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The vertical horopter and the angle of view

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The existence of a vertical horopter which tilts away from the observer at the top suggests that computer users would experience less visual discomfort with a computer screen tilted back at the top. This study presented the monitor at positive, negative and horopter monitor angles, and at gaze angles corresponding to both eye height and a low position. Postural and visual discomfort were greater with the monitor at a negative angle of view (tilted forward). Subjects expressed a marked dislike for work with negatively tilted monitors. They preferred monitor angles tipped back from the vertical. If glare and reflections are not addressed, the potential benefits of a positive tilting monitor will be lost.

1. INTRODUCTION

The angle of view, also known as the angle of incidence, is the angle formed by the line of sight and the plane of the screen. One reason for adjusting the monitor about the horizontal axis has been to avoid reflected glare [1].

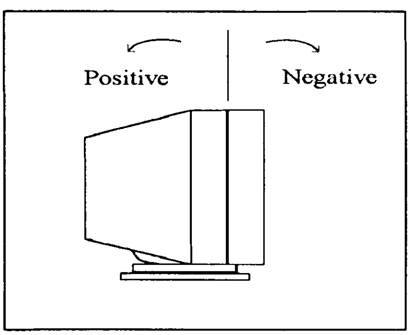

Figure 1. Directions of the angles of view used in this study.

ISO 9241 [2] and ANSI HFS-100 (1988) [3] both allow the angle of view to be from zero to +/- 40 degrees. The top of the monitor may be tilted forward (negative angle of view) or backward (positive angle of view) (Figure 1). Those limits have been intended to reduce the effect of geometric foreshortening. If the only effect of the angle of view is on geometric foreshortening, comfort and preference should vary about equally at both extremes of the allowed limits.

The horopter is the locus of points in space that appear binocularly fused to the observer [4]. Anywhere else in space appears as a double image to the observer. The horopter varies across individuals and with fixation distance and gaze angle.

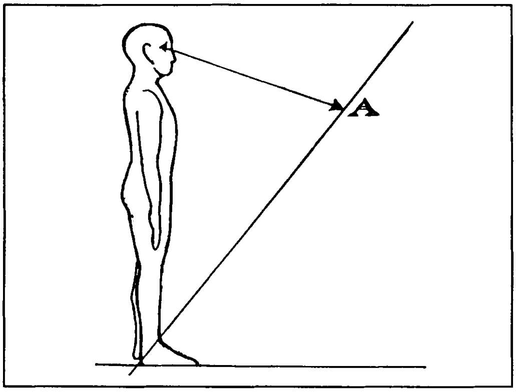

Figure 2. The vertical horopter for fixation at point A.

Horizontally, the horopter is curved with the sides coming closer to the observer [5]. The vertical horopter, however, starts somewhere between the viewer's waist and feet and projects outward, intersecting the point of fixation and continuing in a straight line (Figure 2). If an observer fixates on the center of a vertical wire in the median plane, both ends of the wire will be seen as double until the wire is tilted backward, with its top farther away from the observer [6].

The development of the human visual system is conditioned by its environment during infancy and early childhood [7]. When looking at an intermediate point on the ground, objects below the point of fixation tend to be progressively closer while those above are generally farther away. As a result, the lower visual hemifield is better equipped to see objects nearer than the point of fixation, while the upper visual hemifield is better equipped to see objects that are farther away [8].

For VDT users, a vertical screen orientation results in an angle of view which is inconsistent with the developed abilities of the visual system. In some cases, recommendations have been made to tilt the monitor downward to avoid glare sources [1]. That contradicts the principle of the vertical horopter.

The characteristics of the vertical horopter predict that computer users with a monitor whose top is closer to the eyes than its bottom (negative angle of view) will experience greater discomfort and reduced performance. The present study was conducted to evaluate the effects of monitor height and angle on comfort and performance. The study looks at positive, negative and horopter monitor tilts, and at gaze angles corresponding to both eye height and a low position.

2. METHOD

The subjects were 6 emmetropic students (refractive correction, if needed) with an average age of 21.5 years (range: 20-24) and an average of 6.1 years of computer experience (range: 3-10).

The experimental task involved comparing an accurate list of names, addresses and phone numbers on paper copy to a list on the screen that contained errors. When they found mistakes, subjects corrected the screen image.

There were six experimental conditions involving all combinations of three screen angles and two gaze angles. The three screen angles (measured from the perpendicular to the line of sight) were: "Horopter," tilted back 15 degrees at the high condition and 25 degrees at the low condition, more or less coincident with the horopter [9]; "Positive," tilted back 40 degrees; and "Negative," tilted forward 40 degrees. The gaze angles were: "High," top of screen at eye height; and "Low," top of screen 20 degrees below eye height. The center of the three lines of text on the screen was another 8 degrees lower. The viewing distance was initially set at 66 cm, but subjects were free to alter their postures.

Reflections on the screen were minimized by a combination of indirect lighting and positive screen polarity (dark letters on light background). There was no discernible glare on the screen.

Each session consisted of two 20-minute parts, separated by a 10-minute break. Each subject participated in all six conditions on separate days. The order of conditions was determined by a Balanced Latin Square. At the beginning and end of each condition, subjects rated postural and visual discomfort on a visual analogue scale from 1 to 10 (1 = No, not at all, 10 = Yes, very much). The questions were:

1. I have difficulty seeing.
2. I have a strange feeling around my eyes.
3. My eyes feel tired.
4. My eyes feel numb.
5. I have a headache.
6. I feel discomfort in my neck.
7. I feel discomfort in my upper back.
8. I feel discomfort in my lower back.
9. I feel tired looking at the screen.
10. I feel tired looking back and forth from the screen to the hard copy.

The questionnaire was a modified version of one by Heuer [10] as translated by Jaschinski-Kruza [11]. The last two statements were presented only at the end of the session. At the end of the sixth condition, subjects rated their preferences on a similar visual analogue scale.

3. RESULTS

The change in discomfort was determined by subtracting the initial rating from the rating at the end of the condition. Performance was measured by counting the total number of accurately corrected entries. After participating in all six conditions, subjects rated their preferences. For those scores, higher ratings represent a greater preference for the condition. The data were analyzed initially with a two-way ANOVA. Follow-up tests were performed with a Tukey HSD test. Reported results are significant at the .05 level.

Four measures were found to be significantly different under different viewing conditions: neck discomfort, upper back discomfort, "tired eyes," and "tired looking at the screen."

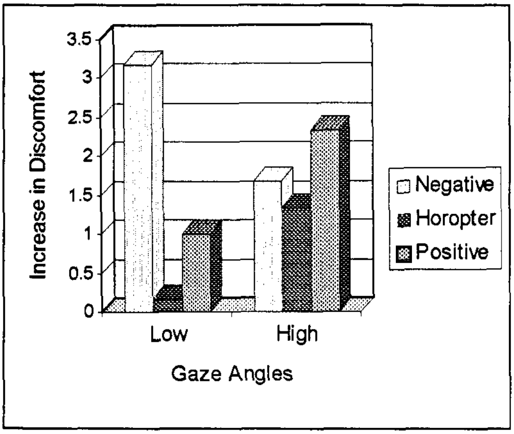

Figure 3. Reported neck discomfort.

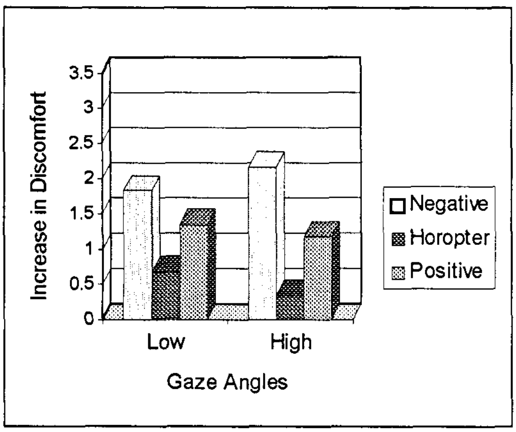

Figure 4. Reported upper back discomfort.

The differences in performance did not achieve significance.

The results for neck discomfort are shown in Figure 3. A significant interaction was found between monitor tilt and gaze angle. At the low gaze angle, the negative monitor angle produced significantly greater increases in discomfort than either of the other angles (p = .0164) At the high gaze angle, no significant differences were found.

The same trend was found in the responses to the statement "My eyes feel tired." An interaction was found between the monitor tilt and gaze angle. At the low gaze angle, the negative monitor angle produced significantly greater discomfort than either of the other angles (p = .0397).

Changes in upper back discomfort are reported in Figure 4. Subjects reported significantly greater increases in discomfort in the negative monitor angle condition over the other two monitor tilt conditions at both the high and low gaze angles (p = .0190). The responses to "I feel tired looking at the screen" followed the same trend with increased discomfort for the negative monitor tilt at both high and low gaze angles (p = .0488).

After participating in all six conditions, subjects rated their preferences (Figure 5). Higher scores represent a greater preference for the condition. As in the analysis of several comfort variables, there was a significant interaction effect between gaze and monitor angle (p = .0110). In the positive monitor tilt condition the low gaze angle was preferred over the high gaze angle. The two negative monitor tilt conditions were the least preferred of all six conditions.

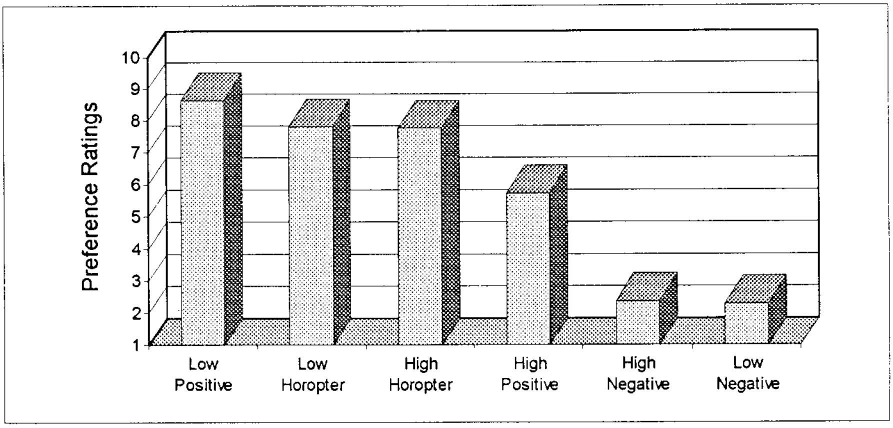

Figure 5. Reported preferences for each condition.

4. DISCUSSION

The results of this study indicate that the vertical horopter may play a role in visual and postural discomfort at computer workstations. A vertical horopter which tilts away from the observer at the top has developed to adapt to a commonly experienced feature of the visual environment. In that environment, objects below a point of visual fixation are usually closer to the observer, while higher objects are usually farther away. In this study, four measures of discomfort, including both postural and visual, showed significant increases when subjects viewed a monitor at an angle of view opposite to the horopter. Subjects clearly disliked the negative monitor tilt condition.

Because the results of this study appear to concur with the physiological mechanism of the vertical horopter, it suggests that monitor tilts opposite to the horopter may contribute to visual and postural discomfort.

In this study, no performance differences were found between any of the conditions. The time period (40 minutes of work) may not have been long enough to reveal effects on performance. Also, because the subjects were working with both hard copy and a screen, the effects of the experimental conditions may have been diluted.

It is inappropriate to consider the angle of view adjustments commonly observed in office environments as reflecting preferred settings due to the constraints of existing lighting systems and equipment. In many offices tilting the monitor back would result in glare from ceiling luminaires. The work environment must be viewed as an integrated whole. If glare and reflections are not satisfactorily addressed, the potential benefits of a positive tilting monitor will be lost.

ACKNOWLEDGMENT

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