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The Effects of Sleep Deprivation on Binocular Convergence and Monocular Accommodation

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ABSTRACT

The purpose of this project was to determine whether either the smooth or striated muscles of the eye are affected by sleep deprivation. Sleep deprivation is considered to be personalistic fatigue, differing from the muscular fatigue that results from over-exerted muscles. To see if there is a correlation between the two types of fatigue, I tested the ability of both striated and smooth muscles in the eyes of 11 participants prior to, and following, a period of 24 hours without sleep. Two different, yet not entirely separate, aspects of vision were compared and tested---vergence, which is governed by the striated rectus muscles, and accommodation, which is governed by the smooth ciliary muscle. Since any binocular eye function will incorporate both vergence and accommodation, I tested accommodation monocularly (devoid of vergence), and tested binocularly the near-point convergence, which minimizes accommodative interference. I found that participants who were deprived of sleep for a period of over 24 hours showed a significant decrease in near-point convergence ability, doubling their adducting distance, where as I saw no significant change in accommodative ability.

INTRODUCTION

Visual perception is the culmination of information processing within stages, with different aspects encompassing distinct visual areas (Randolph, et. al 1998); this includes not only details of specific aspects of vision, but also interrelationships among the different aspects. This project investigated the relationship between binocular convergence (inward aiming of the eye by contraction and relaxation of the rectus muscles), and accommodation (focusing of the lens by contraction of the ciliary muscle) (Trobe, 1996).

There are six extraocular muscles involved with governing eye movement (*Britannica,* 1999). The four we tested are the striated rectus muscles---the inferior rectus (downward movement), the superior rectus (upward movement), the medial rectus (inward movement), and the lateral rectus (outward movement). They are involved in stimulating binocular convergence by equal simultaneous movement of the eyes in opposite directions (Randolph, 1998).

The muscles involved with the focusing ability of the eye lie in the ciliary body---the ciliary muscle, oblique muscles, and longitudinal muscles (Pavan-Langston, 1986). Accommodation is governed by the ciliary muscle, which allows for increased or decreased tension on the lens, resulting in the focusing of the eye.

Initially as a muscle fatigues, there is a drop in force and then, as the muscle fatigues further, there is also a drop in velocity (Fitts, 1996). This accounts for a lower peak power, which is attained at less than the full force capacity. By comparing the participants' initial near-point convergence and accommodative values with their final values, I attempted to determine whether the sleep deprived muscles of the eye also exhibit muscle fatigue characteristics.

Sleep deprivation can be classified as a stressor that can lead to fatigue in the body. Fatigue can be considered as muscle fatigue, defined as the muscular inability to carry on certain functions (such as sustaining force in prolonged or repeated contractions), as well as personalistic fatigue, defined as a kind of felt aversion for exertion and as feelings of inability to perform functions of work (*Britannica,* 1999). This latter type of fatigue is often considered transient impairment, and is the type of fatigue associated with sleep deprivation. Impairment of this sort reflects alterations in the chemical processes that occur within the cells of the body, similar to the effects of alcohol intoxication and lack of oxygen (*Britannica*, 1999).

With muscular fatigue, there is a decrease in the peak tension and power output resulting in a reduced work capacity and a slowing of the contraction and relaxation times (Fitts, 1996). My goal was to determine if there is a correlation between impaired fatigue (due to sleep deprivation) and muscular fatigue in the eye by testing the binocular convergence and monocular accommodation of the rectus and ciliary muscles prior to and following a period of 24 hours without sleep.

MATERIALS AND METHODS

The experiment began with one treatment group, consisting of 20 college students ranging in age from 19 to 23. This limited the variability of differing accommodation strengths due to age (Chia-Fen Chi, et. al 1998). All participants were tested for at least 20/30 visual acuity, and were allowed to wear corrective lenses if needed. In hopes of completing the testing with 12 to 15 students, I initially recruited 20 students, speculating that some would not make it for the duration of the study.

The main purpose of the experiment was to evaluate the effects of sleep deprivation on the rectus and ciliary muscles of the eye. All the participants had their vision tested at two different times:

a) once on the morning of Friday, January 12th

(after a good night's sleep), to obtain the control data for optimal visual perception

b) and then once again, 24 hours later on Saturday morning, January 13th (without any sleep), they were tested to see if any change in perception could be detected.

All students in the treatment group were required to stay awake for a duration of at least 24 hours. They were not allowed to consume alcohol or caffeinated beverages after 6:00 pm Friday evening, since this might have affected their level of impaired fatigue and thrown off the results (*Harvard* 1997). Computers and video games were not allowed due to possible exaggerated eyestrain (Livingston, 1992). The participants were provided with refreshments and entertainment through the night in Dotzour lobby, but were not required to stay together as a group. Since each student was required to sign a statement agreeing to the above conditions, I took everyone's word that no one had violated the agreement.

A local optometrist, Dr. Robert Arnold, opened his clinic two hours early to help me test both Friday and Saturday morning. Dr. Arnold tested near-point convergence, while Chad Premer (an optometry student) helped me conduct the accommodative facility testing. Participants were driven to Dr. Arnold's office in shifts from 7:30 to 9:30 a.m. to undergo testing.

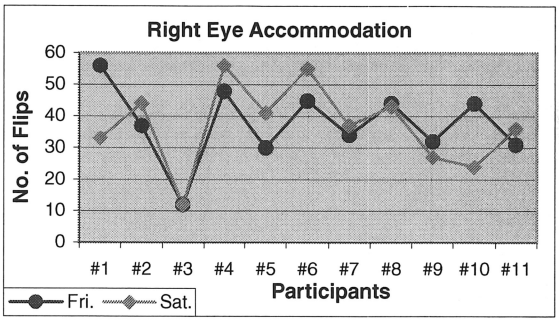
We tested accommodative facility using a -2.0/+2.0 lens rock that was flipped by the participants themselves. We tested both the right eye and the left eye separately, which allowed measurement of accommodation with out the added effect of vergence. The participants were asked to stare at a sentence 40cm away through the –2.0 lens while covering up one eye; when the sentence came into focus, they were then instructed to flip the rock lens and focus on the sentence through the +2.0 lens, and then to flip back to the –2.0 lens when that came into focus, and so on for 90 seconds.

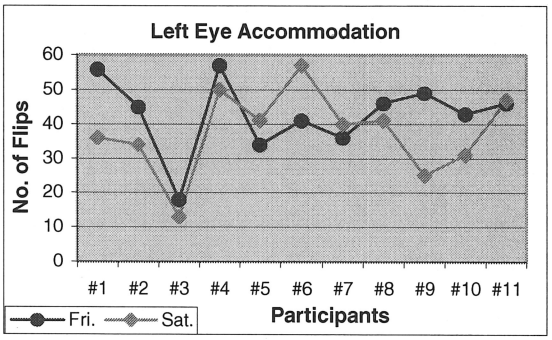
We tested near-point convergence by moving a small object towards the face, and measured the shortest distance at which point the eyes could no longer converge together due to the abduction of one eye, causing the participant to see double.

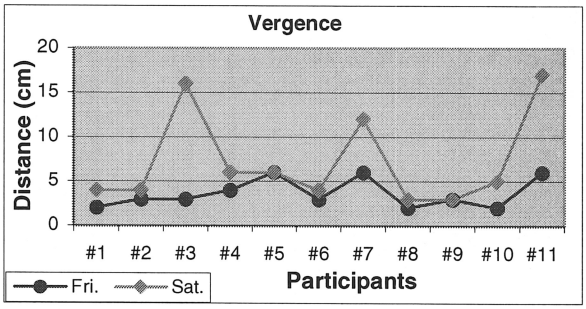
RESULTS

The accommodative test in itself was supposed to temporarily fatigue the eye so that the number of flips in the last thirty seconds would be less than the number of flips in the first thirty seconds. Unfortunately, I did not get substantial data to verify this hypothesis. When comparing the total number of flips for each eye for Friday and Saturday, there was only a slight decrease between the pooled mean value of the participants-----37.41 on Saturday, as compared to 40.18 on Friday.

When comparing the near-point convergence values for both days, I found a significant trend in increasing vergence scores, with the mean doubling from 3.64cm on Friday to 7.27cm on Saturday.







DISCUSSION

The tests were focused on two different, yet not easily separated, aspects of vision: accommodation and vergence. Accommodation deals with the ciliary muscle of the eye, which is a smooth muscle, and regulates the eye's focusing ability in order to see clearly. Vergence deals with the rectus muscles of the eye, which are striated, and regulates the aiming of the eyes in order to see singularly. I tested convergence, which is the eye's ability to converge on a single object with out seeing double. Convergence is the result of contraction of both the medial recti and relaxation of the lateral recti (Pavan-Langston, 1986).

Accommodative facility can be measured by testing each eye separately, while vergence facility involves the combined effects of both eyes. So when monocular tests are performed on each eye, you will be testing only for accommodation. The problem lies in

the fact that when binocular tests are performed on the eyes, both vergence and accommodation play a role in governing the eye's movement and ability. It's more difficult to measure each one's distinct effect; almost all measurements of vergence facility are contaminated by interactions between vergence and accommodation. Distinctly separating the two would have enabled us to see if there is a difference in the way both smooth and striated muscles in the eye are affected by fatigue caused by sleep deprivation.

In conclusion, it appears the striated rectus muscles used for vergence have been found to be significantly affected by sleep deprivation, where as the smooth ciliary muscle used in accommodation didn't seem to be significantly affected, showing that personalistic fatigue can induce striated muscular fatigue in the eye.

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