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Measuring Near Induced Transient Myopia in College Students with Visual Discomfort

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Abstract

Purpose—Visual discomfort is a common problem and our previous research indicated that 17% of college students experience moderate to high levels of discomfort when reading or studying. There have been several visual factors associated with visual discomfort and in this study we focused on measuring the near induced transient myopia (NITM) response in a group of college students with significant visual discomfort.

Methods—Visual discomfort was evaluated with a survey developed by Conlon et al (1999). Twelve college students with high visual discomfort (scoring one standard deviation higher than the mean value) and 12 college students with low visual discomfort (scoring within one-half standard deviation of the mean value) participated in the study. All students had 20/25 or better visual acuity, no strabismus, and no significant uncorrected refractive error. All refractive error and accommodative measurements were made with the WAM-5500 auto-refractor. A pre-task distance refraction at 6 m was taken for 60 sec and then the students read a story for 10 min at 20 cm. After reading the passage the post-task distance refraction was measured for 2 min at 6 m. Values for the pre- and post-task measures were averaged in 10 sec blocks of time.

Results—A mixed ANOVA comparing discomfort group by pre- and post-near work distance refraction showed a significant interaction ($p=0.05$). Comparing the means of the pre and post task distance refraction indicated that the high discomfort group showed no change in refractive error but the low discomfort group showed a myopic shift of 0.13 D.

Conclusions—An NITM response is not associated with high visual discomfort experienced by college students when reading or doing near work.

Keywords

visual discomfort; asthenopia; accommodation; visual fatigue; autorefractor; myopia

Despite normal visual acuity, reading and other near point activities can be an uncomfortable and difficult task for some people due to frequent and severe symptoms, such as asthenopia, text distortions, and double vision.^{1, 2} This condition has several names including, visual

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discomfort¹, visual fatigue^{3, 4}, asthenopia^{5, 6}, and recently, Irlen-Meaers syndrome.^{7, 8} Previous research has indicated that visual discomfort when reading and studying is common in college students.^{1, 2} Several visual factors have been associated with visual discomfort including pattern glare, uncorrected refractive errors, and disorders of accommodation or vergence.⁷⁻¹³ In this study, we have focused on accommodation as a potential source of visual discomfort in college students.

The association of clinical tests of accommodation and visual discomfort symptoms has led to conflicting results. For example, when measuring accommodation facility in adults, some studies have found no association between visual discomfort symptoms and number of cycles per minute achieved by the subject.^{14, 15} In contrast, Wick et al¹⁶, using an approach taking into account the amplitude of accommodation did find an association between accommodative facility and visual discomfort symptoms. In an attempt to address some of the conflicting results in clinical accommodative studies, a recent study by Chase et al¹⁷ compared an objective accommodative measurement of a stimulus response curve to standard clinical tests. The study found that the increase in the lag of accommodation developing over time at a viewing distance of 20 cm was better at predicting visual discomfort symptoms than clinical testing. Chase et al¹⁷ concluded that traditional clinical measures of accommodation rely on tests that require the subjective report of blur, which may not accurately reflect actual accommodative functioning. This result is consistent with others studies that have measured accommodation using clinical and objective measures.¹⁸⁻²⁰

An open field auto-refractor allows for an accurate and objective depiction of accommodation without relying on the individual's interpretation of blur.^{19, 21} Using an auto-refractor, our previous study demonstrated that college students with visual discomfort exhibit an increase in the lag of accommodation over time while viewing a near point target.²² An increase in the lag of accommodation at near has several potential sources including the initial level of tonic accommodation, accommodative insufficiency, inadequate adaptation, abnormal AC/A or CA/C ratios, and fatigue of accommodation. Using computer simulation of two models of accommodation, Schor²³ investigated the relationship between the lag of accommodation and interactions between accommodation and vergence. The results of the simulation found that uncorrected hyperopia and esophoria led to an increase in accommodation lag whereas myopia and exophoria led to a decrease in accommodative lag. One interesting result of the simulation was that inclusion of tonic adaptation in the model led to reduced steady state errors of accommodation for all conditions except when the AC/A was very high. Schor argued that the tonic adaptors of accommodation would relieve the activity of the phasic system which would in turn lead to a reduction of the steady state error of accommodation.

Accommodative adaptation or hysteresis is a transient increase in the magnitude of accommodation following a period of sustained near viewing and can be measured under open or closed loop conditions.²⁴ This is not a true change in the accommodative system and the response returns to the original accommodative level following removal of the near stimulus. The adaptation can be measured by determining the tonic level of accommodation before and after an extended near point task. The apparent increase in the tonic level of accommodation following a near task may reflect the slow decay of the slow blur driven accommodative response to the near stimulus.^{25, 26} The relationship between adaptation and lag of accommodation was investigated by Rosenfield and Gilmartin, who examined accommodative lag during sustained near viewing.²⁶ The subjects were classified as either adaptors (adaptation exceeding 0.30D) or non-adaptors (adaptation less than 0.30). The adaptor group showed a significant reduction in lag during the near viewing activity when compared to the non-adaptor group. This result is in agreement with the model simulation of Schor and suggests that adaptation of accommodation may play a role in determining the magnitude of accommodative lag.

The transient increase in the accommodative response following near point tasks can also lead to specific symptoms of distance blur and possibly visual discomfort and can be measured under closed loop conditions. Ciuffreda and Ordonez assessed 3 subjects complaining of blurred vision following near point tasks using the Near Induced Transient Myopia (NITM) paradigm.²⁷ The pre-task distance refraction was measured, then subjects viewed a near point target at 20 cm for 10 minutes, and a post-task distance refraction was taken. In contrast to measures of tonic accommodation done when blur is removed, the NITM response is measured under closed loop condition that allows for blur feedback to influence the accommodative state. The symptomatic group showed a large post-task myopic shift with perception of transient blur, slowed dissipation of the initial myopic shift, and increased variability in the post-task response. Thus, an abnormally high amount of NITM may lead to blur symptoms after intensive near work in real world viewing conditions.

In contrast to the above study, Fisher et al²⁸ assessed tonic adaptation in symptomatic and asymptomatic adults and found little difference between the groups. Both groups showed significant adaptation during 45 minutes of near viewing at 20 cm, with the symptomatic group showing increasing adaptation during the near viewing task. In this study the primary symptoms were related to near work and not distance vision blur and this may account for the different result when compared to Ciuffreda and Ordonez. A potential criticism of Fisher et al study is that the symptomatic and asymptomatic groups were classified with a non-standardized survey of visual discomfort. Subjects were classified as symptomatic if a response of 3 or lower was made on any individual item on the survey. Recent research using surveys developed by Conlon et al and the Convergence Insufficiency Treatment Trial Group show that many adults report some symptoms of visual discomfort when reading and studying and that the severity of symptoms has to be significant to be considered outside of the normal range that exists within the general population.^{1, 2} In the Fisher et al study, the symptomatic group could have been in the high normal range of symptoms and not in the range that would be considered abnormal. There is a need to investigate accommodative aftereffects in individuals who report moderate to severe symptoms as found by a valid and reliable survey. Thus, we investigated the NITM response in college students with and without significant visual discomfort.^{29, 30}

METHODS

Subject

Students from the Claremont Colleges Consortium (Claremont McKenna, Harvey Mudd, Pitzer, Pomona, and Scripps) participated in this study. These five private, undergraduate colleges collectively have over 6,000 students. Informed consent was obtained from all subjects and the study was approved by the Institutional Review Board at Claremont McKenna College.

The sample was randomly selected from two groups; one with moderate to severe visual discomfort symptoms at the initial testing time and one with symptoms in the normal range for this college sample. Visual discomfort was evaluated with a survey developed by Conlon et al¹ which yields scores ranging from 0 to 69 (see Table 1). Students scoring one standard deviation higher than the mean value for the Conlon et al survey were classified as high visual discomfort and students scoring within one-half standard deviation of the mean or lower were considered low visual discomfort.^{1, 2, 31} An effort was made to recruit equal numbers of students from low and high discomfort groups.

The inclusion criteria were 20/25 visual acuity or better in each eye at distance and near, no strabismus, appreciation of random dot targets and stereoacuity of 70 seconds of arc or better. Exclusion criteria were uncorrected refractive error (myopia of > 0.50 , astigmatism and anisometropia of ≥ 1.00 D, and hyperopia ≥ 1.50 D), and ocular pathology, including color deficiency (pass the Ishihara plates and the L'Anthony D-15 test).

Each subject who participated in this study received a comprehensive optometric evaluation of accommodation and vergence.¹³ The testing was done by one of the researchers (EB). The instructional sets were standardized and EB was masked to the score on the Conlon survey. Vergence was evaluated with four tests: (1) a cover test at 3 meters and 40 cm with prism neutralization to assess phoria; (2) prism bar negative fusional vergence (NFV) and positive fusional vergence (PFV) at 40 cm; (3) near point of convergence using an Astron Rule with reduced Snellen letters (NPC); and (4) vergence facility (12 BO/3 BI). Accommodation was evaluated with four tests: (1) posture of accommodation using the monocular estimation method (MEM), (2) negative relative accommodation (NRA) and positive relative accommodation (PRA) at 40 cm, (3) amplitude of accommodation (push up method), and (4) monocular and binocular accommodative facility (AF) using ± 2.00 diopters flippers at 40 cm. A mean of three measurements was used except for facility testing, cover test, and MEM. A two sample t-test compared the mean values between the high and low visual discomfort groups and showed no significant differences between the two groups on any of the optometric measures of accommodation or vergence ($p > 0.08$ for all tests)

All measurements of refractive error and accommodation were made with the Grand Seiko WAM-5500 auto-refractor which samples continuously at 5 Hz. The data from the WAM-5500 is automatically transferred to a Microsoft Excel file while in the continuous recording mode. This device is similar to the Grand Seiko 5100 which has been evaluated for clinical use.^{21, 32, 33} The accuracy of the WAM-5500 was checked with the supplied model eye. Previous research has shown the within session repeatability of the Grand Seiko 5100 is 0.11 D for the spherical component and a between session agreement of ± 0.50 D for 95% of subjects.²¹

Subjects were dark adapted for five minutes prior to starting the NITM procedure. Baseline refractive error at 20 ft was then taken for 60 sec while the subject viewed the 20/30 line on a Snellen chart. Subjects were then instructed to read chapters from the Count of Monte Cristo for 10 min at a viewing distance of 20 centimeters. The text was printed in Times New Roman 10 point font. The subjects were told to keep the text in focus and to remember what they had read. Recordings were made in a well lit room (85 cd/m² luminance for a white piece of paper). Two 30 sec recordings were taken at 3 and 7 minutes to insure that the students were capable of focusing on the text. Immediately after the reading task, the accommodative posture was measured for 2 min at 6 m while the student viewed the Snellen chart at 6 m. This is the post-task distance refraction.

Data Analysis

Values for the pre- and post-near work distance refraction measures were averaged in 10 second blocks of time with outlier data points of more than three standard deviations removed. Mean values were calculated for the 60 seconds of recording for pre-reading and the 120 seconds of post-reading measures. Post-reading data was trimmed to 110 seconds due to missing data for six subjects during the last ten seconds of recording. Four analyses of the NITM data were performed. First, we made t-test comparisons between the two groups on the pre-task distance refraction mean values and accommodative responses at the 3- and 7-minute points during reading. Second, we compared the average pre- and post-task distance refraction responses in the two groups in a mixed-ANOVA design. Third, we compared the post-task distance refraction in both groups using a repeated measures ANOVA. T-test comparisons were made between baseline and post-reading time points for each group. Fourth, the one-minute pre-reading measures of distance refraction were examined for stability using a mixed-repeated measures ANOVA. Analyses were performed using Statview 5.0 (SAS Institute Inc., Cary, NC) and PASW Statistics 17.0.2 (SPSS Inc., Chicago, IL).

RESULTS

Subjects

Twelve college students with high visual discomfort and 12 college students with low visual discomfort participated in the study. There were 11 females in the high discomfort group and 7 females in the low discomfort group. All subjects were between 18 and 22 years of age. The mean Conlon survey symptom score for the high visual discomfort group was 32.6 (SD = 5.8) which consisted of students with largely moderate symptoms. The mean Conlon survey symptom score for the low visual discomfort group was 10.4 (SD = 5.5).

The mean response for the pre-task distance refraction was -0.22 D (SD=0.39) in the high visual discomfort group and was -0.28 D (SD= 0.29) in the low visual discomfort group. A two sample t-test showed no significant difference between the two groups on the pre-task distance refraction ($t(22)=0.45$, $p=0.66$). We measured the students' accommodative response at 20 cm while the subjects read the story at 3 and 7 minutes for 30 seconds. The mean response at 3 minutes was -4.28 D (SD=0.31) for the high discomfort group and -4.36 D (SD=0.46) for the low discomfort group. The mean response at 7 minutes for the high discomfort group was -4.18 D (SD=0.35) and -4.18 D (SD=0.46) for the low discomfort group. A two-tailed t-test comparison of the means between the high and low groups for 3 minutes ($t(22)=0.50$, $p=0.62$) and 7 minutes ($t(21)=0.01$, $p=0.99$ data missing for one low discomfort patient) were not significantly different.

The mean post-task distance refraction was -0.19 D (SD= 0.42) in the high visual discomfort group and was -0.41 D (SD=0.33) in the low visual discomfort group. A mixed, two factor ANOVA with discomfort group as the between factor and a repeated measure factor of the mean pre- and post-near work distance refractive error showed a significant interaction ($F(1,22) = 4.20$, $p=0.05$) but no main effects (Group: $F(1,22) = 0.95$, $p=0.34$; Pre/post: $F(1,22) = 1.85$, $p=0.19$). Post hoc one-tailed t-tests showed that the high discomfort group did not change in their pre-post task distance refraction ($t(11) = -0.44$, $p=0.67$), but the low discomfort group showed a myopic shift ($t(11)=2.73$, $p=0.01$). (See Figure 1) Using the NITM response of the low visual discomfort group as cut-off criteria (average = 0.1 D, SD = 0.2 D), only 1 of the 12 subjects in the high discomfort group showed a greater than 0.10 D myopic shift. In contrast 9 of 12 students in the low discomfort group showed a greater than 0.10 D myopic shift.

Distance refraction was evaluated over time for both the pre- and post-task data. A repeated-measures ANOVA was conducted for each of the groups with the post-task distance refraction measured over the 110 second time period averaged in ten second blocks as the within factor. Data were examined with Mauchly's test of Sphericity, and a correction was applied to within subject effects when data was non-spherical. Time was a significant factor, $F(10,110) = 3.68$, $p = 0.01$ (Greenhouse-Geisser correction) for the high discomfort group, but there were no significant effects for the low discomfort group. The high discomfort group showed a quadratic trend ($F(1,11) = 15.11$, $p = 0.003$) producing a minor reduction in the post-task distance refraction over the first forty-seconds and then a relatively stable response. Figure 2 shows the baseline, and NITM response in each group over time with t-test comparisons between each data point and baseline values.

A repeated-measures ANOVA examining the pre-task distance refraction data found no significant effect for Time, Group, or Time by Group interaction. Figure 3 presents these data.

DISCUSSION

The high visual discomfort group showed no change in average distance refraction response after 10 minutes of near work. In contrast, the low visual discomfort group showed a small but

significantly different mean myopic shift of 0.13 D. These changes in refraction are unlikely to be due to normal fluctuations in accommodation since the pre-task data were stable for both groups during a one-minute recording period.

The paradigm uses closed loop viewing conditions and other factors could have influenced the NITM response. It could be argued that the high discomfort group may have had more subjects with latent hyperopia. Although we did not perform a refraction with a cycloplegic agent on our subjects, the high visual discomfort mean refractive status was -0.22 in the pre NITM condition after 5 minutes of dark adaptation. The NITM measure was made under binocular condition and another factor that could have influenced the NITM response was the presence of vergence anomalies in the high discomfort group. However, a comparison of near phoria, near point of convergence, and fusional vergence ranges showed no significant differences between the two groups. There was not a difference in the calculated AC/A ratio between the two groups, however, we did not measure the CA/C ratio and cannot rule potential group differences on this parameter. Thus, the group differences found in our study would not likely be attributed to uncorrected refractive errors or a higher frequency of students with significant phorias in the symptomatic group.

The measurement of lag during the near reading task at 3 and 7 minutes for 30 seconds did not show any significant differences in accommodative accuracy between the two groups. This finding indicates that both groups were capable of accommodating accurately to a 5 diopter target. However, we cannot conclude with certainty that both groups maintained the same level of accommodative response for the entire 10 minutes of reading. Previous studies looking at adaptation effects have tended to not use continuous recording of accommodation during the near task and instead, sample the accommodative response at certain times. Our previous study did indicate that students with high visual discomfort tended to show a higher lag over time when viewing a target at 5 diopters. In our previous study the lag of accommodation was measured under monocular conditions as opposed to binocular viewing in the current study. In addition, the previous study measured accommodation for 2 minute intervals instead of 30 seconds. We hope to create a methodology that will allow for both continuous recording of accommodation at near and measurement of accommodative adaptation to address this potential source of bias in the current experimental paradigm.

The NITM response observed in our study was small but similar to previous research using similar methodology. Ciuffreda and Wallis measured NITM in early onset myopes, last onset myopes, emmetropes, and hyperopes before and after a 10 minute binocular task at 20 cm.³⁴ The values for the group ranged from minimal response in hyperopes to almost a 0.4 D myopic shift in the myopic groups during the first 10 seconds following the near task. Our values in the first 10 seconds for the low discomfort group was -0.49 D or a 0.21 myopic shift and for the high discomfort group was -0.29 D or a 0.07 myopic shift. These values fall within the range reported in the above studies and would represent typical NITM values using a 10 minute near task at 20 cm when measuring a group of subjects with mixed refractive errors.

Our results indicate that students with visual discomfort show no NITM response compared to previous studies in young adult myopes who show a more robust NITM response.^{29, 30, 35} Although, we did not take a comprehensive history about the onset of wearing an optical correction in our group, the distribution of students wearing refractive correction was similar between the two groups. In the high discomfort group six students wore no correction, two students wore glasses and four students wore contact lenses and in the low discomfort group five students wore no correction, one student wore glasses, and six students wore contact lenses.

Our results indicate that visual discomfort in our selected group of college students was associated with no NITM response and not an excessive hysteresis response. This finding is

not consistent with the Ciuffreda and Ordonez study where subjects complaining of distance vision blur showed a significantly higher NITM response when compared to subjects who did not complain of blur.²⁷ However, our students with visual discomfort had primarily complaints associated with near vision problems. There may be different sub-types of accommodative dysfunction that could be associated with particular symptoms.

Our results are in conflict with the previous study of Fisher et al²⁸ who found that both symptomatic and asymptomatic groups had a myopic shift after 45 minutes of near work. There are several factors that may have accounted for the contradictory findings between our study and Fisher et al. First, we used the NITM paradigm that uses closed loop conditions instead of open loop measurements. Students with visual discomfort may not show adaptation when assessed using closed loop condition. Second, it should be noted that Fisher et al's near adapting task was 45 minutes long instead of 10 minutes, and they did note that the development of adaptation increased over time in the symptomatic group. Our students may have shown an NITM response with longer near viewing times. Finally, our symptomatic group was based on results of the Conlon et al survey which has been administered to a sample of over 600 students where as, Fisher et al did not use a survey instrument with norm referenced scores. Thus, poor accommodative adaptation may be more likely in students with a higher level of symptoms.

Ciuffreda and Wallis³⁴ have argued that NITM is a closed loop manifestation of the open loop accommodative adaptive response. The lack of an NITM response in the high discomfort group may indicate a problem in the open loop accommodative adaptive response. This may account for the result in our previous study where we found an increase in the lag of accommodation with extended monocular viewing in college students with high visual discomfort. This hypothesis is consistent with the study by Rosenfield and Gilmartin where the amount of adaptation in accommodation was associated with a reduction in the lag of accommodation.³⁶ However, we did not look directly at the open loop adaptation response and lag of accommodation in this study. In a future study we plan to develop a paradigm that looks at the continuous measurement of lag of accommodation and degree of adaptation to investigate the above hypothesis directly.

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Figure 1.

The pre and post task distance refraction for the high and low visual discomfort groups with standard error bars.

Figure 2.

The mean pre-task distance refraction accommodation response (filled symbols), and post-task distance refraction over time are shown for the high and low visual discomfort groups with standard errors bars (± 1 SEM). Data points with significant differences from baseline are identified by asterisks: * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 3.
Distance autorefraction response at baseline with standard error bars (± 1 SEM).

Table 1

Survey developed by Conlon et al.¹ Each question is rated on the following scale and attached a point value as follows: event never occurs (0); occasionally, a couple of times a year (1); often, every few weeks (2); and almost always (3).

01. Do your eyes ever feel watery, red, sore, strained, tired, dry, gritty, or do you rub them a lot, when viewing a striped pattern?
02. Do your eyes ever feel watery, red, sore, strained, tired, dry or gritty, after you have been reading a newspaper or magazine with clear print?
03. Do your eyes ever feel watery, red, sore, strained, tired, dry or gritty, when working under fluorescent lights?
04. How often do you get a headache when working under fluorescent lights?
05. Do you ever get a headache from reading a newspaper or magazine with clear print?
06. When reading, do you ever unintentionally re-read the same words in a line of text?
07. Do you have to use a pencil or your finger to keep from losing your place when reading a page of text in a novel or magazine?
08. When reading do you ever unintentionally re-read the same line?
09. When reading do you ever have to squint to keep the words on a page of clear text from going blurry or out of focus?
10. When reading, do the words on a page of clear text ever appear to fade into the background then reappear?
11. Do the letters on a page of clear text ever go blurry when you are reading?
12. Do the letters on a page ever appear as a double image when you are reading?
13. When reading, do the words on the page ever begin to move or float?
14. When reading, do you ever have difficulty keeping the words on the page of clear text in focus?
15. When you are reading a page that consists of black print on white background, does the background ever appear to overtake the letters making them hard to read?
16. When reading black print on a white background, do you ever have to move the page around, or continually blink to avoid glare which seems to come from the background?
17. Do you ever have difficulty seeing more than one or two words on a line in focus?
18. Do you ever have difficulty reading the words on a page because they begin to flicker or shimmer?
19. When reading under fluorescent lights or in bright sunlight, does the glare from the bright white glossy pages cause you to continually move the page around so that you can see the words clearly?
20. Do you have to move your eyes around the page, or continually blink or rub your eyes to keep the text easy to see when you are reading?
21. Does the white background behind the text ever appear to move, flicker, or shimmer making the letters hard to read?
22. When reading, do the words or letters in the words ever appear to spread apart?
23. As a result of any of the above difficulties, do you find reading a slow task?