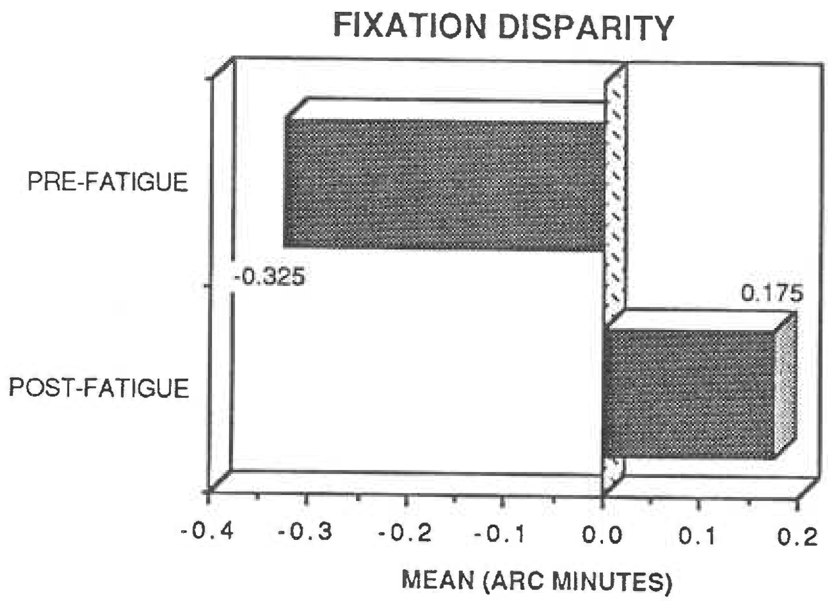

FIGURE 3

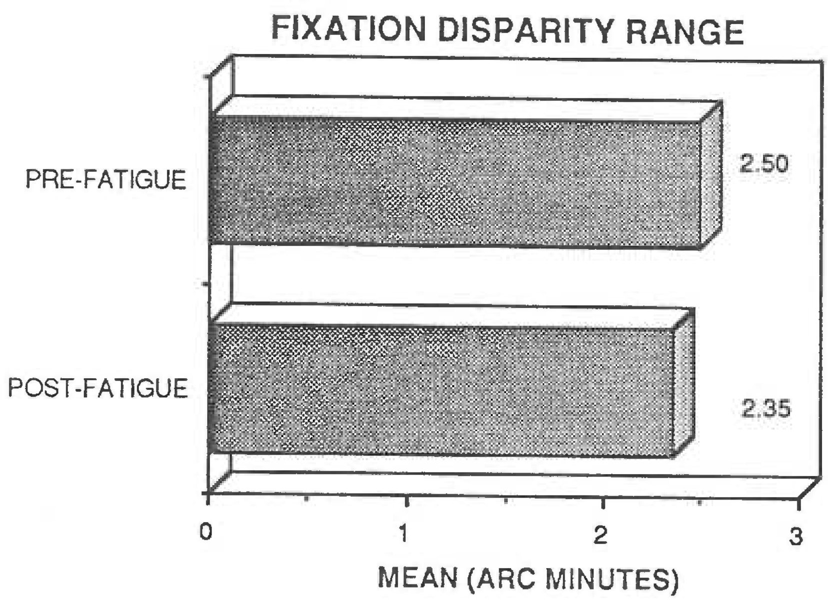

FIGURE 3b

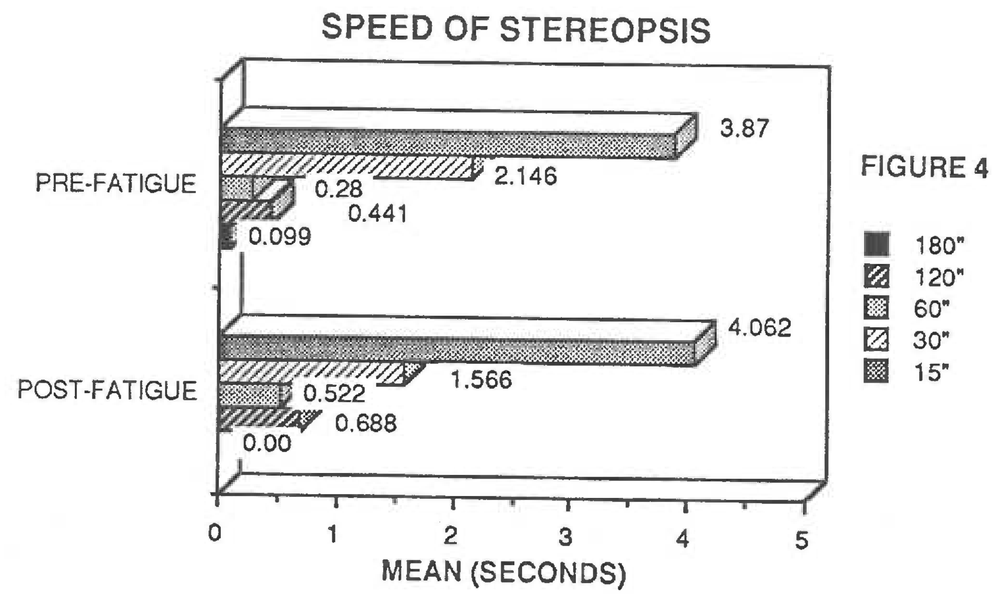

FIGURE 4

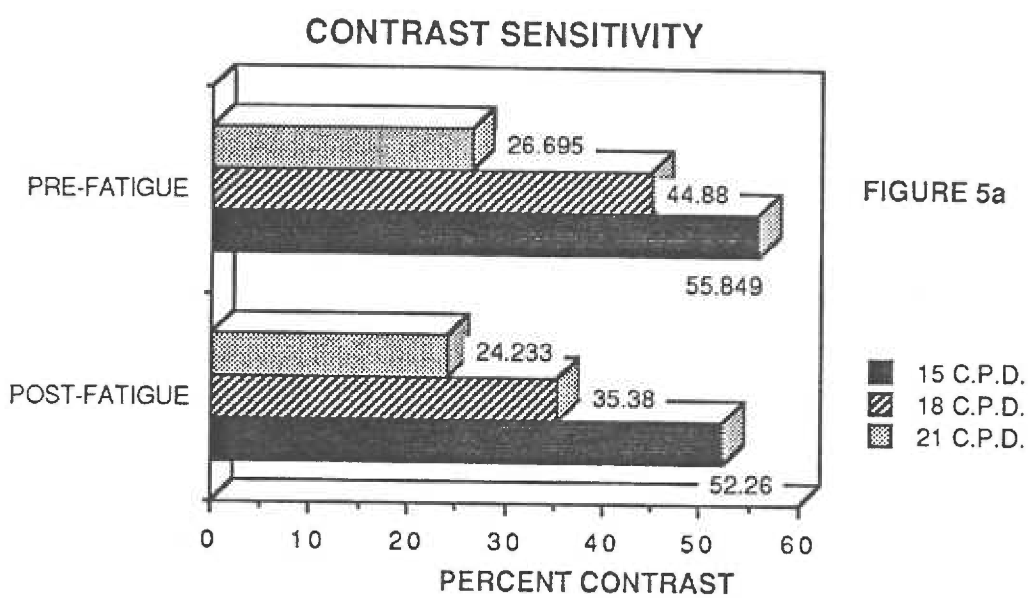

FIGURE 5a

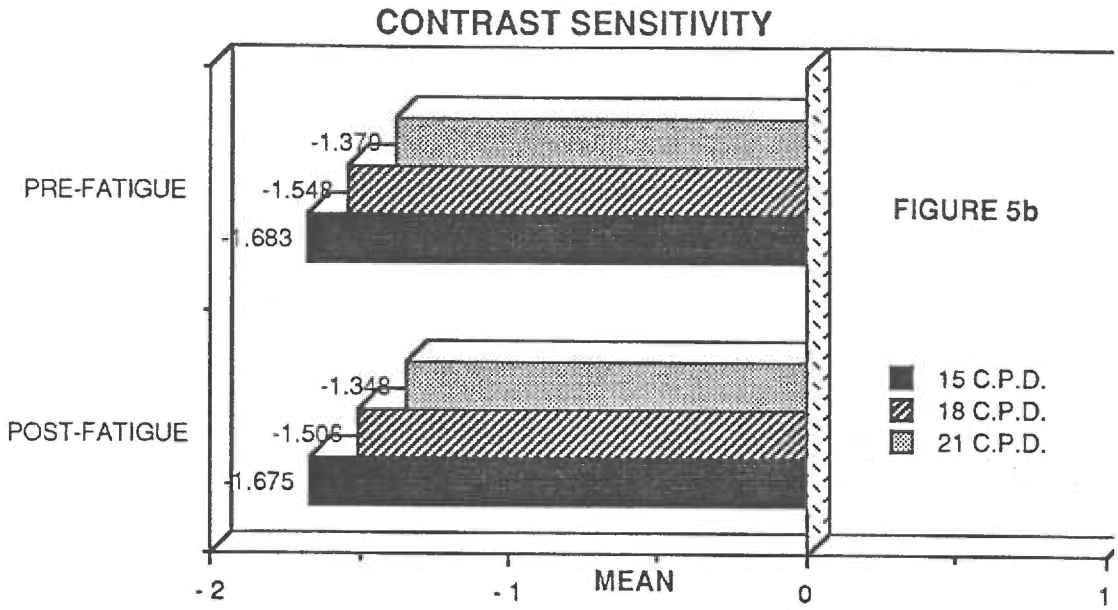

FIGURE 5b

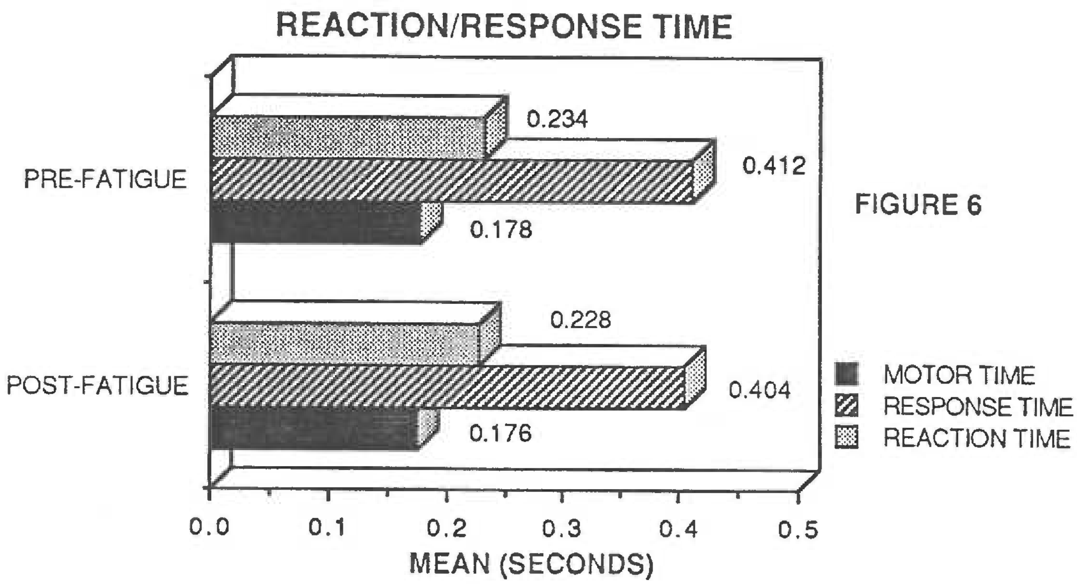

FIGURE 6

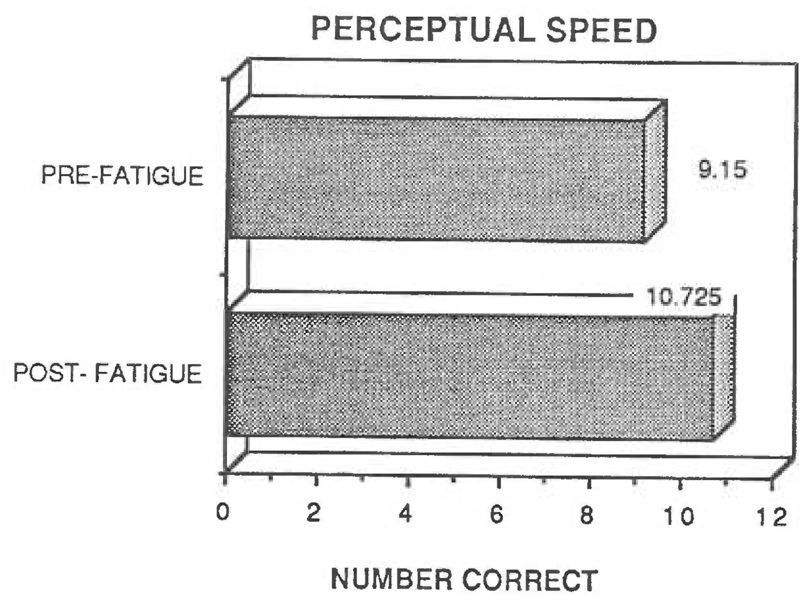

FIGURE 7a

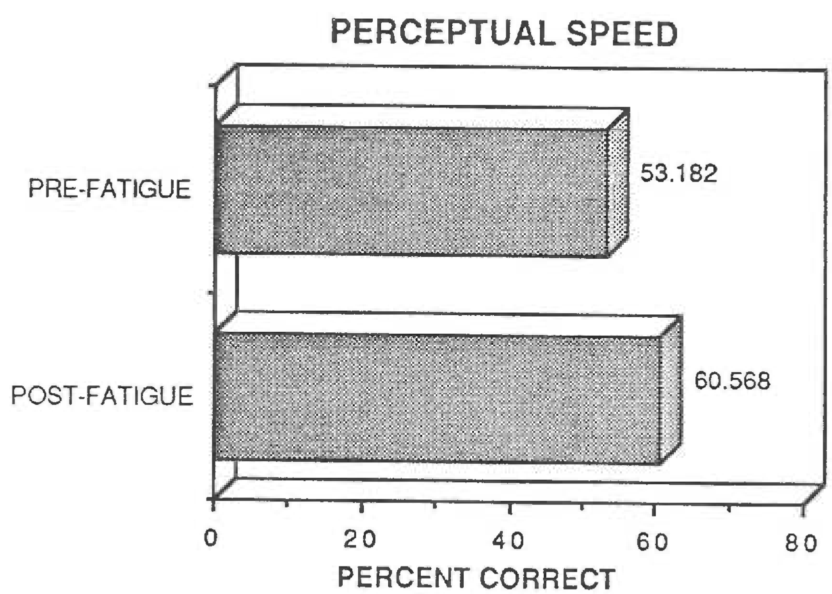

FIGURE 7b

TABLE 2

VARIABLE	UNITS	Pr Mean	Pr Std. Dev.	Ps Mean	Ps Std. Dev.	Probability
6m Ph	Prism Diopters	-0.205	2.15	-0.038	2.593	0.4985
VA OU	Snellen Denom.	17.987	2.150	18.319	3.120	0.4059
FD	Arc Minutes	-0.325	1.538	0.175	1.876	0.0133
FD Range	Arc Minutes	2.500	1.432	2.350	1.545	0.5629
Stereo 240	Seconds	0.000	0.000	0.000	0.000	0.0000
180	Seconds	0.099	0.625	0.000	0.000	0.3235
120	Seconds	0.441	0.901	0.688	1.847	0.2000
60	Seconds	0.280	0.885	0.522	1.342	0.1221
30	Seconds	2.146	2.420	1.566	1.884	0.1866
15	Seconds	3.870	2.096	4.062	2.274	0.7345
CS15	% Contrast	55.849	40.155	52.260	23.352	0.4950
CS 15 mn		-1.683	0.221	-1.675	0.200	0.8099
CS18	% Contrast	44.880	55.485	35.380	15.630	0.2835
CS 18 mn		-1.548	0.254	-1.506	0.199	0.2473
CS 21	% Contrast	26.695	13.590	24.233	9.836	0.1070
CS 21 mn		-1.379	0.203	-1.348	0.185	0.1368
Reaction Time	Seconds	0.234	0.027	0.228	0.024	0.1029
Response Time	Seconds	0.412	0.055	0.404	0.052	0.1916
Motor Time	Seconds	0.178	0.035	0.176	0.033	0.5661
PST#	Number Correct	9.150	2.402	10.725	3.088	0.0010
PST%	Percent Correct	53.182	14.229	60.568	14.368	0.0047

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