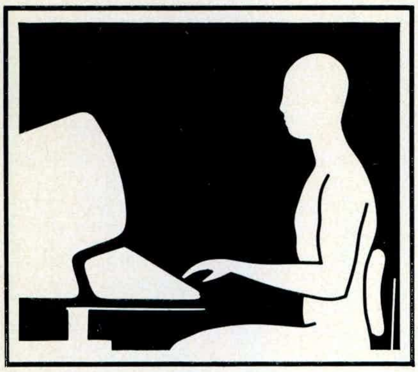

Aspects of Visual Stress in Visual Display Terminal Work

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Abstract

There have been frequent complaints arising from the operation of visual display terminals (VDT's). Radiation, ergonomics, and lighting factors have been intensely investigated,[1,2,3] but visual stress has not received the same attention and study.

This paper discusses inherent deficiencies in the images of a VDT, how the visual system reacts, and how fatigue results from the stress.

Recommendations and solutions for the VDT operator are explored.

Abrégé

L'usage d'écrans cathodiques est fréquemment source de malaises et de plaintes. Les facteurs de radiation, d'illumination et la situation ergonomique ont reçu beaucoup d'attention. Ce n'est pas le cas du "stress visuel". Ce travail enquête sur les déficiences inhérentes des images des écrans cathodiques, sur les réactions du système visuel face à cette tâche et tente d'expliquer le pourquoi et le comment de la fatigue résultant de l'usage de ces appareils.

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Print Material vs. Visual Display Terminal Images

Images are generated on a VDT by a high-voltage electron beam scanning over the phosphor-coated inside surface of a cathode ray tube. These phosphorus particles are excited by the beam to a transient higher energy state. After excitation, the particles drop back to their original energy level, releasing absorbed energy in the form of electromagnetic radiation, some of which is visible light, seen as a VDT image.

These electronic images, or characters, are not considered ideal stimuli for vision. In comparison with printed matter, VDT characters have a number of shortcomings not seen in printed matter, namely flicker, glare, contrast and their dot matrix method of character generation.

Flicker

Flicker refers to the intermittent release of light energy by the phosphor. The rate of flicker is directly related to the rate of scan of the electron beam. This, in turn, is controlled by the rate of polarity reversal of the alternating current, which in North America is 60 cycles per second. Flicker, which requires neurological processing to render an image as continuous is, of course, not present in printed matter.

Glare

Glare refers to the reflection of external sources of light from the surface of the cathode ray tube. These reflections reduce contrast and legibility of characters, but may be controlled by various measures. Installation of anti-glare screens, removal of glare sources and proper lighting design of the VDT environment are examples of such measures. The surfaces of a display unit generally reflect light much better than paper, even glossy white paper.

Contrast

Contrast of images may be reduced by glare, lack of servicing, dust accumulation on screen surfaces or high levels of ambient room illumination. With printed matter, contrast is constant and usually high. Also, most phosphors eventually suffer a permanent loss of light output, which is accelerated by operation at high levels of brightness[2].

Method of Character Generation

Typically, VDT characters are generated by a dot-matrix method in which discrete dots make up the skeleton of the figures. These dots are enlarged and blurred to create complete characters. Resultant figures are complete, but have blurred edges. Printed characters do not usually suffer from this defect. Other factors such as chromaticity and character instability contribute to the list of shortcomings of VDT images.

The Visual Mechanism

The visual system works more efficiently when stimuli are clear, stable and of normal contrast. This type of stimulus is conducive to efficient accommodation, fixation and neural processing. VDT characters, because of their properties, flicker, glare, contrast and edge blur, are not ideal stimuli and have been shown to present difficulties to the visual system. The visual system manifests these difficulties with accommodative instability, fixation difficulties and changes in flicker fusion processing.[6,8]

Accommodative Search and Fatigue

With VDT images, the accommodative system tends to continually focus or search in a futile attempt to produce a clear image from the dot-matrix characters with blurred edges. Stark and Takahashi[5] found that a major stimulus to accommodation, whether accommodation was appropriate or not, is a blurred image. The resultant focussing search in VDT images is higher than in non-VDT images, and more inducive to accommodative fatigue. One important sign of this accommodative fatigue was shown by Murch[6] who demonstrated that VDT images did not elicit optimal accuracy of accommodation. Instead, the accommodative system moved towards the dark focus, or resting point of accommodation, rather than focus accurately on the plane of the VDT screen. The dark focus (as in empty field myopia), or the resting point of accommodation, refers to the refractive state of the eye when there is a lack of useful visual stimuli. This refractive state showed typical values in the -1.00 to -1.50 dioptre range[7]. The tendency of the accommodative system to move toward the dark focus was an indication of the relative inadequacy of VDT images as accommodative stimuli. This inaccuracy of accommodation is a lag of accommodation seen with printed matter.

Fixation and Spontaneous Eye Movements

The fixation of visual targets is accompanied by involuntary spontaneous eye movements. These movements are very small and keep the image projected on the retina in constant motion. Three types of movement have been identified: i) a slow "drift" causing the image to move slowly from the fovea; ii) a high-frequency "tremor" with vibration rates of 30 - 80, and up to 150 cycles per second; iii) a flicking "saccade" that returns the image to the fovea at the end of the "drift". These small eye movements sharpen contrast, transmit edge information and prevent retinal adaptation in attentive fixation[8].

With VDT images, it is probable that the function of these movements is compromised, that interaction of the small eye movements and the 60 cycle per second flicker of the VDT contributes to the perception of character instability, as well as to the difficulties in the neural processing of the image.

Critical Flicker Fusion Frequency and Neural Processing

The frequency at which a flickering stimulus changes in appearance from a discontinuous to a continuous one is the critical flicker fusion frequency (CFF). This is the lowest frequency at which a flickering stimulus is perceived as temporally continuous. A particular flickering stimulus may be continuous under some conditions, yet flicker under others. Many variables affect the value of CFF, some of which are: luminance of the stimulus, spectral composition, retinal position, size, temporal waveform, monocular vs. binocular presentation, stimulus pattern, state of retinal adaptation, pupil size, age of observer and general state of health.

Under the right conditions, the CFF ability of a given operator may approach or exceed 60 cycles per second at which time flicker could be perceived. A hypothetical example is one in which the VDT image is bright and large and is viewed by the light-adapted eyes of a young person in good health. Discussion of the neural processing of a flickering stimulus is complex. Suffice to say that the processing of a flickering image is more taxing than that of a non-flickering image.

Visual Fatigue and VDT Images

As compared to otherwise similar non-VDT work, VDT work has been shown, directly or indirectly, to cause lowered accommodative accuracy, accommodative spasm, accommodative infacility and decrease of CFF. These induced deficiencies are discussed below.

Lowered Accommodative Accuracy

Murch[6] has demonstrated by laser refraction that the visual system does not accommodate as accurately to VDT images as to print copy. Laser refraction is a quasi-objective method of determining refractive status and can be used while the visual system is actively engaged in VDT work. Because it was felt that the visual system under stress would gravitate toward the dark focus[6], working distances were recommended which would allow the plane of the VDT screen to approach the dark focus. This would allow the underaccommodating visual system to maintain a clearer focus. Alternatively, the same result could be obtained with spectacles.

Increased Tonus, or Spasm, and Accommodative Infacility

Ostberg[10], also using laser refraction, found significant changes in the accommodative system after VDT work. Dark focus values increased temporarily indicating transient increased ciliary tonus or spasm. Transient accommodative infacility also occurred resulting in distance myopia and near hyperopia. In a group of nine air traffic controllers, dark focus values changed from 0.94 to 1.62 dioptres and accommodative facility decreased significantly, after two hours' work at a radar screen. For each subject, accommodation became more myopic for distance and more hyperopic for near. Similarly, Holler[11], using conventional refraction, found a 0.25 dioptre increase in distance myopia after four hours' VDT work, with recovery in 15 - 20 minutes in nine of the 14 subjects. These temporary changes in the ciliary muscle or corresponding innervation were suggestive of higher levels of stress in VDT work.

Decrease of CFF

CFF is an individual parameter, as discussed earlier, and an indicator of the ability of the central nervous system to detect a flickering image. This ability was shown to decrease after VDT work, again indicating visual fatigue[12].

Statistical Studies

Two relatively recent surveys of VDT and non-VDT workers in the United States and Canada are The National Institute of Occupational Safety and Health (NIOSH) 1979 survey[13] and the Canadian Labour Congress (CLC) 1982 Labour Education and Studies Centre Survey[14] respectively.

The first of these used, for statistical evaluation, a sample comprised of 42 VDT operators and 16 non-operators from three unions and showed a clear trend toward more problems among VDT operators.

Table 1

Frequent or Constant Vision Complaint	VDT Operator %	Non-VDT Operator %
Tearing or itching	41	24
Burning	37	16
Blurred vision	43	13
Eyestrain or sore eyes	52	18

The CLC survey compared VDT to non-VDT workers in 15 workplaces representing 12 employers and eight unions. There were 2,330 responses, making this the largest survey of its kind done in North America to date.

In the CLC survey, VDT workers experienced eye and vision problems twice as often as otherwise equivalent non-VDT workers. Most severely affected were those workers in intensive-use occupations, e.g. telephone operators, reservation agents, data entry operators and word processing operators. Overall, 41% of all VDT workers reported more frequently a change in lens prescription over the past year than did non-VDT workers (41% vs 35%). Severity and frequency of the symptoms such as burning, aching and blurring increased directly with the total number of hours worked on a VDT, and with the length of time worked without a break.

Both surveys indicated clearly that reports of visual complaints were more frequent and more severe in VDT workers than in their non-VDT counterparts in the groups studied.

Recommendations

The following recommendations have been made to minimize visual stress from VDT work, to increase comfort and efficiency.

Special VDT Spectacles

Non-Presbyopic Operators

With printed matter, the accommodative system of non-presbyopes is usually capable of sustained near work without unusual difficulty. However, with VDT images, the accommodative system of non-presbyopes has been shown to suffer the search[5], gravitation toward the dark focus[6] and accommodative infacility[10] after periods of work. Murch[6] has concluded that when a VDT is located at a distance corresponding to the resting point of accommodation, either physically or optically, any image, optimal or sub-optimal, can be held in more comfortable focus. VDT spectacles in the non-presbyope as a low plus or a near add correction were recommended to allow the dark focus to more easily approach the plane of the VDT image.

Presbyopic Operators

The conventional near correction for 40 cm. is often too restrictive for presbyopic operators. For example, the range of clear vision for a +2.50 addition extends to 40 cm. only. In practice, few VDT situations have working distances less than 40 cm. In prescribing VDT spectacles, consideration should be given to the greater working distances and occurrence of the dark focus. Krueger[15] has suggested values of VDT adds of +1.00 to +1.50 to allow a usable range of clear vision. It must be emphasized that working distances to the different work surfaces be known to determine the best compromise in add power and range of clear vision.

Single Vision vs. Multifocal

Grundy and Rosenthal[2] have felt that bifocals and trifocals would be acceptable, but should be adapted for VDT use by raising segment heights to correspond with the usually high position of the terminal screen. Others[12,15] have rejected multifocals because of the (corresponding) forced head posture, resultant cramps and frustration with segment size limitations. It is clear that optometric judgement is required in situations where either treatment may be used successfully.

Refractive Errors

Correction of ametropias, even small amounts, should be given careful consideration. Under the stress of VDT work, small amounts of astigmatism and hyperopia are apt to contribute to fatigue. The prescribing of a low add could be considered in both presbyopes and non-presbyopes. In low myopias, the removal of the distance correction may be an adequate solution.

Viewing Distances

Recommendations in the literature have been made about placing the display screen, keyboard and copy documents all at equal viewing distances to reduce the need to change accommodation. It has been shown by Krueger[15] that equal distances in the non-presbyopic operator may mean "uneconomical static muscular work" for the ciliary muscle. Deterioration of the accommodative efficiency was observed monocularly after some ten minutes of static accommodation. On the other hand, Krueger has also shown that constant changes in accommodation caused fatigue only after extended periods. Change in accommodation between 6.00 and 0.50 dioptres every four seconds caused fatigue only after 2.5 hours.

It follows that unequal viewing distances are not unduly fatiguing for the non-presbyopic operator. For a presbyopic operator with a lowered accommodative efficiency, equal distances to work surfaces would likely be of benefit. Measures of optimal viewing distances for non-presbyopes have been given by Murch[6] and Snyder[16], the former recommending distances greater than 50 cm. to avoid loss of resolving power and contrast sensitivity. It can be concluded that equal viewing distances are of greater importance to presbyopic than to non-presbyopic operators because of differences in accommodative efficiency.

Visual Hygiene

Visual hygiene refers to habits adopted to relieve the visual system of stress, in the case of VDT's, nearpoint stress. There is a general consensus that hourly rest breaks of ten to 15 minutes and limitation of total daily time spent on a VDT is required. A general recommendation to avoid VDT stress is to relax positive accommodation by, for example, fixating distance targets periodically. Other recommendations involve periodic ocular rotations, jump ductions and vergence exercises, and extra-ocular and ciliary muscle calisthenics to avoid static muscular fatigue. The use of near additions or low plus lenses to compensate for an underaccommodating system has already been mentioned.

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