Experimental study to redesign visual display terminal workstation for bifocal operators

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Bifocal VDT (Visual Display Terminal) operators (50) were studied from different fields (data entry, conversational task, programming, CAD/CAM etc.) through user-product-environment system. Users profile includes experiments pertaining to users reactions, while products profile covers designs, manufacturing and marketing of existing computer furniture in the market. Existing VDT workstations were observed inappropriate for bifocal people facing vision problem, which was analysed thoroughly in simulated laboratory conditions by preparing a test rig with adjustable monitor angle from horizontal. Work posture of VDT operators was assessed with EMG, Photogram Metric Technique, and Centre of Gravity in four stages of test rig. An ergonomics criterion for redesigning VDT workstation was developed. It is appropriate and natural for the man-machine-environment system and also allows comfortable posture and greater efficiency of bifocal and normal VDT operators.

Keywords: Bifocal operators, Ergonomics, Visual display terminal (VDT)

Introduction

Operators1,3 in Visual Display Terminal (VDT) jobs, which are characterized by high pressure to perform and low control over the task, report more visual and muscular discomfort than operators whose job allows greater autonomy and flexibility. Operators, working in cramped spaces with little room to place document holder or manuscript in position, are likely to experience visual discomfort, muscular discomfort and fatigue. Workplace for VDT operator is important for obtaining a proper relationship between user and workplace to support the requirements for interactive work4. The introduction of VDT in offices has limited the number of postures permitted to the employees in traditional office work5.

Older workers become quite vulnerable to problems of poor workstation design because of visual changes such as presbyopia and increased glare susceptibility. The optical correction for near work routinely provided for bifocal spectacles bearer is not appropriate for the distance at which VDT screen is normally visualized6.

In order to view the screen, the worker with bifocal spectacles, must tilt his or her head backwards to look through the bottom part of the spectacles. Continuous bending of head on the backside causes stress on the vertebral column ultimately leading to spondilysis7. This necessitates a thorough analysis of existing VDT station so that a proper VDT workstation can be developed which will be appropriate and natural for man-machine-environment system and which will also allow comfortable posture and greater efficiency by the human being.

This study proposes to redesign the VDT workstation for bifocal operators considering the physical, biomechanical, physiological and psychological limits in conjunction with VDT keyboard, source document along with working environment. The study performs an in-depth ergonomic evaluation of VDT workstation for people wearing bifocal lenses to fulfil the following objectives: i) Evaluation of present working posture adopted by bifocal people while working on computer; ii) Evaluation of existing VDT workstation on the basis of different body dimensional and biomechanical requirements along with comfortability and ease of operation of VDT operator; and iii) Find out criteria for redesigning of computer workstation for bifocal people.

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Methodology
Considering the time frame, a suitably designed questionnaire was formulated consisting a set of questions dealing with the following areas: i) General background information; ii) Medical records; iii) Personal preference regarding work; iv) Design of existing workstation; and v) Environment considerations. The questionnaire was personally administered among 54 bifocal VDT operators. These bifocal VDT operators were selected from fields performing different jobs as data entry, conversational task, programming, word processing etc. To understand the posture adopted by bifocal wearer photographs of 10 VDT operators were taken and studied carefully.

Psycho – physiological Evaluation
The test-rig was prepared on the slotted angles based on the anthropometric measurements of male and female available and dimensional measurements of the existing visual display terminal workstation taken. A 3-point rating scale was prepared to assess the subject’s response as regard to comfort and feelings of physiological stress and fatigue during performance of task on test-rig. The lab experiment was divided into four stages for comparing the existing workstation with respect to desired.

Stage I
It included existing VDT workstation setting, where monitor was placed on table. Keyboard and CPU were placed on same table, which was above 70 cm from ground level.

Stage II
It included incorporation of accessories like copyholder, footrest, wrist-rest, and providing adjustments of keyboard height, book rest according to operator’s desire and comfort.

Stage III
It included removing of the CPU from table and just placing the monitor on the table erect. CPU in this case placed on the right hand side of the person.

Stage IV
In this case, a groove was made in middle of the table, in which the monitor was kept sunk with monitor screen facing upwards towards the eye. The distance from the monitor to the operator and also the angle of elevation could be adjusted according to operators need.

Photogrammetric Technique: Joint-Angle Study
In this technique, video recording was done for all four stages on test-rig for all the bifocal VDT operators as well as for the normal to understand the postural problems faced by a bifocal operator working on the computer and analysed through video position analyser and video measuring gauge. The measurements considered for analysis were: i) Determination of distances from eyes to monitor screen and eyes to keyboard; ii) Monitor angle with respect to horizontal; iii) Head angle in relation to trunk; iv) Monitor height from the fixed table; and v) Elbow height sitting.

Centre of Gravity (CG)
The location of CG in human body is extremely important in determining the state of equilibrium, at any moment. In this study, the segmental method was used to determine CG of the worker in action. This technique uses photograph of the subject and involves finding the location of CG of each of the body segment, with respect to an arbitrarily placed X, Y axis and knowledge of the ratio between the individual, segments, weights and the total body weight. After locating the whole body CG with the segmental method, percentage of CG displacement was derived.

Market and User Survey
A market survey of the existing computer furniture in the market was conducted by asking the different companies involved in manufacture of computer furniture to send their catalogues along with their price list. The user’s survey was done by taking dimensional measurement (static and dynamic) of 50 computer workstations used by the bifocal VDT operators.

Environmental Factors
The effect of temperature, light, noise and vibrations on production quality level and physiological functioning of human beings is considerable. It is therefore necessary to provide following environmental facilities to workers while designing VDT workstation: i) Visual environment; ii) Illumination level; iii) Luminance ratio relationship; iv) Glare; v) Auditory environment; vi) Sound level; vii) Thermal environment; viii) Temperature; ix) Humidity; and x) Radioactive state.

Results and Discussion
Out of 54 questionnaires distributed, 50 were considered for final compilation because three were not returned back and one was rejected, as it was incomplete. Half of the respondents were observed working on the computers for more then 6 years. In a
day, 48 percent of them worked for 2-4 h, while 36 percent worked for 4-6 h at a stretch on computers. More than 4/5th of the bifocal VDT operators faced problems of vision while working on computers. Approx 1/7th of the respondents had adapted themselves to the situation, they did not realize about their constraint postures, which could lead to chronic muscular disorders later on, if not attended to after continuous hours of work. Majority of VDT operators (88%) did feel fatigue and pain. Major area of pain was in neck region.

Environmental Considerations
The temperature and sound level inside the computer centre was found to be tolerable. Nearly half of the VDT operators were satisfied with the present colour of the tabletop, while rest opted for light colours. Operators (46%) often moved and repositioned their workstation to escape glare.

Psycho-physiological Evaluation: Subjective Ranking
The stage 4 of the test-rig was definitely preferred by most of VDT operators (Table 1), who welcomed the incorporation of accessories (wrist support, copy holder, foot rest, back rest, keyboard height adjuster etc) as it made the VDT workstation more comfortable for the specified person.

Photogrammetric Techniques
In this technique, monitor-horizontal angle, head-trunk angle, eye-monitor distance and elbow height from seat surface were determined. In stage IV, the average angle preferred by the bifocal operators was $116.3^\circ$ ($\pm$ 0.63). The head-trunk orientation, which was closer to normal in case of stage IV for the bifocal person, was maximum in stage I. From the viewpoint of head neck relationship, adaptation of stage IV will definitely reduce the muscular skeletal stresses and occupational related injuries at cervical region of the vertebral column. Stage IV will also help to cover up better viewing area in comparison to stage I. There was an increment of 2 cm in stage IV in comparison to stage I while observing eye-keyboard distance. There was a slight difference in elbow height in stage I as compared to other stages because of the incorporation of wrist support and adjustment of keyboard height according to individual requirements. In comparison to stage I, respondents preferred to have monitor height lower than usual, especially bifocal operator who had to see through the bottom part of the glasses (Table 2).

Centre of Gravity Analysis
To find out the degree of significance among the shift in CG at different stage of test-rig (Stages I-IV), t-test was carried out. In case of bifocal people, a drastic shift in CG location in horizontal plane was observed. In comparison to stage IV verses other stages, CG line was observed closer to the body (Table 3), thereby reducing the muscular stress on the back and front side of the trunk.

Electromyographical Evaluation
No apparent change in electrical activity was picked up by surface electrode. Normal head trunc relationship was maintained by deeper, finer muscles rather than superficial major group of muscles\(^8\).

Market Survey
The computer furniture in market includes tables for monitor and keyboard, printer tables with provision for stationary. Several manufacturers offer adjustable furniture for use as VDT. The need to have keyboard at a lower height than monitor has been solved in most of the cases by having part of table

### Table 1—Preference ranking of the subjects

<table>
<thead>
<tr>
<th>Scale</th>
<th>Bifocal (N = 5)</th>
<th>Normal (N = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stages</td>
<td>Stages</td>
</tr>
<tr>
<td>1</td>
<td>1: II</td>
<td>1: IV</td>
</tr>
<tr>
<td></td>
<td>80% 20% 80%</td>
<td>67% 67% 100%</td>
</tr>
<tr>
<td>(Comfortable)</td>
<td>(4) (1) (4)</td>
<td>(2) (2) (3)</td>
</tr>
<tr>
<td>0</td>
<td>-   40% 20%</td>
<td>-</td>
</tr>
<tr>
<td>(Neutral)</td>
<td>(2) (1)</td>
<td>-</td>
</tr>
<tr>
<td>-1</td>
<td>20% 40% 33%</td>
<td>33%</td>
</tr>
<tr>
<td>(Uncomfortable)</td>
<td>(1) (2)</td>
<td>(1) (1)</td>
</tr>
</tbody>
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depressed or a small pullout drawer to house the keyboard. Most of these tables have structure of mild steel frame with laminated plywood for the worktop. The space for writing is usually absent in most of the workstations. The tables have sharp edges and corners, which are inconvenient for resting elbow. No consideration has been given to the various wire connections from the CPU and monitor, and the result is the cluster of wires behind this unit, which are unsafe and ugly. They do not have provision for document holder, manuals, floppy boxes etc. Chairs have adjustment for height and back rest tilt, though controls are not neat and easy in all cases.

The manufacturers while designing the computer furniture takes it for granted that human body is very adaptable. For this reason, an incompatibility of VDT workstation may cause no difficulty in normal operation and may even be accepted as defect free workstation, until crisis situation occurs, when incompatibility leads to human error and disaster occurs.

Users’ Survey

VDT workplaces (50) were surveyed and the observations revealed that the present computer workstation used by the people were not at all appropriate for the bifocal VDT operator nor for the normal VDT operator thus, hampering their efficiency.

Recommendations

The following recommendations were made from the study for the VDT workstation:

Table 2—The angle and different distances of bifocal VDT operators and normal VDT operator on test-rig

<table>
<thead>
<tr>
<th></th>
<th>Bifocal (N = 5)</th>
<th>Normal (N = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stage I</td>
<td>Stage II</td>
</tr>
<tr>
<td>Monitor angle</td>
<td>100°</td>
<td>100°</td>
</tr>
<tr>
<td>Head angle (forward)</td>
<td>σ = ±8.12</td>
<td>σ = ±8.4</td>
</tr>
<tr>
<td>Eye monitor</td>
<td>X = 42.28</td>
<td>X = 49.4</td>
</tr>
<tr>
<td>Distance, cm</td>
<td>σ = ±4.76</td>
<td>σ = ±4.78</td>
</tr>
<tr>
<td>Eye keyboard</td>
<td>X = 42.2</td>
<td>X = 44.28</td>
</tr>
<tr>
<td>Distance, cm</td>
<td>σ = ±3.28</td>
<td>σ = ±5.26</td>
</tr>
<tr>
<td>Monitor height, cm</td>
<td>X = 26.5</td>
<td>X = 26.5</td>
</tr>
<tr>
<td>height, cm</td>
<td>σ = ±0.12</td>
<td>σ = ±0.12</td>
</tr>
<tr>
<td>Sitting elbow</td>
<td>X = 17.58</td>
<td>X = 17.4</td>
</tr>
<tr>
<td>Height, cm</td>
<td>σ = ±1.51</td>
<td>σ = ±1.80</td>
</tr>
</tbody>
</table>

Table 3—Mean value (%) and standard deviation of the centre of gravity displacements horizontally (H) and vertically (V) for bifocal and normal operator

<table>
<thead>
<tr>
<th></th>
<th>Bifocal (n=5)</th>
<th>Normal (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>V</td>
</tr>
<tr>
<td>Stage I</td>
<td>40.96</td>
<td>±9.9</td>
</tr>
<tr>
<td>Stage II</td>
<td>31.94</td>
<td>±8.06</td>
</tr>
<tr>
<td>Stage III</td>
<td>30.69</td>
<td>±8.0</td>
</tr>
<tr>
<td>Stage IV</td>
<td>28.54</td>
<td>±8.82</td>
</tr>
</tbody>
</table>

Fig. 1—Recommended VDT workstation
The height of the tabletop should be kept at 70 cm and 6 cm of triangular wooden edge (height × length = 6 cm × 20 cm) should be placed underneath the monitor to adjust it against the visual axis of bifocal or normal operator (Fig. 1).

The height of the keyboard support should be kept at 70 cm which helps forearm to be at 90° with upper arm and enough thigh clearance for even 95th percentile person.

The chair height should be 40-45 cm (adjustable) with 15° backward-forward tilt of backrest.

A footrest (40 cm × 40 cm) should be provided with in the adjustable angle up till 10° from the ground to compensate for seat height and comfortability.

A copyholder should be provided on top of the monitor screen in order to avoid sideways twisting of the head. It can be suspended by ball and socket joint so that its orientation can be adjusted according to operator’s requirements.

References
4 Gandotra V, Oberoi K & Sharma P, Essentials of Ergonomics, 1st edn (Dominant Publisher and Distributers, New Delhi) 2005, 21-68.