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, 1988). 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
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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.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Mr. Chad Premer for his effort and enthusiasm supporting my project. I would also like to sincerely thank Dr. Robert Arnold for donating his time and office facilities, Dr. Kent Noffsinger for his guidance, and Becky Amiot, Trevor Austin, Cora Coleman, Chris Curran, Kylie Funk, Lacey Funk, Bryan Lucore, Keiko McDermott, Kara Reiff, Brisa Saks, and Eric Trujillo for staying awake for 24 hours and participating in my study.

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