Effect of Computer Monitor Distance on Visual Symptoms and Changes in Accommodation and Binocular Vision

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ABSTRACT Visual symptoms are the most common complaints associated with prolonged computer use. We investigated effects of accommodation and vergence demands specified by the computer monitor viewing distance on the development of visual symptoms and visual function changes. Ten 18-35 year-old subjects performed a two-hour, visually demanding, text-viewing task at three viewing distances over three days. The visual angle of the character size was held constant. We measured changes in several static and dynamic properties of accommodation and binocular vision before and for 90 minutes after the viewing task. The 100 cm viewing distance induced less lead effect for accommodation to a distant target and less lag retention for accommodation to a near target. On the other hand, the viewing distance of 33 cm introduced less eye irritation or tearing symptoms and a higher overall dynamic convergence response compared to longer viewing distances. There were weak associations between changes in binocular functions and visual symptoms. While the symptoms were influenced by the viewing distance, they cannot be fully explained by the changes in the visual functions measured here.

INTRODUCTION

Visual symptoms such as blurred vision and eyestrain are the most common symptoms associated with prolonged computer use. In addition, reduced productivity among office workers may be due to small uncorrected refractive errors even when symptoms are unreported (Daum et al., 2004). Approximately 75% of optometric patients who use a computer regularly (2 hrs and more a day) are likely to be symptomatic (Salibello & Nilsen, 1995). Excess demands on the oculomotor systems of accommodation (eye's ability to focus) and vergence (the ability to simultaneously fixate with both eyes together on the target of interest) have been suggested to be a cause for non-specific visual symptoms associated with computer use (Sheedy et al., 2003). Viewing distance typically determines the focus and fixation demands on the viewer. Longer viewing distances (e.g. 70-100 cm vs. 50 cm) are preferred if the relative character size is held constant (Jaschinski-Kruza, 1988, 1990). However, if the character size is not changed, closer viewing distances reduce symptoms and improve convergence recovery (Rempel et al., 2007). Questions remain regarding associations between visual symptoms and the accommodation and convergence demands during computer use (Collins et al., 1990; Neugebauer et al., 1992).

PURPOSE

Our goal was to quantify the effects of monitor distance during a two-hour, visually demanding, text-viewing task and examine associations between visual symptoms and objective measures of accommodation and vergence. The outcome measures were collected at 30-minute intervals for 90 minutes following the viewing task.

METHODS

Ten normally sighted subjects, aged 18-35, participated in this study. On three separate days, each subject performed a visually demanding reading task on a computer monitor over a two-hour period. The assigned viewing distance was 100, 50, or 33 cm for the workstation shown in Figure 1. The order of viewing distance was randomized. These viewing distances present accommodation demands of 1, 2, and 3 diopters (D), and convergence demands of 6, 12, and 18 prism diopters (PD) respectively. The size of the characters was adjusted so that the angular subtense of the characters was the same at the different viewing distances.

The chair and monitor heights were adjusted to the subject's anthropometry. The subject's head position was stabilized by a chin rest and brow bar. One of the three high-resolution LCD monitors was placed on a ramp at the assigned distance along a gaze angle of 14.3 deg to the center of the monitor. The three monitors were selected so that the relative resolution was the same at the three distances. Luminance level of each monitor was measured and adjusted so that the luminance was the same for each display condition. Apertures were used to cover the display frame to minimize accommodation bias due to perceived size of the monitor and to maintain a constant field of view. The distances and sizes of the apertures were calculated to allow binocular viewing of the test area. The room was lit at a recommended office lighting level.

Figure 1 The workstation with the monitor set up at 100cm viewing distance.

The visually demanding task was a visual search task, similar to common document editing, involving the use of a mouse. A paragraph of random character words consisting of 16 lines of text at 30 characters per line (Figure 2) was displayed in the center of the computer screen. Each word was between 1 and 10 characters separated by a space. The size of the font was adjusted to correspond to about 10 arcmin on the retina. Monitor resolutions and sizes were chosen to vary letter size while maintaining similar pixel characteristics of the fonts. Subjects inspected nonsense words and identified when one word began with the same letter that ended the previous word by clicking on the space between the words with the mouse cursor, akin to common document editing tasks (Jaschinski-Kruza, 1990; Rempel et al., 2007). After finishing a page, the subject right clicked the mouse to continue, and a page showing the number of mistakes appeared for one second before moving onto the next page.

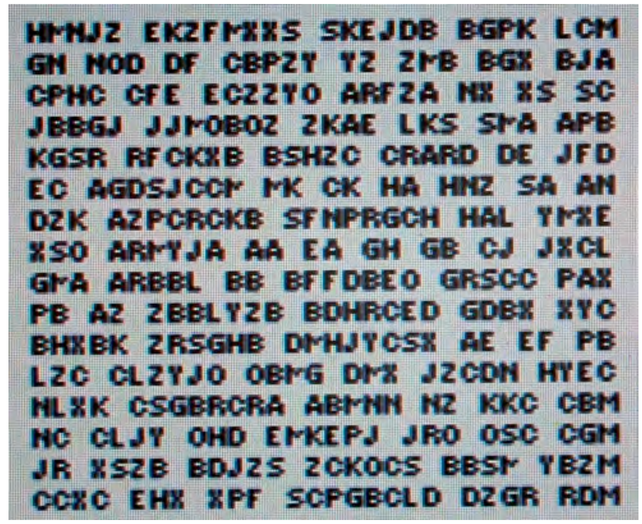

Figure 2 Snapshot image of the visual search task.

Outcome measures were collected before the task began (‘t1’), and at 0 (‘t2’), 30 (‘t3’), 60 (‘t4’), and 90 (t5) minutes after completion of the task (Figure 3).

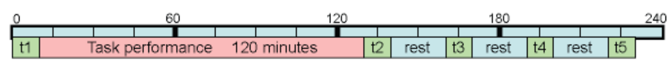

Figure 3 Time course of a session: ‘t1’ to ‘t5’ represent the baseline, post-task, and three recovery measurements.

Objective outcome measurements included static and dynamic accommodative and vergence responses to various oculomotor function tests (Table 1). Most accommodative and vergence responses were measured with Power Refractor II (Plusoptix GmbH, Nuremberg, Germany) using infrared photoretinoscopy technology at the measurement station.

Outcome Measures		
SYMPTOMS	ACCOMMODATION	CONVERGENCE
Questionnaire *Visual analog scale* **1. Blurred vision** **2. Eye strain** **3. Irritated eyes** **4. Headache** **5. Neck tension** **6. Jumbled vision**	**Accommodation Accuracy** *Monitor accommodation* At 40cm and 400 cm Hold 30 seconds, 20/20 target **Accommodation Facility** *Monitor accom response during* +2D/-2D flipper at 40 cm; 20/40 Monocularly 6 cycles in 30 secs Binocularly 4 cycles in 30 secs	**Convergence range** Near Point of Convergence Time maintaining NPC **Vergence Facility** *Monitor vergence response* Jump vergence demand at 40 cm: 20/40 target 6 BI / 6 BO 10 cycles in 30secs

Table 1 Summary of outcome measures: (1) Subjective rating of visual symptoms including blurred vision, eye strain, eye

irritation or tearing, headache, neck or back tension, and eye movement instability indicated by jumbling words or losing places of the prints while reading, using a 100 mm visual analog scale with four verbal anchors (none, slight, moderate, and severe); (2) static accommodative responses at near (20/20 target at 40 c) and at distance (20/20 target at 4 m); accommodative lead (over-focusing) and lag (under-focusing) were computed in MATLAB ('Near Lead/Lag', 'Dist Lead/Lag'); (3) static and dynamic accommodative responses to 33 cm, 40 cm, 50 cm, 100 cm, and 4 m 20/20 targets; (4) dynamic divergence and convergence reflex fusion responses to 6PD BI and 6PD BO prisms changing at the rate of 12 cycle per minute for 10 cycles each; vergence facility amplitude indicated by the average interpupillary distance changes during the test was computed in MATLAB ('VFBI Diffavg', 'VFBO Diffavg'); (5) dynamic accommodative response to the 2D lens flipper (accommodation facility) at the rate of 12 cpm for six cycles monocularly and at the rate of 8 cpm for four cycles binocularly; combined lead and lag was computed in MATLAB ('AFMono Diffavg', 'AFBino Diffavg'); (6) near point of convergence ('NPC') and endurance time.

Correlations between symptoms and objective measures were calculated after the values were normalized to the range of changes using the following formula: (Xi- min)/(max - min), where Xi is the i^{th} outcome measure value and min/max is the minimal/maximal value of the measurement in the data from one subject.

Accumulation of an outcome measure was calculated by integrating the area under the outcome curve throughout the experiment. Post-task retention of an outcome measure was the area under the curve from 't2' to 't5' (Figure 4).

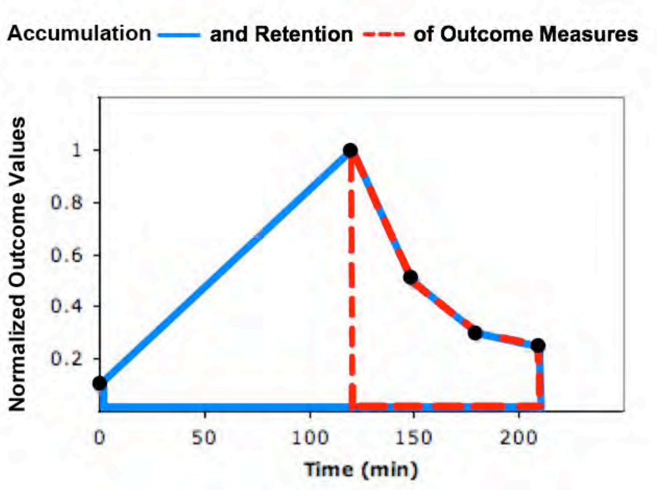

Figure 4 Accumulation and retention measure of each outcome measure was calculated as the area under the t1 to t5 curve (outlined in blue) and under the t2 to t5 curve (outlined by a red dotted line).

Using SAS software, repeated measures ANOVA and the Tukey follow-up test were used to compare the effect of viewing distance on outcome measures. In the figures, the error bars represent SEM.

RESULTS

Symptoms were typically mild and elevated after the two hours computer task. An example for 'blurred vision' is shown in Figure 5.

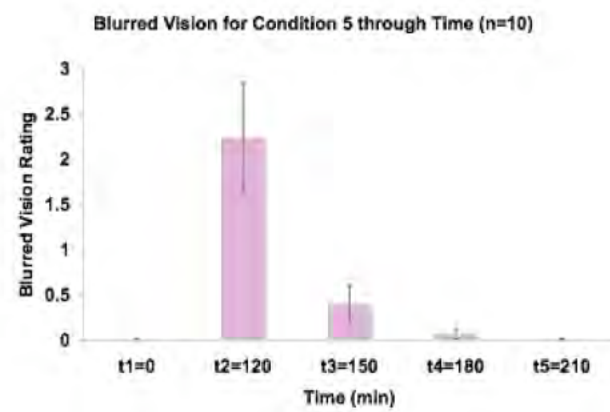

Figure 5 Mean subjective ratings of blurred vision symptom over time (n=10).

Eye irritation and tearing intensity was induced less at the 33 cm viewing distance than the 50 cm condition (Figure 6, $p<0.05$).

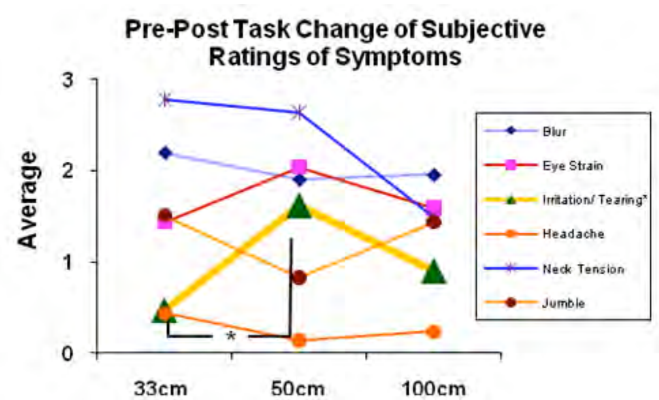

Figure 6 Differences between the baseline (t1) and the post-task (t2) subjective ratings for the six symptoms. Eye irritation/tearing is significantly higher in the 50 cm condition than that in the 33 cm condition ($p=0.03$).

After performing the visual search task at 33 cm viewing distance, subjects showed a stronger accommodative response (more negative refraction values) to the stimuli compared to the 100 cm viewing condition (Figure 7, p=0.05).

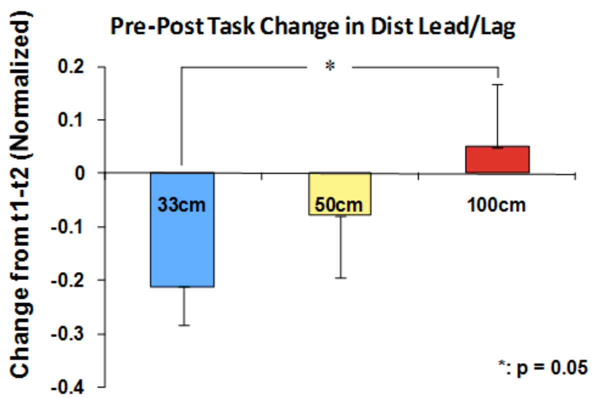

Figure 7 Differences between the baseline and the post-task accommodative lead and lag for a 20/20 distant target at 4 m.

It was noted that the retention measure of the objectively measured accommodative lag, which is the difference between the amount the eye should accommodate to focus on the target and the amount it actually accommodates, for the near 20/20 target at 40 cm was larger when the viewing distance was at 33 cm compared to 100 cm (Figure 8, p=0.08).

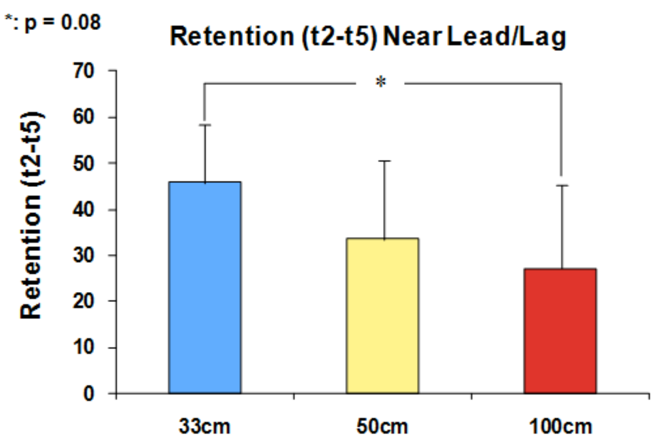

Figure 8 The retention measure of accommodative lag (positive refraction values) at near within 1.5 hour is larger in the 33 cm viewing condition than the 100 cm condition.

The cumulative measure of the dynamic convergence response was slightly larger for the 33 cm viewing condition than the 100 cm viewing condition (Figure 9, p=0.06). Given that the t1 and t2 values in both conditions were similar (data not shown), the results suggest that increased convergence response remained larger for longer if the change was induced by a closer viewing distance.

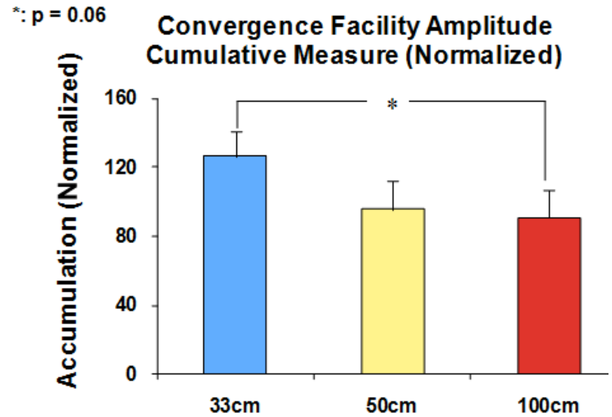

Figure 9 The cumulative measure of the convergence facility amplitude was larger for the 33 cm viewing condition as compared to the 100 cm viewing condition.

Using the data from the five time points for ten subjects performing three viewing conditions (n=150), objective measures of accommodative and convergence responses demonstrated only modest associations with subjective symptom ratings (Figure 10, p<0.1).

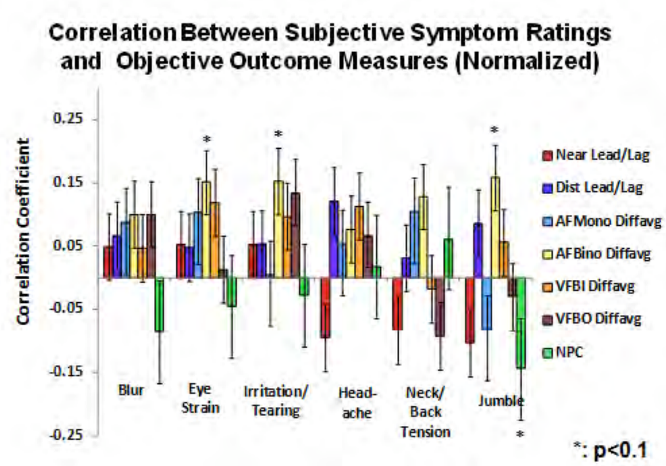

Figure 10. Correlation between subjective symptom ratings and objective outcome measures.

DISCUSSIONS AND CONCLUSIONS

When the visual angle of the character size was maintained and other visual factors controlled for, the visual demand of a visual task mainly depends on accommodation and convergence demands. The two-hour visual task using a computer monitor induced small changes in symptoms and visual functions of accommodation and convergence. Some of these changes persisted for up to 90 minutes after exposure.

Some of these findings complement the results in the previous study by Rempel et al. (2007). There was less post-task eye irritation or tearing and overall larger dynamic convergence response at the closest viewing condition (33 cm) compared to the longer viewing distances (Figure 6 and 9). Similarly, the Rempel study also found that a closer viewing distance (52 cm compared to 73 cm and 85 cm) was associated with less irritated eyes and improved convergence recovery.

Despite higher accommodation and vergence demands viewing at 33 cm compared to 50 cm, eye irritation and tearing symptom is less. Previously, Sheedy et al. (2003) associated this symptom with dry-eye inducing conditions such as holding eye lids open and small font as well as accommodative and vergence stress. Subjects may squint less or blink more during the two-hour exposure at a closer viewing distance and therefore experience a less severe symptom.

After performing the task at a 33 cm viewing distance, there was an increased accommodative response to a distant target. Such a response did not occur at the 100 cm condition (Figure 7). This result supports the phenomenon reported by Schor et al. (1984) that adaptation to a near stimulus for 30 minutes lead to a temporarily elevated tonic accommodation level. Interestingly, the retention of accommodative lag for a focusing task on a near target is larger during the 1.5-hour recovery period in the 33 cm viewing condition (Figure 8), indicating a fatiguing effect following the spasm aftereffect immediately after the exposure.

There were weak associations between changes in binocular functions and visual symptoms (Figure 10, $p<0.1$). Larger combined lead and lag during the accommodation facility test ('AFBino Diffavg'), which indicates a lower capability to keep up with the dynamic accommodative demand introduced by a 2D lens flipper, had a moderate association with eye strain, eye irritation/tearing, and jumble symptom (eye movement instability during reading). A numerically larger 'NPC' indicates a smaller range of convergence. Therefore, the negative correlation between 'NPC' and the jumble symptom suggests that when a subject has a higher capability to converge, either naturally or being induced by a visual task, he or she is more likely to experience this symptom.

In conclusion, while visual symptoms are influenced by the viewing distance, they cannot be fully explained by the changes in the accommodation and convergence functions measured in this study.

ACKNOWLEGEMENT

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