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EFFECTS OF VDT MONITOR PLACEMENT AND SINGLE *VERSUS* BIFOCAL GLASSES ON SOMATIC DISCOMFORT AND POSTURAL PROFILES IN DATA ENTRY TASKS

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A study was conducted to determine the effects of VDT monitor positions and the use of single vision *versus* bifocal glasses on somatic elements in the data entry task. Eight male subjects performed data entry using a word processor in eight half-hour sessions with the four different monitor placements, i.e. "eye-level", "shoulder-level-front", "shoulder-level-side", and "sunken-level", wearing the two types of glasses. A subjective discomfort rating questionnaire covering 12 somatic elements was completed by the subject after each session. The head inclination and angle of gaze to the monitor were measured with a goniometer. The results revealed that the somatic elements which were affected significantly by the placement of the VDT monitor and the type of glasses were discomfort in the neck and back regions and eyestrain, respectively. The neck-back discomfort scores were highest at the "eye-level", lowest at the "sunken-level", and intermediate at the "shoulder-level-side" position. The "shoulder-level-front" position was not significantly different in the discomfort from other three positions. The eyestrain was significantly greater with the bifocal than with the single vision glasses. The lower the monitor was placed, the more forward was the head and gaze inclined. The head was inclined less forward, or even more backward, and the gaze was inclined more forward, with the bifocal than with the single vision glasses. As a conclusion, the VDT operators were advised to avoid the "eye-level" and "shoulder-level-side" positions and to prefer the "sunken-level" and "shoulder-level-front" positions as the first and second best choices, respectively. The preference becomes more critical for the wearers of bifocal glasses that suffer from postural constraints in viewing.
Key Words: single vision glasses, bifocal glasses, VDT, musculoskeletal discomfort, monitor placement

INTRODUCTION

Musculoskeletal discomfort among VDT users

Musculoskeletal problems among office workers have become subject of growing concern with the ever-increasing use of the video display terminals (VDTs), representing a wide array of conditions commonly referred to as cumulative trauma disorders (CTDs) or repetitive strain injuries (RSIs). Research shows that computer work and design of the workstation can interact to amplify the risks of musculoskeletal disorders. Statistics illustrate increasing number of carpal tunnel syndrome and RSIs in both the United States and the United Kingdom for keyboarding activities (Mallory and Bradford, 1989; Hill, 1989). In general, musculoskeletal problems among VDT users have been discussed with respect to three main factors; repetitive motions due to keyboard typing (Ferguson, 1984), incorrect posture (excessive bending of the neck, changes in the lumbar curvature when sitting, wrong elbow angle, etc.) and immobilization (National Research Council, 1983).

A comprehensive study of workstation design and musculoskeletal discomfort among VDT data entry operators was conducted by Sauter et al. (1991) which attempted to clarify the contribution of

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workplace ergonomic factors to musculoskeletal problems. The study objective had special significance given the statistical evidence pointing to the increased incidence of musculoskeletal disorders in upper extremities, the hand and the wrist in particular, among VDT workers in the United States (Eisen and LeGrande, 1989; Pasternak, 1989; NIOSH, 1991). What these disorders appear to have in common is a work environment characterized by awkward positions, localized pressure, holding a static position without movement, excessive use of force, and repetition without rest breaks (Herman Miller Research and Design, 1991). Some of the suggestions for environment and workstation design include low placement of the keyboard, avoidance of low seats to prevent leg discomfort, preference for an erect sitting posture and backrest height adjustments, physical exercise during work, and frequent rest breaks.

Visual complaints among VDT users

Eye and visual discomforts associated with VDT use is a common and growing health problem in the workplace. When doing visual near work, a person's ciliary muscle of accommodation changes the optical power of the lens of the eye to form a sharp image on the retina, and the horizontal extraocular muscles converge the axes of the eyes to fuse the two retinal images. These oculomotor mechanisms of accommodation and convergence are increasingly strained as the viewing distance shortens. A study conducted by the American Optometric Associations (AOA) found more than 10 million Americans experience visual discomfort and related symptoms due to operating VDTs (Leavitt, 1995). In another survey conducted by the same association, eyestrain, headaches, and blurred vision were ranked as the top three vision complaints associated with the use of VDTs (Sheedy, 1992).

Aged adults working with VDTs face a different problem; the loss of eye focusing that invariably accompanies advancing age, presbyopia or far-sightedness, requires special prescription lenses for the adult population (Sheedy, 1992). Presbyopia is usually corrected by bifocals, trifocals or single vision glasses. In a survey, 30 % of all VDT patients received prescriptions for bifocals and 19 % for trifocals (Sheedy, 1992). Bifocal and trifocal users may experience neck and back problems in addition to vision complaints as they attempt to accommodate two or three visual focal points.

The American Optometric Association estimates that among the 70 million eye exams a year, 10 million patients require eye exams because of problems with VDTs (Sheedy, 1992). Thirty-seven percent of these complaints are attributed to environmental visual factors such as lighting, poor screen resolution, and glare. Neck- and backaches are also reported together with these vision complaints due to high VDT placement.

Corrective lenses among VDT users

A study conducted by Hagberg and Sundelin (1986) on single vision lens wearers reported discomfort and load on the shoulder muscle when operating a word processor. On the other hand, Vassilieff and Dain (1986) evaluated potential problems with the operation of a VDT workstation by people wearing bifocal glasses. From a theoretical analysis of the optical problems of presbyopic operators, the authors concluded that (a) bifocal lens wearers up to 50 years of age should be able to use a VDT successfully, (b) bifocal lens wearers over the age of 55 years will experience problems when using a VDT, and (c) bifocal lens wearers between 50 and 55 years may have problems, the extent of which will depend on the amplitude of accommodation.

Similar presumptions were outlined by Chackman and Guest (1983) who attributed the unsuitability of presbyopic corrections for VDT usage to the higher angle of gaze and the longer viewing distances required for reading the screen. Suggestions for the solution of these problems were that the reading segment of the bifocal glasses be raised closer to the pupil, or the workplace be adjusted to allow reading glasses to be used. A contradictory clinical opinion suggested that there should be no particular problems associated with the use of bifocal glasses while using a VDT workstation (Cole, 1979).

In another study using presbyopic subjects with bifocal correction lenses, between the age group of 47 and 58, a substantial postural change and adaptation was required to view the keyboard and screen, as the head tended to move two or three times more among bifocal lens wearers than among single vision lens wearers (Martin and Dain, 1988). Kumar (1994), in his study on bifocal lens wearers, evaluated three different VDT monitor placements, namely, (a) sunken and inclined backward by 35 degrees (b) placed on desk top level and horizontal, and (c) placed horizontally but raised by CPU beneath it. The study concluded that the sunken position was the most appropriate based on the elimination of postural stress and need for significant movements of the head and neck, and bringing the keyboard and monitor into a single vision zone.

The primary objective of the present study was to compare the four different monitor positions in terms of the associated somatic discomfort and postural profiles in VDT tasks wearing single vision or bifocal glasses. Specifically, the research aimed at determining the optimal workstation set-up for single vision and bifocal lens users with respect to the four positions of the display terminal, that is, when the top of the display terminal is: (a) in line with the eye-level, (b) in line with the shoulder-level in the front, (c) in line with the shoulder-level on the left side at an angle of 30 degrees, and (d) sunken below the table surface.

METHODS

Subjects and eyeglasses

To accomplish the research objectives, the experiment was performed with four different monitor positions, each comprising of two sessions, one with single vision glasses and the other with bifocal glasses.

The experimental subjects consisted of eight healthy male students with normal vision. The mean age, weight and height were 24.5 years, 161 lbs (73.2kg) and 69" (175cm). The subjects were experienced in word-processing and had keyboarding skill ranging from 30 to 40 words per minute. All subjects were informed about the purpose of the experimental protocol and were asked to notify any record or history of neck- and backaches.

Since the experiment employed young students who did not wear bifocal glasses and thus to simulate an actual bifocal lens wearer performing data entry task, the top part of the lens was covered with an opaque tape so that the participant was able to see only from the bottom part. The eyeglasses used for this study were of zero dioptre. Participants who wore prescribed glasses were allowed to use their own eyeglasses and an opaque strip was fixed to replicate bifocal setting. The glass coverage was approximately 2/3 of the glass area and had an "executive" type of a viewing configuration where the bifocal lenses were placed horizontally on the bottom part of the frame (Jalie, 1977).

Monitor positions

Experiments were conducted with four different VDT monitor placements with respect to the vertical position and horizontal direction of the monitor. The distance between the eyes and VDT screen was kept between a range of 50 – 55 cm. The monitor placements were: a) The top of the VDT screen was placed in front of the subject in level with the eye, that is, when the person performed the data entry task, the monitor and eye were positioned in a straight line horizontally (Figures 1 and 2). This was termed as the "eye-level" position. b) The top of the VDT screen was placed in front of the subject in level with the shoulder, that is, the monitor and the shoulder of the participant were positioned in a straight line horizontally (Figures 3 and 4). This was termed as the "shoulder-level-front" position. c) The top of the VDT screen was set in level with the shoulder of the subject but the screen was placed at the left side of the subject with an angle of 30 degrees from the mid-sagittal line (Figures 5 and 6). This was termed as the "shoulder-level-side" position; d) The monitor screen was sunken mid-way below the surface of the computer desk (Figures 7 and 8). A distance of approximately 50-cm was maintained from the center of the screen to the eye. An inclination thereby made by the VDT was between 40 to 45 degrees. This position was termed as "sunken-

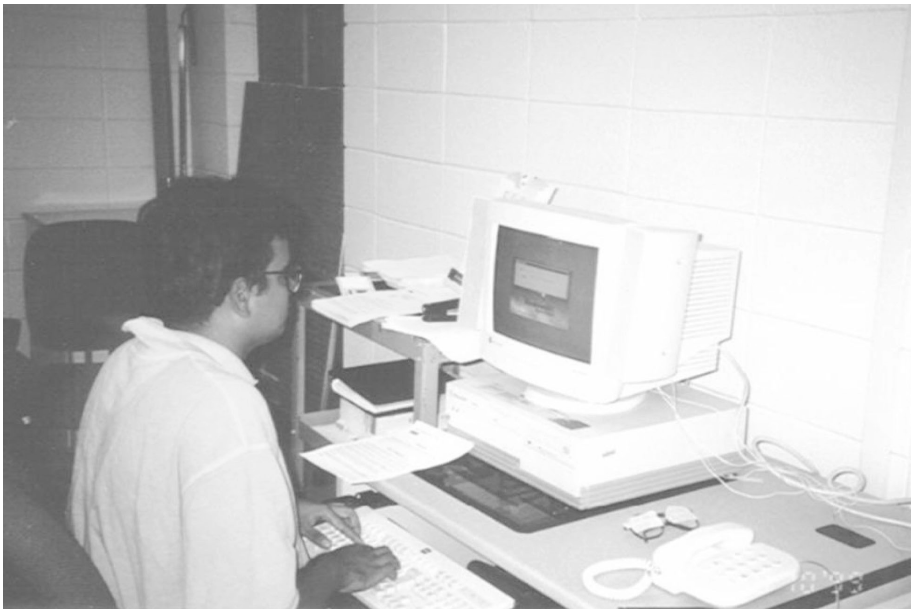

Fig. 1 A subject performing data entry wearing single vision glassses with the monitor placed at “eye-level”.

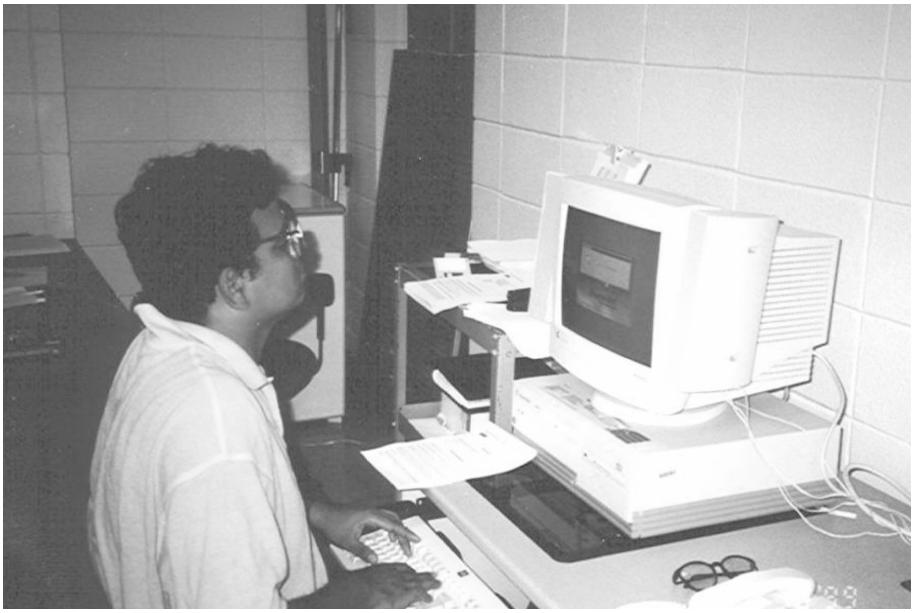

Fig. 2 A subject performing data entry wearing bifocal glassses with the monitor placed at “eye-level”.

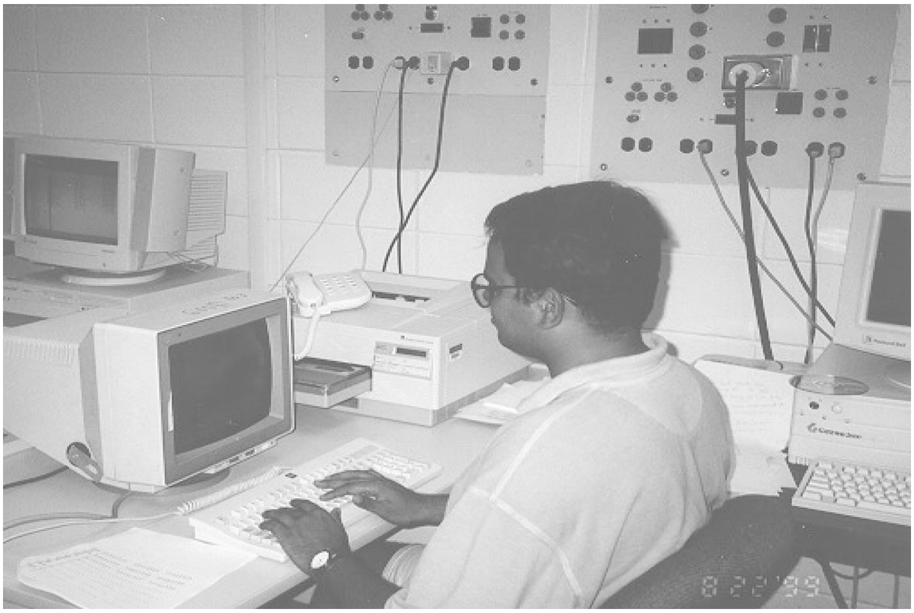

Fig. 3 A subject performing data entry wearing single vision glassses with the monitor placed at "shoulder-level-front".

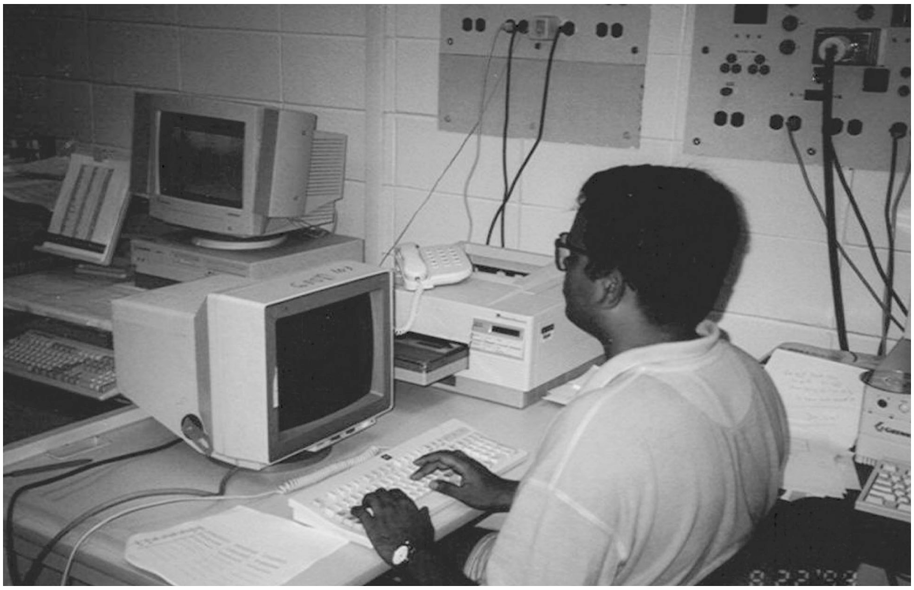

Fig. 4 A subject performing data entry wearing bifocal glassses with the monitor placed at "shoulder-level-front".

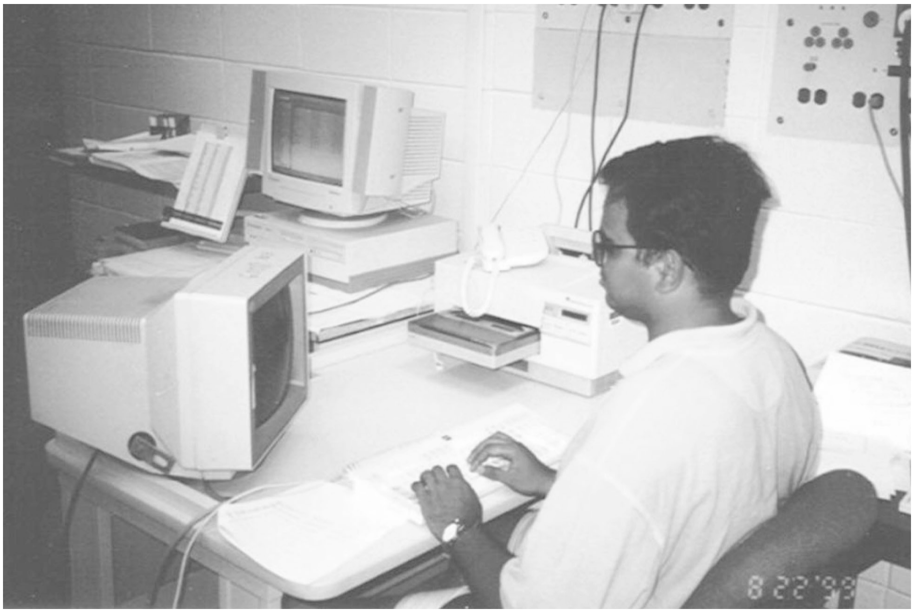

Fig. 5 A subject performing data entry wearing single vision glassses with the monitor placed at “shoulder-level-side”.

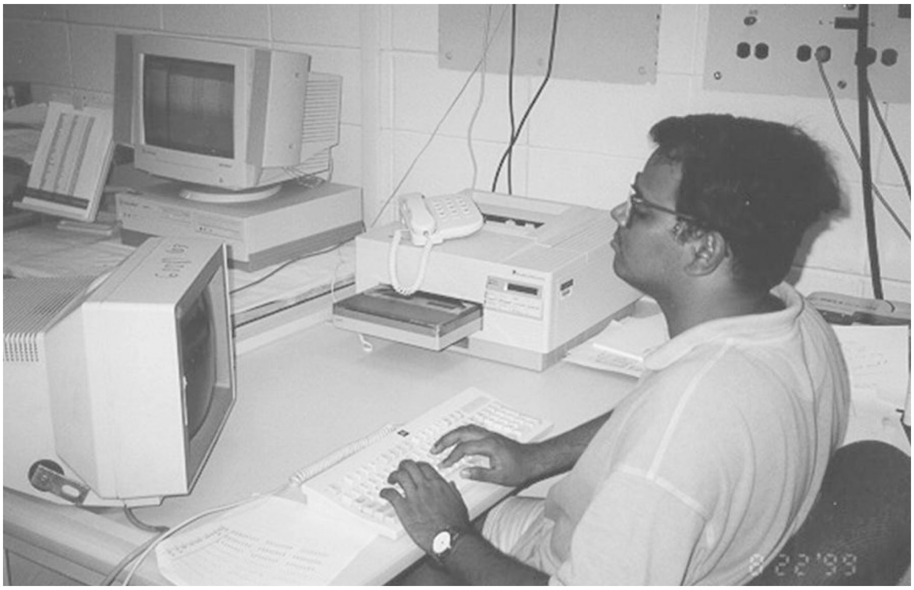

Fig. 6 A subject performing data entry wearing bifocal glassses with the monitor placed at “shoulder-level-side”.

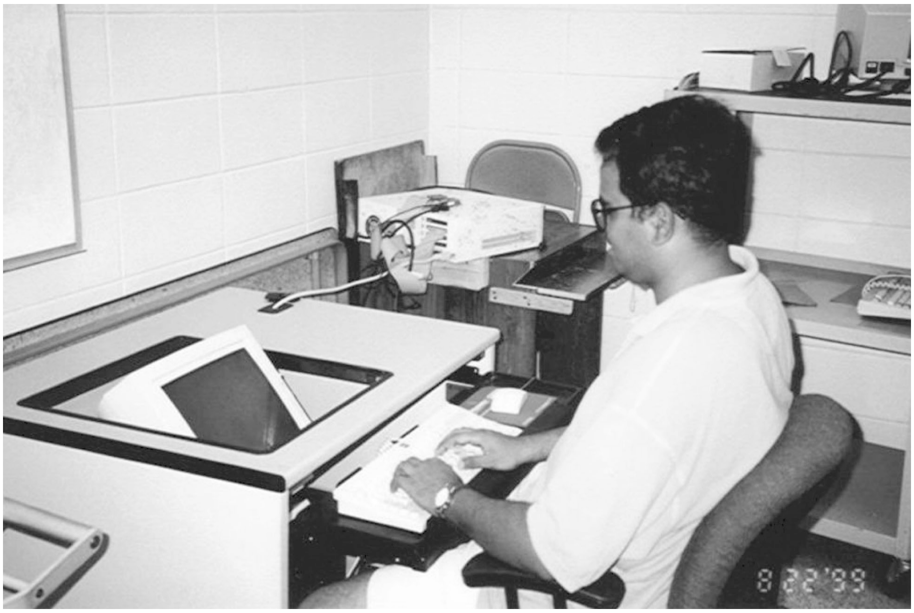

Fig. 7 A subject performing data entry wearing single vision glassses with the monitor placed at “sunken level”.

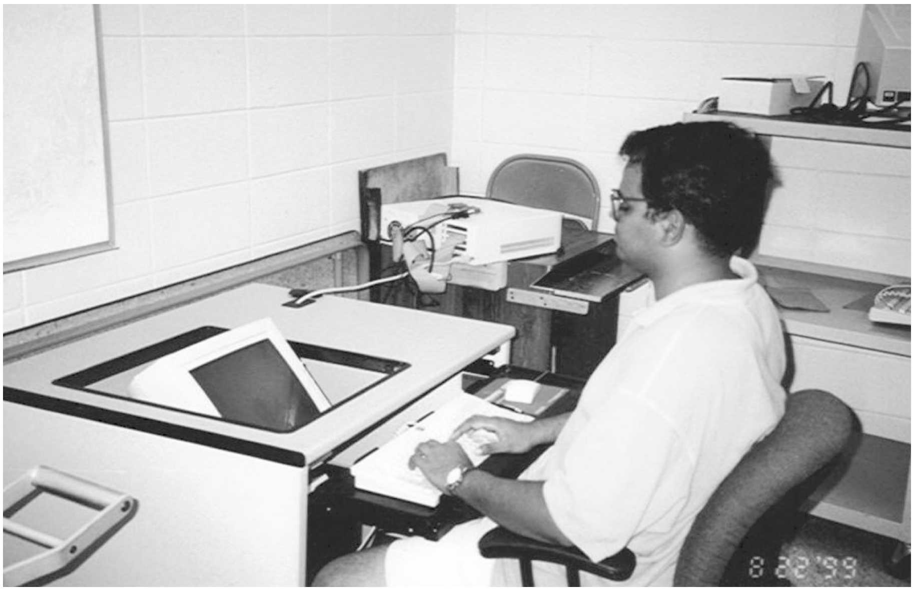

Fig. 8 A subject performing data entry wearing bifocal glasses with the monitor placed at “sunken-level”.

level."

The monitors were different for each of the four positions but had the same screen resolution of 800 x 600 pixels and were 15 inches in size.

Two different computer desks were used for the experiment. For the "eye-level", "shoulder-level-front" and "shoulder-level-side" positions, a "standard desk" having dimensions of 28" (70cm length) x 58" (150cm breadth) x 27" (68cm height) was used. No special arrangement was present for placing the keyboards. For the "sunken-level" position, a specially designed computer desk by Nova, The Natural Solution™ (Austin, Texas) of 36" (91cm length) x 30" (76cm breadth) x 30" (76cm height) with a center slot of 18" (46cm length) x 20" (50cm breadth) to accommodate the monitor, was used. The monitor was sunken midway and inclined so that a distance from the center of the screen to the subject's eye was 50 cm. The desk had an adjustable surface for the keyboard.

Experimental protocol

The subjects were asked to perform data entry task, sitting in a supported relaxed erect middle posture spine, wherein the center of mass is directly above the ischial tuberosities and the floor supports about 25% of the body weight (Chaffin and Andersson, 1991). The support was provided by the adjustable backrest of the chair.

The data entry task lasted half an hour (Kumar 1994) for each of the four monitor positions with different eyeglasses, cumulating to 4 hours. The 4 x 2 experimental conditions were randomized within each subject. The subjects performed data entry in a word processor (MS-Word) from continuous text handed to them prior to the experiment. To maintain consistency, all participants entered data in 12-size font - Times New Roman and single-spaced. The text used by the subjects was "document with meaning", different across the four monitor positions, but same within each position, placed on the left-hand side of each subject on top of the desk. Accuracy of the data entry was calculated by computing the percentage of correctly typed words to the total number of words typed during each half-hour session.

Measurements of head inclination and gaze angle

Based on the review of prior research and various guidelines for VDT workstation design (Cakir et al., 1980; Human Factors Society, 1988; Kroemer and Hill, 1986), the angle of head inclination and the angle of gaze to the screen were measured. The angle of head inclination is defined as the difference between "angle I" and "angle J" as shown in Figure 9 (Sauter et al., 1991). The "angle I" was defined as an angle made by the ear-eye line and the vertical line when the subject is viewing the VDT. The "angle J" was defined as an angle made by the ear-eye line and the vertical line when the subject was looking straight ahead without the glasses for all eight sessions.

Fig. 9 Measuremen of the head inclination as difference between "angle I" and "angle J". For explanation, see text.

The angle of gaze to the monitor as illustrated in Figure 10 was defined as an angle between the ear-eye line and the line of sight to the center of the screen (Kroemer and Grandjean, 1997).

A goniometer was used to measure the angle of the head inclination and the angle of gaze to the monitor. The instrument has two long arms, one longer relative to the other. The shorter of the arm is used as a reference to the horizontal or the vertical plane whereas the longer arm measures the angle.

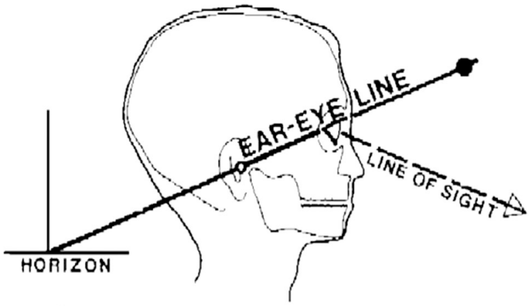

Fig. 10 Measurement of the angle of gaze as an angle between the ear-eye line and the line of sight to the center of the monitor or keyboard. For details, see text.

Somatic discomfort measures

A participative discomfort rating form was completed by each subject after each experimental session. Employing the method of Corlett and Bishop (1976), the form was designed to include musculoskeletal discomfort in body areas displayed in Figure 11, as well as tiredness, eyestrain, and drowsiness. The discomfort rating was recorded on a zero to 10 scale; zero being no discomfort and 10 the most serious discomfort (Turville et al., 1998).

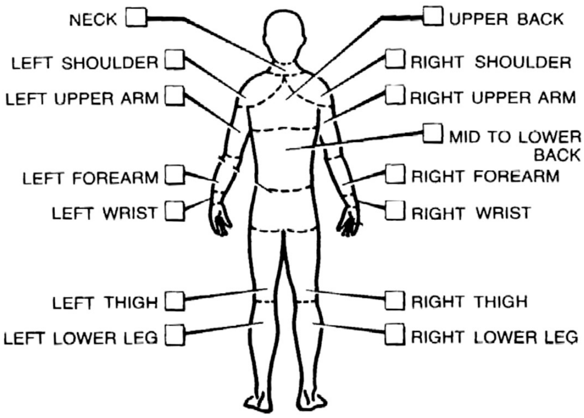

Fig. 11 Pictograph used for rating subjective musculoskeletal discomfort.

Statistical analyses

The experiment is a "two-factorial randomized block design" with the subjects being blocked to avoid any confounding effect that may have arisen during the experimentation. Within the block, the order of the subjects performing the experiments was completely randomized. Also all the set-ups were randomized. This statistical model assumed the interaction between block and treatments as negligible. Multivariate analysis of variance (MANOVA) was followed by the analysis of variance (ANOVA). Duncan's multiple range test was used to compare the pairs of means. The significance level was fixed at p=0.05 for the experiment.

RESULTS

Analysis of subjective discomfort ratings

Table 1 compares the subjective discomfort rating with the single vision glasses for the different monitor placements. The neck discomfort has the highest average in the “shoulder-level-side” monitor position, and the upper- and lower back show peak average scores when the monitor is in the “eye-level”. It is noted that almost all average ratings of the “sunken-level” positions are close to or lower than those of the other three monitor positions studied. Except for the neck, the “shoulder-level-side” position also yields relatively low scores in somatic discomfort.

Table 1. Mean and SD of somatic discomfort ratings and postural profiles under four VDT monitor positions with single vision glasses.

Somatic elements	Monitor positions							
	Eye-level		Shoulder-level-front		Shoulder-level-side		Sunken-level	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Somatic discomfort								
Neck	2.81	1.07	2.81	1.16	4.19	2.00	2.63	1.27
Shoulder	3.13	1.25	3.41	1.73	2.44	1.05	2.44	1.45
Upper Arm	2.13	1.55	2.31	2.43	2.00	1.34	1.56	1.29
Forearm/Elbow	2.81	2.51	3.56	3.32	1.81	1.36	2.38	2.25
Wrist	3.63	1.48	3.78	3.28	2.63	1.69	2.88	1.38
Thigh	1.88	2.10	1.13	2.10	1.13	1.36	1.19	1.56
Lower leg	1.75	1.75	0.75	1.75	1.00	1.51	1.13	1.55
Upper back	3.75	1.04	3.06	1.43	3.00	1.41	3.25	1.39
Lower back	4.00	2.33	3.69	2.76	3.13	1.64	3.00	1.51
Tiredness	2.75	1.67	2.25	1.98	2.75	2.25	2.75	1.28
Eye strain	2.75	2.05	3.44	2.69	3.00	2.00	2.25	1.39
Drowsiness	2.13	1.89	2.00	2.20	2.00	2.20	2.00	2.00
Postural profiles								
Head inclination	16.9	3.5	21.0	3.5	22.3	2.9	26.9	8.6
Angle of gaze	3.2	1.5	5.9	1.0	7.2	2.6	6.7	3.8

Table 2 illustrates the discomfort scores with bifocal glasses. The “sunken-level” position has the lowest discomfort average for several elements including the neck. Here, too, the upper and lower back scores are fairy high when the monitor is placed at “eye-level”.

Comparing the discomfort between the single vision and bifocal glasses, the scores appear to be generally higher if wearing the bifocal glasses. It is particularly noticeable that the eyestrain with the bifocal glasses is fairy high irrespective of the monitor positions; the strain at the “eye-level” with the bifocal glasses is almost two times as high as that with single vision glasses. Table 3 shows the results of ANOVA for the effect of corrective lenses (single vision *vs*. bifocal) and monitor positions on the somatic discomfort. The effects of corrective lenses and monitor positions are statistically significant only for the upper back discomfort ($p<0.05$) and eyestrain ($p<0.001$), respectively.

Table 4 summarizes the results of Duncan's multiple range test for the mean somatic discomfort scores with the different glasses. The mean discomfort scores are not significantly different between the glasses except for the eyestrain, which is 75 % less with single vision than with bifocal glasses. In Table 5 are shown the results of Duncan's multiple range test with respect to the monitor positions. While the positions have significant effects ($p<0.05$) on the neck, upper back, and lower back discomfort, the positional effects are not significant on the tiredness and eyestrain. More specifically, significant differences are identified between the following comparisons; “shoulder-level-side”>“sunken-level” for the neck; “eye-level”>“sunken-level” and “eye-level”>“shoulder-level-side” for the upper back; “eye-level”>“shoulder-level-side” for the lower back.

Table 2. Mean and SD of somatic discomfort ratings and postural profiles under four VDT monitor positions with bifocal glasses.

Somatic elements	Monitor positions							
	Eye-level		Shoulder-level-front		Shoulder-level-side		Sunken-level	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Somatic discomfort								
Neck	3.88	2.60	3.56	1.80	3.69	1.51	2.94	1.88
Shoulder	3.06	2.60	2.69	1.31	2.75	1.36	2.50	2.12
Upper arm	2.69	1.83	3.00	2.35	1.94	0.94	1.44	1.55
Forearm/Elbow	2.56	1.70	3.44	2.83	2.88	2.46	2.59	2.16
Wrist	3.25	2.19	3.44	2.16	4.06	1.70	2.63	1.75
Thigh	2.00	2.20	1.63	2.39	1.31	1.49	1.25	2.31
Lower leg	2.88	2.70	1.13	1.89	1.44	1.40	1.44	2.23
Upper back	4.38	2.45	3.63	1.69	2.75	1.39	2.69	1.87
Lower back	4.38	2.83	3.75	1.98	2.75	1.04	3.56	2.16
Tiredness	3.50	3.16	3.50	2.20	3.38	2.20	2.75	2.49
Eyestrain	5.38	2.50	5.13	2.30	4.88	2.20	4.38	2.90
Drowsiness	3.13	3.09	2.88	2.59	3.13	2.90	2.75	2.82
Postural profiles								
Head inclination	-1.9	3.5	7.3	4.8	10.3	4.7	17.5	5.6
Angle of gaze	10.1	2.0	11.9	2.3	12.5	2.3	14.3	3.8

Table 3. F statistics for the effects of corrective lenses and monitor positions on the somatic discomfort ratings and postural profiles.

Somatic elements		Test criteria	Lens	Monitor positions
Somatic discomfort				
	Neck	F value	0.88	1.23
		P	0.3518	0.3078
	Shoulder	F value	0.06	0.57
		P	0.8098	0.6396
	Upper arm	F value	0.38	1.38
		P	0.5414	0.2571
	Forearm/Elbow	F value	0.14	0.75
		P	0.7065	0.5293
	Wrist	F value	0.05	0.54
		P	0.8186	0.6574
	Thigh	F value	0.20	0.48
		P	0.6594	0.6989
	Lower leg	F value	1.42	1.62
		P	0.2389	0.1941
	Upper back	F value	0.05	1.75
		P	0.8190	0.0317
	Lower back	F value	0.09	1.05
		P	0.7684	0.3766
	Tiredness	F value	1.40	0.10
		P	0.2415	0.9617
	Eyestrain	F value	13.11	0.33
		P	0.0006	0.8003
	Drowsiness	F value	2.26	0.03
		P	0.1387	0.9917
Postural profiles				
	Head inclination	F value	137.80	28.07
		P	0.0001	0.0001
	Angle of gaze	F value	84.95	9.63
		P	0.0001	0.0001

Table 4. Duncan's multiple range test for the effect of corrective lenses on the somatic discomfort. Means corresponding to different letters in grouping are significantly different at $p < 0.05$.

Somatic discomfort	Lens	Mean	Grouping
Neck	Single	3.516	A
	Bifocal	3.109	A
Upper Back	Single	3.359	A
	Bifocal	3.266	A
Lower Back	Single	3.609	A
	Bifocal	3.453	A
Tiredness	Single	3.281	A
	Bifocal	2.625	A
Eye Strain	Single	4.938	A
	Bifocal	2.859	B

Table 5. Duncan's multiple range test for the effect of VDT monitor positions on the somatic discomfort. Means corresponding to different letters in grouping are significantly different at $p < 0.05$.

Somatic discomfort	Monitor positions	Mean	Grouping
Neck	Shoulder-level-side	3.938	A
	Eye-level	3.344	B A
	Shoulder-level-front	3.188	B A
	Sunken-level	2.781	B
Upper back	Eye-level	4.063	A
	Shoulder-level-front	3.344	B A
	Shoulder-level-side	2.969	B
	Sunken-level	2.875	B
Lower back	Eye-level	4.188	A
	Shoulder-level-front	3.719	B A
	Sunken-level	3.281	B A
	Shoulder-level-side	2.938	B
Tiredness	Eye-level	3.125	A
	Shoulder-level-side	3.063	A
	Shoulder-level-front	2.875	A
	Sunken-level	2.750	A
Eyestrain	Shoulder-level-front	4.281	A
	Eye-level	4.063	A
	Shoulder-level-side	3.688	A
	Sunken-level	3.563	A

Analysis of angular measurements

The angular measurements under different monitor positions with the single vision and bifocal glasses are presented in Tables 1 and 2, respectively. For each type of glasses, the head inclination and gaze angle tend to increase in correspondence to the height of the monitor, from the "eye-level" to the "sunken-level". While the head inclination is larger with the single vision glasses, gaze angle is larger if wearing the bifocal glasses. Variability of the head inclination according to the monitor position appears different between the glasses; the angular range in terms of mean score between the "eye-level" and "sunken-level" is 10 degrees for the single vision glasses and nearly 20 degrees for the bifocal glasses.

Results of ANOVA applied to angular measurements are presented in Table 3. The effects of corrective lenses and monitor positions each are statistically significant for both the head inclination (p<0.001) and gaze angle (p<0.001). In Tables 6 and Table 7 are illustrated the results of Duncan's multiple range test for the effect of glasses and monitor positions on angular measurements, respectively. It is obvious that the type of glasses have significant effect (p<0.05) on both of the head inclination and gaze angle. Besides, these angular measurements are significantly affected (p<0.05) by a number of monitor positions, the "eye-level" and "sunken-level" in particular. More specifically, significant differences in the angles are identified between the following comparisons; "shoulder-level-side">"eye-level", "shoulder-level-front">"eye-level", "sunken-level">"eye-level", "sunken-level">"shoulder-level-front", and "sunken-level">"shoulder-level-side".

Table 6. Duncan's multiple range test for the effect of corrective lenses on the postural profiles. Means corresponding to different letters in grouping are significantly different at p< 0.05.

Postural profile	Lens	Mean	Grouping
Head inclination	Single	21.766	A
	Bifocal	8.281	B
Gaze angle	Single	6.234	A
	Bifocal	12.203	B

Table 7: Duncan's multiple range test for the effect of monitor positions on the postural profiles. Means corresponding to different letters in grouping are significantly different at p< 0.05.

Postural profile	Monitor positions	Mean	Grouping
Head inclination	Sunken-level	22.219	A
	Shoulder-level-side	16.250	B
	Shoulder-level-front	14.156	B
	Eye-level	7.469	C
Gaze angle	Sunken-level	11.469	A
	Shoulder-level-side	9.844	B
	Shoulder-level-front	8.906	B
	Eye-level	6.656	C

DISCUSSION

Our experiments revealed that the somatic elements which were affected significantly by the placement of the VDT monitor and the type of glasses were, respectively, the neck-back discomfort and eyestrain. The discomfort in the neck and back regions during the data entry task varied with the monitor positions. Generally, the discomfort scores were highest at the "eye-level", lowest at the "sunken-level", and intermediate at the "shoulder-level-side", with the mutual differences statistically significant. The "shoulder-level-front" position was not significantly different in the discomfort score from other three positions. The discomfort, however, was not affected significantly by the type of glasses.

We also showed that the head posture and gaze direction both differed significantly between the glasses-types and monitor positions. The lower the monitor was placed, the more forward was the head inclined. The head was inclined less forward, or even more backward, with the bifocal than with the single vision glasses. The gaze angle was greater with the monitor placed lower than higher as well as with the bifocal than with the single vision glasses. The alteration of the head posture and gaze angle as above are naturally predicted if one consider the positional relation between the head and the monitor, and between the visual axis and visible area in the bifocal lens.

Knave et al. (1985) found, among VDT operators, that as the time spent in front of the VDT monitor increased, significant risk factors for neck pain proportionally rose. Therefore appropriate monitor placements are required for data entry operators who spend almost the entire day in front of the monitor. The dependence of the neck-back discomfort on the monitor positions mentioned earlier, i.e. the incidence of discomfort was higher at the "eye-level" and "shoulder-level-side" positions but reduced at the "sunken-level" position, can be attributed to the posture assumed at each position, including turning of the head sideways, which may cause static loading on the muscles in the neck and back region.

In general, if the VDT monitor is placed onto the casing of a personal computer, the center of the screen is about 40 cm above the table. Assuming a table height of 72 cm (which is recommended for none-adjustable tables), gaze direction is horizontal, or even elevated, for all subjects with an eye level above the floor of 112 cm or less. Thus, placement of a VDT monitor onto the personal computer casing on a conventional table may result in an adverse condition for many operators. The condition may turn worse if the operator wears bifocal glasses, since he/she has to lift the head to view the screen.

With improved designs of computers, the monitors are designed to tilt backward and forward. In our experiment, the monitor was lowered by sinking and tilting it backward in the table top and the head was inclined forward by 26.9° for single vision and 17.5° for bifocal glasses in average, causing the least neck-back discomfort. The present state of knowledge suggests that the head and neck should not be bent forward by more than 30° when the trunk is erect, otherwise fatigue and troubles are likely to occur (Chaffin et al., 1999). It may follow then that the "sunken-level" monitor placement should be evaluated as the optimum position for data entry workers.

The degree of eyestrain, in contrast with the musculoskeletal discomfort, was dependent upon the type of glasses and independent of the monitor positions. The eyestrain was significantly larger with the bifocal than with the single vision glasses. Our results, however, differ from the clinical opinion proposed by Cole (1979) that there should not be any particular problems associated with the use of bifocal glasses among VDT users. Also different are the conclusions of Vassilieff and Dain (1986) that bifocal wearers up to the age of 50 years will not experience problems while viewing the VDT monitor. The reason for these discrepancies are not clear, but may partly be owing to the fact that our experimental subjects were young and had no experience of wearing the bifocal glasses.

For the bifocal glasses, the eyestrain was greatest at the "eye-level" and reduced with lowering of the monitor position, although the trend of dependence on the monitor position was statistically not significant. This lack of significance may possibly be due to the moderate number of our subjects employed. If this is the case, the higher incidence of eyestrain with the bifocal glasses may have arisen, as cited by Weston (1962), as a consequence of discomfort in the neck region caused by the postural change due to wearing bifocal glasses.

As conclusions drawn from the foregoing discussion, we recommend the data entry workers to adjust placement of the VDT monitor; the "eye-level" and "shoulder-level-side" positions should be avoided while the "sunken-level" and "shoulder-level-front" positions are the first and second best choices, respectively. The placement becomes more critical for the wearers of bifocal glasses that suffer from postural constraints in viewing near objects.

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