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Effect of cumulative nearwork on accommodative facility and asthenopia

Rafael Iribarren[1], Andrea Fornaciari[2] & George K. Hung[3]
[1]*Department of Ophthalmology, Centro Médico San Luis, San Martín de Tours 2980, (1425) Capital Federal, Argentina;* [2]*Facultad de Ciencias Jurídicas, Universidad del Salvador, Secretaría Académica, Tte. Gral. J. D. Perón 1818, (1040) Capital Federal, Argentina;* [3]*Department of Biomedical Engineering, Rutgers University, 617 Browser Road, Piscataway, NJ 08854-8014, USA*

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Abstract

Purpose: To investigate quantitatively in young adults the relationship between long-term cumulative nearwork, degradation of dynamic accommodative ability and the presence of asthenopic symptoms. *Methods:* Subjects consisted of 87 young students and office workers between 18 and 31 years of age with uncorrected visual acuity of 20/30 or better in each eye. The amounts of nearwork, dynamic accommodative facility, and level of asthenopic symptoms were measured for each subject. *Results:* Total cumulative nearwork time was negatively correlated with accommodative facility and positively correlated with the number of asthenopic symptoms. Furthermore, significant correlations were found between total nearwork time and blurred vision, and blurred vision and reduced accommodative facility. Moreover, the sub-category of "hours spent reading over the years" was found to be significantly correlated with decreased accommodative facility. *Conclusions:* The correlations suggest a relationship between cumulative amount of nearwork, decreased accommodative facility and asthenopia.

Introduction

In clinical practice, it is believed by many that there is a close association between nearwork-related asthenopia and accommodative disorders [1, 2]. Recent findings related to accommodative adaptation [3] and nearwork-induced transient myopia (NITM) [4] have clearly demonstrated both subjectively and objectively that short periods of intense nearwork can produce blurred vision due to slowed accommodative dynamics, both near and at distance. Accommodative effort [5] and daily nearwork [6], as well as NITM [2], have also been implicated in myopia progression.

The present study was developed to investigate the relationship between the amount of nearwork, dynamic accommodation, and asthenopia. For this purpose, we measured cumulative nearwork time, accommodative facility (AF), and number of asthenopic nearwork symptoms in a sample of young students and office workers.

A variety of measures of accommodative function have been used in clinics (i.e., amplitude, facility, lag, positive and negative relative accommodation) [7]. More complex measures have been used in research (such as tonic accommodation or accommodative adaptation) [8]. For this study we used lens flippers for measuring dynamic accommodative facility [7]. Previous studies have established norms and methodology for the lens flipper test [9, 10]. Hennessey et al. [10] showed an association between AF and asthenopic symptoms in school children. Siderov & Johnston [11] demonstrated that standardization of test distance and size of the letters was very important to obtain reproducible data. Levine et al. [12] emphasized the use of monocular lens flipper training in a young student population, and they furthermore demonstrated an association between monocular lens flipper facility rates and asthenopia.

Hennessey et al. [10] and Levine et al. [12] used questionnaires for their assessment of asthenopia. Each consisted of eight and six questions, respectively,

concerning asthenopic symptoms such as blurring, headaches, burning or tired eyes. Answers were scaled in five possibilities, from never to always. A similar questionnaire was used in the present study (see Appendix). The innovative aspect of this study was that, in addition to the AF and asthenopia that have been measured in previous studies, the cumulative amount of nearwork was also measured.

Material

Subjects consisted of 87 individuals between 18 and 31 years of age, with a mean age of 23.1 $\pm$ 3.2 years. They were selected from outpatients who came to a private practice clinic for a routine vision examination. Patients came to the clinic during the morning before work-time to perform a general health check-up, which consisted of clinical and cardiological examinations and a vision test. We followed the tenets of the Declaration of Helsinki. One examiner (IR), who had no previous knowledge about the amount of nearwork or the asthenopic symptoms of the subjects, evaluated all of the individuals.

Methods

Apparatus

Clinical examination

Uncorrected visual acuity (VA) at distance was obtained using projected Snellen optotypes at 3 m. Distance phoria was measured using the Maddox rod technique with rotating prism, at 3 m [7]. Near phoria was measured with the Thorington test at 33 cm, as this is considered the most reliable test for this measure [13]. Interpupillary distance (in mm) was measured with a millimeter ruler. Moreover, using the last three test results, the distance/near stimulus AC/A ratio was calculated. Furthermore, the near point of convergence was measured using the push-up method [7].

Flipper test

Binocular accommodative facility was measured by means of a $\pm$2 D lens flipper test (in cycles per minute) [7].

Questionnaire

The frequency of asthenopic symptoms and number of hours dedicated to nearwork were obtained from a questionnaire. It was developed by one of the authors (IR) and tested to ensure accuracy and clarity. A pilot sample of fifteen subjects was asked to complete the questionnaire, and they were subsequently queried verbally by the examiner to check for accuracy and clarity. The questions were modified based on the subjects' responses until there was no doubt about the meaning of the questions. Our questionnaire queried the following areas: the number of hours spent daily either working with a computer (PC) or reading hardcopy (during the week and at weekend); the number of months or years performing these tasks; the frequency of asthenopic symptoms (headaches, pain in the eyes, watery eyes, red eyes, double vision, blurred vision, burning eyes).

Procedure

Clinical examination

Selection criteria considered for the study were: previous lens use, the uncorrected visual acuity test at distance, performance under retinoscopy, including fogging with plus lenses, to find hyperopia, and phoria measurement using the cover/uncover test [7] at distance. Cycloplegic refractions were not performed because examinations took place in the morning before work-time and that practice would have interfered with subject's task during the rest of the day. Those subjects found to have been using lenses to correct any manifest refractive error, those who had more than one diopter of hyperopia in the horizontal and vertical meridians under retinoscopy, those with strabismus, or those with uncorrected visual acuity lower than 20/30 in either eye were excluded from this study. Subjects included were asked to participate following informed consent. Then, far and near phorias, interpupillary distance, and the nearpoint of convergence were measured in each subject following the method previously described in Apparatus.

Flipper test

For the binocular flipper test [7, 8], the subject was instructed to fixate and focus upon letters on the 20/40 VA line of a Snellen near-point card at 40 cm distance. As all subjects had a distance VA of 20/30 or better in either eye, and were pre-presbiopic, they could fixate binocularly the 20/40 VA line of the near-point card without problems. The examiner then flipped the $\pm$2 D

lens flipper in front of the subject's eyes in the spectacle plane, instructing him or her to say "now" each time the blurred letters became clear, and to do so as rapidly as possible. Each time the subject said "now", the examiner changed the lens pair (i.e., from -2 to $+2$, and so on). After 20 seconds of practice, when the subject was familiar with the task, the examiner counted the number of responses in the subsequent 30 seconds. This measure was converted to cycles per minute.

Questionnaire

Following these tests, the subject completed the questionnaire. He or she was instructed to reply to the questions to the best of their knowledge.

To obtain "total nearwork time", we summed each subject's number of daily hours of computer use plus hard copy reading. The number of hours of nearwork per weekday was multiplied by five, and that for the weekend was multiplied by two: this gave the total number of hours spent on nearwork in an entire week. This number was multiplied by four times the number of months to obtain the number of hours over the time ("total nearwork time"). The time options were 3 months, 6 months, one year, two years, three years and more. Sixteen percent of the subjects answered one year or less, 15% two years, 16% three years and 53% more time. If a symptom was answered as "never", it was considered as negative. If it was present at least once a week, it was considered positive. The "number of symptoms" was obtained as the sum of the positive symptoms.

All of the above data were analyzed using either a chi-square test for dichotomous variables, or regression analysis in the case of quantitative variables. For testing possible relations between nearwork and either AF or number of symptoms, we performed a regression analysis calculating, the r value as an indicator of the significance of the dependence. Two-tailed Student t-tests (95% confidence limits) were performed to obtain the significance of the slope of the regression. We then tested possible correlations between each symptom and AF or nearwork. As "presence or absence of each symptom" is a dichotomous variable, we used chi square analysis after converting "nearwork" or "AF" into dichotomous variables. In the case of nearwork, we used the median value and considered at risk the group with a high number of working hours. In the case of AF, values under 8 (moderate) or under 4 (definitely severe) cycles per minute were categorized as abnormal [9].

Results

Some of the questionnaire results were examined to check for consistency. For example, average nearwork (hardcopy + PC use) during a weekday was found to be 9 ± 3.7 hours. This is a reasonable time spent in near work for young students who are also engaged in office tasks. Second, in this particular group of subjects, 49% reported headaches at least once a week, 29% pain in the eyes, 32% red eyes, 31% blurred vision, 39% burning eyes, 33% watery eyes but the symptom "double vision" was only present in 2 of the 87 subjects. These two were included among the only three subjects with esophoria in the sample. The small percentage of subjects who complained of double vision is consistent with the results of Hennessey et al. [10], who found that diplopia did not appear to be a significant symptom in subjects with accommodative problems.

The median uncorrected VA was the same for both eyes (0.97 in decimal notation). In all, 74% of the subjects had a VA of 20/20 in either eye. Since the whole sample was over 20/30 in either eye, and every subject with manifest refractive error (already using lenses) was excluded, it is possible that most subjects were near emmetropia.

Average distance phoria was 1.03 ± 1.73 prism diopters; near phoria was -1.65 ± 2.98 prism diopters (exo). Stimulus AC/A ratio was 5.01 ± 0.71 prism diopters/diopters. The data were clustered except for a few outliers. For example, only six of the phoria measurements exceeded the normal range (3 eso and 3 exo) [9]. Seven subjects had manifest convergence insufficiency (nearpoint greater than 6 cm). Table 1 shows that there was no correlation between time spent on nearwork and near phoria in this sample.

Accommodative facility (AF) exhibited less clustered data (Figure 1). Our most important finding was a negative correlation between "total nearwork time" and AF ($r = 0.213$; $p \leq 0.048$). This correlation achieved statistical significance for the subcategory of "hours spent reading over the years" ($r = 0.244$; $p \leq 0.022$). (See Table 1 and Figure 2). To check if this association could be an effect of lower accommodative performance or more cumulative reading as age increased, we separated the subjects into two group ages with a median of 22.5 years. The younger subjects had on average, spent 4224 hours reading over the years and the older ones 4378 hours; this difference was not significant (Student t test $p \leq 0.715$). The average cycles per minute for

Table 1. Correlations

Variables		*R*	*p* value	Conclusion
Hours of reading during a week	vs. Number of symptoms	0.244	0.022	Significant
Hours of PC use during a week	vs. number of symptoms	0.087	0.418	–
Hours of reading + PC use during a week	vs. number of symptoms	0.255	0.017	Significant
Hours of reading over the years	vs. number of symptoms	0.251	0.018	Significant
Hours of PC use over the years	vs. number of symptoms	0.126	0.243	–
Total nearwork time	vs. number of symptoms	0.241	0.024	Significant
Hours of reading during a week	vs. AF	0.15	0.150	–
Hours of reading over the years	vs. AF	0.244	0.022	Significant
Hours of PC use over the years	vs. AF	0.08	0.461	–
Total nearwork time	vs. AF	0.213	0.048	Significant
Near phoria	vs. AF	0.052	0.630	–
Hours of reading during a week	vs. near phoria	0.054	0.616	–
Hours of PC use during a week	vs. near phoria	0.112	0.299	–
Hours of reading + PC use during a week	vs. near phoria	0.13	0.226	–
Hours of reading over the years	vs. near phoria	0.087	0.422	–
Hours of PC use over the years	vs. near phoria	0.048	0.655	–
Total nearwork time	vs. near phoria	0.086	0.425	–

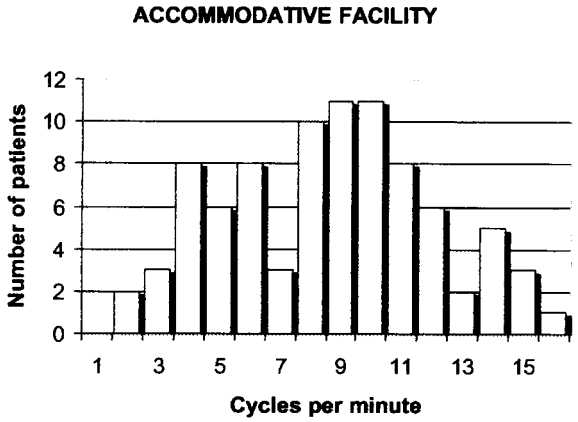

Figure 1. Accommodative facility distribution (average AF: 8.7 ± 3.5 cycles per minute).

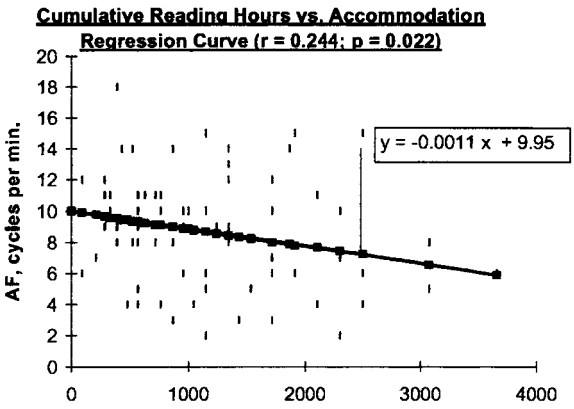

Figure 2. Regression curve for cumulative reading hours vs. AF.

the flipper test was 8.8 for the younger and 8.5 for the older group, which was not significant (Student *t* test $p \leq 0.6812$). Thus, the nearwork correlations were not related to age.

Chi-square analysis was used to compare presence or absence of symptoms with either AF or nearwork (converted into dichotomous variables). A positive correlation was observed between "total nearwork time" and "number of symptoms" ($r = 0.241$; $p \leq 0.024$) (Table 1 and Figure 3), achieving greatest significance for the subcategory of "blurred vision" ($X^2 = 9.516$; $p \leq 0.002$) (see Table 2). Furthermore, there was a significant association between "blurred vision" and moderately reduced values of AF (<8 cycles/min.) ($X^2 = 9.379$; $p \leq 0.002$), as well as severely reduced values of AF (<4 cycles/min.) ($X^2 = 10.418$; $p \leq 0.001$) (see Table 2). We recalculated the correlation of the values AF vs. blurred vision, taking into account reported frequency (as a continuous variable), and found a similar negative correlation ($r = 0.28$; $p \leq 0.0097$) (i.e., the greater frequency of blurred vision, the lower AF value) (Figure 4).

Table 2. Chi square analysis

Variables		Chi-square value	*p*	Conclusion
Hours of reading during a week	vs. blurred vision	3.940	0.047	Significant
Hours of reading during a week	vs. burning eyes	4.800	0.028	Significant
Hours of reading + PC use during a week	vs. blurred vision	8.410	0.004	Significant
Hours of reading over the years	vs. blurred vision	9.516	0.002	Significant
Hours of reading over the years	vs. burning eyes	3.400	0.065	Trend*
Hours of PC use over the years	vs. red eyes	6.420	0.011	Significant
Total nearwork time	vs. red eyes	5.612	0.018	Significant
Total nearwork time	vs. blurred vision	9.516	0.002	Significant
AF < 8	vs. blurred vision	9.379	0.002	Significant
AF < 8	vs. watery eyes	4.535	0.033	Significant
AF < 4	vs. blurred vision	10.418	0.001	Significant
AF < 4	vs. watery eyes	5.471	0.019	Significant

* Although the *p* value is greater than 0.05, it is very near the level of significance; with bigger population *p* values, could be smaller than 0.05.

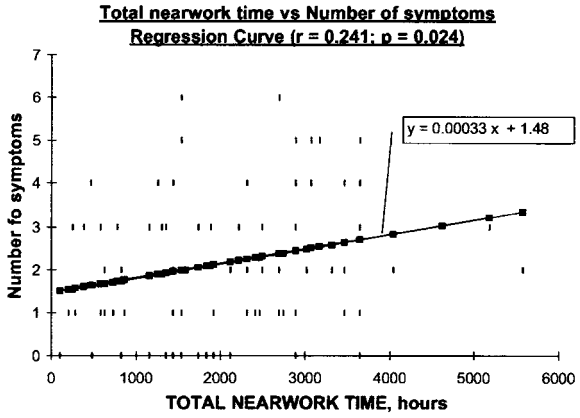

Figure 3. Regression curve for total nearwork time and number of symptoms.

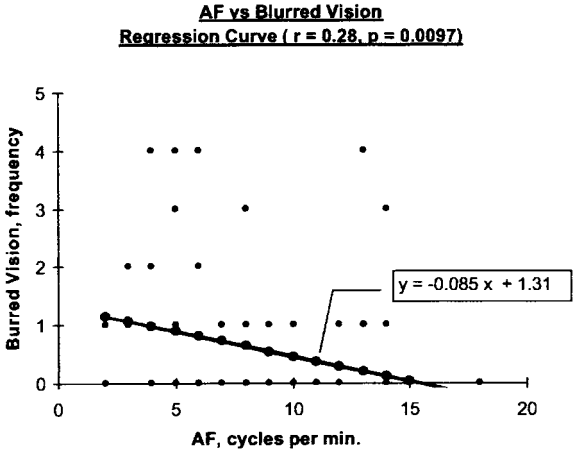

Figure 4. Regression curve for AF values and frequency of blurred vision, from never (0) to always (4).

Discussion

In the present study, it was found that increased nearwork was significantly correlated with decreased AF and increased asthenopic symptoms (especially blurred vision). These results suggest a relationship between performing nearwork and reduced AF values. This is supported by recent findings on accommodative adaptation [3] and nearwork-induced transient myopia [4], which demonstrated that "blurred vision" may be related to short periods of sustained and intense nearwork. Accommodative adaptation to a 20-minute task elicited similar changes in both accommodative decay following nearwork and the monocular AF responses [14]. Intense nearwork has been associated with adult-onset myopia progression in a prospective study in adult microscopists [6]. We have now shown for the first time a retrospective correlation between cumulative nearwork and AF.

Another important issue is the comparison between computer use and reading habits. Cole et al. [15] studied two groups of office workers, one with and one without the use of computers (PC). They did not find a significant difference in asthenopic symptoms between the two groups. In their study, symptoms related to glare, red eyes, and blurred vision, were slightly more frequent among the PC users. In the

present study (Table 2), the number of symptoms was more associated with hardcopy reading than with PC use. Also, the symptoms of "blurred vision" and "burning eyes" were associated more with reading hard copy than with PC use, whereas the symptom of "red eyes" was associated more with PC use (Table 2). We agree with Cole et al. [15] in the sense that PC use under current ergonomic conditions is no different from hardcopy with respect to the development of asthenopic symptoms. However, our data show the importance of reading in the development of asthenopic symptoms. Reading typically presents a greater stimulus for accommodation, because it is usually done at 40 cm (2.50 D) distance, while computers are viewed at 70 cm (1.4 D) and hence represents only about 50% of the near demand. As shown in Table 1, the correlation of AF with reading had a greater significance level than that of AF with the use of computers.

The AF test is a dynamic measure, which is important for assessing the overall time course or "speed" of the accommodative response; in contrast, the accommodative amplitude, relative accommodation and lag of accommodation can be considered static or steady-state measures. Wick & Hall [16] measured accommodative amplitude, facility and lag in a sample of schoolchildren, and they found only a moderate relationship among them. Moreover, Jackson & Goss [17] showed that other tests measuring accommodation, which were mostly static rather than dynamic measures, were not well correlated with AF tests. Thus, the AF test appears to be a valuable test for measuring the overall dynamics of accommodation in the clinic, as it is correlated with symptoms and nearwork duration.

The present results also confirm previous findings [10] of an association between accommodative facility and asthenopia (especially with the symptoms of blurred vision). We also found a correlation between the amount of nearwork and some of the asthenopic symptoms (e.g., blurred vision, burning, and red eyes). More importantly however, a correlation was found between the cumulative amount of time spent on nearwork over a period of years and reduced accommodative facility. This suggests that the cumulative amount of nearwork adversely affects dynamics of the accommodative system in young individuals. Perhaps this can be conceptualized as producing a very mild conditioned spasm of accommodation due to sustained focusing at near stimulus levels over extended periods of time (months and years). This is consistent with recent findings [2, 4] demonstrating very slow and irregular decay of NITM in symptomatic individuals, even under binocular viewing conditions with the presence of blur and disparity feedback.

Therefore, we propose that accommodative facility should be routinely assessed in asthenopic patients, as well as in asymptomatic individuals performing intense nearwork. It would be diagnostic in the former and preventative in nature in the latter group. To provide remediation in symptomatic patients with low AF measures, orthoptic treatment is a possible recommendation if future research confirms its effectiveness [8, 18, 19, 20].

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Appendix – Patient Symptom Questionnaire

Feel free to respond to this questionnaire because it is anonymous. The data you provide will be analysed with the data of many other people, and then published.
(Make an X where necessary)

1. In **A WEEK DAY**, summing up work, study and pleasure,

How many hours do you spend reading? None, 1, 2, 3, 4, 5, 6, 7, 8, 9, More.

How many hours using a computer? None, 1, 2, 3, 4, 5, 6, 7, 8, 9, More.

2. On **SATURDAYS OR SUNDAYS**, summing up work, study and pleasure,

How many hours do you spend reading? None, 1, 2, 3, 4, 5, 6, 7, 8, 9, More.

How many hours using a computer? None, 1, 2, 3, 4, 5, 6, 7, 8, 9, More.

3. How long have you been doing this amount of nearwork?

3 months 6 months 1 year 2 years 3 years More time

4. During a week, you may experience:

	Never	1 or 2 days	3 or 4 days	5 or 6 days	Every day
Headaches					
Pain in the eyes					
Red eyes					
Blurred vision					
Double vision					
Burning eyes					
Watery eyes					

. . . . . .

Thank you for your help.

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Address for correspondence: R. Iribarren, Department of Ophthalmology, Centro Médico San Luis, San Martín de Tours 2980, 1425 Capital, Argentina
Phone/Fax: 54-11-4801-8050; E-mail: rafael@ar.inter.net