AN INVESTIGATION OF THE HEALTH AND FATIGUE EFFECTS RESULTING FROM VIDEO DISPLAY TERMINAL USAGE

by

Helen Dorothy Ward
B.Sc.Honors(Kinesiology) Simon Fraser University 1980

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE (KINESIOLOGY)
in the Department
of
Kinesiology

© Helen Dorothy Ward 1983
SIMON FRASER UNIVERSITY
November 1983

All rights reserved. This work may not be reproduced in whole or in part, by photocopy or other means, without permission of the author.
APPROVAL

Name: Helen Dorothy Ward
Degree: Master of Science (Kinesiology)
Title of Thesis: An Investigation of the Health and Fatigue Effects Resulting from Video Display Terminal Usage

Examining Committee:
Chairman: Dr. D. Goodman

Dr. J. Dickinson
Senior Supervisor

Dr. T.J. Smith

Dr. J. Jahtzi

Dr. B. Beyerstein
External Examiner
Psychology Department
Simon Fraser University

Date Approved: March 5th, 1984
PARTIAL COPYRIGHT LICENSE

I hereby grant to Simon Fraser University the right to lend my thesis, project or extended essay (the title of which is shown below) to users of the Simon Fraser University Library, and to make partial or single copies only for such users or in response to a request from the library of any other university, or other educational institution, on its own behalf or for one of its users. I further agree that permission for multiple copying of this work for scholarly purposes may be granted by me or the Dean of Graduate Studies. It is understood that copying or publication of this work for financial gain shall not be allowed without my written permission.

Title of Thesis/Project/Extended Essay

An Investigation of the Health and Fatigue Effects Resulting from Video Display Terminal Usage

Author:

(signature)

H. Ward

(name)

March 26/94

(date)
ABSTRACT

The video display terminal (VDT) has become an integral part of the modern office. While increased productivity has been emphasized, the needs of the operator have often been overlooked. Complaints from VDT workers include symptoms of visual discomfort due to poor image quality and glare, musculoskeletal discomfort due to poor workstation design and somatic discomfort due to stress.

A work environment survey questionnaires was designed to assess the physical and psychosocial influences on the health of 1100 VDT operators in the New York district. A higher percentage of professional VDT operators experienced the greatest number of health-related complaints. Stress factors were particularly relevant to the professional workers. Complaints about the physical environment, particularly the quality of room air, were expressed by professional VDT operators. When data from one building which housed each professional and clerical VDT and non-VDT group were analyzed, differences in complaints of the physical environment and health symptoms were minimized. Only for stress factors was there a significant difference in the responses (chi-squared analysis, p<0.05) in which professional workers had a higher percentage of complaints. An overview of the data reveals that symptoms of poor health appear related to air quality complaints.

The experimental session consisted of a two-hour VDT work period followed by a fifteen minute rest break. The same twelve
Subjects served as controls during another two-hour period without VDT exposure. Critical flicker fusion frequency, contrast threshold at 40 cycles per eleven cm and accommodative facility showed significantly different decrements in visual function after the two-hour session as compared to before (repeated measures ANOVA, \( p < 0.05 \)). For contrast threshold at 30 cycles per eleven cm, accommodative response and the control sessions no significant differences were discerned. Ten of fourteen dipolar psychological fatigue indicators showed significant differences after the experimental session from before while none of the control measures did (repeated measures ANOVA, \( p < 0.05 \)). Recovery was evident in that most experimental visual function and psychological fatigue variables returned to previous levels. The results of the experiment indicate that the recommendation of a two-hour VDT exposure period may be too long.
ACKNOWLEDGEMENTS

I would like to thank all the members of my thesis committee for their invaluable support and encouragement. I am indebted to Dr. Jantzi for his advice on visual function measurement. TDS Ltd. provided needed support by allowing me to contribute major input into the Health and Work Environment Survey conducted in cooperation with local 90 of the Office and Professional Employees International Union. I thank Diane Hartell-Kobayashi in particular for administering the questionnaire in New York. My husband, Richard gave me hope and love when I needed it most. Thank you.
TABLE OF CONTENTS

Approval ...........................................................................................................ii
Abstract ...........................................................................................................iii
Acknowledgements .........................................................................................v
List of Tables .................................................................................................viii
List of Figures ...............................................................................................ix
A. The Health Effects of VDT Use .................................................................1
   I. Introduction ............................................................................................2
   Overview of the VDT Problem ...................................................................2
   VDT Mechanics .........................................................................................4
   II. A Literature Review of VDT Health Effects ................................. 5
   Summary of the Radiation Hazard ............................................................5
   The Symptoms of Visual Discomfort .......................................................6
   Visual Discomfort Due to Image Quality ..............................................10
   Visual Discomfort due to Glare ...............................................................15
   Musculoskeletal Discomfort ....................................................................21
   Somatic Discomfort .................................................................................28
B. Evaluation of VDT Problems by Questionnaire ..................................34
   I. The Questionnaire Study ....................................................................35
   Rationale for the Questionnaire ..............................................................46
   Methods ....................................................................................................47
   Results .......................................................................................................48
   Discussion .................................................................................................63
C. An Experimental Study to Determine Visual Function
   Effects of VDT Use ................................................................................67
   I. The Experimental Study ....................................................................68
LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Description</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Job Type by Percent Complaining of Health Problems at Least Once a Week</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
<td>Job Type by Percent Complaining of Stress</td>
<td>54</td>
</tr>
<tr>
<td>3</td>
<td>Job Type by Percent Complaining of the Physical Environment</td>
<td>56</td>
</tr>
<tr>
<td>4</td>
<td>Job Type by Ability to Control Environment</td>
<td>57</td>
</tr>
<tr>
<td>5</td>
<td>Frequency of VDT Use by Complaints Found to be Significantly Different Between Groups by Chi-Squared Analysis (p&lt;0.05)</td>
<td>59</td>
</tr>
<tr>
<td>6</td>
<td>Job Type versus Stress in a Building where Stress was Significantly Different Between Groups (Chi-squared Analysis, p&lt;0.05)</td>
<td>62</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>MEAN EXPERIMENTAL CHANGES IN CFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean Experimental Changes in CFF</td>
</tr>
<tr>
<td>2</td>
<td>Mean Experimental Changes in Contrast Threshold at 30 cycles/11cm</td>
</tr>
<tr>
<td>3</td>
<td>Mean Experimental Changes in Contrast Threshold at 40 cycles/11cm</td>
</tr>
<tr>
<td>4</td>
<td>Mean Experimental Changes in Accommodative Response</td>
</tr>
<tr>
<td>5</td>
<td>Mean Experimental Changes in Accommodative Facility</td>
</tr>
<tr>
<td>6</td>
<td>Mean Contrast Threshold at 40 cycles/11cm - Experimental vs Control</td>
</tr>
<tr>
<td>7</td>
<td>Mean Accommodative Facility - Experimental vs Control</td>
</tr>
<tr>
<td>8</td>
<td>Mean Contrast Threshold at 40 cycles/11cm by VDT group</td>
</tr>
</tbody>
</table>
A. The Health Effects of VDT Use
I. Introduction

Overview of the VDT Problem

The character of traditional office work has undergone a metamorphosis not unlike the one created through the introduction of the typewriter over a half century ago. The video display terminal (VDT or VDU), the T.V.-like computer terminal, has become an integral part of the modern office. With its ever expanding range of applications the VDT has permeated a wide range of government and private industries. Publishing, communications, banking and airline concerns are but few examples. VDTs have even begun to invade the sanctuary of the home as attested to by the recent proliferation of personal home computers and computer games. There are currently at least 250,000 of the video display terminals in use across this country (Donoghue, 1983). The National Institute for Occupational Safety and Health (NIOSH) estimates that seven million workers in the U.S. now operate VDTs (Bergman, 1980). By 1985 the number of computers, terminals and electronic office machines in the United States is expected to grow to 35 million, which will amount to about one computer-based machine for every three persons employed in the white-collar work force (Bhise and Rinalducci, 1981). With the continuation of this trend we shall
see, as Ostberg succinctly puts it, the "rapid evolution of the species homo termino-videns (the VDT-viewing man)" (Ostberg, 1980).

The major selling point of the VDTs has been the potential increase in productivity which they afford. Unfortunately, the needs of the human operator have often been overlooked. Almost universally the video display terminals are installed into established office surroundings rather than within an environment more compatible with operator comfort and protection. As a result "the dialogue with the computer implies not only uncomfortable physical conditions at work (visual, acoustic, climatic conditions) but also mental strain and a new type of constraint on productivity" (Rey et al., 1977).

More illustrative of this failure is the growing disenchanted and resistance of the operators towards using the units. Increasing concern over the potential health hazards which may accrue through full-time use of the machines is being voiced. For instance, 250 conference typists and translators at the United Nations staged a walk out to protest the management's refusal to shut down the VDTs until a health study had been carried out (Ostberg, 1979). According to the Director of Research and Information at the Newspaper Guild in the U.S., "No other factor in the work environment not indeed, all others combined - has ever created such a torrent of health complaints and problems as have VDTs" (Bergman, 1980).
VDT Mechanics

The visual display terminal provides a quick and convenient means of accessing and manipulating the storage of a central computer. It comprises three main elements: a display screen, a keyboard and an electronics pack with power supply. These may all be contained within a metal, fibreglass or plastic housing with the operating temperature kept stabilized by means of an internal fan.

The cathode ray tube, or CRT, is the basic element around which display terminals are constructed. The CRT is basically an evacuated glass tube with an electron gun at one end and a screen which is coated with a light emitting phosphor at the other. When a high voltage is applied to the electron gun the stream of electrons produced is focused and deflected by an electronic lens system to the face of the screen by means of an electrostatic or electromagnetic force. This moving electron beam scans across the entire screen in a series of regularly spaced horizontal lines, activating tiny glowing phosphor dots. For the commonly used "refresher" CRTs the electron beam switches on and off so that a matrix of dots is formed according to the desired shape of the character. The ratio of the height to width of this matrix ranges from a 5 x 7 dot matrix to a 7 x 9 dot matrix. Most VDT screens are about 15 to 20 cm high and 20 to 25 cm wide and have a normal capacity of up to 80 characters per line (Cakir et al., 1979; McGrath, 1981).
II. A Literature Review of VDT Health Effects

Summary of the Radiation Hazard

The topical issue of whether VDTs pose a radiation hazard will not be covered in detail. The experimental protocol and questionnaire survey used for this thesis do not provide the scope to cover the radiation issue. In addition, numerous recent studies of this potential hazard have been unanimous in their conclusion that no harmful levels of x-ray and non-ionizing radiation exist. A focal issue is the effect of long term exposure to low levels of electromagnetic radiation. For example, the U.S. currently has an exposure standard to nonionizing radiation of 10 mw/cm². Yet, according to Dr. Morris Shore, Director of the Division of Biological Effects at the Bureau of Radiological Health in 1977, (cited in Flewelling, 1980)

"There are mistakes that have been made in the past, and I would hope that these could be avoided. A specific example is the certification of safety of 10 mw/cm² for indefinite human exposure in the absence of any studies in animals or in man that tested the chronic or lifetime effects of exposure to 10 mw/cm². Such certification, based on ignorance, strains the credibility of a level that is recommended as being adequate to protect health and safety particularly of the general population."

In Canada, recent publicity has centred on groups or "clusters" of abnormal pregnancies (miscarriages and birth defects) among
some VDT workers which may be due to chance alone. The controversy still has not been settled; currently under consideration are amendments to the Canada Labor code which would allow pregnant women to transfer away from VDTs (Labour Canada, 1982).

The Symptoms of Visual Discomfort

The complaints expressed by operators of VDTs have included such ocular symptoms as the eyes feeling tense, heavy, dry, itchy or uncomfortable. A burning pain may be felt and the eyes may be generally tender on pressure. There may also be an ache from within or behind the eyes or twitching of the eye muscles. The visual symptoms may include some difficulty in fixating objects and in gazing in certain directions for more than a short period. Vision may be blurred, single objects may seem to have color fringes or appear double and there may be subsequent problems in watching a television or movie screen (Ostberg, 1975).

Gunnarson and Ostberg (1977) for example, found 75% of the interviewed VDT operators (totalling 48 persons) experienced some sort of eye problems every day or a few times per week. Of these, 46% reported that the problems were great or very great. The complaints were defined primarily as eye fatigue (60%), burning, feeling of gravel or itching in the eyes (48%), double or blurred vision (19%) and eye redness (15%). The job factors
perceived as the most eye straining were looking at the display screen (56%), shifting from screen reading to manuals (15%), and reading manuals (29%). More conservative estimates of visual problems were given by Grandjean (1980). He estimated that in general, 10 to 15% of the VDT operators had almost daily pains or irritations in their eyes, while 40 to 50% reported occasional impairments. Lautli et al. (1980) demonstrated that these ocular symptoms may persist during the evening until bedtime.

"All these authors conclude that continuous work on VDUs is for a relevant part of the operators - associated with a pronounced impairment of the well-being in the sense of excessive fatigue of the eyes often associated with painful reactions and decrements of visual performances. In general, these impairments are considered rather as reversible and functional troubles than as persistent injuries to health" (Grandjean, 1980).

Clinical evidence (as cited in Dainoff, 1979) is provided by Sparks and Hebert. Both researchers indicated that a large number of visual complaints and requests for corrective lenses have been made by VDT workers.

It is important to determine whether eye problems appear with a greater than normal incidence among VDT operators. For example, Stone (1981) cited Brundrett's study in which 40% of general office workers complained of ocular discomfort.

All the research on VDT operators to date has concurred with Rey and Meyer's (1980) conclusion that "VDU operators complained more often of visual impairment than other operators of the same age". This difference was increased with work
duration and 75% of the VDU operators complained after working 6 to 9 hours in front of the screen.

Gunnarsson and Ostberg (1977) showed that there was a large variation in viewing distances required during the course of a work day. Approximately 38% of operator viewing time was allocated to the "close vision" range of distances (0-45 cm); 47% to the median range (45-100 cm) and 15% to the far range (greater than one meter). The authors suggested that this degree of variation in viewing distances placed a heavy demand on the visual capacities of the operators. Cakir et al. (1979) also point out the burden involved in changing viewing distances between the screen, keyboard and document. They recommended that visual objects should be ideally situated at the same distance from the users' eyes. Recent findings in a study by Quebec ophthalmologists supported this observation. The most common visual complaints by VDT operators were found to decrease when the users learned to glance back and forth less often from the screen to the hard copy (The Province, 1982).

This notion of looking at fixed distances has not received unanimous support. Cullen (1982) emphasized that staring at a fixed distance can cause ciliary muscle spasm and subsequent visual fatigue. He recommends "exercising" the accommodative system by shifting one's gaze to objects at differing distances. According to Krueger (1980) the common recommendation of an equal viewing distance for the display, keyboard and document derives from the fact that accommodation and convergence demand
for different distances require time. At the same time such a recommendation means tiring static muscular work for the ciliary muscle.

A problem that results when the VDT operator spends a prolonged amount of time focusing at a fixed distance and not periodically shifting her gaze to a far point, is fatigue of the intrinsic and extrinsic eye muscles. Eventually this fatigue may cause a decreased ability to maintain a fixed gaze or focus on distant objects. Double vision may be a result in the more extreme cases (Arndt, 1980). The eyes must be allowed to "rest" and an empty field surrounding the immediate task is to be avoided (Ostberg, 1975). Coe et al. (1980) indicated that the workplaces of input VDT operators had a relatively low percentage (52%) of distant locations where they could look in order to rest their eyes from close work. These operators also reported higher levels of the irritant component of asthenopia.

Light/dark adaptation is the ability of the retina to change its sensitivity with varying illumination levels. It is suggested that this can be adversely affected by the large contrasts of the surface luminances between screen and source documents, as well as between the screen and surrounding elements, like windows, walls and light sources (Grandjean, 1980). During reading, and most probably, VDT-viewing, the blink rate decreases from a normal rate of twelve times per minute to about five times per minute, which results in corneal and conjunctival dessication. This accounts for the symptoms of
"burning, grittiness", and also partly for "tiredness".

**Visual Discomfort Due to Image Quality**

The image quality of the VDT is determined by a number of interacting parameters. These include: (1) character patterns (2) chromaticity (3) luminance and contrast and (4) stability.

Character Patterns

Dot matrix character generation is most commonly defined by a selected set of dots from a rectangular matrix of dots as the electron beam scans through its raster pattern. For viewing at a close range, dot matrices of 5 x 7 or 7 x 9 are considered to be best for the recognition of small letters, the 7 x 9 matrix being preferable (Rosenbaum, 1981). If the characters are too large the dots will appear to separate. The optimal character size would subtend about 20 - 25 minutes of arc at the eye (about 3.0 mm at a 50 cm viewing distance). A width of 70-80% of character height is recommended. Character and line spacing is also important for good legibility. Between 20% and 50% of the character width is recommended for character spacing whereas interline spacing should be between 100% and 150% of the character height. The display capacity of most text input and editing VDTs thus typically contains 25 to 30 eighty character lines (Cakir et al., 1979; Stewart, 1979; Hart, 1976).
Chromaticity

The background color of the display screen is determined by the emission characteristics of the phosphor with which the inner surface of the screen is coated. Color affords a contrast component which increases the distinction of the characters against the reflection on the glass plate. Since retinal sensitivity is greatest for wavelengths from the middle part of the spectrum (555 nm), yellow/green characters on a darker background are favored (Birnbaum, 1978). A black/white combination is sometimes preferred as it ensures good legibility and contrast with less strain on the eye due to glare. Other color combinations which have been used include blue/grey, green/black and orange/amber (Hart, 1976).

Dr. Merrill Allen has even suggested that the typical display of bright letters on a dark screen is harmful. Reversing the display to a negative contrast "is also more natural, comparing favorably with a typewritten page on white paper" (Word Processing World, 1976). Visual acuity was found to be lower with the positive contrast of light characters on a dark background, than with negative contrast (Rey, Meyer and Degoumois, 1977). These researchers found, however, that scintillation of video white can induce ocular fatigue over the long run. Yet recent improvements have resulted in the West German government approving new equipment safety laws in which
the major terminal design requirements include negative images of dark characters on a light background (Manuel, 1982).

Luminance and Contrast

The question of screen luminance and thus brightness contrast between the characters and the background must be considered in relation to the overall illumination of the room at the terminal station. Gould in 1968 (as reported in Dainoff, 1979) pointed out that in theory, to achieve a comparable contrast ratio that is found for clearly typed letters (1:7) the measured screen/letter contrast ratio should be 30:1. This is because the face of the screen reflects ambient light back to the observer (veiling glare). However Grandjean (1980) reported that contrast ratios found varied from 2:1 to 30:1, the median value being 9:1. Near visual acuity in low contrast conditions causes ocular fatigue when reading screens.

The average brightness in the total visual field determines the level of retinal adaptation and must thus be matched to the brightness of the surrounding visual objects. To avoid disturbing contrast changes in the peripheral vision of the operator, the recommended ratio between screen brightness to that of the surroundings should be 1:3 for areas immediately surrounding the VDT (near field) and 1:1 for other areas (far field, Dainoff, 1980a). Field trials have revealed much higher luminance ratios. For example Laubli et al. (1980) upon measuring 162 VDT workplaces found that contrast ratios of
screen background to source document (near field conditions) were in the order of 1:25 whereas average values of 1:300 were observed for screen background to window (far field) ratios. Significant correlation coefficients in the order of 0.25 were found between the contrast ratios and eye impairments. Laubli et al. (1981) found high luminance contrasts between screen, source document and the surrounding space to be associated with an increase in eye problems. They concluded that high contrast, especially between the source document and the screen, can contribute to long lasting ocular symptoms.

Stability

Display instability distracts and fatigues the viewer. In some VDTs, interlaced scan lines are used to improve small matrix characters by filling in a dot where two dots meet diagonally. If the refresh rate is 50 Hz, then each interlaced field will be refreshed at 25 Hz with adjacent scan lines refreshed alternately. A disturbing "jittering" effect may result. Mains interference in the D.C. supply circuitry may cause "drift". This is reduced by careful positioning of the components. More sporadic types of image instability can also occur as the result of short term surges of power in an unstabilized power supply.

The usual type of instability encountered is "flicker" due to the decay of the phosphorescent image before it is refreshed
by the electron scan. While increasing the persistence of the phosphor could overcome flicker, problems with tube life, burn resistance and smear could emerge. The refresh rate is currently fixed at between 50 and 60 Hz due to bandwidth and other technical constraints.

In general, the brighter, the more dense and the larger the display, the more noticeable is the flicker. With increasing age the ability to detect rapidly flickering objects diminishes (Cakir et al., 1979). Subjective discomfort to flicker is quite variable. Ostberg (1977) found that of a group of proofreaders using VDTs, 40% found regeneration rates less than 60 Hz uncomfortable. Results from a questionnaire as reported by Stammerjohn et al. (1981) show that 68% of the VDT operators complained about flicker with 26% of them indicating that it was "often bothersome". Cakir et al. (1979) found significant correlations of perceived flicker with character recognizability, eye strain, headache and fatigue. Laubli et al. (1981) found increased oscillating luminance of screen characters to be associated with lower visual acuity and a higher incidence of subjective symptoms of eye irritation including more frequent use of eye drops for relief of sore eyes.

Essentially, use of a short or medium persistence phosphor and reliance on a higher refresh rate of the order of 50 to 60 Hz alleviates the problems of flicker (Cakir et al., 1979; Grändjean, 1980). As an alternative a West German firm has
developed a flat 2 1/4 inch thick display. The short electron acceleration distance, the absence of deflection systems and the high picture-repetition rate of 80 Hz result in a no-jitter flicker-free display (Manuel, 1982).

Visual Discomfort due to Glare

Another problem of placing a VDT in a modern office results from unsuitable lighting conditions such as large bright windows, high level of illumination and white or pastel painted walls and ceilings.

"What is good lighting design for a clerical paper-handling task is not necessarily good for a clerical CRT-viewing task and may actually be bad" (Ostberg, 1975).

According to Ostberg (1978) glare (reflected light not visually processed) is a major source of distraction and discomfort to VDT operators. The diffuse reflection of the screen surface may be as high as 22% to 27% and with the smooth glass outer surface directly reflecting about 4% of the light which falls on it, the image of the operator is usually clearly visible on the screen. This reduction in contrast between the characters and the background reduces legibility (Stewart, 1979).

Reflected light from windows, floors, work surfaces and the keyboard may arise when the display units are set above and at an angle to the flat work surface. According to Ostberg (1975) and Busch (1976) many VDTs are used in offices with an effective
glare index of 24 rather than the acceptable level of 16. This results in 50% of the operators experiencing discomfort. With advancing age, sensitivity to glare increases (Cakir et al., 1979). Stammerjohn et al. (1981) found that glare sources were observed in 87% of the 22 measured work stations and on 17% of the terminals reflected glare was so high that reading was difficult.

In order to avoid window reflection on the VDT screen, one possibility is to position the back of the VDT towards the window. However, this results in contrast glare. Hultgren and Knave (1974) found extremely high contrasts in luminances of up to 1:500 between the screen and the window background. With a background of walls and furniture, luminance ratios ranged for 1:3 to 1:24. According to these researchers a ratio of 1:10 between the fixation point of the visual field and its periphery is recommended.

The U.S. Illuminating Engineering Society recommends an illumination level of 1000 lux for large offices. Recommendations of artificial illumination for VDT workplaces range from 100 lux to 1600 lux (Stammerjohn et al. 1981). The rationale for the lower value is that reflections on the screen can be avoided. However most suggestions concur with the assertion that "field studies have also repeatedly shown that VDT operators, where it is possible for them to do so, turn down the lighting to levels corresponding to the range 300 to 500 lux" (Cakir et al., 1979). Yet even at this reduced illumination
level, Gunnarson and Ostberg (1977) found in their field investigations that the lighting was reported to be strong. At the workplaces where ceiling illumination was considered to be satisfactory, light intensities between 150 and 300 lux were measured on the working surfaces.

Stammerjohn et al. (1981) upon surveying the illumination levels of 22 VDT workstations in the U.S. found that only 11% fell within the 300-500 lux range. Seventy-five percent of the observed sites fell within the 500-700 lux range while 10% were observed to be greater than 1000 lux. In contrast Coe et al. (1980) in New Zealand found that the majority (63%) of the VDT workplaces surveyed, showed illumination levels between 250 and 500 lux, 31% were lower than 250 lux and only 10% were higher than 500 lux. Dainoff et al. (1981) found 37% of the VDT operators surveyed complained of lighting. Complaints of visual fatigue and lighting were positively correlated with the amount of time spent looking at the VDT. Smith et al. (1982) also found that VDT users more often found the main lighting to be too bright and to cause glare.

A number of suggestions have been offered as means of avoiding glare. Optimally, light sources should be installed in a direction which is parallel to the workstation while concealed lighting reflecting from upper walls is probably best (ASTMS, 1979). Ambient illumination of VDT workstations should not exceed 300 lux, while local desk illumination should be no more than 500 lux. Desk lamps should be fitted with dimmer switches.
to adjust the ambient luminance to the manuscript. Surrounding equipment and furniture should have matte surfaces or be dark or muted to avoid reflection from these sources. Keytops are one obvious sources of reflections which may be reduced with a matte finish. Cakir (1978) found that one-third more people felt strain and 50% more had headaches if they operated a keyboard with shiny tops compared to those using matte keys. Windows should be fitted with adjustable blinds or curtains. Stewart (1981) surveyed 34 different workplace environments and found glare sources such as lights and windows in the operators field of vision in 66% of the cases. Only in 65% of the cases were the windows fitted with internal blinds. The need to modify lighting was recommended in 70% of the instances.

Screen reflection may be reduced by means of a filter, but usually at the expense of resolution and image brightness. The CRT tube usually has a neutral density filter built into its faceplate. Though it uniformly reduces the amount of light passing through and so reduces internal reflections, the image brightness is reduced. The diffusing surface method involves etching, coating or roughening the surface in order to break up the reflected image. However, degradation of the screen image or a masking illumination which itself causes glare could appear. Special thin-film optical coatings may be vacuum-deposited on glass to alter the physics of the air/glass interface so that less light is reflected. Crane (1979, cited in Dainoff, 1980b) compared eleven operators whose screen contained a matte surface
anti-glare coating, and twenty operators whose screens had no coatings. Levels of complaints were lower for the operators with coated screens; 45% complained about glare and lighting and 36% of eyestrain; this compares to figures of 80% and 60% found for the clear glass group.

The occurrence of ocular symptoms while working with VDTs cannot necessarily be attributed completely to environmental sources. Personal sources may be involved. These include such general systemic factors as fatigue, subnormal health and the use of alcohol and drugs (Ferguson et al. 1974 as cited in Dainoff, 1979). It is estimated that up to one-third of the employee population have uncorrected or insufficiently corrected visual defects which affect both visual and general comfort (Colever and Warr, 1979). Residual uncorrected refractive errors caused by the use of inappropriate eyeglasses may cause eye problems. In particular, hypermetropic individuals require greater than normal accommodative effort for close work, putting excessive strain on the ciliary muscles. About half the general population are estimated to be afflicted with hypermetropia (Dainoff, 1979). Heterophoria is a muscular condition in which there is a latent tendency of the eyes to deviate from their "correct" orientation to maintain bifoveal fixation. This is a common condition and moderate heterophoria is probably also a factor which may accelerate the onset of ocular fatigue in terminal operators, especially when there is an exophoric (diverging) tendency (Ostberg, 1978).
A particular visual problem associated with the presbyopic or aging eye is a normal process of aging in which the lens loses its flexibility thereby reducing its range of focus. Presbyopia, or the beginning of it, may well be one of the main contributors to visual stress while doing near work (I.E.M., 1978) especially in those greater than 40 years of age. Between the ages of 20 to 60 years of age the amplitude of accommodation is reduced from about +10 to +12 D. to 0 to 0.5 D. Accommodative fatigue is often encountered in the 35-45 age group, since these subjects may not yet wear glasses (Rey, Meyer and Degoumois, 1977). The near point of accommodation recedes from about 10 cm (+10 D.) to 200 cm (+5 D.) in the course of a normal working lifetime (Hart, 1976). The presbyopic person poses a special problem of optical correction. Good vision at three distances - the screen, manuscript and keyboard - is needed. While reading glasses, bifocals or trifocals may be prescribed they are not always adequate. Abnormal posture involving very rigid positioning of the head may occur. Frequent reading of upper lines of the display screen through the lower part of bifocal spectacles may result in neck and shoulder muscular pain associated with the cervical syndrome (e.g. Johnson and Wolfe, 1972 as cited by Ostberg, 1978).

Warr (1981) quotes Reading (1979) and Grundy and Rosenthal (1980) as putting great emphasis on the presence of "visual deficiencies" in workers before operating VDTs. They maintained that only the unhealthy or uncorrected eye exhibits symptoms of
ocular discomfort, thus they emphasized pre-screening. Yet Laubli et al. (1981) found that work at VDTs caused ocular symptoms in operators both with or without eye defects. They were not able to predict who would experience such symptoms by the usual screening tests. MacKay (1982) presents Gilbert's interim report in which tests on unaided vision, visual resolution (acuity), spherical and cylindrical refractions and the amplitude of accommodation were assessed on VDT users and non-users. Over two years later, "very little change" had taken place in either the test or control groups. However it was admitted that the VDTs were used for only relatively short periods.

Musculoskeletal Discomfort

A second major potential source of fatigue is due to the awkward postures an operator may be forced to adopt because of inadequate workstation design. A previously acceptable workplace may prove uncomfortable upon the installation of a VDT. The heavy and bulky VDT unit is resistant to manipulation; as a result, individual operators may compromise their own comfort in order to view the screen clearly.

Numerous studies give evidence that musculoskeletal discomfort is a common experience of the majority of VDT operators. For instance, Gunnarsson and Ostberg (1977) reported that 65% of mostly young terminal operators complained of some
sort of muscular discomfort; of these, 19% indicated that the discomfort was severe. The location of the muscular aches included the shoulders (54%), the lower back (32%), the legs (24%), the neck (18%) and the head, arms and hands (6%).

Cakir (1978) reported that 60% of their VDT operators had back pains while 51% experienced neck pains. Grieco et al. (1980) also found that more than 50% of VDT users complained of aching necks and backache during and at the end of their shift. Tenderness and paresthesias of the legs were also reported. The higher incidence of back and neck pains shown in these two studies as compared to Gunnarsson and Ostberg's (1977) study may, in part, be attributed to possible workstation design differences. Carlsen (1975, as cited in Dainoff, 1979) conducted electromyographic studies of neural activity in muscle fibres which indicated that the cause of upper back pain lay in the working postures demanded by the visual and motor interactions with VDTs.

Hunting et al. (1980) provided some controls and showed that while all types of office workers complained of almost daily muscular pains, the highest percentage with serious impairments were those operating data-entry VDTs while the lowest figures were found among those occupied with traditional office work. At first, static efforts may produce painful localized fatigue in the muscles concerned. These problems are acute and reversible. However, according to Hunting et al. (1980), if the static load associated with high work-speed in
fingers and hands is repeated daily over a long period of time, more or less permanent aches will appear with possible damage to the tendons and joints.

Two characteristics of the VDT in particular cause postural problems for many operators. They are the fixed size of the unit used by operators of various sizes, plus the lack of a document holder.

The fixed size of the unit, especially when the keyboard is attached to the screen, causes many problems for the "non-standard" sized operators. The optimum height for the screen is such that the line of sight of the operator is about 35 to 40 degrees below the horizontal. The optimum height of a keyboard is such that the forearms are approximately horizontal (Stewart, 1979). Obviously, as the optima are dependent on the size of the operator, many operators will encounter difficulties either in keying or viewing comfort. Due to its position the keyboard viewing angle can never be optimal. The potential neck and back strain makes it a necessity to touch type whenever possible. Ostberg (1976, as cited in Dainoff, 1979) photographically surveyed typical VDT operator working postures. He observed that the positions of arms, neck and direction of gaze were all too high as a result of the keyboard and display screen being higher than was appropriate.

The working level, defined as the distance between the underside of the thighs and the palms of the hand is one of the most important characteristics of working posture while in the
sitting position. The desk top, desk frame and keyboard should be as thin as possible in order to ensure a working level of between 220 and 250 mm, which is comfortable for most people. To satisfy requirements for sufficient knee clearance the keyboard height should be about 30 mm, yet they typically are between 50 and 120 mm. As a result, Cakir et al. (1979) favors a partially adjustable desk top which permits adjustment of the keyboard and screen height. Tables are now available that not only satisfy this requirement but also have provisions for rotating the screen or moving it closer to or farther from the operator, as differing visual needs dictate (AFC-CIO, CLC, 1981).

Adjustable foot rests for shorter VDT operators should also be included in the workstation. Of 24 different types of VDT workplaces surveyed by Stewart (1981) only in 8% of the cases were footrests provided to individuals that needed them. They should be adjustable in both height and angle, wide enough to cover the entire leg room area and designed to allow changes in foot position.

A second source of problems is the document holder - or more typically the lack of a document holder. Cakir et al. (1979) estimated that about 80% of VDT operators also work with hardcopy. Placing documents on the flat desk surface at the side of the VDT where they can be easily handled results in awkward twisting and bending in order to reduce the viewing distance. The provision of an adjustable lecturn type document holder at the side of the unit helps to alleviate the problem. If
correctly positioned, its use will reduce unnecessary neck strain. The neck is the most highly stressed part of the body and more effort is expended when the head is moved in the vertical plane than when the head is rotated side to side. Thus the holder should allow for placing the document on the same level as the display screen and inclined at about 20 degrees away from the vertical to compensate for the forward tilt of the head. Not only does this tilt of the document optimize the line of sight to be at right angles to the plane of the paper, it also approximately halves the luminance of the copy. This reduces the contrast between the display screen and the document.

The importance of having a source document holder was indirectly brought out in the field study conducted by Hunting et al. (1980). They found the surprising result that the incidence of physical impairments in 162 VDT operators was lessened when working levels were higher than the recommended levels. However, upon observation of the workplaces they found that nearly all operators had their source documents lying on the desk. The researchers concluded that the higher the desk level, the higher were the source documents, thus the better the posture of head and trunk. They still recommended the lower working levels, however, only if an adequate support for the source documents with independently adjusted height is provided.

Poor posture becomes an even greater problem if the operator has uncorrected visual defects or wears bifocal lenses.
One manufacturer of CRT displays for offices has gone so far as warning against the use of bifocal glasses during long-term VDT work because people with such glasses tend to adopt a fatiguing head posture which requires elevated levels of static muscle efforts of the neck and trunk.

A well-designed chair can favorably affect the operator's posture and the amount of effort required to maintain it, and as a consequence the circulation and amount of pressure on the spine. A good adjustable backrest helps maintain the natural inward curve of the lower spine and may take some body weight off the spine. Good sitting posture will result in even pressure on the spinal discs. The uneven pressure resulting from poor posture, if maintained too long, may result in back problems caused by the deformation of the discs (Cakir et al., 1979).

The shape of the chair seat should facilitate frequent changes of position and, in combination with seat height should permit most of the body weight to be transferred to the seat through the buttocks, not the thighs. Seat height should be adjustable (from the seated position) so that the operators' thighs are horizontal and the feet are flat on the floor. In this position the stabilising work required to maintain the sitting position is kept to a minimum as is the static stress in the back and leg muscles. A chair that is too high may result in extra pressure on the lower thighs which may impair circulation whereas if it is too low the pelvis will tend to rotate and promote an outward curve of the lower spine. If the seat surface
is too hard, pressure may become too concentrated and cause discomfort and possibly hemorrhoids due to the pooling of blood. A reasonably firm seat which compresses about two cm is recommended. If it is too soft, extra muscle activity is required to maintain a given position (I.B.M., 1978). Seating posture is so important to the operators' comfort and health that in Scandinavia physiotherapists are often used to train operators how to sit and adjust their chairs.

While various workplace design considerations particularly relevant to VDT use have been recommended, in practice they are seldom followed. Stewart (1980) surveyed 17 different types of workplace designs and found typical workplace design faults including the keyboard being non-detachable (50% of 10 models), too high (67%) and with no adjustability (94%). Insufficient leg room was encountered in 59% of the cases due to obstructions under the desks or the desk tops being too thick. Poor chair adjustment was found in almost all the cases (95%) with 27% of the chairs having absolutely no adjustability. The chairs with poor adjustability were seldom adjusted as typically it involved getting off the chair and exerting considerable force on a knurled knob. Stewart (1981) added that in all of the 24 different types of workplaces surveyed in the U.K., there was no guidance available to the individual operators to help them to achieve an optimal adjustment of the chair. Coe (1980) found that 64% of non-adjustable seats were of incorrect height. More surprisingly, 99% of the seats in which only height was
adjustable and 71% of the fully adjustable seats were incorrect in height.

Even when the VDT operator is provided with a properly designed workplace, any posture becomes bad when it has to be fixed or maintained for too long a period. The freedom and ability to change posture at frequent intervals contributes greatly towards delaying subjective feelings of fatigue. For instance, the keyboard should be moveable so as to permit frequent changes of arm, shoulder, and spine position. Hunting et al. (1980) observed that dialogue operators using moveable keyboards and taking advantage of short waiting periods by resting their hands or forearms on the desks or keyboards, had a lower incidence of problems with the hands and arms. The researchers therefore recommended that all VDT workplaces with keyboards should also provide special forearm/hand supports. Wright (1982) adds that this also reduces operator error, which is the principal barrier to increased productivity. On a more general note Stewart (1979) suggested that movement can also be encouraged by a suitable task design. Wherever possible, VDT use should be part of the users job rather than all of it.

**Somatic Discomfort**

Complaints concerning general body discomfort as a result of VDT use have also been voiced.
(I) Skin rashes - During 1979 and 1980 doctors in Norway notified the Directorate of Labor Inspectorate of about 35 cases of facial rashes among VDT operators (Tjonn, 1980). This "exanthema" developed after less than two hours of work - up to about five to six hours - and then usually disappeared during the first few hours after work. A great deal of static electricity was observed in the work areas. The researchers thus hypothesized that the winter air conditioning around the VDTs could have created static electric fields which attracted dust to the skin.

(II) Epilepsy - Of a much more serious nature is the possibility for susceptible victims of VDT-induced epilepsy. This problem is rare however (ASTMS, 1979). In particular, this problem may surface when interlaced scan lines are used to round out character corners. This effectively reduces the refresh rate from 50 Hz to 25 Hz. Twenty-five hertz is extremely effective in inducing a seizure in photo-sensitive epileptic individuals.

(III) Systemic symptoms - Systemic symptoms of headache and fatigue are commonly found, especially among full-time VDT operators. The headaches are often localized in the forehead area above the eyes and are sometimes accompanied by stabbing pains. Cakir (1978) found that the incidences of headache were highest in the high input acquisition workers (45%), intermediate for clerical workers (30%) and lowest for programmers. Relatively large significant correlations were found between headache, backache and eye strain. This is not
unexpected as all the symptoms are fatigue reactions.

General fatigue is a more psychological form of reaction to stress. The stress-fatigue relationship is additive. The subjective reactions such as "boredom, weariness, depression, lassitude, anger and exhaustion also cause diminished skill in performing the tasks required of them...fatigued workers pay less attention, receive new visual information more slowly, need longer reaction times and show marked decreases in motivation and performance" (Busch, 1976). Repeated daily fatigue often leads to chronic fatigue which is characterized by such changes as loss of appetite, headache, dizziness, indigestion, insomnia, depression, irritability, anger and nervousness.

Laubli et al. (1980) found that continuous work at VDTs was associated with a high workload, which produces excessive fatigue in some operators. Some data entry terminal operators reported that fatigue symptoms may not only persist in leisure time but even after sleep they do not find complete recovery. Smith et al. (1981) showed that clerical VDT operators were significantly higher in the fatigue scale than were professional VDT operators and non-operator controls.

(IV) Physical Stressors - Stress is a central element in the VDT health problem. Every error in the design of the machine, and the workplace job design adds directly and indirectly to the total stress of the job. Since stress increases with the interaction of combined effects; attention must be paid to stress however insignificant each may seem
individually (Bergman, 1980). Stress begins even before the VDTs are introduced. Automation of the office represents to the operator the threat of being replaced by a machine. An uncomfortable work environment, including such physical hazards as noise and heat, repetitious or monotonous tasks, inefficient machine response and work pressure are all contributors to stress. For example, Dainoff et al. (1981) found 42% of the VDT workers surveyed suffered from physical and mental stress.

(1) Noise - VDT keyboards are relatively silent in comparison to typewriters. The cooling fan with the unit may hum and the high tension electric circuitry may cause a high pitched whine. While the levels are too low to cause hearing damage, high frequencies (18,000 to 20,000 Hz) may be distracting or irritating, especially to younger people who are more sensitive (Turner, 1979). Standing wave or focussing effects might further increase sound levels if the VDT is in a corner or alcove (SciQuest, 1981). In addition, excessive background noise can be produced by other nearby office equipment, such as typewriters and telephones.

For example, Stewart (1980) surveyed 16 VDT offices and found that 63% of the operators complained of too much noise which often interfered with communication or concentration. Fatigue and emotional stress can lead to eventual hearing loss. An acceptable non-stress level is in the range of 50-70 decibels. However office tabulating machines for example have a decibel level of eighty (Love, 1978). Grandjean (1978) found
that 35% of the respondents indicated that they were greatly disturbed by noise in their offices. However there was no correlation between noise intensity and frequency of complaints. Rather, disturbing conversations seemed to be the principal culprit.

(2) Heat - All VDTs and related equipment emit heat, often as much as 400 Watts from a single unit. The thermal output of a number of units close together may create unpleasant hot spots. According to Cakir et al. (1979) air conditioning calculations have shown that the thermal loading at VDT workstations may be between 30 - 150% greater than the situation without VDTs. This statement differs dramatically from MacArthur's (1980) assertion that "the 100 w or so from a typical VDU can normally be handled by convection. For comparison, a human body also dissipates about 100 w".

The thermal load imposed through the operation of VDTs is a pervading problem. Stewart (1980) surveyed eight workplaces and found that 100% of the operators complained of a poor thermal environment. "The heating and ventilation systems evaluated were seldom capable of controlling the temperature, airflow and humidity to an adequate degree even when operating perfectly (which is seldom the case)". Thus Cakir et al. (1979) recommended that the causes rather than the effects of too great a thermal load be controlled by using VDTs with low thermal emission, directing the heat dissipated by the unit away from the operator or neighboring operators, and by evenly

32
distributing and limiting the number of VDTs installed in a room as much as possible.

(3) Machine Pacing - Stress may also arise from the intense concentration often required in working with VDTs. Particularly stressful is the adjunct use of the terminal for error detection and production monitoring. One of the severe strains in the work environment is sheer information load. The degree of stress-induced fatigue is directly proportional to the rate of processing the data. The crucial matter is the lack of relief pauses. During the course of the operation of display units there are frequent pauses as the computer searchers for and retrieves material for display. Rather than being restful, the opposite is true. These delays act as stressors because the operators do not know exactly when they will occur and how long the pauses will be. Waiting and preparing for the computer response creates more rather than less fatigue (Warr, 1981).

Anxiety is also liable to occur whenever the VDT clerk acts as the interface between the organization and its outside clients and does not fully understand the peculiarities of the computer system (Ostberg, 1975).
B. Evaluation of VDT Problems by Questionnaire
I. The Questionnaire Study

To address the question of whether the VDT per se is responsible for the health complaints reported, an adequate evaluation should cover the physical environment and the psychosocial influences of the workplace in addition to the ergonomics of the VDT unit itself.

Physical Environment

Increasing concern is being voiced over the burden of indoor air pollution (see Sterling and Kobayashi, 1977, for example). Most offices today use mechanical ventilation systems. These air-conditioning systems often pick up whatever is being emitted into the air and continuously recycle it. Thus workers are constantly exposed to tobacco smoke, dusts and fumes (Love, 1978). Grieco et al. (1980) for instance found a source of complaints to be the air-conditioning system. VDT operators complained of "stagnating air and the presence of odors". Potential chemical exposures include ammonia, methanol and ozone from copying machines, the highly toxic solvent trichloroethylene which is contained in opaque correction fluid, and other solvents in stencil machines.
Field industrial hygiene measurements have been conducted by a team of NIOSH investigators in San Francisco (see Murray et al., 1981, for details). The occupational sources of airborne chemical contaminants that the researchers identified were photographic darkrooms, photocopiers, other reproduction equipment and smoking. The chemicals on which measurements were attempted included hydrocarbons, carbon monoxide, acetic acid and formaldehyde. General VDT area hydrocarbon levels ranged from 1.4 to 4.4 ppm. The peak levels near some terminals were as high as 10.5 ppm. Carbon monoxide levels ranged from 1.0 to 3.0 ppm. Neither acetic acid or formaldehyde were present in detectable quantities. All the chemical pollutants measured were below any hazardous level.

Heating and ventilation systems are seldom capable of controlling the temperature, airflow and humidity to an adequate degree. Grandjean (1978) found that general measurements of large scale open plan offices were found to be within standard conditions. However temperatures greater than 24 degrees centigrade were judged as being too warm. Almost 33% of the workers complained of drafts but there was no apparent relationship between degree of measured air movement and frequency of complaints.

Cakir et al. (1979) found that excessive heat was perceived as a problem by 50% of VDT operators who worked in non-air-conditioned offices, and by 30% of operators who worked in air-conditioned offices. A high correlation (r=0.54) was
found between complaints of drafts and neck pain among those who worked in air-conditioned offices. With regard to relative humidity, two-thirds of the participants believed the air in their offices was too dry. However, objective measurements of relative humidity in these offices varied in the 30-70% range considered as comfortable. Accordingly, the authors suggested that the lower limit for comfort be raised to 50%.

Coe et al. (1980) stated that a relative humidity of over 45% is recommended so that drying out of the mucous membranes of the respiratory tract and conjunctival and corneal epithelia are avoided. Stone (1981) found that dehydration of the cornea occurred with high ambient temperatures, low humidity and high air movement causing drafts. According to Cakir et al. (1979) air movements of only 0.01 m/sec give rise to an uncomfortable draft for 23% of people questioned and cause in some cases dryness and burning sensations in the eyes.

Cakir et al. (1979) surveyed eight hundred VDT operators. Of those who made a large number of complaints related to back, neck and headache, 75% worked in air-conditioned offices. Likewise, 74% of those who had high rates of room climate complaints worked in air-conditioned offices. The authors advised that due to the circulation of air, dry air is felt to be even more dry. To ensure the workers' comfort, it is necessary to avoid even very small air currents in the room at head and neck height. Coe et al. (1980) provided supporting evidence. Only 17% of the VDT group and 25% of the control group
reported uncomfortable temperatures. Of those who found the environment uncomfortable 45% of the VDT users complained of temperature variability. However they could find no relationship between dry air and the presence of symptoms of asthenopia.

Psychosocial Influences

While many studies have concentrated on the ergonomic aspect of the VDT problem comparatively few have researched the psychological stresses involved in the computerized workplace.

Gunnarson and Ostberg (1977) queried VDT operators about stressful elements in their jobs. About one-third of all the operators felt that the workplace was too fast. In a department where operators had little control over their job tasks, 72% complained of monotony. When asked if their job was stressful 64% said yes. Unfortunately, no comparison control group was used. For example, Grandjean (1979) cites the study by Cakir et al. (1978) in which they found that the feelings of stress expressed by VDT operators did not differ in magnitude from those expressed by other worker groups examined in previous studies. However another set of job stress questionnaire item correlations revealed that the amount of time spent working at the VDT was correlated with boredom, fatigue, monotony and perceived job satisfaction. On the other hand, Coe et al. (1980) found no differences between VDT and control workers with respect to questions concerning job stress. Sauter et al. (1983)
likewise found that none of the well-being indices measured showed a strong indication of increased stress for the VDT users.

The study by Cakir et al. (1979) showed that VDT operators working on a piece-rate pay system had poorer scores in sociability, frame of mind, and state of stress, fatigue and inner security when compared with hourly paid VDT workers. After work, both groups showed significantly higher levels of stress and sleepiness and lower levels of well-being, positive frame of mind, self-confidence, social awareness, sociability and willingness to undertake further activity than they did before work. Of clerical VDT operators who had been reduced in status to copy typing, 85% felt their job was monotonous while 90% found it extremely fatiguing.

Psychological reactions to VDTs will depend on the type of work, the way the new job is organized and introduced and on personal attitudes (Grandjean, 1980). In general, computerization has made the operator tasks highly specialized and routine. According to Ostberg (1975) clerical computer terminal operators are sometimes more alienated than shop-floor assembly line workers. Simple, repetitive work, lacking interest and full use of the operators' capacities, and its psychological consequences explain in large part the job dissatisfaction expressed by the majority of operators. This also explains the higher frequency of psychosomatic disorders, nervous disturbances and inadequate sleep patterns (Elias et al., 1980).
The degree of fatigue is directly proportional to the rate of processing data. Fatigue-inducing jobs are spreading with the same pace as technological advances. "As a result, in the near future it will be necessary to select clerks from among those people having a high stress tolerance" (Elias et al., 1980).

According to Snyder (Sciquest, 1981) much bad design can be traced to employers who are looking for the cheapest possible system and drive workers in a dehumanizing fashion trying to get the most return for the least cost out of VDT installations and employees alike. Shiftwork has a profound effect on the body's circadian rhythms. The phase shifting of waking and sleeping times takes place without a corresponding shift in the phasing of the dominant synchronizers (Coe et al., 1980). The result may be subjective fatigue and somatic complaints as well as a disruption in performance (see the September 1979 issue of Ergonomics for a thorough review of shiftwork effects).

Stress and fatigue is a common problem in any office environment and thus it is not confined to VDT causes. A NIOSH research team was asked to evaluate five participating work sites in San Francisco in which VDTs were routinely used (Smith et al., 1981). A questionnaire dealing with working conditions, job stress factors, health complaints and psychological mood state was filled out by approximately 250 VDT operators and 150 non-operators. For statistical purposes, the results from all five workplaces were pooled. The respondents to the questionnaire survey were put into three groups based on their
work activities. These were (1) professionals using VDTs such as reporters, editors, copy editors and printers. These jobs afforded a great deal of self-control over work activities which provided variety and challenge. The operators were not tied to their VDTs for any set time period and could set their own workplace within deadline limits. (2) The clerical VDT operators included data entry clerks, data retrieval clerks, classified advertising clerks, circulation and distribution clerks and telephone inquiry clerks. These jobs were highly regimented, with little operator control over work activity. The operators were tied to their workstation for fixed time periods except for formalized work/rest breaks and had little control over their workspace. (3) Non-VDT users served as control subjects. Their jobs were identical to those of the clerical VDT operators, except they did not use the VDT in performing their job tasks. Their working conditions were almost identical to those of the clerical VDT operators.

Significantly more clerical VDT operators reported job stress problems than did professionals using VDTs or control subjects, while both clerical and professional VDT operators reported more career problems than did control subjects. In terms of the ten dimensions of the work environmental scale all groups reported less involvement, less cohesion, less staff support, less autonomy, greater work pressure, less task orientation, less clarity, less innovation and less physical comfort than the norms. Only the professional VDT workers
reported positively with respect to test norms in that they reported less supervisory control than the norm. Also, the clerical VDT operators had significantly less peer cohesion and job autonomy, more work pressure and greater control by their supervisors than either professionals using VDTs or control subjects. They reported less involvement and staff support than the professionals using VDTs.

The nine job demand dimensions developed by the Institute for Social Research again showed systematic negative responses when compared with norms. Clerical VDT operators reported higher workload, more boredom, greater work dissatisfaction, greater job future ambiguity and lower self-esteem than either the professionals using VDTs or the control subjects. They also reported more role ambiguity than the professionals using VDTs while the latter reported less boredom than the controls. Again the same general pattern of stress response was observed in that clerical VDT operators showed the highest stress levels, followed by control subjects and the professional VDT operators.

Of the six scales of the profile of mood states, only for the fatigue scale was there a significant difference - the clerical VDT workers reported more fatigue than did either the professionals using VDTs or the control subjects. Health complaints by the VDT operators were of a visual, musculoskeletal and emotional nature. Twenty-six of 59 health complaints examined were significantly higher for the clerical VDT workers than for the controls.
The professional VDT operators differed significantly from the controls in that complaints of burning eyes, eye strain and irritability were higher while complaints of fainting, pain down the arm, and colds were fewer in number. However a curious finding pointed out by these researchers is that there were even more differences in the number of health complaints between the clerical and professional VDT operators (33 in number). This led the authors to conclude that "The results indicate that job content factors and VDT use interact to contribute to VDT operator problems...The problem does not lie solely with VDT use" (Smith et al., 1981).

The authors readily admit some problems with the study design:

"This evaluation may have limited generalizability, since the study sites were not selected at random, but rather were known sources of union complaints about health problems. Moreover, participants were not selected randomly, but were volunteers, and difficult labor negotiations were underway at the time of data collection."

All groups evaluated, including the control subjects, reported high levels of psychosocial job stress when compared to worker groups examined using similar measures in previous studies. The strained labor negotiations produced by difficult employee/management relations which were alluded to above, may have contributed to this heightened stress level. The control subjects in particular had the potential for great stress in that they were aware that they would be converting to VDTs within months. This elevation may account for the lack of
extensive differences in stress level and health complaints between the professionals using VDTs and the control subjects.

The authors also admit to differences in the demographics of the three groups. Significant differences were found in the percentages of respondents in the various categories for age, sex, ethnic background, level of schooling, marital status, years with current employer and years at the current job.

Whether there were differences in environmental and VDT variables among the three groups is a pertinent matter. Stammerjohn et al. (1981) conducted an on-site evaluation of VDT workstation design at the same five establishments. Unfortunately because the survey was anonymous, it was not possible to link questionnaire responses to specific design features. However, important physical environment and VDT workstation variables which may have influenced the symptomology were present.

The illumination levels found were between 300 and 1200 lux. A range of 300 to 500 lux is recommended. Reflected glare from windows and light fixtures was found in most of the VDT screens surveyed. Many of the viewing angles were larger than recommended especially for male operators of greater than median dimensions. Few chairs had any form of arm rest.

In response to a group of questions concerning the office environment, most employees (63%) rated summer temperatures and level of distraction as too high. A significantly larger proportion of the VDT operators (80%) than the non-operators
(62%) reported glare from workstation lighting. The most frequent complaints were screen glare (85%), character brightness (70%), readability (69%), flicker (68%) and screen brightness (62%).

It is interesting to note that while Smith's report emphasized VDT clerical versus professional operator differences, Stammerjohn's report only gave a cursory comparison. The clerical VDT workers found their chairs significantly less comfortable than did either the professional VDT workers or the non-VDT operators. It is noted that for both professional and clerical VDT operators, a significant relationship existed between visual function complaints and the employee rating of the workplace design parameters including glare, screen angle, noise from the VDTs and screen flicker.

A most important distinguishing factor appears to separate clerical from professional VDT work. That is the workload, as defined by the amount of time spent doing VDT work and the number of formal and informal rest breaks allowed. Professional VDT operators "were not tied to their VDTs for any set period and could set their own workspace". In contrast, clerical VDT operators "were tied to their workstations for fixed time periods except for formalized work/rest breaks". In fact these researchers showed a statistically significant positive correlation between the number of hours worked on the VDT and the total number of health complaints. The researchers conceded that the reporting of significantly more vision problems than
the control subjects could be related to workload.

The research by Smith et al. (1981) is of value in that it accounted for psychosocial stress contributions to observed health complaints. An important consideration is the contribution of the video display terminal towards the enhancement of stress in the office environment. Separating VDT workers according to their professional or clerical status allowed a differential analysis according to relative VDT job demands. The following study was designed to allow a comparison of both professional and clerical VDT and non-VDT groups. Both psychosocial and environmental variables in the office milieu were assessed.

Rationale for the Questionnaire

Of the VDT research that has been reviewed there has been a serious lack of good controls. For example even Smith's (1981) innovative use of office staff as controls had the disadvantage of lacking a professional non-VDT control group for the professional VDT workers. The questionnaire used in this study allows identification of comparison workers who are of the same professional or clerical status as the VDT operators.
Methods

Subjects

The subjects for the questionnaire study were 1100 workers belonging to the Office and Professional Employees Union in New York. Four hundred ninety-seven males and six hundred one females participated. The subjects ranged in age from 19 to 65 years, the average age being 35.5 years.

For the purposes of this analysis subjects were divided into professional or clerical VDT or non-VDT categories. The Dictionary of Occupational Titles (1977) was used to classify each job title as belonging in the "Professional, technical and managerial occupations" category or the "Clerical and sales occupations" category. In Appendix B the appropriate DOT three-digit occupational group designation for each job title is listed. VDT cases were chosen from those answering "usually or always" for the VDT/CRT section of the question on the type of equipment used for work, while non-VDT cases are those indicating "rarely" or providing no indication at all.

Administration of the Questionnaire

The questionnaire was handed out in January 1982 by union stewards to O.P.E.I.U. union members working in New York and New
Jersey offices. Eleven hundred replies were received by mail.

The questionnaire used covered demographic variables, job description, psychosocial aspects of the work environment, physical environment features, VDT particulars, personal habits, health symptoms and health history. See Appendix A for a copy of the Work Environment Survey questionnaire. For the preliminary analyses all questionnaires received were evaluated, regardless of the type of office or building the respondent worked in.

Results

Whether questionnaire respondents were professional or clerical VDT or non-VDT workers was cross-tabulated with such characteristics as health symptoms, stress factors, ergonomic complaints and smoking habits. The null hypothesis was that there would be no differences in physical, psychological and behavioural parameters between VDT workers and their controls.

It became clearly evident that professional VDT workers experienced the greatest number of health-related complaints. Table 1 exhibits the health symptoms which were experienced at least one to three times a week. The percentages among the types of workers which are indicated by an asterisk were significantly different (Chi-squared analysis, p<0.05).
**Table 1a: Job Type by Percent Complaining of Health Problems at Least Once a Week**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Prof. VDT</th>
<th>Clerical VDT</th>
<th>Prof. non-VDT</th>
<th>Clerical non-VDT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Blurred vision</td>
<td>36.5</td>
<td>21.9</td>
<td>16.0</td>
<td>15.5</td>
</tr>
<tr>
<td>*Eye irritation</td>
<td>42.9</td>
<td>29.0</td>
<td>21.7</td>
<td>18.8</td>
</tr>
<tr>
<td>Split or double vision</td>
<td>12.7</td>
<td>8.4</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td>*Trouble focusing</td>
<td>30.2</td>
<td>20.6</td>
<td>20.8</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>Cardiorespiratory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Nose irritation</td>
<td>28.6</td>
<td>21.9</td>
<td>16.0</td>
<td>15.3</td>
</tr>
<tr>
<td>Breathing difficulty</td>
<td>14.3</td>
<td>12.9</td>
<td>12.3</td>
<td>10.6</td>
</tr>
<tr>
<td>Chest pain or tightness</td>
<td>12.7</td>
<td>7.7</td>
<td>6.6</td>
<td>8.0</td>
</tr>
<tr>
<td>*Racing heart</td>
<td>14.3</td>
<td>8.4</td>
<td>17.0</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>Somatic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Nausea</td>
<td>14.3</td>
<td>9.0</td>
<td>11.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Skin rashes</td>
<td>7.9</td>
<td>3.9</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Ringing in ears</td>
<td>19.0</td>
<td>12.9</td>
<td>18.9</td>
<td>8.8</td>
</tr>
<tr>
<td>*Sore throat, cold</td>
<td>25.4</td>
<td>15.5</td>
<td>18.9</td>
<td>12.1</td>
</tr>
<tr>
<td>*Frequent urination</td>
<td>25.4</td>
<td>23.9</td>
<td>23.6</td>
<td>16.1</td>
</tr>
</tbody>
</table>

* p<0.05 by Chi-squared analysis
<table>
<thead>
<tr>
<th>symptom</th>
<th>prof. VDT</th>
<th>clerical VDT</th>
<th>prof. non-VDT</th>
<th>clerical non-VDT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Musculoskeletal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Neck ache</td>
<td>42.9</td>
<td>31.6</td>
<td>34.9</td>
<td>21.1</td>
</tr>
<tr>
<td>*Sore arms/hands/wrists</td>
<td>23.8</td>
<td>17.4</td>
<td>18.9</td>
<td>12.8</td>
</tr>
<tr>
<td>*Backache</td>
<td>46.0</td>
<td>29.0</td>
<td>37.7</td>
<td>28.0</td>
</tr>
<tr>
<td><strong>Psychosomatic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Headache</td>
<td>46.0</td>
<td>34.8</td>
<td>33.0</td>
<td>29.0</td>
</tr>
<tr>
<td>*Dizziness</td>
<td>19.0</td>
<td>8.4</td>
<td>7.5</td>
<td>7.2</td>
</tr>
<tr>
<td>*Fatigue</td>
<td>60.3</td>
<td>41.3</td>
<td>39.6</td>
<td>31.8</td>
</tr>
<tr>
<td>*Sleepiness</td>
<td>63.5</td>
<td>51.0</td>
<td>50.0</td>
<td>38.8</td>
</tr>
<tr>
<td>*Moodiness</td>
<td>41.3</td>
<td>29.0</td>
<td>34.0</td>
<td>22.8</td>
</tr>
<tr>
<td>*Depression</td>
<td>41.3</td>
<td>17.4</td>
<td>30.2</td>
<td>18.6</td>
</tr>
<tr>
<td>*Lightheadedness</td>
<td>28.6</td>
<td>16.1</td>
<td>14.2</td>
<td>13.5</td>
</tr>
<tr>
<td>*Confusion</td>
<td>19.0</td>
<td>15.5</td>
<td>19.8</td>
<td>11.5</td>
</tr>
</tbody>
</table>

* *p*<0.05 by Chi-squared analysis
Professional VDT workers exhibited the highest percentage of health complaints for 17 out of 19 symptoms which were significantly different. Visual, cardiorespiratory and psychosomatic symptoms showed a decreasing percentage in response for professional followed by clerical VDT workers and next for professional followed by clerical non-VDT workers. The exceptions were the complaints of racing heart and confusion, which were highest for professional non-VDT workers. As well, the complaints of moodiness and depression followed a pattern whereby next after professional VDT workers, professional non-VDT workers showed a higher percentage of complaints than clerical VDT workers. This pattern was repeated for musculoskeletal and somatic symptoms. It is of interest to note that all musculoskeletal and psychosomatic symptoms showed a significant differential response according to job category. This indicates that these type of symptoms in particular are affected by VDT use as well as job definition. The pattern of health complaints is reflected in absenteeism in that professional workers had the longest periods off work. The frequency found for nine or more days off work was 15.0% of professional non-VDT workers and 9.5% of professional VDT workers. In contrast, clerical workers had a frequency of 5% and less.

Various elements which could contribute to the differential response to health problems were considered. Stress factors were perceived as playing a primary role in the job discomfort.
experienced by professional workers, both in the VDT and non-VDT categories. The following stress factors, as indicated by an asterisk in Table 2, were found to differ significantly for each job type as a result of chi-squared analysis (p<0.05).
Table 2: Job Type by Percent Complaining of Stress

<table>
<thead>
<tr>
<th>stressors</th>
<th>prof. VDT</th>
<th>clerical VDT</th>
<th>prof. non-VDT</th>
<th>clerical non-VDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>*No decision-making</td>
<td>31.7</td>
<td>12.3</td>
<td>37.9</td>
<td>15.9</td>
</tr>
<tr>
<td>*No job freedom</td>
<td>41.3</td>
<td>22.2</td>
<td>38.8</td>
<td>19.2</td>
</tr>
<tr>
<td>*Can't set work speed</td>
<td>38.1</td>
<td>20.6</td>
<td>44.7</td>
<td>13.3</td>
</tr>
<tr>
<td>Can't affect work policy</td>
<td>72.1</td>
<td>72.7</td>
<td>70.6</td>
<td>64.3</td>
</tr>
<tr>
<td>*Poor job security</td>
<td>9.7</td>
<td>5.3</td>
<td>22.2</td>
<td>6.6</td>
</tr>
<tr>
<td>*Job loss or layoff</td>
<td>3.2</td>
<td>4.0</td>
<td>3.8</td>
<td>5.1</td>
</tr>
<tr>
<td>*Job requires fast work</td>
<td>61.9</td>
<td>34.0</td>
<td>32.7</td>
<td>26.6</td>
</tr>
<tr>
<td>*Requires concentration</td>
<td>68.3</td>
<td>56.5</td>
<td>63.1</td>
<td>47.6</td>
</tr>
<tr>
<td>*Job is monotonous</td>
<td>30.6</td>
<td>18.7</td>
<td>23.1</td>
<td>18.6</td>
</tr>
<tr>
<td>Must exert physical effort</td>
<td>7.9</td>
<td>10.5</td>
<td>10.7</td>
<td>9.9</td>
</tr>
<tr>
<td>*Awkward work motions used</td>
<td>14.3</td>
<td>5.2</td>
<td>14.7</td>
<td>5.2</td>
</tr>
<tr>
<td>No help from co-workers</td>
<td>14.5</td>
<td>11.6</td>
<td>16.7</td>
<td>14.7</td>
</tr>
<tr>
<td>No help from supervisor</td>
<td>12.9</td>
<td>17.0</td>
<td>12.9</td>
<td>17.1</td>
</tr>
<tr>
<td>*Abuse from customers</td>
<td>22.4</td>
<td>12.0</td>
<td>16.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Abuse from supervisors</td>
<td>5.2</td>
<td>4.7</td>
<td>5.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Abuse from co-workers</td>
<td>7.3</td>
<td>2.7</td>
<td>4.1</td>
<td>6.5</td>
</tr>
<tr>
<td>*Not enough people</td>
<td>22.2</td>
<td>39.9</td>
<td>27.3</td>
<td>46.2</td>
</tr>
<tr>
<td>*Remain in one location</td>
<td>73.0</td>
<td>70.6</td>
<td>65.4</td>
<td>62.0</td>
</tr>
</tbody>
</table>

* p<0.05 by Chi-squared analysis
Two-thirds of the 18 potential stressors were found to differ significantly according to the type of job. The stress of being required to work fast showed the greatest differential response with 61.9% of professional VDT workers complaining in comparison to the next highest rate of 34% for clerical VDT workers. Only for the stressors of not having enough people in the department and facing job loss or layoffs was there a greater percentage of complaints from clerical non-VDT workers, followed by clerical VDT workers.

No significant difference in smoking habits was discerned. For example, current smokers formed 64.5% of professional VDT workers and 61.5% of professional non-VDT workers while 51.8% of clerical VDT workers and 55.6 of clerical non-VDT workers were smokers. There appears to be a trend of more smokers among the professionals. Yet when smoking at work was evaluated a significant difference was seen in which clerical non-VDT workers included more smokers who were permitted to smoke at work. Reports of smokers being allowed to smoke at work were given by 59.5% of the clerical non-VDT workers, 47.7% of the clerical VDT workers, 41.0% of the professional VDT workers and 32.5% of the professional non-VDT workers.

When age was considered, professional VDT workers were composed of the younger age groups. Of the 40-65 age group, the percentage of professional VDT workers was a low of 11.3% while clerical non-VDT workers formed the high of 33.2%. Clerical VDT
workers had a majority of females (64.3%), while professional non-VDT workers had the least (35.2%).

Table 3 lists those physical environment variables that were found to differ significantly between job types (Chi-squared analysis, p<0.05).

An evaluation of the physical environment of the workers revealed that professional VDT personnel voiced the most complaints particularly about the quality of room air.
Table 3: Job Type by Percent Complaining of the Physical Environment

<table>
<thead>
<tr>
<th>complaint</th>
<th>prof. VDT</th>
<th>clerical VDT</th>
<th>prof. non-VDT</th>
<th>clerical non-VDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Too little air movement</td>
<td>62.3</td>
<td>36.4</td>
<td>21.6</td>
<td>34.4</td>
</tr>
<tr>
<td>Too much air movement</td>
<td>8.3</td>
<td>5.4</td>
<td>9.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Lighting too bright</td>
<td>6.6</td>
<td>10.0</td>
<td>2.0</td>
<td>8.5</td>
</tr>
<tr>
<td>*Lighting too dim</td>
<td>23.0</td>
<td>10.5</td>
<td>18.8</td>
<td>15.3</td>
</tr>
<tr>
<td>*Glare on work surfaces</td>
<td>19.4</td>
<td>22.5</td>
<td>13.0</td>
<td>13.6</td>
</tr>
<tr>
<td>*Unpleasant odors</td>
<td>26.2</td>
<td>15.3</td>
<td>15.0</td>
<td>12.9</td>
</tr>
<tr>
<td>Temperature too cold</td>
<td>17.5</td>
<td>26.5</td>
<td>16.8</td>
<td>25.2</td>
</tr>
<tr>
<td>Temperature too hot</td>
<td>17.7</td>
<td>16.4</td>
<td>9.0</td>
<td>16.7</td>
</tr>
<tr>
<td>*Air too dry</td>
<td>34.4</td>
<td>26.7</td>
<td>15.0</td>
<td>19.8</td>
</tr>
<tr>
<td>Air too moist</td>
<td>3.3</td>
<td>2.0</td>
<td>1.0</td>
<td>2.9</td>
</tr>
<tr>
<td>*Air too smokey</td>
<td>27.9</td>
<td>14.9</td>
<td>6.0</td>
<td>11.7</td>
</tr>
<tr>
<td>*Air too stuffy</td>
<td>45.2</td>
<td>32.7</td>
<td>18.0</td>
<td>24.3</td>
</tr>
<tr>
<td>*Uncomfortable seating</td>
<td>40.7</td>
<td>20.4</td>
<td>32.6</td>
<td>18.3</td>
</tr>
</tbody>
</table>

* p<0.05 by Chi-squared analysis
The greatest differential response was observed for the complaint of a lack of air movement. Of the professional VDT workers, 62.3% thought it was a problem as compared to the next highest value of 36.4% of clerical VDT workers. The clerical VDT workers did report that glare on work surfaces was a problem on a slightly more frequent basis.

As shown in Table 4 professional VDT workers had the least freedom to control such environmental parameters as ceiling lighting, air conditioning, heating and ventilation. In particular, air quality would be affected by a lack of control of ventilation, a complaint expressed by all the professional VDT workers.

Table 4: Job Type by Ability to Control Environment.

<table>
<thead>
<tr>
<th>Unable to control:</th>
<th>prof. VDT</th>
<th>clerical VDT</th>
<th>prof. non-VDT</th>
<th>clerical non-VDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>*ceiling lighting</td>
<td>98.4</td>
<td>82.8</td>
<td>91.9</td>
<td>83.1</td>
</tr>
<tr>
<td>*air conditioning</td>
<td>96.7</td>
<td>93.9</td>
<td>96.0</td>
<td>83.0</td>
</tr>
<tr>
<td>*heating</td>
<td>98.4</td>
<td>93.2</td>
<td>96.9</td>
<td>87.6</td>
</tr>
<tr>
<td>*ventilation</td>
<td>100.0</td>
<td>94.6</td>
<td>87.0</td>
<td>86.7</td>
</tr>
</tbody>
</table>

* p<0.05 by Chi-squared analysis

VDT use has been an important element in the differential responses seen. The subsequent analyses will focus on the
relationship between the extent of VDT use and the percentage of complaints found.

Only three of nine parameters describing bothersome VDT characteristics were found to differ significantly from one another according to extent of VDT use. Flickering of the screen was often bothersome for 12.3% of usual VDT users compared to 5.4% of those who rarely use them. Similarly bright lighting showed a 22.7% response rate for usual VDT users in comparison to 16.7% of half-time users and to 10.8% of the rare VDT users. Brightness of letters was similarly bothersome to both usual and rare VDT users.
Table 5: Frequency of VDT Use by Complaints Found to be Significantly Different Between Groups by the Chi-Squared Analysis.

<table>
<thead>
<tr>
<th>Health Symptoms</th>
<th>rarely</th>
<th>&lt;1/2 time</th>
<th>1/2 time</th>
<th>often</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>35.5</td>
<td>40.3</td>
<td>45.2</td>
<td>48.5</td>
</tr>
<tr>
<td>Sleepiness</td>
<td>46.7</td>
<td>37.7</td>
<td>47.6</td>
<td>55.9</td>
</tr>
<tr>
<td>Neck ache</td>
<td>26.6</td>
<td>26.0</td>
<td>33.3</td>
<td>36.7</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>19.4</td>
<td>20.8</td>
<td>9.5</td>
<td>26.2</td>
</tr>
<tr>
<td>Eye irritation</td>
<td>24.8</td>
<td>22.1</td>
<td>11.9</td>
<td>34.1</td>
</tr>
<tr>
<td>Trouble focussing</td>
<td>17.4</td>
<td>19.5</td>
<td>7.1</td>
<td>24.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stressors</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No job freedom</td>
<td>21.9</td>
<td>9.2</td>
<td>11.9</td>
<td>27.8</td>
</tr>
<tr>
<td>Poor job security</td>
<td>10.7</td>
<td>1.3</td>
<td>9.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Job requires fast work</td>
<td>27.5</td>
<td>31.2</td>
<td>35.7</td>
<td>43.6</td>
</tr>
<tr>
<td>Requires concentration</td>
<td>49.8</td>
<td>48.1</td>
<td>50.0</td>
<td>61.4</td>
</tr>
<tr>
<td>Abuse from customers</td>
<td>9.9</td>
<td>6.7</td>
<td>5.3</td>
<td>17.4</td>
</tr>
<tr>
<td>Remain in one location</td>
<td>60.0</td>
<td>61.0</td>
<td>54.8</td>
<td>71.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Environment</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Too little air movement</td>
<td>33.1</td>
<td>37.7</td>
<td>35.7</td>
<td>45.1</td>
</tr>
<tr>
<td>Glare on work surfaces</td>
<td>13.1</td>
<td>9.2</td>
<td>19.5</td>
<td>22.3</td>
</tr>
<tr>
<td>Unpleasant odors</td>
<td>12.6</td>
<td>5.3</td>
<td>16.7</td>
<td>19.4</td>
</tr>
<tr>
<td>Air too dry</td>
<td>17.9</td>
<td>21.1</td>
<td>24.4</td>
<td>29.9</td>
</tr>
<tr>
<td>Air too smokey</td>
<td>11.1</td>
<td>6.5</td>
<td>12.2</td>
<td>20.0</td>
</tr>
<tr>
<td>Air too stuffy</td>
<td>22.4</td>
<td>22.4</td>
<td>29.3</td>
<td>36.9</td>
</tr>
<tr>
<td>Uncomfortable seating</td>
<td>20.2</td>
<td>10.4</td>
<td>24.4</td>
<td>26.7</td>
</tr>
</tbody>
</table>
Table 5 lists those complaints of ill-health, stress and of the physical environment which were found to differ significantly according to the extent of VDT use. A survey of the data reveals that for the majority of cases the least percentages of complaints were made by those spending half of their time or less than half-time on the VDTs. The recommendation of limited use of the VDTs during the work day is supported by this data.

The afore-mentioned data were based on questionnaires filled out by 1100 members of an O.P.E.I.U. local in New York. The professional and clerical VDT and non-VDT workers belonged to many different organizations and were located in a large number of facilities. The social and physical environment at work thus was varied in nature. To overcome the discrepancies among the workers in their social milieu and physical work environment, analyses were conducted on one mechanically ventilated buildings in which workers from each of the job type classifications were represented.

In total the responses of 199 workers were involved. As expected, indicators of the workers' physical environment were comparable among job types. There were no significant differences among professional and clerical VDT and non-VDT workers on all facets of the physical work environment, except for glare on the work surfaces and too little air movement. For the latter, it was the professional VDT workers that had the largest percentage of complaints (39.3%). Clerical VDT workers
had the next highest percentage of 24.0%. This group had the highest percentage of complaints about glare (20.0%) while the lowest percentage of complaints were from professional VDT workers (7.1%). Otherwise the percentage of complaints concerning the quality of air and temperature were relatively similar across all job types.

Only one out of twenty-four possible health symptoms were recorded at a frequency of one to three times a week. The complaint of neck ache, for which professional VDT workers had the highest percentage of 37.9%; the other values ranged from 16.7% for clerical VDT workers to 37.7% for professional non-VDT workers.

Where differences among the job types did become evident was in the stress elements encountered in their work. The following stressors were found to be significantly different among professional and clerical VDT and non-VDT workers (Chi-squared analysis, p<0.05, Table 6).


Table 6: Job Type versus Stress in a Building where Stress was Significantly Different Between Groups (Chi-squared Analysis, \( p < 0.05 \)).

<table>
<thead>
<tr>
<th>stressors</th>
<th>prof. VDT</th>
<th>clerical VDT</th>
<th>prof. non-VDT</th>
<th>clerical non-VDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>No decision making</td>
<td>48.3</td>
<td>20.0</td>
<td>59.0</td>
<td>29.1</td>
</tr>
<tr>
<td>No job freedom</td>
<td>55.2</td>
<td>31.0</td>
<td>54.1</td>
<td>38.5</td>
</tr>
<tr>
<td>Can't set work speed</td>
<td>58.6</td>
<td>50.0</td>
<td>67.2</td>
<td>29.1</td>
</tr>
<tr>
<td>Poor job security</td>
<td>10.3</td>
<td>17.2</td>
<td>37.9</td>
<td>23.3</td>
</tr>
<tr>
<td>Job requires fast work</td>
<td>79.3</td>
<td>43.3</td>
<td>42.6</td>
<td>38.0</td>
</tr>
<tr>
<td>Requires concentration</td>
<td>75.9</td>
<td>50.0</td>
<td>72.1</td>
<td>38.0</td>
</tr>
<tr>
<td>Too much physical effort</td>
<td>10.3</td>
<td>17.2</td>
<td>13.1</td>
<td>26.9</td>
</tr>
<tr>
<td>Awkward work motions</td>
<td>17.2</td>
<td>6.7</td>
<td>20.0</td>
<td>27.6</td>
</tr>
<tr>
<td>Not enough people</td>
<td>37.9</td>
<td>34.5</td>
<td>44.8</td>
<td>23.1</td>
</tr>
</tbody>
</table>
The professional workers had the highest percentages in the categories of enhanced stress. Work pressures were represented by differential responses even within a common social framework. The greatest difference in response frequencies was again observed for the complaint of being required to work fast. For professional VDT workers, 79.3% thought this to be a problem as compared to the next highest response rate of 43.3% among clerical VDT workers. Clerical non-VDT workers did express a greater frequency of complaints about using awkward work motions and having to exert physical effort.

Discussion

Among all the respondents, professional VDT workers had a larger percentage of health complaints than did clerical VDT workers or controls. This result differs from that of Smith et al. (1981) who found that clerical VDT operators were most likely to suffer from health and stress problems. However the professional VDT workers in our study had a larger VDT workload in that they spent the majority of their time on VDTs, while Smith's professional VDT workers "were not tied to their VDTs for any set time period".

An overview of the analysis of the New York data indicates that symptoms of poor health were related to air quality complaints. Relevant visual problems (blurred vision, eye irritation and trouble focussing) respiratory (nose irritation)
and psychosomatic symptoms (sleepiness, fatigue, headache, confusion, dizziness, depression, moodiness and lightheadedness) coincided with a predominance of air quality complaints (too little air movement, air too stuffy, dry, smokey and unpleasant odors). Analysis of the groups in one building revealed that where physical environment problems were reduced to only two complaints, only one health symptom was reported. Thus in a common physical environment the health complaints were vastly reduced.

Many recent reports have focussed on the problems of building-related illness due to indoor pollution (see Spengler and Sexton, 1983; Sterling and Kobayashi, 1977). The symptoms which are linked to building-associated illness include headache, respiratory problems, fatigue and visual distress. It was for the professional VDT workers that a greater incidence of air quality complaints were observed. They also had the least control over the ventilation of their office environment. It becomes readily apparent that good ventilation of office space is a prerequisite for comfort at work.

The VDT workers' complaints of visual and somatic discomfort were somewhat conservative in frequency compared with those reported in the literature. Gunnarson and Ostberg (1977) for example found 60% of their VDT workers complained of at least a few times a week of eye fatigue while 19% complained of blurred vision. Grandjean (1980) found 40-50% of the VDT operators interviewed complained of occasional visual
impairments. Of the professional VDT workers who responded to the questionnaire given in this study, 42.9% complained of eye irritation at least once a week, while a figure of 29.0% was found for clerical VDT workers. Blurred vision was a problem to 36.5% and 21.9% of professional and clerical VDT workers respectively. Neck aches were a problem to 42.9% of VDT professional workers and 31.6% of clerical VDT operators. To 46.0% of the professional VDT operators and 29.0% of the clerical VDT operators backache was apparent more than once a week. Cakir et al. (1978) reported that 51% of their VDT users had aching necks while 60% had back pains.

Psychosocial stresses were evident among professional VDT workers. A particular problem to 61.9% of them was being required to work fast. Gunnarson and Ostberg (1977) in contrast found about one-third of their VDT operators felt the workspace was too fast. This agrees with the figure of 34% found for clerical VDT workers in this study. Of the full-time VDT operators 22.7% complained of bright lighting, while a figure of 37% was found for the VDT workers surveyed by Dainoff et al., 1981).

Differences in the percentages of VDT operators expressing symptomatic, psychosocial or environmental complaints among the studies can be attributed to differences in task definition, as well as the social stress and physical environments imposed upon the VDT workers.
The length of time spent on a VDT appears to be an important factor to regulate. Where operators spent half of their time or less than halftime using the terminals the frequency of complaints concerning health, stress and the physical environment decreased. Recommendations for a four hour limit of VDT use put forward by such organizations as AMSTS (1979) seems particularly relevant.

The questionnaire approach has a number of limitations. Response was voluntary and therefore not random, though by having controls non-respondants could be similarly represented in each job category. In some instances due to limitations in the wording of some questionnaire categories, missing values became representative of a non-response. For example, the lowest category of symptoms was a frequency of once per month. Non-response was assumed to represent a never category. Another limitation of any questionnaire is the lack of objective measurements of the environment. Rather, it is the employees' subjective perceptions of their environment that was evaluated.
C. An Experimental Study to Determine Visual Function Effects of VDT Use
I. The Experimental Study

Rationale for the Experiment

Acute Visual Function Changes

"In speaking about visual fatigue we are speaking about something which has no precise and unique definition" (Collins, 1959).

Eyestrain involves processes that take place in the sensory cells of the retina, fatigue of the outer and inner muscles of the eye, changes of attention and central nervous system phenomena, and finally, a general fatigue of the entire body.

Disturbances of the subject's normal clarity of vision may occur because the ciliary and oculo-motor muscles cannot steadily maintain the proper focus and fixation of the eyes. The fogging of vision is accompanied by a feeling of irritation and a sense of difficulty in maintaining attention. Accommodation involves alteration of the converging power of the crystalline lens of the eye, which makes it possible for the eye to focus either for near or distant objects, by action of the ciliary muscle. The work of accommodation results in fatigue of the ciliary muscle while convergence, leads to a sense of fatigue resulting from an inability to supply nervous energy from within.
the mid-brain nuclei subserving eye movements.

Several hypotheses have been proposed to explain visual fatigue. These include an overtaxing of the retina; constant shifting between intra-ocular and extra-ocular muscles in attempts to obtain a clear image; and increased intraocular pressure caused by neuro-hormonal action (Smith, 1979).

Sharit and Salvendy (1982) cite Cameron's work (1971, 1973) in which fatigue is viewed as a generalized response to stress over a period of time. In this context, cumulative effects become important and suggest that the time required for recovery may be the appropriate index for quantifying fatigue.

Compared to those studies which use single sampling methods, there are few studies in which certain visual parameters were measured before and after use of the VDT. Holler et al. (1974) provided the first definitive work in this area. The fourteen subjects used were all experienced VDT operators who had either normal eyesight or wore appropriate eyeglasses or contact lenses. The subjects were tested before and after four hours of VDT work, and after two one-hour periods. Tests included visual acuity determined by wall boards of hooks and figures, color tests using the Helmholtz Apparatus and a subjective color scale and questionnaires.

About one-half of the subjects reported a deterioration of visual acuity and burning of the eyes, about one-third complained of headache and one-fourth of flickering before the eyes. Surprisingly, the data from the four-hour condition hardly
differed from the two one-hour conditions.

Most subjects showed slight changes in color vision, with two in the four-hour condition showing above normal shifts. Up to twenty minutes were needed for recovery. Five subjects showed definite changes in color vision in the subjective colour scale.

Related to the preliminary value, the work at the screen for four hours was, in nine cases followed by a myopia averaging one-fourth diopter. For most of these subjects, 15 minutes was sufficient recovery time. At the end of the two one-hour conditions subjects showed a reduction of an average of 1/8 diopter. Yet 15 minutes later only two subjects had recovered. While the authors concluded that they had proven changes in the functional state of the optical system after extended work at the display screen, it was not regarded as a health hazard. The issue of whether slight measurable changes in visual function are indicative of permanent damage remains controversial.

Haider et al. (1980) have shown that after a four hour VDT work period with breaks, a clear and long lasting temporary myopization having a magnitude of about 1/4 diopter occurred. It took ten to fifteen minutes to regain good distance vision. They theorized that the temporary myopization is probably due to accommodative strain.

Mourant et al. (1981) using controls in their study, measured accommodative facility. VDT usage for three hours produced measurable visual fatigue in the eye movement and/or accommodation mechanism, as measured by increased durations in
moving from a near point focus to a far point focus (and vice versa). Such visual changes were not present in a hard copy visual search task.

Finally Dainoff et al. (1981) found, by questionnaire, that VDT workers had significantly more fatigue, tension, eye strain, blurry vision, neck and shoulder problems, focus problems and lower back problems after work than before. However there were no indications of any pre-post changes in the optometric measures of visual acuity, and lateral and vertical phoria as a function of VDT work. However Dr. Haider indicated to them in a personal communication that the lack of significant change in the optometric results may be due to the fact that the subjects were permitted to take informal work breaks on their own initiative. The presence of such breaks may have acted to minimize any optometric effects.

Length of Exposure

One of the factors that influence the likelihood of an occupational disease or injury is the amount of time that the worker is exposed to the source of the risk. According to Grall (1974, as cited by Ostberg, 1975) good work organization and efficient use of rest pauses can be far more important in combatting fatigue than an otherwise ergonomically good workplace design. One of the big selling points of VDTs has been the potential for increased output. Such claims that an employee
should be able to type 80% more letters are made. However they would have to hit 80% more keys. Thus the job content or amount of time spent on various tasks is redistributed. For example, filing time, error correction and information retrieval is reduced. All the work can be done at one station. Unfortunately these changes tend to increase the monotony and boredom of the job while at the same time fatigue is increased because of the repetition or lack of relief. Tasks are designed with consideration of computer speed rather than the capacity of the worker (Arndt, 1980).

A rest pause is a means of overcoming or avoiding the condition of occupation ally-induced fatigue. It is not only the length of a rest pause that is important, it is also a question of when the pause is taken. Depending upon the nature of the job, the cumulative level of fatigue can be markedly reduced and overall performance improved in spite of the reduction in working time produced by having frequent but short duration rest pauses (Cakir et al. 1979). It is very difficult to specify appropriate work/rest cycles for work at visual display units. Their length and frequency depend upon the individual, the task, the environment, the equipment and a range of other factors. Regardless of the figures laid down there will be circumstances when the standard is too long (and therefore unproductive) or too short (and therefore results in unnecessary fatigue). According to Stewart (1979) the individual is the best judge; some flexibility to allow the individual to arrange his work to
suit himself or to rest would be much better than statutory rest pauses. Where possible VDT use should be part of the user's job rather than all of it. This allows for task mixes which avoid excessive fatigue or ocular symptoms.

In the CLC-LESC survey (1982) workers spending seven to eight hours per day on VDTs generally experienced visual and muscular problems "almost daily" about two to three times more often than workers using VDTs for two hours a day or less. The largest increases in levels of reported problems occurred between those working four hours or less and those working five or more hours on the VDT. Visual, musculoskeletal and stress problems were generally experienced about two to four times more often in those working at least two hours on the VDTs without a rest break than in those working thirty minutes or less at a time on their VDT.

In a VDT health collective bargaining kit, newspaper guilds were recommended to make rest-time allowances the number one issue. NIOSH recommended a 15-minute break be given after two hours of continuous VDT work under moderate visual demands or workload. In a stronger move, a 15-minute break was recommended after one hour of continuous VDT work under high visual demand, high workload and/or repetitive work tasks (Dooley, 1981).

ASTMS felt that the maximum VDT work in one day should be no more than four hours. The National Graphical Association, The National Union of Journalists, and APEX are among the other unions that agreed with this approach. C.U.P.E. demanded that
every forty minutes of VDT operation must be balanced by a twenty minute rest period in a relaxing place (Lambert, 1980). In the Norwegian government's recent labor inspectorate's draft document there were provisions for workers to spend only 50% of their time at work on terminals, with no more than two hours spent on a terminal at any one stretch (Computing, 1981). Even more radical is the Austrian Federation of Salaried Employees in the Private Business Sector's demand for "one hour off after one hour on".

As a result of the recent report of the Labour Canada task force on micro-electronics and employment (1982) amendments to the Canada Labour code have been proposed in which VDT operators will be allowed a formal rest break every hour. As well, recommendations have been made to reduce total VDT work time to five hours of the work day.

Experimental evidence so far appears to support many of these recommendations. Hart (1976) suggested that there is some evidence that with four hours of continuous screen viewing, temporary eye afflictions such as eye-strain and disturbed colour perception occur. Haider et al. (1980) have shown that even after a four hour work period with breaks, a clear temporary myopization having a magnitude of about 1/4 diopter occurs. A three hour continuous work period without breaks showed the strongest effect. However, Holler et al. (1975) found that even after two continuous hours of VDT work, some operators experienced a reduction in visual acuity. Average recovery time
was ten minutes. Based on this evidence, the researchers concluded that extensive VDT exposure caused a change in the functional state of the visual structure. This change acts potentially as a general systemic, as well as a visual stressor. Thus VDT operators are recommended to be given at the very least, a fifteen minute break every two hours.

Finally, Coe et al. (1980) found that within the group of VDT operators whose rate of taking informal workbreaks was always low (less than five per hour), 62% reported asthenopia; this differed significantly from the 42% figure found for the operators with medium/high rates. The authors concluded that the taking of informal workbreaks alone is not sufficient to reduce the prevalence of asthenopia. But that those who also take a low frequency of informal breaks are more likely to report asthenopia.

From the review of the literature it was apparent that many studies to this date have been lacking in several features:
1. use of adequate control groups,
2. use of standardized optometric evaluation procedures, and
3. an evaluation of the consequences of recommended VDT exposure and rest periods.

The thesis experiment was designed in consideration of these three factors.
Choice of Visual Function Measures

(1) Critical Flicker Fusion Frequency

The critical flicker fusion frequency measure (CFF) has been used more frequently than any other visual test as an index of general CNS fatigue. It was proposed in 1941 by Simonson and Enzer (cited in Bartley and Simonson, 1976) as a test reflecting subjective fatigue. They found a significant drop of the CFF in clerical workers and laboratory technicians (-5.4 and -4.6 cps respectively). In their subsequent studies amphetamine prevented the drop, together with relief of subjective fatigue. After it was found that a drop of CFF after alcohol ingestion was related to the alcohol content of blood rather than to sensation it was concluded that the CFF was an index of the general state of excitability of visual pathways and probably of the CNS.

However Simonson and Brozek in 1948 (cited in Bartley, 1976) found an identical drop in CFF after two hours of strenuous visual work under adequate as well as inadequate illumination levels. It was suggested that the drop in CFF was related to general fatigue rather than to visual stress per se. Schmidtke in 1951 (cited in Bartley, 1976) found not only a significant drop in CFF in types of work involving visual effort (fine assembly, linotype and microscopy) but also found such a drop after mental calculations performed by a blindfolded subject. Naturally he concluded that depression of CFF is related to general fatigue rather than strictly to visual
fatigue. Caution must be placed on this interpretation as foveal CFF during dark adaptation has been reported by Brown (1968) to fall.

Dull, repetitive and monotonous situations also produce a drop in CFF. The study by Grandjean et al. (1977) is illustrative of this situation. The monotonous condition consisted of a repetitive activity (counting nails to a set pace for three hours). An activating condition involved stimulating and pleasant activities such as psychomotor tests and music. In the monotonous situation a decrease in CFF of two hertz was found as well as a shift of the self-rated subjective state towards a decrease of motivation and ability for action. In the activating situation CFF did not change during the three hour session.

Little if any lowering of CFF results from work that requires only moderate mental effort, and which allows the comparative freedom of action, or which involves physical effort. Examples given by Grandjean (1979) are office work, sorting jobs and repetitive work at a moderate mental level, while reading was consistently found not to produce a significant depression of the CFF (Bartley and Simonson, 1976). The results for clerical workers are not consistent. For example, Saito et al. (1981) found critical flicker fusion frequency to deteriorate with time both in inspection work and clerical work.
According to Bartley and Simonson (1969) the relatively poor control of field conditions in occupational work is a major factor in the discrepancies found. As well, there is a lack of standardization of the technique of CFF determination. The CFF depends on the size, brightness and color of the test patch, surrounding illumination, state of adaptation and the light:dark ratio, amongst other things.

The only investigators to measure the CFF of VDT operators were Cakir et al. (1978, cited by Ostberg et al. 1979). A drop of CFF found at the end of the work shift correlated highly with muscular and visual complaints.

(2) Contrast Sensitivity

Visual acuity is the capacity to discriminate the fine details of objects. It is specified in terms of the minimum dimension of some critical aspects of a test object that a subject can correctly identify. This requires a frequency of seeing determination, and the threshold size is given as the visual angle of the detail that can be correctly detected 50% of the time. The Snellen eye chart, containing letters and digits of graduated size in high contrast, is the traditional optometric tool to measure visual acuity. But visual acuity alone is a poor predictor of overall visual performance (Sekuler and Mülvanny, 1982).

Another way to assess visual function is to determine contrast threshold - the minimum contrast needed to perceive a particular pattern. A grating of any coarseness can be made
imperceptible by reducing the difference between the luminance of the light bars and the luminance of the dark bars (Thomas, 1975). Contrast sensitivity varies with age and depends, among other things, upon the condition of the eye's crystalline lens. Subtle lens changes, not serious enough to lower visual acuity, can impair contrast sensitivity. On the job exposure to certain chemicals or to infrared or microwave radiation can affect the lens (Sekuler and Mulvanny, 1982).

According to Woo (1982) contrast sensitivity testing can provide an "early warning" and can be used to detect subtle changes in vision. As VDT work may promote visual fatigue he conducted a pilot study to measure the contrast sensitivity function of VDT workers after varying work periods. The average curve of contrast threshold by spatial frequency did not change after work. However many individuals did show marked changes in their contrast sensitivity function curves. Woo suspects length and intensity of VDT work are important determining factors of reduced contrast sensitivity.

(3) Accommodative Response

The change in the refractive power of the eye when the image of a near object is brought into focus on the retina is described as accommodation (Davson, 1976). The radius of curvature of the lens surfaces becomes shorter, that is, more convex. The lens thickens and the pupil contracts. The Helmholtz theory states that the lens is more convex or thicker for near vision because of a reduction in zonular tension resulting from
contraction of the ciliary muscle (Campbell et al. 1974). The classical view is that the least effort of accommodation will be observed when the stimulus is at a far distance, as the extrinsic and intrinsic eye muscles will be relaxed then. Ostberg et al. (1980) support an alternative hypothesis that the resting focus does not correspond to infinity, but to an intermediate position of about one meter.

Gunnarsson and Soderberg (1983) measured the near point of accommodation by first establishing the smallest line of letters that could be read clearly from 30 cm along a near point ruler. As the line of letters was moved closer to the subject the near point of accommodation was determined as the point where the letters started to appear blurred. After a work day which included six hours of VDT work this near point of accommodation was found to increase an average of 3.5 cm.

(4) Accommodative Facility

Collins and Pruen (1962) using a rotating sector disc, had subjects view single Landolt rings at two different distances. They concluded that the time required to perceive accurately objects at two different distances is worth considering as an indicator of fatigue.

Krivohlavy et al. (1969) used two panels of Landolt rings to measure visual performance in convergence and accommodative situations. The subject had to read two Landolt ring panels in a serial manner. The first panel was .5 meters away from the subject and the second was 5 meters away. The time necessary for
reading and the number of errors was ascertained. Using this method, Krivohlavy et al. (1969) found that for six female machinists, mean performance in convergence and accommodation steadily diminished during a work shift. Krivohlavy's method unfortunately brought in the confounding factors of higher-order information processing rather than physiological reflex phenomena. In addition to accommodative time lag, perception of the Landolt ring gap position is required. Extraneous factors such as subjective mood will have a greater effect upon response time with this method.

The accommodative facility of VDT workers was measured by Mourant et al. (1981). Accommodative facility was found to decrease after VDT work, yet not after a hard-copy visual search task.

Other objective measures of general fatigue such as the slowing of perceptual-motor performance as evidenced by an increase in reaction time have been considered. However due to the specificity of mental fatigue, psychomotor tests may cause a temporary arousal which could mask any possible sign of general fatigue (Grandjean, 1979).

**Purpose**

The purpose of the experiment was to assess whether any visual function changes or evidence of psychological fatigue occur over a two hour VDT session. The experimental task
consisted of two hours of text-editing on a VDT terminal. Subjects were instructed to maintain intensity of interest towards the task throughout the experimental session. Interest was maintained by allowing the subject to choose his or her own text to edit. During the two hour control session no VDT work was allowed. Subjects were free to read and relax at will.

Materials and Methods

Subjects

Seven males and five females participated in the experimental study. They ranged in age from 23 to 43 years; the average was 30 years of age.

Four of the subjects did not require corrective lenses to operate the VDT. Five subjects were myopic and wore glasses, while three wore contact lenses. The majority had never smoked. Only one subject was a current smoker of about three cigarettes a week while one other was a former smoker.

All subjects were paid volunteers. They were given $10.00 for participating in both the experimental and control conditions.
Protocol

All experimental sessions were conducted in a laboratory room. The temperature ranged from 69 F to 73 F, averaging 71 F. The humidity, which was determined with a sling psychrometer (Taylor Instrument Co., New York) averaged 44%. Room illumination was constant at 1150 lux as measured by a Gossen Panlux illumination level meter.

During the experimental session subjects were seated in an office chair which was adjustable for height. On their own initiative, no one deemed it necessary to alter the adjustment. The IBM model 3101 display terminal was placed on a desk, 72.5 cm high. The keyboard distance was adjustable with the keyboard height averaging 7 cm above the table level. The video screen dimensions were 20 by 25.5 cm with green letters being formed from a 7 x 9 dot matrix on a dark background. Up to 24 lines of 80 characters each could be entered on the screen. Reflections from the overhead fluorescent lighting were noticeable on the screen face.

The order of the visual tests, which were given before and after the two hour experimental session and after a 15 minute rest break, were counterbalanced between the critical flicker fusion (CFF) and contrast sensitivity measures, as well as the two accommodative measures. For the control session, these measurements were done before and after the two hour period only.
Five visual function measurements were obtained in the following manner:

1. Critical Flicker Fusion - The subject was positioned so his or her eyes were 50 cm away from the flicker fusion viewing chamber (model 12026, Lafayette Instrument Co., Indiana). The percentage light was set at 33. The flicker rate of the flicker fusion apparatus (model 12025, Lafayette Instrument Co., Indiana) was adjusted by the experimenter in 0.1 Hz increments until the subject could no longer see any flicker of the stimulus lamp through foveal vision. This procedure was repeated twice. Accuracy of the instrument was +/- 0.1 Hz.

2. Contrast Threshold - Subjects were seated 4.3 meters from an oscilloscope which displayed sine wave gratings at a display frequency of either 30 or 40 cycles per display of 11 cm. This was equivalent to 20 and 27 cycles per degree of visual angle, respectively. The particular spatial frequencies used were chosen due to preliminary findings which showed that displays of 20 or less cycles, or 50 or more cycles exceeded the contrast range. For this same reason, a seating distance of 4.3 meters was chosen. The contrast function dial allowed simultaneous reciprocal adjustment of the luminance of the adjacent light and dark bars of grating so that the overall screen luminance was constant regardless of the grating contrast. The range of contrast varied on an arbitrary scale of 0 to the highest contrast of 200. Contrast was progressively diminished by the experimenter in decrements of 1 unit, until the presence of the
grating could not be distinguished from a uniform field. This procedure was done six times in all, with the order of the set spatial frequencies given randomly.

3. Accommodative response - This measure was determined by the Badal Optometer method. A target pin was adjusted for maximum clarity while aligned directly behind a fixed 10 dioptre lens. A Snellen eye chart was placed at a 50 cm distance. Subjects were positioned on an upright rest so that through the left eye (which was 10 cm away from the lens) they could see the pin behind the lens while through the right eye, the eye chart was viewed. The subject adjusted the pin-to-lens distance from past the optical infinity point until the pin image became clear while maintaining the view of the eye chart.

The principle upon which the procedure was based was Hering's Law of Equal Innervation. A stimulus to accommodation (the eye chart) was presented to one eye while the response to accommodation (the pin-to-lens distance) was measured in the other. The procedure was conducted three times.

4. Accommodative facility - This visual function was measured with a standard Snellen eye chart placed 6 meters away and a near point chart viewed from a distance of .25 meter. Subjects alternated their gaze between the far and near charts, using the point at which the letters became clear as the signal to change. A period of 15 seconds was used to record the number of times the subject's view became clear after returning to the far chart. The procedure was not repeated due to the fatigue effect.
of performing the task.

The rationale for the use of accommodative facility is that VDT work involves accommodative and convergence functions, due to the need for changing the focus of the eye to the different distances of VDT screen, keys and document and maintaining a fixed gaze at the screen.

Questionnaires were filled out before and after the experimental condition and after the 15 minute rest period. Similar questionnaires were given before and after the succeeding control period of non-VDT activity. Repeated questions included a psychological fatigue scale of 14 dipolar factors developed by Grandjean et al. (1977). As well, health complaints rated from none to severe were included. Following the experimental condition additional questions evaluated the physical conditions in the laboratory and physical parameters of the VDT. Answers were on an ordinal scale of "none", "slight", "moderate" and "severe". A copy of each questionnaire is given in Appendix C.

Results

An analysis of variance for repeated measures (BMDP, 1981) was conducted on each of the visual function tests. A significant effect (p<0.05) for time of measurement (before and after the experiment and after rest) was found for CPP, contrast threshold at 40 cycles per 11 cm, and accommodative facility.
Figures 1 to 5 show the graphs of the means of the values of each visual function at each measurement occasion. The error bars are +/- one standard error of the mean. A partitioned F test for multiple comparisons revealed that it was the difference between the means after and before the experimental condition that contributed to the significant difference (p<0.05).
Figure 1. Mean Experimental Changes in CFF.
CRITICAL FLICKER FUSION

C. F. F. [cycles/sec]

37.5
36
34.5
33
31.5
30

BEFORE 2HRS
AFTER 2HRS
AFTER 15MIN REST

MEASUREMENT OCCASION

88b
Figure 2. Mean Experimental Changes in Contrast Threshold at 30 cycles/11cm.
CONTRAST THRESHOLD AT 30

C. S. 30

BEFORE 2HRS

AFTER 2HRS

AFTER 15MIN REST

MEASUREMENT OCCASION
Figure 3. Mean Experimental Changes in Contrast Threshold at 40 cycles/11 cm.
CONTRAST THRESHOLD AT 40

C. S. 40

BEFORE 2HRS

AFTER 2HRS

AFTER 15MIN REST

MEASUREMENT OCCASION
Figure 4. Mean Experimental Changes in Accommodative Response.
ACCOMMODATIVE RESPONSE

ACCOMMODATIVE RESPONSE [diopters]

BEFORE 2HRS  AFTER 2HRS  AFTER 15MIN REST

MEASUREMENT OCCASION
Figure 5. Mean Experimental Changes in Accommodative Facility.
ACCOMMODATIVE FACILITY

MEASUREMENT OCCASION

ACCOMMODATIVE FACILITY [cycles/15 sec]

BEFORE 2HRS
AFTER 2HRS
AFTER 15MIN REST

5.5
6.1
6.7
7.3
7.9
8.5
For the control session, an analysis of variance for repeated measures showed no significant effect for any of the visual function values. A MANOVA (SPSS, 1981) analysis was run to take into account the relationships between the measures on the effect of time of measurement. The result showed that the level of significance was just above the rejection level (p=0.06).

A two-way analysis of variance was used to determine if there was any significant effect or interaction between time of measurement and type of treatment (experimental or control). While for accommodative facility, type of treatment alone was significantly different, both for contrast threshold at 40 cycles/11 cm, and accommodative facility a significant interaction (p<0.05) was observed. Both figures 6 and 7 reveal that after a two hour period there was a decrement of visual function in the experimental treatment group; this being the opposite trend of the control group. For example, contrast threshold values increased by the end of the experimental session while with the control treatment a decrease, which indicates an improvement, occurred.

An analysis of variance was also conducted with a grouping factor based on VDT parameter complaints. Subjects were classed as low, medium or high in the VDT parameter complaint scale as to the frequency in which they perceived faults in the VDT. As observed in figure 8 those with high VDT complaints had the highest contrast threshold values, while the low VDT complaints
group consistently had the lowest contrast threshold values 
(p<0.05). The lower contrast values imply a greater ability to
detect contrast differences between the adjacent bars of light 
of the grating.
Figure 6: Mean Contrast Threshold at 40 cycles/11cm - Experimental vs Control.
Figure 7: Mean Accommodative Facility - Experimental vs Control.
ACCOMMODATIVE FACILITY

A. F. [cycles/15 sec]

CONTROL

EXPERIMENTAL

BEFORE 2HRS

AFTER 2HRS

MEASUREMENT OCCASION
Figure 8: Mean Contrast Threshold at 40 cycles/11cm by VDT group.
Psychological fatigue variables were measured on a linear scale. An analysis of variance for repeated measures was run for the experimental measures. Significant differences (p<0.05) were found in the direction of the fatigue variable for the psychological dipolar scales of strong-weak, happy-sad, refreshed-tired, interested-bored, energetic-lazy, vigorous-exhausted, awake-sleepy, stimulated-sedated, able to concentrate-unable and no feeling of discomfort-extensive. No significant differences were found for those psychological measures tested before and after the control condition. A partitioned F test for multiple comparisons indicated that it was the before-after combination which was significantly different (p<0.05).

Pearson correlation coefficients were obtained on each of the three measurement trials done on CFP, contrast sensitivity and accommodative response at each measurement occasion. Pearson correlation coefficients showed strong relationships of each measurement trial with the other, with r values ranging from 0.82 to 0.94 for CFP; 0.94 to 0.99 for contrast sensitivity; and 0.62 to 0.89 for accommodative response.

Whether physical symptoms were present before or after the experimental condition or after rest was analyzed according to Friedman's test of significance (Bradley, 1968). The health symptoms of eye irritation and heavy eyelids were found to differ significantly after the experiment as compared to before. The complaint of irritated eyes occurred in 75% of the subjects
after the VDT session while complaints of heavy eyelids, blurred vision and burning eyes occurred in 58.3%. To 41.7% white colour appeared pinkish, while 33.3% experienced neck aches.

In the post-experimental condition, environmental variables were assessed. Seventy-five percent of the subjects found the seating uncomfortable and the room lighting too bright. For 50% the room was stuffy, 41.7% thought the room was noisy and 33.3% complained that the room was too hot. However when the ratings of these environmental variables done after a two hour VDT session were compared with ratings done by twenty other subjects before working in the room, no significant differences were identified using a Mann-Whitney U analysis of independent measures (p<0.05).

Finally, VDT parameters were evaluated. To 58.3% of the subjects, glare on the screen was a problem. The height of the keyboard and the distraction of bright lights above or behind the VDT were indicated by 50% of the subjects to be bothersome. For 41.7% the distance to the keyboard was not optimal while for 33.3% the brightness of the screen and a high pitched noise were bothersome.

Discussion

Exposure to two hours of intensive work at a video display terminal appears to have an effect on the visual function parameters of critical flicker fusion, contrast sensitivity and
accommodative facility. In all instances measures showed a decrement in function after the experimental condition. Recovery was evident to some extent in all of the visual measures after 15 minutes rest. Changes in the psychological fatigue dipolar scale also indicated that the experimental session was subjectively more fatiguing. Most dipolar psychological fatigue indicators increased in degree in the direction of the fatigue variable after the experiment compared with before.

The average drop in CPP of 1.1 cps after the two-hour experimental session was small, but consistent in its trend. Bartley and Simonson (1976) report findings of a greater drop in CPP of 4.6 to 5.4 cps in intense close work after a full work day, rather than a two-hour work period. A significant change in contrast threshold at 40 cycles/11cm was found where an average contrast reading of 90.8 before the session increased to 102.6 after. Woo (1982) in comparison found no consistent trend in the total contrast threshold function curve. However, analyses of changes in individual frequencies were not presented. The drop in accommodative facility of 1.3 cycles when viewing charts at two different distances, agrees with the findings of a decrease in accommodative facility by Mourant et al. (1981).

Accommodative response showed a slight change of .35 diopters. Yet because of individual variation any consistent effect was not evident. However Heller et al. (1975) with only a change of .25 diopters, commented on its potential significance to appropriate vision. The task of accommodative response was
the most difficult to assess as subjects found that focussing on the target pin while maintaining a clear image of the Snellen chart a difficult process.

Limitations to this experiment were evident. The task which the subject performed could be made more standardized so that the rate of work could be monitored. For the control group, likewise, monitoring work such as typewriting in the same room environment would have been beneficial in order to assess whether psychomotor fatigue was evident from the typing element of VDT work. The time delay between the completion of the experimental task and visual function measurement may have promoted some recovery. At issue is what a decrement in CPP really indicates. The descriptive term "visual fatigue" is relatively meaningless. Subjects maintained fixed distances from the instruments without any mechanical assistance. Slight changes in viewing distances may affect the results somewhat. Finally, complete analysis of the contrast sensitivity function would require use of equipment with a more encompassing range of contrast. This would permit the plotting of a contrast threshold function curve which would more conclusively indicate which frequencies of sinusoidal wave gratings were affected.

According to the current literature, the question of whether acute changes in visual function promote any degradation in permanent visual functioning remains unresolved. However the fact that visual function changes were evident after two hours of VDT work and not in a two hour free period involving reading
and rest, indicates that a two-hour uninterrupted period of intense visual work using the VDT may be too long. Incomplete recovery after 15 minutes rest in some individuals also promotes this conclusion. In light of these findings, a shorter work period, possibly of a one-hour maximum of VDT work followed by a formal rest break would be more appropriate. The encouragement of informal rest breaks also may help to alleviate any undue visual stress. Such slight changes in visual function may hinder the operators' visual comfort during a VDT task. Accommodative function changes especially would affect the subject's ability to focus on the material. It can be expected that after a longer VDT work period (that typically found for an average VDT operator's work day) there would be a greater effect of VDT work on visual function. Rest breaks must be of sufficient frequency and duration to promote recovery.

Further research into the more permanent repercussions of acute visual function changes is recommended. Changes in accommodative response may be particularly relevant as it showed the least amount of recovery on the average. Delineating factors that may ease visual stress such as lighting and glare control and the optimal spacing of rest breaks is a further recommendation. A potential aid in this regard is the use of appropriate specialized prescription glasses which may ease the strain of accommodative work.
REFERENCES


9. Birnbaum, R. Health hazards of visual display units. A review for the Information and Advisory Service, London School of Hygiene and Tropical Medicine, 1978.


34. Dwyer, M. High miscarriage rate found in group of VDT operators. Computing Canada: 18, April 15, 1982.


39. Gosch, J. Viewing the flat-screen future. Electronics 55:


50. Holler, H., Kundi, M., Schmid, H., Stidl, H., Thaler, A.,


75. Ostberg, O. Office participation, workplace design considerations and the reduction of visual stress. Paper read at the NATO Advanced Study Institute on Man-computer interaction, Greece, September, 1976.

76. Ostberg, O. Review of visual strain, with special reference
to microimage reading. Paper read at the International Micrographics Congress, Stockholm, September, 1976.


100. Stewart, T.F.M. Eyestrain and visual display units: a review. Displays April, 1979.


102. Stone, P.T. Issues in vision and lighting for users of VDTs. In the HUSAT Research Group, Health Hazards of VDUs? II. Some Solutions to the Common Problems.


<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The Work Environment Survey Questionnaire</td>
<td>114</td>
</tr>
<tr>
<td>B</td>
<td>D.C.T. Occupation Codes</td>
<td>119</td>
</tr>
<tr>
<td>C</td>
<td>Experimental Questionnaires</td>
<td>122</td>
</tr>
</tbody>
</table>
Appendix A: The Work Environment Survey Questionnaire
INSTRUCTIONS: Please answer the following survey by blackening the most appropriate circle(s) as shown at left. All information given will be confidential and anonymous. This survey is being used to determine the quality of your work place. Begin with #1 following the example.

1. **BIRTHDATE**
   - **MONTH**
     - JAN 0
     - FEB 0
     - MAR 0
     - APR 0
     - MAY 0
     - JUN 0
     - JUL 0
     - AUG 0
     - SEP 0
     - OCT 0
     - NOV 0
     - DEC 0
   - **DAY**
     - 1
   - **YEAR**
     - 1950

2. **DAYS STARTED PRESENT JOB**
   - **MONTH**
     - JAN 0
     - FEB 0
     - MAR 0
     - APR 0
     - MAY 0
     - JUN 0
     - JUL 0
     - AUG 0
     - SEP 0
     - OCT 0
     - NOV 0
     - DEC 0
   - **MONTH**
     - JAN 0
     - FEB 0
     - MAR 0
     - APR 0
     - MAY 0
     - JUN 0
     - JUL 0
     - AUG 0
     - SEP 0
     - OCT 0
     - NOV 0
     - DEC 0

3. **EMPLOYMENT STATUS**
   - Full time
   - Part time
   - Temporary
   - Other

4. **RACE**
   - Black
   - Hispanic
   - Oriental
   - White
   - Other

5. **MARITAL STATUS**
   - Single
   - Married
   - Separated
   - Divorced
   - Widowed
   - Other

6. **SEX**
   - Male
   - Female

7. **NUMBER OF CHILDREN**
   - One
   - Two
   - Three
   - Four or more

8. **EDUCATION**
   - Grade 9 or less
   - Some high school
   - High school (completed)
   - Junior college
   - Technical training
   - Some college
   - Undergraduate college degree
   - Graduate school

9. **IN THE QUESTIONS THAT FOLLOW CHOOSE ONE BEST ANSWER UNLESS OTHERWISE INDICATED.**
   - **Are you the primary source of income in your household?**
     - Yes 0 No 0
   - **Were you laid off or fired?**
     - a) in the past 6 months? Yes 0 No 0
     - b) in the past year? Yes 0 No 0
   - **On the average how many hours a day do you work?**
     - 01 to 2
     - 03 to 4
     - 05 to 6
     - 07 to 8
     - 09 to 10
     - Over 10
   - **How many days a week do you usually work?**
     - 01 day
     - 02 days
     - 03 days
     - 04 days
     - 06 days
     - 07 days
   - **How many days have you been absent from work during the past 6 months? (Do not include vacation days).**
     - None
     - 01 to 2
     - 03 to 5
     - 06 to 8
     - 09 to 12
     - More than 12
   - **In the past 6 months how many days have you left during work due to illness?**
     - None
     - 01 to 2
     - 03 to 5
     - 06 to 8
     - 09 to 12
     - More than 12
31. In your primary work area (that in which you spend the most time) do you feel there is:

<table>
<thead>
<tr>
<th></th>
<th>NEVER OR RARELY</th>
<th>SOME TIMES</th>
<th>OFTEN OR ALWAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>too little air movement</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>b)</td>
<td>too much air movement</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>c)</td>
<td>lighting too bright</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>d)</td>
<td>lighting too dim</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>e)</td>
<td>glare on work surfaces</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>f)</td>
<td>unpleasant odors</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>g)</td>
<td>temperature too cold</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>h)</td>
<td>temperature too hot</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>i)</td>
<td>air too dry</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>j)</td>
<td>air too moist</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>k)</td>
<td>air too smoky</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>l)</td>
<td>air too stuffy</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>m)</td>
<td>uncomfortable seating</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

32. What type of equipment do you use at work? (Choose all appropriate responses):

<table>
<thead>
<tr>
<th></th>
<th>NEVER OR RARELY</th>
<th>SOME TIMES</th>
<th>OFTEN OR ALWAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>transcriber</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>b)</td>
<td>typewriter</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>c)</td>
<td>VDT/CRT</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>d)</td>
<td>laser printer</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>e)</td>
<td>photocopier</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>f)</td>
<td>mimeograph</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>g)</td>
<td>adding machine or calculator</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>h)</td>
<td>telephone(s)</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>i)</td>
<td>filing</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Go on to question 33 on the next page
33. If you work on a VDT/CRT, answer this question. (If you do not work on a VDT/CRT, go to question 34).

Are the following bothersome:

- a) flickering of screen? 
- b) brightness of screen? 
- c) height of screen? 
- d) distance to screen? 
- e) bright lights above or behind VDT/CRT? 
- f) size of lettering? 
- g) brightness of letters? 
- h) height of keyboard? 
- i) distance to keyboard? 
- j) Is the keyboard attached?

34. Is your work area:
- enclosed
- not enclosed

35. Can you see a window from your primary work position?
- Yes
- No

36. Approximately what distance are you from a window?
- Less than 5 feet
- 5 to 10 feet
- 10 to 20 feet
- Over 20 feet
- No windows nearby

37. Do the windows open?
- Yes
- No
- Yes, but not allowed

38. On how many sides are there privacy partitions?
- None
- One
- Two
- Three
- Four

39. Is your work area lighted by:
(Choose all that apply)
- (flourescent ceiling light
- (flourescent table light
- incandescent ceiling light
- incandescent table light
- natural window light

40. Are you able to control:
- ceiling lighting
- air conditioning
- heating
- ventilation

41. In the past year have you brought to work:
- extra heater
- extra fan

42. Do you now or have you ever smoked cigarettes?
- Yes
- No
- Yes, but only in designated areas
- Yes, but not much time to smoke

43. Are you able to smoke at work?
- Yes
- No
- Yes, but only in designated areas
- Yes, but not much time to smoke

44. Do you wear corrective lenses at work?
- No
- Bifocals
- Reading glasses
- Contact lenses
- Regular glasses

45. How many cups of coffee do you drink on the average each day at work?
- None
- 1 or less
- 1 to 3 times a week
- 4 to 6
- 6 or more

46. How many cups of tea do you drink on the average each day at work?
- None
- 1 or less
- 2 to 3
- 4 to 5
- 6 or more

47. How often have you had alcoholic beverages in the past 6 months?
- None
- 1 or less
- 1 to 3 times a week
- 4 or more times a week

48. Do you use the following appliances in your home? (Choose all that apply)
- Gas stove
- Gas heating
- Electric stove
- Electric heating
- Oil furnace
- Air conditioner
49. Have you ever experienced any of the symptoms listed below while at work? (Choose all that apply):

| a) headache | b) dizziness | c) fatigue | d) sleepiness | e) nausea | f) skin rash | g) ringing in ears | h) nose irritation | i) breathing difficulty | j) chest pain or tightness | k) racing heart | l) neck ache | m) sore arms, hands, or wrists | n) backache | o) blurred vision | p) eye irritation | q) split or double vision | r) trouble focusing eyes | s) sore throat or cold symptoms | t) moodiness | u) frequent urination | v) depression | w) lightheadedness | x) confusion |
|-------------|--------------|------------|--------------|-----------|-------------|------------------|------------------|----------------------|-------------------|--------------|-------------|-----------------------------|--------------|-----------------|----------------|-------------------|----------------|-------------------|----------------|--------------------|----------------|-----------------|-----------------|----------------|-----------------|----------------|
| O           | O            | O          | O            | O         | O           | O                | O                | O                    | O                 | O             | O            | O                          | O            | O               | O              | O                  | O              | O                  | O              | O                  | O              | O               | O              | O               | O              | O               | O              |

50. Are you currently taking any of the following medications? (Choose all that apply):

<table>
<thead>
<tr>
<th>a) aspirin</th>
<th>b) stomach or digestive aids</th>
<th>c) cough, cold or sinus medication</th>
<th>d) stimulants (pep pills)</th>
<th>e) prescription medicine</th>
<th>f) laxatives</th>
<th>g) depressants (e.g., valium)</th>
<th>h) sleep inducing aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

51. Have you ever been diagnosed by a doctor as having: (Choose all that apply)

<table>
<thead>
<tr>
<th>cancer</th>
<th>hypertension</th>
<th>heart disease</th>
<th>diabetes</th>
<th>kidney disease</th>
<th>liver disease</th>
<th>asthma</th>
<th>dermatitis</th>
<th>allergies</th>
<th>nervous disorders</th>
<th>anemia</th>
<th>glaucoma</th>
<th>ulcers</th>
<th>cataracts</th>
<th>respiratory illness (other than colds)</th>
<th>eye infections</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

52. How many times have you been to a doctor in the past 6 months?

<table>
<thead>
<tr>
<th>None</th>
<th>Once</th>
<th>Twice</th>
<th>3 to 4</th>
<th>5 to 6</th>
<th>7 to 8</th>
<th>More than 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

53. Do you have trouble sleeping?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

54. Have you or your spouse ever experienced: (Choose all that apply)

<table>
<thead>
<tr>
<th>miscarriage</th>
<th>still birth</th>
<th>offspring with birth defect(s)</th>
<th>difficulty becoming pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

*THANK YOU VERY MUCH*

This work environment survey was developed at Simon Fraser University and at Columbia University.

© E. Sterling, D. Sterling, D. Kobayashi
Appendix B: D.O.T. Occupation Codes

<table>
<thead>
<tr>
<th>Professional job categories</th>
<th>Dot Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative or staff assistant</td>
<td>169</td>
</tr>
<tr>
<td>Auditor</td>
<td>160</td>
</tr>
<tr>
<td>Bulletin Editor</td>
<td>132</td>
</tr>
<tr>
<td>Buyer</td>
<td>162</td>
</tr>
<tr>
<td>Claims examiner</td>
<td>168</td>
</tr>
<tr>
<td>Computing programmer</td>
<td>007</td>
</tr>
<tr>
<td>Executive, chief, coordinating secretary</td>
<td>189</td>
</tr>
<tr>
<td>Field abstracter</td>
<td>119</td>
</tr>
<tr>
<td>Librarian</td>
<td>100</td>
</tr>
<tr>
<td>Reporter</td>
<td>131</td>
</tr>
<tr>
<td>Senior draftsman</td>
<td>007</td>
</tr>
<tr>
<td>Service, complaints, investigation</td>
<td>168</td>
</tr>
<tr>
<td>Staff or administrative assistant</td>
<td>169</td>
</tr>
<tr>
<td>Statistician</td>
<td>020</td>
</tr>
</tbody>
</table>
### Clerical Job Categories

<table>
<thead>
<tr>
<th>Job Category</th>
<th>Dot Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS expeditor</td>
<td>221</td>
</tr>
<tr>
<td>Account, billing clerk</td>
<td>216</td>
</tr>
<tr>
<td>Accounting</td>
<td>216</td>
</tr>
<tr>
<td>Bond, reserve clerk</td>
<td>216</td>
</tr>
<tr>
<td>Claims approver</td>
<td>209</td>
</tr>
<tr>
<td>Clerk (unclassified)</td>
<td>209</td>
</tr>
<tr>
<td>Clerk-typist</td>
<td>203</td>
</tr>
<tr>
<td>Coder</td>
<td>209</td>
</tr>
<tr>
<td>Collector</td>
<td>241</td>
</tr>
<tr>
<td>Computer operator</td>
<td>213</td>
</tr>
<tr>
<td>Computing (unspecified)</td>
<td>213</td>
</tr>
<tr>
<td>Customer service, account representative</td>
<td>210</td>
</tr>
<tr>
<td>Data control</td>
<td>209</td>
</tr>
<tr>
<td>File clerk</td>
<td>206</td>
</tr>
<tr>
<td>Gate, ticket clerk</td>
<td>211</td>
</tr>
<tr>
<td>Information and message distribution</td>
<td>237</td>
</tr>
<tr>
<td>Intermarket trading system operator</td>
<td>216</td>
</tr>
<tr>
<td>Keypunch</td>
<td>203</td>
</tr>
<tr>
<td>Legal secretary</td>
<td>201</td>
</tr>
<tr>
<td>Mail clerk</td>
<td>209</td>
</tr>
<tr>
<td>Medical secretary</td>
<td>201</td>
</tr>
<tr>
<td>Messenger</td>
<td>239</td>
</tr>
<tr>
<td>Miscellaneous office machines</td>
<td>209</td>
</tr>
<tr>
<td>offset, mimeo machine operator</td>
<td>207</td>
</tr>
<tr>
<td>page</td>
<td>249</td>
</tr>
<tr>
<td>Reception, appointments clerk</td>
<td>237</td>
</tr>
<tr>
<td>Registration clerk</td>
<td>249</td>
</tr>
<tr>
<td>Secretaries (unclassified)</td>
<td>201</td>
</tr>
<tr>
<td>Senior clerk</td>
<td>206</td>
</tr>
<tr>
<td>Statistical clerk</td>
<td>216</td>
</tr>
<tr>
<td>Stacker</td>
<td>249</td>
</tr>
<tr>
<td>Statistical typist</td>
<td>203</td>
</tr>
<tr>
<td>Stock exchange employees</td>
<td>216</td>
</tr>
<tr>
<td>Switchboard operator</td>
<td>235</td>
</tr>
<tr>
<td>Telephone operator</td>
<td>235</td>
</tr>
<tr>
<td>Tube clerk, can boy</td>
<td>239</td>
</tr>
<tr>
<td>Typist (unclassified)</td>
<td>203</td>
</tr>
<tr>
<td>VDT/CRT</td>
<td>213</td>
</tr>
<tr>
<td>Xerox machine operator</td>
<td>207</td>
</tr>
</tbody>
</table>
Appendix C: Experimental Questionnaires
PRE-CONDITION QUESTIONNAIRE

Name_________________________________________ Age__________

Date_________________ Time______________________

Type of corrective lenses__________________________________________

How many cups of coffee have you had today?____________________

How many cups of tea have you had today?____________________

Have you eaten a snack or meal in the last 2 hours?_______

Smoking status. never______ former______ current______

How many cigarettes have you smoked today?____________________

At the moment are you suffering any visual, musculoskeletal or any other type of health symptom? Please specify.

__________________________________________________________________________

Please mark the point on the scale appropriate to your present mood. e.g. good___________/___________bad

strong_________________________ weak

relaxed________________________ tense

happy_________________________ sad

refreshed_______________________ tired

interested_____________________ bored

energetic_______________________ lazy

vigorouss_______________________ exhausted

exhilarated____________________ angry
awake _______________ sleepy
stimulated _______________ sedated
efficient _______________ inefficient
attentive _______________ distracting
able to concentrate _______________ unable
no feeling of discomfort _______________ extensive
POST-CONDITION QUESTIONNAIRE

Name______________________________________________________________

Date_________________________ Time______________________________

Physical Status: Please indicate if any of the conditions listed below occurred during the test condition.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>none</th>
<th>slight</th>
<th>moderate</th>
<th>severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>White appears another color</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burning eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritated eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy eyelids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing sparks before eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twitching eyelids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blurred vision</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck stiffness or ache</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm soreness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist, hand stiffness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backache</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightheadness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If any of these symptoms were present before the experiment please put an asterisk (*) before the appropriate symptom.

Mental status: Please mark the point on the scale appropriate
to your present mood. e.g. good________/___________bad

strong____________________weak
relaxed_________________________tense
happy_________________________sad
refreshed________________________tired
interested_________________________bored
energetic_________________________lazy
vigorous_________________________exhausted
exhilarated_________________________angry
awake_________________________sleepy
stimulated_________________________sedated
efficient_________________________inefficient
attentive_________________________distractive
able to concentrate_________________________unable
no feeling of discomfort_________________________extensive

Did you notice any problem with the following environmental variables?

<table>
<thead>
<tr>
<th>Uncomfortable seating</th>
<th>none</th>
<th>slight</th>
<th>moderate</th>
<th>severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room lighting too bright</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stuffiness of the room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room too hot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room too cold</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drafty room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>None</td>
<td>Slight</td>
<td>Moderate</td>
<td>Severe</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------</td>
<td>--------</td>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td>Air too dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bad odors noticable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While working with the VDT did you have any problems with the following parameters?

- Flickering of screen
- Glare on the screen
- Brightness of the screen
- Height of screen
- Distance to screen
- Bright lighting
- Size of lettering
- Distance between lines
- Brightness of lettering
- Height of keyboard
- Distance to keyboard
- High pitched VDT noise
- Heat from the VDT
**POST-REST-BREAK QUESTIONNAIRE**

Name ____________________________________________

Date ___________________________ Time ___________________________

Physical Status: Please indicate if any of the conditions listed below occurred during the test condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>none</th>
<th>slight</th>
<th>moderate</th>
<th>severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>White appears another color</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burning eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritated eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy eyelids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing sparks before eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twitching eyelids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blurred vision</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck stiffness or ache</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm soreness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist, hand stiffness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backache</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightheadness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please mark the point on the scale appropriate to your present mood. e.g. good______________/___________bad

strong________________________________________weak

127
<table>
<thead>
<tr>
<th>Description</th>
<th>Tense</th>
<th>Sad</th>
<th>Tired</th>
<th>Bored</th>
<th>Lazy</th>
<th>Exhausted</th>
<th>Angry</th>
<th>Sleepy</th>
<th>Sedated</th>
<th>Inefficient</th>
<th>Distractive</th>
<th>Unable</th>
<th>Extensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relaxed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Happy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refreshed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interested</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energetic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vigorous</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhilarated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stimulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attentive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Able to concentrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feeling of discomfort</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>