Systems Approach to Lighting Design for VDT Workstation

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The paper presents the results of research for defining the interactions between the lighting and biomechanical major extrinsic adjustments (variables) and their consideration for ergonomic lighting design at workstation with video display terminal (VDT).

Abstract

Good lighting design of the VDT work station should account the major user characteristics and the tasks performed. Ideally it should provide the best lighting conditions for work performance with the longest delay in the development of discomfort and visual and musculoskeletal disorders (MSD) and fatigue.. This paper focuses on the adjustment of the many components of a VDT workstation and more particularly on the inter-relationships between the components and the human user. The approach of only studying a lighting variable singly (or in combination with one or two others) could partly explain the reasons of the discrepancy in the ergonomic recommendations for the best zone for different adjustments and the resulting conflicts in certain circumstances. It is obvious that internal interaction exists between the factors affecting the performance and the resulting effect of changing a single adjustment could be amplified, diminished or neutralized.

Introduction

The analysis of scientific studies and recommendations for the best value of a single variable for different components at the VDT workstation reveals many discrepancies and apparent paradoxes. For example, Susumu and Sotoyama (1) reported more visual effort with upward vertical gaze direction than with downward gaze direction, while Kumar (2) recommended mean viewing angle of 35 deg below eye level for bifocal viewers based on lower muscle activity and subjective assessments. The results of de Wall at al. (3) showed 90 percent preferences at +15deg monitor positioning than at -15 deg due to a reduction in requirement for neck extensor activity. Some conflicts are between visual and biomechanical considerations.

Approach:

The literature was searched for relationships between the following **Major Extrinsic Workstation Adjustments** (variables) :Seatpan Height (Hs), Seatpan Angle (θs), Seatpan Angle (θb), Head Support :Yes/No (Hsup),Arm Support: No/Elbow/Forearm (Asup), Mouse Position (Lm), Mouse Height (Hmou), Keyboard Height (Hk), Keyboard Rake(θk), Keyboard Width (Wk),Monitor Height (Hm), Monitor Angle (θm) Monitor Distance (Dm), Luminaire Position (Lp) Luminaire Angle (Lθ). These are shown in Figure 1. The focus of the report is not on the effect of each of the identified dimensions but rather upon their inter-relationship. This took two main forms:

1) The response to one variable changes at different values of the other variable. The response may be comfort, injury potential or performance. This can be tested as a statistical interaction of variables. Not recognising this means that many conflicting study results for the first variable may appear, depending on the value of the other variable.

2) Different values of a second variable dramatically changes the response to the first variable, ie raising or lowering its value.

Relationship of Variables Separately to Discomfort, MSD or Performance

Evidence of inter-relationships was documented for the variables listed and the strength of the inter-relationship and the weight of evidence found. The strength of the relationship was rated as, in the absence of many studies documenting inter-relationships, as **strong, moderate, weak, independent or unknown**. Similarly the evidence was categorized as **unknown, anecdotal, relationship shown** (from data) or a **quantified relationship** (from a design where both variables were varied

independently).
Although not the focus of this research, the effect of a change in each dimension separately was summarized to provide a background for the documentation of inter-relationships. Lastly the inter-relationships uncovered and noted in Table 1 were briefly documented.

Interaction between the visual factors
at VDT Workstations
VDT workstation performance comprise three main visual tasks:
- reading a text displayed on the screen
- recognition of letters or function symbols on the keyboard
- reading a written or typed text on a document placed at a normal reading distance close to the terminal

Other objects also must be viewed, and the conditions for optimum visibility may be far different from a VDT screen's. In addition, a wide range of non-VDT-related tasks may be ongoing at the same place.
Each of these tasks imposes specific visual needs.

Visual tasks and Visual requirements
The type of the activity at the VDT station affects the visibility requirements as well. The emphasis given to each task varies with the nature of the activity: information entry, data enquiry or dialogue.
To perform all these three visual tasks optimally, good visual conditions should be provided. One of the difficulties in obtaining such conditions is that operator has to perform almost simultaneously two visual tasks, corresponding to two different adaptation levels of his eyes. Other obstacle is that the requirements to obtain optimal conditions in each case are not compatible. In addition to that there are many zones where the light sources can give veiling reflections and glare effect (Fig.2).

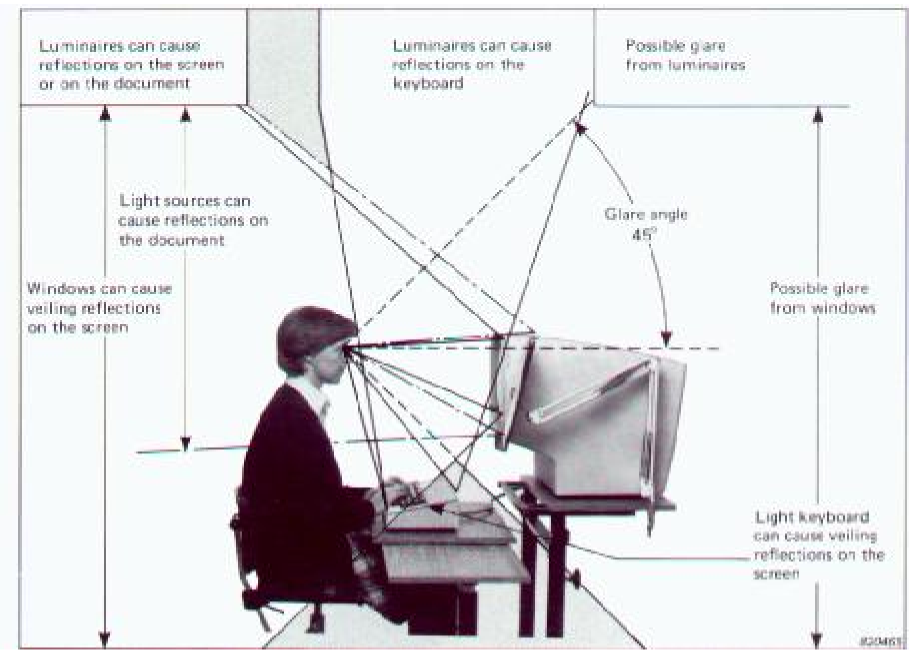


Fig. 2 The three different task: screen, document and keyboard and zones around the screen terminal where light sources can give reflections or cause glare effects (4)

Extrinsic Variable		H_s	θ_s	θ_b	H_{hp}	A_{sp}	L_m	H_{mo}	H_k	θ_k	W_k	H_m	θ_m	D_m	L_p	L_θ
Seatpan Height	H_s		M2					S3,k	S3	S2		S3,k				
Seatpan Angle	θ_s			M1	M1	M1										
Backrest Angle	θ_b				M2	M1						W1			W1	W1
Head Support	H_{hp}											W1	W1			
Arm Support	A_{sup}						S2	S2	M2							
Mouse Position	L_m										S1,k					
Mouse Height	H_{mo}								M1							
Keyboard Height	H_k									S3		K				
Keyboard Rake	θ_k															
Keyboard Width	W_k															
Monitor Height	H_m												W1	S3	S3	S3
Monitor Angle	θ_m														S3	S3
Monitor Distance	D_m														S3	S3
Luminaire Position	L_p															S3
Luminaire Angle	L_θ															

Luminaire
Chair
Arm Support
Input Device
Monitor

RATING SCHEME

Kinematic Constraint
k

Strength of Relationship
S *Strong*
M *Moderate*
W *Weak*
I *Independent*
blank *Unknown*

Evidence of Relationships:
1 Anecdotal relationship
2 Relationship shown
3 Quantified relationship

Table 1: Inter-relationships between the Major Workstation Dimensions

Operator's visual capability and visual comfort

Readability of the text on the document requires a relatively high ambient illumination level , which corresponds to better visual acuity. However, a high ambient illumination level may reduce the readability of the text displayed on the screen.
Many parameters influence the readability on the screen, such as dimensions of characters and the sharpness of their contours, contrast between the letters on the screen and the background, and the colours of the characters and their background.
Readability on keyboard and on the document depends on the reflectance characteristics of the key surfaces and of the document (paper), the contrast between characters and their background, and the way of they are lit.

Inter-relationships between Variables:

Distance : Line of sight
The viewing distance to the reading materials varies in the different ergonomic recommendations and settings at the experiments carried from the researchers for test of the visual performance. Hill and Kroemer (5) found that preferred declination of the line of sight become lower as the object of view become closer.
The optimum viewing distance for office work in the seating position is defined 600 mm with tolerance 150 mm (ISO/FIES 9241-5)

Monitor Height: Monitor Angle
The visual capability and the feeling of visual comfort are affected of the position of the screen surface in relation to normal viewing line. This position of the screen is defined by tilt angle of the monitor with vertical plane and height of the monitor.

The best viewing conditions are achieved when the surface of the screen is situated at 90 degree (perpendicularly) to the viewing direction, position approved from many researchers and ISO9241/5. Since many recommendations for visual comfort favour a download eye inclination, approximately at 15 degree, it was widely accepted monitors to be placed at or slightly below eye-level. The new ISO/FDIS 9241-5:1998(E) constitute the top line of display not to be higher than eye-height. The screen should be at right angles to the angle of view. The best viewing conditions are achieved when the surface of the screen is situated at 90 degree (perpendicularly) to the viewing direction, position approved from many researchers and ISO 9241-5.

Monitor Height: Monitor Distance
Interaction between viewing distance and monitor height described shown in Table 2. Monitor close and at eye level was rated as giving higher eyestrain than other combinations. Interaction is statistically significant according to Jaschinsky et al.,(6).

Table 2: Interactions of Monitor Height and Distance and Eyestrain

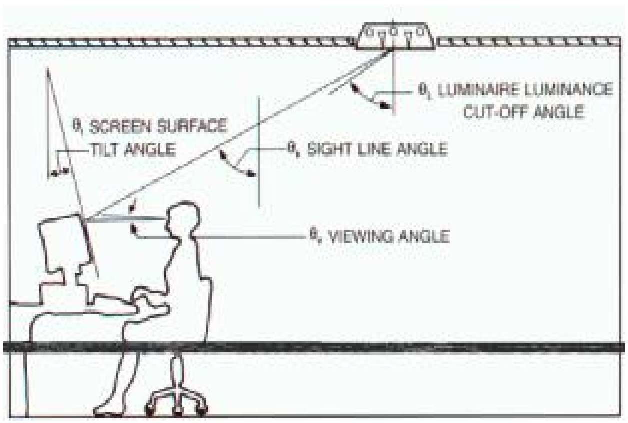
	Monitor Low	Monitor High (eye level)
Monitor Near	12*	14
Monitor Far	12	11

** Eyestrain values (higher is worse) estimated from Figure 2 of* Jaschinsky et al., (1998**)**

Monitor Height : Head Support
At monitor heights above eye level there is a suggestion that operators will not tilt the head back but will use an upwards gaze angle Kietrys et al.,(7). This may be due to a feeling of instability of the head “on the balance point” which head support would remove**.**

Monitor Tilt : Luminaire
Position : Luminaire Cutoff Angle
Fig 3. The three angles that should be considered in order to escape the glare: the viewing angle and screen tilt angle govern the angle from vertical of the sightline from the screen to ceiling, IES RP-24-1989(8). A factor that may affect monitor location is the interaction between glare and monitor tilt.
In many offices lowering and tilting the monitor back will result in unacceptable level of glare.
The commonly found minimum sight-line angle determines the maximum luminaire luminance cut-off

angle. In order to prevent bright luminaire reflections in the screen, the cut-off angle should not exceed the sight line angle.
Findings:
The research defines the major interactions between the major workstation components using literature review. It is shown that many of the dimensions of the workstation are interrelated.As a self-luminous vertical task, the VDT screens present special problems for lighting design. The luminaires should be situated in a way to escape the direct glare and reflections on the screen(Fig.2). The direct and reflected glare not only reduce the visual capabilities, but they also force the operator to change his posture into uncomfortable position to escape their disturbing effect. The disturbance rate correlates with luminance modulation due the reflected image, the effect of ambient light on the display, and the degree to which the display blurs reflected images (a function of screen specularity), Lioyd (9).



θ_v Viewing Angle (Degrees)	θ_s Screen to Ceiling Sight Line Angles From Vertical — For Screen Tilts Angles θ_t (Degrees)				
	0	5	10	15	20
0	90	80	70	60	50
5	95	85	75	65	55
10	100	90	80	70	60
15	105	95	85	75	65
20	110	100	90	80	70

General, ambient light that would be required for paper task becomes a veiling luminance on a VDT screen. This could be the explanation for the preference of the low luminance at VDT offices, Shahnavaz (10). The veiling reflectance reduces the contrast between the characters and screen’s background and has a predictable effect on the visual performance, Rea(11), Topalova (12).
We therefore recommend that studies and analysis approaches should be enhanced to address this issue. The results of this study suggest that:
1) When a user adjusts a dimension of their workstation, as they are frequently exhorted to, in many cases other dimensions will need to be changed to maintain a healthy computing environment.
2) The inter-relationships of the major workstation variables should be considered in the design and analysis of experimental studies on VDT workstations for visual comfort, MSD or performance.

Conclusions

The conducted research confirmed that the design of an efficient and comfortable workplace with VDT require a proper system approach.

It is obvious that the further ergonomic study should incorporate the geometry of lighting setting with viewing parameters and neck-shoulder strain. Systematic study from these three stand points will allow us to define the best dynamic optimal parameters for designing of scientifically based ergonomic VDT workplace.

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