Report of the Task Force on Video Display Terminals and Workers'Health

BILANS DE CONNAISSANCES

Raynald Pineault
Diane Berthelette

May 1984 S-003

REPORT

IRSST
Institut de recherche en santé et en sécurité du travail du Québec

La recherche, pour mieux comprendre

L'Institut de recherche en santé et en sécurité du travail du Québec (IRSST) est un organisme de recherche scientifique voué à l'identification et à l'élimination à la source des dangers professionnels, et à la réadaptation des travailleurs qui en sont victimes. Financé par la CSST, l'Institut réalise et finance, par subvention ou contrats, des recherches qui visent à réduire les coûts humains et financiers occasionnés par les accidents de travail et les maladies professionnelles.

Pour tout connaître de l'actualité de la recherche menée ou financée par l'IRSST, abonnez-vous gratuitement au magazine *Prévention au travail,* publié conjointement par la CSST et l'Institut.

Les résultats des travaux de l'Institut sont présentés dans une série de publications, disponibles sur demande à la Direction des communications.

Il est possible de se procurer le catalogue des publications de l'Institut et de s'abonner à *Prévention au travail* en écrivant à l'adresse au bas de cette page.

ATTENTION

Cette version numérique vous est offerte à titre d'information seulement. Bien que tout ait été mis en œuvre pour préserver la qualité des documents lors du transfert numérique, il se peut que certains caractères aient été omis, altérés ou effacés. Les données contenues dans les tableaux et graphiques doivent être vérifiées à l'aide de la version papier avant utilisation.

Dépôt légal
Bibliothèque nationale du Québec

IRSST - Direction des communications
505, boul. de Maisonneuve Ouest
Montréal (Québec)
H3A 3C2
Téléphone : (514) 288-l 551
Télécopieur: (514) 288-7636
Site internet : www.irsst.qc.ca

Report of the Task Force on Video Display Terminals and Workers'Health

Raynald Pineault
Université de Montréal

Diane Berthelette
IRSST

BILANS DE CONNAISSANCES

REPORT

This study was financed by the IRSST. The conclusions and recommendations are those of the authors.

Montréal, January 26, 1984

Mr. Yves Martin
Director General
Institut de recherche en santé
et en sécurité du travail du Québec
505, boul. de Maisonneuve Ouest
Montréal, Québec
H3A 3C2

Dear Mr. Martin,

We are pleased to present you with the final report of the task force on visual display terminals (VDTs). The mandate you gave us in January 1983 was:

1) to review the current state of knowledge about the possible health hazards from VDT use;

2) to recommend, if possible, measures that might be adopted in order to eliminate risks at the source and to protect the workers;

3) to suggest avenues of research that appear the most promising.

We believe that we have fulfilled this mandate.

Yours truly,

Raynald Pineault

Presentation

The question of the effects visual display terminals (VDTs) may have on health was raised in the very first months of the Institut's existence. At the time, it was mainly workers at the Commission de la santé et de la sécurité du travail and in community health departments (Départements de santé communautaire) that expressed concern over the issue. Members of the Institut's board of directors also discussed the question at several meetings, and over the past three years the Institut has been receiving many inquiries about the hazards. The "Projets spéciaux" section of the Institut began to examine the question, turning its attention to an analysis and survey of the scientific information available. On November 16, 1982, the group submitted a document entitled "Rapport d'étape — Dossier des écrans cathodiques" to the administration. This interim report described the principal areas to be addressed in a study of the potential effects on health of video display terminals.

In response to this report, the Institut's governing bodies (Conseil scientifique, Comité exécutif and its board of directors) approved the creation of a task force to study visual display terminals. It appeared to us that the nature of the problems discussed in the report warranted a dual approach with the following characteristics:

- *It should be multidisciplinary. The question of VDTs required that technical, physical, ergonomic, medical, epidemiological and genetic information be handled. The principles underlying the composition of the task force were based on this consideration, as can be seen by the specializations and fields of its members.*
- *The entire issue had to be approached from a public health perspective. This occupational health problem is very closely associated with concerns that go beyond the limits of a single move, since it is part of a context of technological change affecting all of society. The very nature of the health problems that raised such concern justifies a public health approach centered on social and preventive aspects of the question.*

The Institute wanted the task force to be able to function independently, free from any influence that might work against the requirements of scientific rigor and put the credibility of its work into question. Yet, the Institute participated closely since all the work was conducted in the framework of its special projects program.

The entire work and the recommendations it contains should, however, be viewed as the opinion of the task force - who deserve our sincerest thanks — and not an official position of the Institut de recherche en santé et en sécurité du travail du Québec.

Lucien Lewys Abenhaim
Program Director
Projet spéciaux
IRSST

Yves Martin
Director General
IRSST

Members of the Task Force

Raynald Pineault, M.D., Ph.D., F.R.C.P., chairman of the task force, Chairman of the Department of Social & Preventive Medicine, Faculty of Medicine, Université de Montréal.

Diane Berthelette, M.Sc., secretary of the task force, Projets spéciaux, Institut de recherche en santé et en sécurité du travail du Québec.

Jacques Bures, Ph.D., professor, Department of Engineering Physics, École Polytechnique.

Ide Dubé, M.D., F.R.C.S.(C), associate professor, Department of Ophthalmology, Faculty of Medicine and University Hospital, Université Laval.

Claire Infante-Rivard, M.D., Ph.D., F.R.C.P., assistant professor, Department of Social & Preventive Medicine, Université de Montréal, Department of Community Health, St. Justine's Hospital.

Abby Lippman, Ph.D., F.C.C.M.G., assistant professor, Department of Epidemiology & Health, McGill University, Centre for Human Genetics.

Monique Lortie, Engineer, D.Sc., assistant professor, Department of Industrial Engineering, École Polytechnique.

Michèle Tremblay, M.D., resident III, Department of Social & Preventive Medicine, Université de Montréal.

Consultant

Luc Desnoyers, Ph.D., professor, Department of Biological Sciences, Université du Québec à Montréal, acted as consultant to the task force.

Acknowledgements

We would like to express our thanks to Dr. Gilles Thériault, Director of the School of Occupational Health, McGill University, for his comments on the first draft of this report.

We would also like to thank the following members of the special projects program of the IRSST:

— Pierrette Côté, assistant to the head of Projets Spéciaux, for organizing technical and administrative support.

— Annie Düb, Danielle Charlebois and Denise Mallette for secretarial assistance.

— Lorraine Lacharité for bibliographical assistance.

And lastly, we wish to thank Daniel d'André of the Documentation Centre of the Commission de la santé et de la sécurité du travail (C.S.S.T.).

Table of contents

1. Introduction

1.1 Nature and Scope of the Problem

The first video display terminals (VDTs) appeared in the workplace about fifteen years ago, and their use has expanded quickly: in Canada, an estimated 250,000 VDTs were in use in 1980, and it is predicted that the number will increase in the United States from the original three million in 1981 to five or even seven million in 1984 (Rosenbaum, 1981; Villedieu, 1981). They are used mainly in the service sector, where most of the workers are women. In Québec, it is likely that changing technologies will lead to an increase in the number of VDTs installed, not only in industry, but also in education and research. It is also likely that home use of VDTs will become more common.

Interest in the possible health hazards to VDT users began in the last decade. Since then, complaints from workers have been flowing in continuously: in 1977, 250 typesetters and translators at the United Nations protested against the administration's refusal to suspend use of VDTs until their harmful effects on health could be studied (Rosenbaum, 1981).

The main concern over the terminals centered at first on the health hazards from emissions of electromagnetic radiation. This aspect of the question captured the attention of workers, researchers and the public because of the emphasis in the press on cases of cataracts, birth defects and spontaneous abortions observed in employees using VDTs and because of the seriousness of these problems. A number of reports appeared in the *New York Times* in 1977 (two cases), then in the Baltimore *Sun* (two cases), the Chicago *Reader*, and later, in 1981, in Thunder Bay (one case) about workers who discovered they had cataracts and attributed the problem to the radiation emissions of the terminals. Their applications for compensation were turned down (Rosenbaum, 1981; Villedieu, 1981). Unfortunately, most of these cases were not studied scientifically.

In 1980, four of the seven pregnant workers in the classified advertising department of the Toronto Star gave birth to infants with congenital defects. Then there were reports that of the seven pregnant women working in a federal government office, not one carried to term and gave birth to a normal infant. In a British Columbia hospital, of the six pregnant women using VDTs, two apparently had miscarriages and of the four workers who carried to term, only one delivered a perfectly healthy infant. Finally, the Canadian Air Line Employees' Association reported seven spontaneous abortions in the thirteen workers using VDTs at Dorval airport (Rosenbaum, 1981; Villedieu, 1981). These widely publicized events frightened workers; in Québec, a number of women asked for preventive transfer for pregnancy when they were assigned to a job involving the use of a cathode-ray screen.

Although the press has concentrated mainly on the possible effects of exposure to radiation on pregnancy and vision, these problems have not received much attention in the scientific literature, where the most frequently studied problems relate to visual fatigue. Attempts are being made to measure this aspect and identify the factors responsible for the symptoms often complained of by workers.

The growing number of workers involved in this type of work and the importance the problems have taken on make it urgent to examine the question.

1.2 Mandate of the Task Force

A task force was created in the hopes of elucidating all aspects of the question. The mandate given the group by the administration of the Institut de recherche en santé et en sécurité du travail (IRSST) in the framework of its Projets spéciaux (special projects section) was the following:

1) to review the current state of knowledge about the possible health hazards from VDT use;
2) to recommend, if possible, measures that might be adopted in order to eliminate risks at the source and to protect the workers;
3) to suggest avenues of research that appear the most promising.

1.3 Perspective and Method Adopted

The problem was approached as a whole, and a broad definition of the concept of "health" was adopted. Furthermore, VDTs were considered not merely radiation emittors, but also tools that considerably modify the organization of work. Thus, the program called for an analysis not only of health problems associated with exposure to electromagnetic radiations, but also of those associated with the tasks and the organization of the work of VDT operators.

Our procedure was to examine, in a critical way, the research reports and articles we could obtain on the subject. Naturally, there were other equally valid possibilities, such as consultation with groups concerned with the issue. However, we considered that our expertise would be most productive if it were applied to a critical review of the literature.

Health problem found

Hypothesis confirmed .... **Risk factor(s)** .... **Mean(s) of intervention evaluated**
identified

- frequency
- severity

— effective ______ recommendation(s)
— ineffective ______ recommendation(s)

Risk factor(s) not identified

— lack of research
- hypothesis? ______

— study(ies) with methodological problems- study(ies) with - study(ies) with methodological methodological problems
- research strategy(ies)?

— satisfactory study(ies) showing no statistically *significant differences*

Mean(s) of intervention not evaluated

— lack of research
- hypothesis? ______ recommendation(s)

— study(ies) with methological problems
- research strategy(ies0? ______ recommendation(s)

Hypothesis not confirmed

— lack of research ______ recommendation(s)

study(ies) with methodological problems
- research strategy(ies) ______ recommendation(s)

— satisfactory study(ies) showing no statistically significant differences

Figure 1 Analysis grid for published studies (from Abenhaim and Dab, 1982)

Figure 1 shows the analysis grid used in the critical review of the literature. The grid allowed for a measure of the scientific value of studies that demonstrated or failed to demonstrate a relation between a given health problem (for example, visual fatigue) and one or more specific factors in exposure. Thus, a population study that included one or more control groups (or even better if it were a random sample) was considered to provide a better scientific demonstration of such a relation than a clinical report. These are, of course, extreme cases, and there are other criteria for scientific value than good experimental design with random distribution of subjects: size of the groups, control for possible bias, instruments used for measurement, etc. For each health problem, we attempted insofar as possible to assess the scientific value of demonstrations of a relation between a physiological disorder and factors associated with VDTs. The following criteria were applied to determine a study's value:

1) Population studies

a) With one or more control groups and random distribution of subjects

- Size of sample
- Internal validity of the study (control for bias in selection, comparability of the groups, etc.)
- Appropriateness of statistical analyses
- Specificity and sensitivity of the measurement method

b) Including one or more control groups without random distribution of subjects

- Size of sample
- Internal validity of the study (control for bias in selection, comparability of the groups, etc.)
- Appropriateness of statistical analyses
- Specificity and sensitivity of the measurement method

The results of investigations respecting these criteria provide good evidence for the presence (or absence) of a relation between the health problem and the risk factors under consideration.

2) Experimental studies

a) On humans

- Number of subjects
- Value of the method, design and experimental conditions
- Explicit statement of the probable physiopathological mechanisms underlying the relation between the problem under study and the risk factor implicated
- Appropriateness of the statistical analyses

b) On animals

- Number of subjects
- Value of the method, design and experimental conditions
- Explicit statement of the underlying physiopathological mechanisms that could justify extrapolation to humans
- Appropriateness of the statistical analyses

3) Clinical reports

- Number of cases
- Explicit statement of the probable physiopathological mechanisms underlying the relation between the problem under study and the risk factor implicated
- Sensitivity and specificity of the measurement methods

Demonstrations in the second and third groups were considered acceptable if the studies met the criteria.

In interpreting our analysis of a situation, one should note that even if no study demonstrates a relation between a potentially harmful agent and a health problem, it cannot be concluded that there is definitely no occupational hazard. While the scientific value of a study determines whether one can conclude if such a relation exists, one can never eliminate every element of doubt. This is where research and practice differ: research findings can help a practitioner, but can never take his place.

The second stage in our procedure called for measures and strategies to prevent risks from exposure to VDTs and from their use. The report on this stage appears at the end of this document with the recommendations proposed by the group.

At this stage, an attempt was made to apply as scientific and rigorous an analysis grid as that used in analysing the relation between the risk factors and health problems. However, the group soon realized that a strictly scientific approach could be somewhat restrictive since it might not provide broad enough answers to all the questions raised. Thus, in addition to the weight given to scientific demonstrations of the effectiveness of preventive measures, the group considered it appropriate to incorporate economic and social considerations into some of its recommendations.

Furthermore, the group chose not to limit its recommendations by basing them on a strictly epidemiological analysis in which the relation between a risk factor and a health problem must be demonstrated before thought is given to intervention. In other words, even in the case of health problems where it is difficult to demonstrate that VDT exposure is the cause, when the problem is important in the work environment, more general recommendations were formulated that do not apply exclusively to environments using VDTs, but rather, include those in which the work organization has comparable features.

The report is presented as follows: the first part describes the typical work environment where VDTs are used. The second part contains an examination and discussion of the main health problems associated with this type of work. The third part presents a summary of the first two, along with recommendations for preventive strategies and measures.

2. Environment

This section describes the environmental factors studied that might lead to health problems in VDT operators. It contains technical data which, although they may seem dry, are nevertheless necessary if the characteristics of a work environment containing VDTs are to be understood.

The variables considered by researchers in evaluating the work environment and the possible risks to the health of VDT operators can be grouped into three categories:

- material work environment,
- task content,
- work organization.

These categories include several elements which may interact with each other.

A) The material work environment can be described as a system composed of interlocking sections.
   - The terminal represents the first section.
   - The workstation is the second section: in addition to the terminal, the workstation includes the furniture and the various objects (printed documents, telephone, etc.) the operator must use.
   - The final section concerns the ambient lighting. The type, location and intensity of the light sources are considered.

B) The tasks performed by operators can be divided into five main categories: data entry, data acquisition, interactive communication, word processing and professional work (graphics, journalism, programming, etc.). The activities of operators must be analyzed so that the requirements of the tasks they perform and the strategies they use can be identified.

C) Lastly, work organization includes such features as the pace and duration of the work, the scheduling of rest periods, control of productivity and work quality, structuring of the task, and so on.

2.1 Description of the Material Environment

This section describes the different elements of the material work environment examined in studies dealing with the working conditions of VDT operators and the incidence of health problems in these workers. The results of analyses of the work environment are presented and evaluated in Section 2.2.

2.1.1 Video display terminals

A) Display

The image or characters which appear on the screen are generally produced by bombardment of the fluorescent substance which coats the inside of the screen by an electron beam. When the electrons interact with the granules of the fluorescent substance, the granules light up at each point of impact. The light intensity of the points is determined by the efficiency of the fluorescent substance, i.e., the percentage of energy from the electron beam that is converted into light energy.

The scan of the beam on the fluorescent coating can be either linear or random. Screens now on the market generally use the first type of scan: the beam sweeps across the screen in a series of horizontal lines, thus periodically refreshing the image. This periodic refreshing is necessary since the luminance of the image is not constant: as soon as the character is projected onto the screen, the luminance fades at a speed that depends on the remanence (or persistence) of the fluorescent substance.

Alphanumeric characters are usually formed by a rectangular matrix of luminous dots. They can also be made up of line segments (vectors).

The display presentation on the screen is usually in negative contrast (light characters or image on dark background). A black-white contrast is frequently used, but a number of screens now offer a colored display. The visible color of the display depends on the chromaticity of the fluorescent substance used, i.e., on the wavelengths it produces. The color therefore results from the perception, by the eye, of the different wavelengths of the light.

B) Production of electromagnetic radiation

The radiations likely to be emitted by VDTs are of three types and cover much of the electromagnetic spectrum, ranging from extremely low frequency radio waves (a few Hz) to x-rays (10^{18} Hz). Only the latter type produces ionizing radiation.

1) Radiofrequency waves (from a few Hz to 300 MHz) are produced by the circuits of the horizontal deflection system, the transformers and the coils. These elements behave like small antennas which radiate energy.
2) Visible, infrared (I-R) and ultraviolet (U-V) radiation (from 10^{11} to 10^{16} Hz) is due to bombardment of the fluorescent substance of the screen by electrons. Atoms of the fluorescent substance go from an excited state (under the action of the bombardment) to a ground state by emitting photons in this frequency band.
3) X-rays (from 10^{17} Hz to 10^{18} Hz) are produced in two ways:
   a) from rapid deceleration of high-speed electrons arriving on the screen. The spectrum of these x-rays is continuous and its maximum frequency is proportional to the square of the velocity of the electrons. This phenomenon produces white x-rays in a continuous spectrum;
   b) from ejection of electrons on shells close to the nuclei and their replacement by others from deep shells: electron transition takes place and a characteristic X photon is emitted from the material bombarded (fluorescent substance and glass of the VDT). This spectrum is discontinuous.

It should be noted that microwaves (300 MHz to 300 GHz) cannot be emitted by VDTs (Health and Welfare Canada, 1983).

2.1.2 Workstation configuration

Figure 2 summarizes the principal elements of a VDT workstation which should be evaluated. One of the main differences between reading a screen display and a document is that the screen is fixed: VDT users cannot adjust the eye-task distance as easily as they can with a sheet of paper.

Standards based on the anthropometric characteristics of the population concerned must be established for each of these elements. The minimum and maximum values for each element (those between which the furniture must be adjustable) should correspond respectively to the 5th and 95th percentiles of the anthropometric values. Such data are not available for the Québec population.

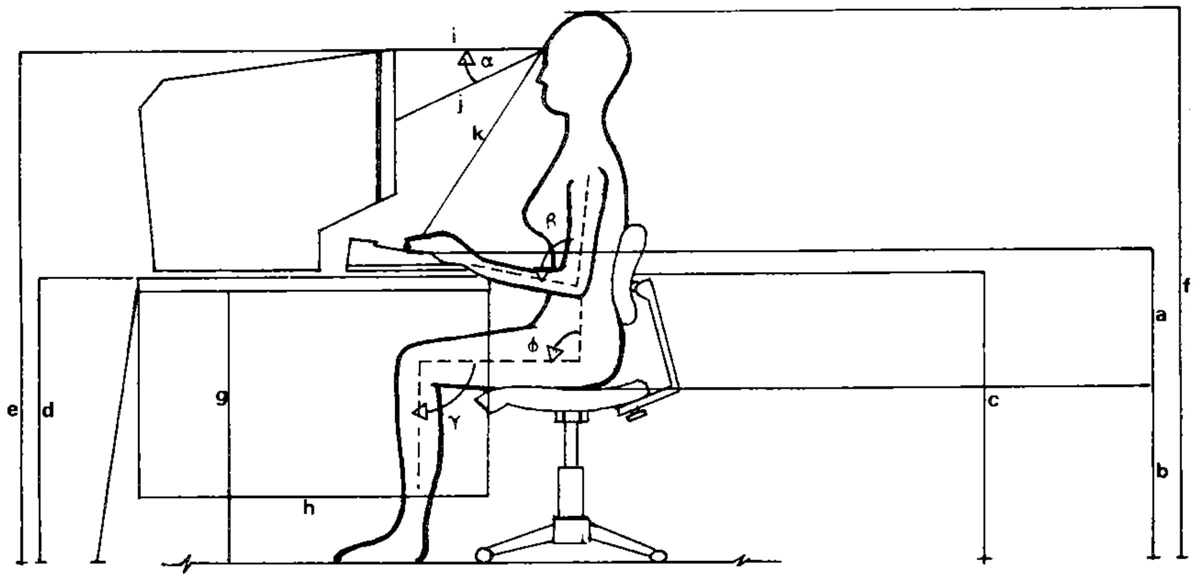

Figure 2 Dimensions of VDT workstation[1]

a- level of work
b- height of chair seat
c- height of back-rest
} **height of work surface**
d- height of desk
e- height of terminal
f- height of seated operator
g- height of clearance space for lower limbs
h- width of clearance space for lower limbs
i- horizontal viewing distance
j- distance between eye and center of screen
k- distance between eye and center of keyboard
α- visual angle relative to the horizontal
β- angle of forearm, arm
φ- angle of trunk, thigh
γ- angle of thigh, leg

Where documents are consulted, the eye-document distance should also be measured.

1. The posture and equipment shown on this drawing are incidental. The main purpose of Figure 2 is to illustrate the dimensions of the workstation that have to be taken into account.

2.1.3 Lighting

Photometric units

Visible light refers to electromagnetic radiation whose wavelength ranges from 400 nm to 700 nm. When light sources emit these waves, a certain amount of energy is produced and picked up by lighted surfaces (receptors).

The eye is sensitive to light, and when a sufficient number of photons strike the retina, they give a sensation of light. But the retinal receptors are not uniformly sensitive to light of all wavelengths. The sensitivity varies with the wavelength and, in daylight, reaches a maximum at 555 nm (yellow-green). The variation in the eye's sensitivity as a function of wavelength of light is described by the spectral sensitivity curve of the eye.

Through photometry, we can study the amount of energy emitted by light sources and picked up by the receptors. These amounts are measured in energy units. Some measurements describe the effects of visible light on the eye and take into account the eye's spectral sensitivity. These measurements are expressed in luminous or photometric units.

The following example helps to illustrate the differences between energy units and light units:

A flux of 1 watt (energy unit) for a wavelength of 555 nm (yellow-green) produces about 680 lumens (luminosity unit). For a wavelength of 450 nm (blue), this same watt gives about 60 lumens. These differences in perception illustrate the concept of average luminous efficacy (lumens/watts) for white and fluorescent sources.

Table 1 lists the units of measure used in photometry.

Table 1: Energy and luminous units

	Energy units	Luminous units
Source and receptor	Flux: watt or joule/second or photons/second	Lumen
Source	Intensity (pinpoint): watt/steradian Luminance (surface): intensity/m^2	Candela Candela/m^2 or nit
Receptor[2]	Illuminance: watt/m^2 Exposure: watt x second (joule)	Lumen/m^2 or Lux Lumen x second
Reflecting surface (secondary sources)	Luminance (function of Illuminance and of reflection coefficient); same units as for sources	Candela/m^2 or nit[3]

Light sources and reflecting surfaces

Both general and local lighting are usually found in workplaces. Electric bulbs and fluorescent lamps are the main light-emitting sources: the first provides a point source and its intensity is expressed in candelas; in the second case, light is emitted by a surface and its luminance is measured in nits. It should be noted that this luminance generally depends on the direction of the radiation.

2. Include measures of power and energy meters (including the eye) as well as reflecting surfaces considered as energy receptors.

3. Other units employed: lux equivalent and the apostilb (1 apostilb = $(1/\pi)$cd/m^2).

Illuminance from reflecting surfaces (i.e., the density of the incident light flux on a surface) is measured in lux. These surfaces can, however, be a secondary source of light emission if they are sufficiently diffusing. The phenomenon of reflection from surfaces is related to their absorption, which varies according to color, and how mat or shiny they are. Luminance from secondary sources must also be considered; for instance, in the case of a perfect diffuser (identical reflection in all directions), the luminance equals the product of the light from the surface multiplied by its average coefficient of reflection divided by π to take into account the diffusion of the light in all directions. In practice, ordinary reflecting surfaces are far from perfect diffusers: their luminance depends on direction and is not so simply related to the illuminance. In any case, this luminance is, as with light sources, expressed in candela/m^2 in the system of luminous units.

Illuminance of the different parts of a workstation depends:

1) on the lighting (main light sources: intensity of point sources and luminance of illuminated surfaces);
2) on the luminance of reflecting surfaces (secondary sources);
3) on the distance and angle of the receptors relative to the sources.

The VDT screen has special characteristics. It is primarily an emitter (it produces luminous dots and characters) but it is also a receptor (it receives light from the lighting and secondary sources). Finally, it is a reflecting object and therefore creates problems of glare. The following elements can therefore be measured photometrically:

1) intensity of luminous dots (candela)
2) luminance of characters (nit)
3) luminance of screen background (nit)
4) illuminance of screen background (lux)
5) luminance from screen reflection (nit)

2.2 Evaluation of Material Environment

The purpose of this section is to briefly summarize the results of analyses of the environment of VDT users and the conclusions drawn by the researchers.

2.2.1 Characteristics of visual display

It seems that most studies on VDTs focus on features of the image itself (Snyder et al, 1978), but such investigations are scarce compared with those dealing with printed texts.

The main variables studied are the factors influencing the legibility of display and the characteristics of how information is presented. Legibility refers to the possibility of distinguishing differences in shape between the characters and of identifying them. The formal presentation of information can affect the way the words are interpreted and the sentences are understood (Cakir et al, 1980).

In general, research on visual display is fragmented and the results are not comparable owing to differences in 1) the parameters considered, 2) how information is presented on the screen[4] and 3) the variables used to measure the effects of display quality on performance[5]. These elements can be combined in many ways.

Character legibility

Reading a screen and reading a printed text differ in two fundamental ways:

- The outline of screen characters is blurred: there are no clear frontiers between the character and the background of the screen. The distribution of luminance within a character is not uniform. Liquid crystal displays (used for calculators, for example) are immune from this problem but are not yet used in VDTs.
- Problems of luminance are more acute: first, the VDT is itself a source of light and, second, the display is usually in negative contrast[6]. It is therefore difficult to adjust the luminance so as to obtain adequate contrast between the characters and the background of the screen: when character luminance is increased, background luminance also increases. Moreover, the lighting must be adapted to transitional vision[7] and be arranged in such a way that it does not produce screen reflections which could obscure the characters: this is not always compatible with the requirements of other tasks to be performed.

4. This refers to display formats (e.g., data sequence) and modes (e.g., graphics) that have to be designed so as to facilitate interpretation of the words and understanding of the sentences that appear on the screen.

5. In these studies, the subjects had to perform a task on VDTs with different display characteristics. The tasks involved transcribing data and reading a text in order to detect errors or answer questions, for example. Performance was measured in terms of the time taken to complete the task or number of errors made by the subjects.

6. In the case of negative-contrast displays, luminous characters appear on a dark background. With positive contrast, the characters are dark and the background light.

7. Transitional: vision under twilight conditions. In photopic vision, light is that of daylight, while scotopic vision refers to night vision.

The following variables can affect character legibility:

— presentation mode (vectorial or by a dot matrix);
— diameter and density of dots: the memory size determines the number of dots;
— shape of characters;
— size of characters (height and width);
— distance between characters;
— reading distance;
— relation between size of character and viewing distance;
— relation between size of character and reading angle;
— sharpness of characters;
— luminance of characters;
— character-background contrast;
— color of characters and of background;
— characteristics of ambient lighting;
— presence of flicker.

These parameters are inter-related: the optimal value of each depends on the optimal value of the others.

Research results show that:

- The vectorial display mode (characters formed by lines) is preferable to the matrix mode (characters formed by a dot matrix), but the luminance of the characters is more irregular and can be a source of discomfort (Gould, 1968). The letters tend to merge as luminance increases (Meyer et al, 1979).
- Larger dots and reduced distance between them improve reading performance.
- The optimal shape of the letters is different from that of printed characters (Gould, 1968; Vartabedian, 1971).

Presentation format

The visible surface of most screens measures about 170 mm x 230 mm. In general, the screen accommodates 32 lines of 64 characters. The presentation of information as well as screen size must be established in relation to:

- the task;
- type of display (alphanumeric characters, graphics, etc.)
- height of characters;
- amount of information presented;
- optimum length of lines (determined by the last two elements).

A number of recommendations have been made which could be applied; two of these merit special attention:

— Bouma (1982) suggested that the 4:3 width/length ratio of the screen be replaced by a 3:4 ratio as used in printed texts. This would make it possible to reduce the size of the characters and the lines as well as the spacing between the lines and increase the number of letters perceptible each time the screen is fixated. With a 3:4 ratio, the field of vision can cover up to 20 letters.
— Rey et al (1977) recommended that programmers be trained to take difficulties of perception into account when they design presentation formats.

These aspects are dealt with in Section 3 of the Appendix, and the recommendations of the task force are given in Chapter 5.

2.2.2 Flicker

When the refresh rate is too low for a fluorescent substance with a given persistence, the operator perceives a blinking, or flickering, which causes discomfort. Meyer et al (1979b) have noted that perception of the flicker leads to a sharp decline in performance.

Flicker perception depends on several factors. It increases with:

- — an increase in luminance;
- — a decrease in the persistence of the fluorescent substance;
- — an increase in the response time of the fluorescent substance; slow substances help to reduce the effect of flicker but have the disadvantage of disappearing slowly and the images that follow may be superimposed. When displays are changed frequently, the use of slow fluorescent substances is not recommended;
- — increase in the size of characters (Gould, 1968);
- — decrease in wavelengths (Gould, 1968); certain filters reduce perceived flicker because they eliminate shorter wavelengths;
- — perception by the operator of images at the periphery of his visual field (Krueger, 1982). This perception causes eye movements which make flicker appear;
- — eye shift: sensitivity increases when the eyes explore the screen (Meyer et al, 1982).

According to a survey published by Gould in 1968, the refresh rate varies between 20 Hz and 60 Hz. Meyer et al (1979b) found that, for frequencies of 50 to 60 Hz and a luminance of 20 cd/m^2, most operators in the sample said that they perceived flicker. It should be noted that for a given frequency, older subjects are generally less sensitive to flicker.

At present, flicker perception for a given refresh rate can be reduced by taking into account the factors discussed earlier. However, decisions about changes to be made must take the task performed into account.

2.2.3 Measurement of electromagnetic radiation emission levels

In this section, we report on studies dealing with levels of the different types of electromagnetic radiation emitted by VDTs. These results appear in the following references: Moss et al, 1977; Muc, 1981; Murray et al, 1981; NIOSH, 1981; Purdham, 1980; Health and Welfare Canada, 1983; U.S. Department of Health and Human Services, 1981; Weiss et al, 1979; Weiss, 1983.

Radiofrequency waves

All the studies conclude that absorption doses are either non detectable or well below the American standard of 10 mW/cm^2 established for frequencies above 10 MHz (Health and Welfare Canada, 1983). As for radio frequencies below 10 MHz[8], not enough is known at present to permit an evaluation of the risks to which operators are exposed, and there is no American standard. However, a study conducted jointly by the U.S. Bureau of Radiological Health and the World Health Organization found that 95% of the radio frequencies emitted by the screen terminals studied were between 15 and 125 kHz[9]. In the absence of data on the biological effects of this type of radiation, the authors of the report stated that they could not come to any firm conclusion on the question. However, they considered the probability of serious biological effects small in view of the low interaction of this amount of radiation with the human body.

Very low frequency radiation fields (VLF, i.e., 3 kHz to 30 kHz) are pulsed and highly directional (Marha et al, 1983). Intensity levels are usually very low in front of the screen. Relatively high levels can however be measured on the sides or at the back of the terminal (Marha, 1983). Unfortunately, most studies report measurements taken in front of the screen. These vary between 0 and 300 v/m at a distance of 10-30 cm from a VDT surface.

Only one study deals with extremely low frequency radiation (ELF, i.e. < 3 kHz). This study was conducted by a group of researchers from Health and Welfare Canada (1983), and the results indicate that the intensity of a magnetic field of radiation with a frequency of between 5 and 500 Hz would be negligible and comparable to the intensities emitted by other ordinary electric and electronic devices.

According to Cohen (1983), this conclusion is premature. In fact, the extremely low frequency radiation produced by VDTs is pulsed, unlike that of the other electric equipment measured in the study, and leads to the emission of higher frequency radiation. Therefore, pulsed low frequency waves are obtained with a peak value probably several times greater than the average.

Visible, ultraviolet and infrared radiation

According to the studies, emission levels of this type of radiation by VDTs are below American standards. This radiation presents no danger given the fact that higher levels of luminance are found in natural light (which contains ultraviolet and infrared rays in not inconsiderable amounts) than in video display terminals.

X-rays

All the studies consulted indicated that the radiation absorbed from x-rays emitted by VDTs is about 0.01 mrem/h (occasionally, 0.03 mrem/h). These exposure levels are below the international standard of 0.5 mrem/h (about 500 mrem/year) and are the same as average background radiation of natural origin.

Furthermore, an average daily exposure of 6 hours[10] over 240 days of work per year produces an accumulated total annual dose of 14 mrem, or 0.014 rem, which is lower than natural radioactivity (from the standpoint of ionization).

The possible biological effects of this radiation are described in the section dealing with cataracts and problems associated with reproduction and pregnancy.

2.2.4 Ambient lighting

A number of photometric studies have been conducted in order to evaluate the luminance of the char-

8. 1 MHz = 10^6 Hz.

9. 1 KHz = 10^3 Hz.

10. Allowing for the rest periods scheduled during an 8-hour working day, the level of exposure is calculated for 6 hours of real work.

acters and screens used in various work environments. These studies have also provided information on light ratios (or contrasts) between the characters and background of the screens, as well as between the screens and other elements in the surroundings.

This section will cover the results of studies on the following luminance levels and contrasts:

a) characters relative to the background of the screen;
b) screen relative to other elements in the workstation;
c) screen relative to the room.

2.2.4.1 Characters relative to background of the screen

Luminance ratios

Few studies have considered the specific context of the screens, and most recommendations are based on our current views of photopic visual acuity (Timmers et al, 1982). All tables with desirable levels of lighting are designed for visual tasks on a reflecting object (Rey et al, 1977). But a screen is primarily a source of light.

Increasing the contrast between the characters and the background results in a greater reading field (Bouma, 1982).

Timmers et al (1982) have shown that when contrast is decreased, both error rate and response time increase, especially in parafoveal reading[11]. Response time is more affected than number of errors, however, in foveal reading[12]. These results indicate that decreased contrast has a negative effect particularly on the process of recording information.

The specifications given by VDT manufacturers for adjusting the luminance levels of the characters and the background are often better than what can actually be achieved, since by increasing the luminance of the characters, the background luminance also goes up. This leads to greater perception of flicker and character blurring. These secondary effects explain differences in the behavior of users: some increase the luminance of the characters, while others decrease it (Meyer et al, 1979).

Some authors recommend contrasts (luminance ratios between the characters and the background of the screen) of from 6:1 to 10:1 when the background luminance is between 10 and 20 cd/m^2. However, not all authors agree: Snyder and Maddox (1978) suggest a ratio of 15:1, while Gould (1968) prefers 20:1 because of blurring of character edges and variability in lighting conditions. It should be pointed out, however, that there are not enough data on the question to determine luminance levels that would prevent problems in accommodation.

Polarity (positive and negative contrasts)

Most screens on the market use negative contrast, yet more and more researchers, especially in Europe (Cakir et al, 1980; Santucci, 1978; Radl, 1982), are recommending that positive-contrast screens be used. The main arguments in their favor are:

11. Parafoveal: retinal region used in transitional vision.

12. Foveal: retinal region used in perception of detail in daylight conditions.

— Better contrast between the characters and the background of the screen. The possibilities for adjusting the luminance of the screen to create satisfactory contrast are very limited with negative-contrast screens (Rey et al, 1977). When the luminance of the characters is increased, they are reflected against the background and increase its luminance as well. Thus, the contrast between the characters and the background is poorer than intended.

— Easier to harmonize with surrounding surfaces, especially with documents. It is generally recommended that the maximum ratios of luminance in the center of the visual field be 3:1, while the ratio between the center of the visual field and the periphery should be 10:1. The ratios are much higher with negative-contrast screens (Fellman et al, 1982).

— Greater compatibility between the lighting needed to work with the screen and for reading documents: with a negative-contrast screen, the recommended luminance levels are different from optimal levels for reading documents.

— Similarity to photopic reading conditions (diurnal vision) under which the ability to localize images is better. When the background of the screen is dark, vision is transitional; this might explain the increased sensitivity of users to dazzle and peripheral interference on the screen (Meyer et al, 1979).

— Better visual acuity and improved performance (Rey et al, 1977; Radl, 1982; Bauer et al, 1982). Rupp (1981), however, has questioned this, correctly pointing out that the experimental results could be related to differences in the shape of the characters on positive- and negative-contrast screens, rather than to the type of contrast per se.

— Greater visual comfort as perceived by operators (Radl, 1982; Bauer et al, 1982).

— Fewer problems with reflections on the screen.

Positive-contrast screens, on the other hand, have two major defects that limit their efficiency:

— Need for a greater refresh rate: since the characters are more luminous, flicker is more easily perceived and, thus, the frequency has to be higher on a positive-contrast screen than on a negative-contrast screen.

— Increased perception of imperfections in the background.

Color

Some screens have a colored, usually yellow or green, display. The choice is based on the fact that the sensitivity of the eye to light under photopic conditions is greatest with a wavelength of 555 nm, corresponding to yellow-green. However, with negative-contrast screens, when vision is transitional, the sensitivity of the eye is greatest with a wavelength of between 555 and 505 nm, the lower figure being the value for sensitivity under scotopic conditions. These facts do not provide a rationale for using any specific color.

Investigators have found no relationship between the color of the display and performance (Haider et al, 1982; Bouma, 1982; Radl, 1982). Chromaticity appears to be merely a secondary factor, and operator preference seems to be due to psychological factors. The following comments have been taken from the documents consulted:

— Accommodation appears to be less demanding in photopic vision with wavelengths over 555 nm (approaching red) (Santucci, 1978; Krueger et al, 1982). However, screens are read with transitional vision.

— Colored displays might lead to a decrease in the microfluctuations in accommodation due to spectral bimodality. This hypothesis has not been tested. A black-and-white contrast appears less favorable since the eye would have to accommodate successively to blue and yellow (Rey, 1977; Meyer et al, 1979). A pure color would reduce microfluctuation if fixation time were short enough to prevent the complementary color from appearing.

The color combination, however, seems to be an important factor. Using a transcription task, Radl (1982) observed error rates ranging from 4% to 95%, depending on the combinations used. The choice of color combination should take into account the sensitivity of the eye under transitional and photopic conditions.

The screen and the workstation

The main problem here is with highly contrasting areas. Given the wide differences in luminance between the screen and other surfaces at the workstation, the operator may have to alternate between activities requiring transitional and photopic vision. With frequent alternation between different luminance levels, the mechanism for pupillary adaptation may be overtaxed (Meyer et al, 1980). It should be noted that Rupp (1981) has contested this hypothesis, but the task force does not accept his arguments.

The screen and its placement

Reflections on the screen are the main source of discomfort, after the contrast problems discussed above.

Images can be superimposed on characters because of reflections on the surface of the screen, masking the display and decreasing the contrast between the characters and the background of the screen.

The recommendations (see Appendix) for placement of light sources do not take into account the fact that the operator's visual angle is between 20° and 40°. Poor positioning and inadequate luminosity of the main light sources lead to reflections on the screen. This problem can also occur when there are secondary light sources near the screen.

2.3 The Tasks, Work Organization and Mental Workload

The introduction of a VDT into a workplace is usually accompanied by changes in work content (demands, repetition, etc.) and in the organization of the work (worker-machine interactions, time spent working on the screen, breaks, etc.).

After all the consideration given to the physical environment of the VDT operator, it appears important to examine the complexity of the relationship between the worker, the demands of his work and the organizational restrictions. These aspects must be considered in evaluating the mental workload and performance of an operator.

This section contains a definition of the concept of mental workload, a review of the methods used in its analysis and the problems associated with it.

The tasks carried out by VDT operators are also described, and the results of studies on the mental workload of VDT users are given.

2.3.1 Mental workload

Spérandio (1980) defined "mental workload" as a quantitative or qualitative measure of the level of activity required to accomplish a given task. The concept implies that the workload depends on the characteristics of the task, the conditions under which it is carried out, the characteristics of the worker (e.g., age, level of training) and the means used to meet the demands of the task.

In terms of methodology, the definition implies two analyses: one of the demands of the tasks (the characteristics of the work and the conditions under which it is performed), the other, on the activities of the worker and the associated psychophysiological functions. Two types of workload are usually distinguished: mental and physical.

The notion of physical workload is relatively clear. It is studied with physiological measures, such as heart rate, blood pressure, respiratory rhythm, etc.

In contrast, there is no universally accepted definition of mental workload. Spérandio (1980), for example, differentiates between mental and sensory activities, while Wisner (1981) prefers to use the terms "cognitive" and "psychic" workloads. Lucas (1980) combines them into one concept. The definition of Lucas is used here: ". . . we tend to consider mental workload as the result of the effects that any type of work has on the mental activities or organs that are the site of psychic activity. Used in this sense, mental workload is associated primarily with states of stress".

This definition implies that elements of work that are not cognitive, but that may be associated with states of stress (or psychological suffering) define a mental workload. Thus the concept includes cognitive[13] and motor[14] tasks. Hence a monotonous, repetitive task performed under time pressures, or which demands for example, high precision of movement in order to reduce the amount of time it takes, may result in a large mental workload.

It is important to note that it is easy to produce neurotic reactions in a subject experimentally by asking him to perform an apparently simple task with characteristics such as ambiguity, considerable use of short-term memory, the need to make minor decisions, and the like, if certain temporal conditions are imposed: irregular, random, and massive presentation of information, or large number of acts to be carried out per unit time, etc. (Wisner, 1974). Thus,

13. Cognitive task: a task involving acquisition of knowledge about something through perception, reasoning . . . The motor component is usually limited (e.g., programming).

14. Motor task: a task involving a motor, or observable, response to a stimulus (e.g., data-entry).

mental workload is not defined solely in terms of cognitive acts. It is also dependent on the conditions under which a task is performed.

Measuring mental workload poses a number of as yet unsolved problems. The many models that have been proposed (Moray, 1979; Welford, 1977) reflect this fact. Table II summarizes the most common instruments and methods for measuring mental workload. It is beyond the scope of this report to discuss the various models and the implications of methods used in measuring this concept.

Table II: Principal instruments and methods for measuring mental workload

1) Behavioral indices
   - Time and movements (e.g., reaction time tests)
   - Vigilance, based on errors (e.g., tracking task)
   - Performance limits (e.g., the input is increased until errors appear)
   - Second task added

2) Psychophysiological indices
   - Heart rate or sinus arrhythmia
   - Pupillary dilation
   - Galvanic skin response
   - Biochemical measures (e.g. catecholamine levels)

3) Subjective indices (e.g., effort felt by the subject)

2.3.2 Tasks performed by VDT operators

The tasks performed on VDTs are divided into five groups (Brown et al, 1982):

1) Data entry

Workers transmit data usually from printed documents to a computer via a keyboard. Remuneration is often based on the number of units produced, and performance is usually measured by the computer. The work pace is rapid, the task rigid, monotonous and repetitive.

2) Data acquisition

The task mainly involves asking for information on the screen and then manipulating the data received. It requires considerable visual work (constant dialogue with the computer) via the screen.

These two tasks are often combined, and require little in the way of qualifications.

3) Interactive communication

This type of work is performed by travel reservation agents, for example. It involves question and answer interaction with the computer.

In this type of work, there are greater possibilities for choosing strategies and controlling the rhythm of the work (except when the pace is determined by an external system directing telephone calls to the operator). It is generally more diversified than the first two, and includes telephone or direct contact with the public.

4) Data processing

The operator's task is much more varied, allows for more autonomy and demands greater experience and skills than the preceding tasks. The work consists of introducing and organizing the presentation of texts and correction.

5) Professional work

This category includes professionals who use VDTs solely as instruments of work (programmers, graphic artists, reporters). Work on the screen is therefore only part of the individual's duties and is entirely under the operator's control.

2.3.3 Studies on the activities of VDT operators

Nearly 80% of all VDTs are now being used for office work (Brown et al, 1982). In general, introduction of a VDT, and, therefore, of computerized systems, is accompanied by a reorganization of tasks to an extent that is often underestimated. It is rare that computerization of data, and its collection and processing, does not modify tasks, fragmenting them into separate units. This fragmentation is partially responsible for the increase in percentage of non-specialized tasks following computerization (Brown et al, 1982).

Furthermore, the introduction of computerized systems results in increased task rigidity (Roussel et al, 1980). Orders cannot be modified. But workers often deviate from official standardized procedures (Bensaid-Singery et al, 1979), and such deviations make it possible to remedy shortcomings in the procedures laid down. Computerization limits these possibilities.

Pinsky et al (1982), for example, observed in a study of activities in an entry-correction task that programs developed by programmers may contain major errors: the messages transmitted by the computer may seem illogical and erroneous. In such cases, operators have trouble interpreting the information on the screen and have to develop novel strategies to respond to the computer.

The only detailed study on the tasks of VDT operators to our knowledge was conducted by Pinsky et al (1979). These authors made a qualitative analysis of the mental workload of operators performing entries and numerical coding of information from a survey. The information concerned the occupation and professional categories of the people surveyed as well as the name, economic activity and address of the firm employing them.

The task characteristics were studied in terms of the objectives the operators had to reach, the methods they could use and the impediments they encountered to actually applying the methods.

The authors summarized the main demands of the task that led to an increase in the operators' workload as follows:

1- adapting to a variety of problems in a relatively rigid context,
2- mastering the semantic fields of the people surveyed,

3- mastering the terms (occupations and economic activities) and the files on the firms (name and address),
4- overcoming the problems of a »dialogue» with a computer poorly adapted to the task,
5- awareness of the performance pressures,
6- adjusting to hazy orders and inadequate definition of the work to be done.

The study pinpointed aspects of the work situation that should be modified and defined strategies that could be adopted in order to implement the changes.

The work also showed that the demands of apparently similar tasks and the resulting mental workload may vary. The findings of the following studies illustrate this fact.

Bagnara (1982) studied variation in the performance of VDT operators as measured by the types of errors they could find in a series of seven texts. The first type of error involved letter substitutions in words; the second involved repetition of words or parts of sentences.

The results showed:

a) that performance declined as a function of time at work;
b) that there was significantly more neglect of errors of repetition than of substitution.

According to this investigator, detecting errors of repetition requires conceptual analysis by subjects, while detecting errors of substitution involves visual analysis. The relations between each of these mechanisms and (1) the characteristics of the VDT and (2) the effects of fatigue may differ. The author suggests that visual fatigue may be related to the demands of the tasks workers have to perform.

Duraffourg et al (1979) observed differences in the visual activities and mental workload in workers in the newspaper industry who were responsible for data entry and correction.

The operators' tasks, which were carried out in a rigid context, seemed a priori to have the same characteristics. However, the authors observed that the organization of the work (number of employees participating in the entry and correction of the same text, use of the original document for proofreading, etc.) and the characteristics of the texts (presentation, syntactical structure, etc.) might vary, and these differences could explain variations in the time spent looking at the screen during the workday.

Furthermore, the perceived difficulty of the work was related to the operator's experience and the characteristics of the keyboard.

The activities of operators must be analysed if we are to have a good understanding of the problems associated with introduction of VDTs and their implications. With the exception of the many studies conducted on air controllers and the recent work on type-setters and proofreaders in the newspaper industry in France (Duraffourg et al, 1979), the tasks of VDT users have received scant attention. Detailed studies on office tasks, such as the one carried out by Pinsky et al (1979), are essential, but unfortunately, very few have been conducted.

2.4 Conclusions on Environmental Factors

A) Very important problems whose effects are strongly suspected:

1) Technical problems

- Reflections on the screen: reduced display legibility is the main effect observed.
- Flicker: this problem is more acute with positive-contrast screens.
- Negative-contrast screens:
  — Insufficient contrast between the characters and the background of the screen.
  — Lighting problems: incompatibility between the luminance required for reading the screen and reading printed texts.

2) Problems with tasks and work organization

- The effect of reorganizing the tasks and the work on the physical and mental workload.

B) Important problems whose effects are strongly suspected:

- Poor workstations design and prolonged maintenance of the same position.
- Blurred edge of the characters.
- Poor presentation of information on the screen.
- Unsatisfactory combination of the display colors.

C) Important problems whose effects are not very likely:

- Emission of very low frequency radiation. While its effects are not known, they are not likely to be harmful.

D) Problems in dispute

- Emission of ionizing radiation, ultraviolet rays, infrared rays, micro-waves and high-frequency waves: the levels are very much below those at which effects have been found.

3. Health Problems

Studies and/or publications on health problems experienced by VDT operators can be divided into seven categories:

1) Oculovisual; 2) musculoskeletal; 3) obstetrical; 4) congenital; 5) dermatological; 6) neurological and 7) stress-related.

This chapter contains a critical review of studies on each of these problems. It should be noted that the few studies that have been carried out on the health of VDT operators contain major methodological problems.

3.1 Ocular and Visual Problems

From an epidemiological point of view, studies on the ocular and visual problems suffer from poor design. Prevalence rates and severity of the ocular and visual symptoms and clinical signs in VDT operators have not been systematically compared with other groups of workers performing similar visual tasks. Moreover, few studies have used validated questionnaires with demonstrated reliability. Since most of the questionnaires did not respect these criteria, their results are of limited usefulness.

The incidence of ocular and visual problems reported by VDT operators varies from study to study. The lack of agreement is due in part to differences in 1) the variables measured; 2) the populations studied and 3) the methods employed.

Most studies concentrate on subjective reports of ocular and visual problems, and very few used physiological indices. In general, the studies are cross-sectional. They do not clarify questions about the incidence, severity, cause and significance of ocular and visual problems possibly linked to VDT use. Furthermore, most of the work on variation in the symptoms and clinical signs over time only considers the short-term effects of VDT use on ocular and visual functions.

The most common term used by investigators to define the object of their studies is "eyestrain", yet workers in the field do not agree on the definition of the concept and the methods to be used in its measurement. There is also some confusion in the scientific literature over the definition of the ocular and visual problems studied and the functions they relate to. We think it is important to define these terms.

The symptoms and signs investigators have studied can be classified into three groups of phenomena: sensory, sensitivity and motor. Sensory phenomena refer to visual functions, while sensitivity and motor phenomena concern the eye itself. Table III summarizes the signs and symptoms in each of these categories.

3.1.1 Results of the studies

Clinical evaluation and prevalence of symptoms

Three clinical reports containing an evaluation of the ocular apparatus in VDT operators were found. The first two (Gilbert et al, 1981; Dubé and Michaud, 1982) attempted to determine whether VDT use could lead to medium-term ocular and visual alterations.

The results of these studies should be interpreted with care since both contain methodological problems. First, the criteria applied in selecting subjects at the beginning of the study and the characteristics of operators who were later observed are not specified. Secondly, few independent variables were controlled and, often, the tasks of the subjects are not stated. Such variables must be controlled in order to identify the possible health risks to the different groups of workers. Finally, the rather simple statistical analyses do not allow for an evaluation of the effects of the independent variables on the variation observed.

The work by Gilbert et al (1981) used 278 subjects (139 VDT operators and 139 subjects, whose occupation was not specified, in the control group).

Ophthalmological tests on 1) visual acuity (with and without eyeglasses), 2) amplitude of accommodation and 3) spherical and cylindrical refraction were conducted at the beginning of the study and repeated 26.5 months later.

Visual acuity in the left eye (with or without eyeglasses) was lower at the end of the study in VDT operators. According to the authors, this change was not significant from the optometric point of view. They also found a decrease in the amplitude of accommodation in the two groups. The differences in accommodation between VDT operators and the control group were not statistically significant.

The authors concluded that when VDTs are used regularly for short periods of time, they have no measurable effects on vision for up to two years.

The group studied by Dubé and Michaud (1982) contained 392 VDT operators. All the subjects were examined ophthalmologically at the start of the study. A subsample of 50 people was then examined every year for visual acuity, muscular function and condition of the corneal endothelium. At the end of the study, 68 people had been examined. The authors do not state the criteria they used in selecting subjects for the subsample, nor do they explain why 18 extra people underwent the yearly examination.

The authors compared: 1) the results of operators working full-time on VDTs to those whose work was divided between the screen and other office tasks (the number of subjects in each of these groups was not clear), and 2) the year-by-year results in the subsample followed over a five-year period.

Table III: Symptoms and signs associated with phenomena of visual and ocular function

Visual Function		Ocular Function			
(Sensory phenomena)		(Sensitivity phenomena)		(Motor phenomena)	
Symptoms	Clinical signs	Symptoms	Clinical signs	Symptoms	Clinical signs
1. Poor vision	1. Lower visual acuity	1. Itching	1. Redness	1. Blurred vision	1. Changes in proximal point of convergence
2. Dazzle and sensitivity to light	2. Visual field affected	2. Tearing	2. Tearing	2. Double vision	2. Problems in accommod-ation
3. Sensation of spots of light	3. Changes in color sense	3. Heaviness of eyes	3. Photophobia	3. Eye pain-pinpricks	3. Changes in refraction
4. Blurred and clouded images	4. Changes in perception of objects	4. Dryness of eyes	4. Changes in eyelids	4. Periorbital pain	4. Diplopia
5. Colored edge around objects		5. Burning	5. Dryness	5. Difficulty in fixating objects	
6. Images persisting after work		6. Pain response to pressure		6. Difficulty in looking in the same direction for a long time	

The results indicated that the control group had less serious symptoms than the full-time VDT operators. Furthermore, the excessive sensitivity to light and dazzle found in over a third of the subjects tended to persist. The investigators attribute this to sudden variations in luminance of the screen and the ambient light, but provide no demonstration of such variations.

The analysis of the results of the yearly examinations revealed no changes in visual acuity or refraction in 42 of the 68 subjects examined. The modifications found in the other subjects could not be attributed to VTD use according to the authors, but rather to pathologies of the eye detected at the start of the study.

The team concluded that continuous work on a VDT over a five-year period has no adverse effects on visual and ocular function.

The clinical study by Arnaud et al (1982) was designed to evaluate sensitivity of the ocular apparatus. It used 243 people working in a firm specialized in data processing who spent at least half their work-time using a screen.

The clinical examination included tests of visual acuity of each eye separately, then of the two together for distant and close objects, visual perception of relief, muscle balance, color vision, astigmatism and refractivity. These measures were complemented by an examination of the media and the fundus of the eye.

The results indicated that 87% of the operators suffered to some extent from one or more ocular disorders. Only 47% of these individuals wore corrective lenses.

The team also used a questionnaire to study the incidence of subjective ocular and visual problems. The results showed that 18% of those with no objective problem complained of disturbed vision. The frequency of complaints was higher in those with objectively verifiable problems: 61% with myopia, 70% with hypermetropia, 67% of those with astigmatism; 76% of far-sighted subjects and 65% of people with altered binocular vision have these complaints. These symptoms usually decreased or disappeared with appropriate care.

In general, studies on the incidence of ocular and visual complaints have shown that operators frequently report symptoms. More than half of VDT operators complain of visual discomfort. When control groups are used, the incidence of symptoms found in them is lower than in VDT operators (Brown et al, 1982; Gilet et al, 1978; Laubli et al, 1982; Rey, 1982).

Ergonomic studies

The following facts have emerged from ergonomic studies:

— Visual acuity appears to improve with increased luminance and contrast within normal photopic limits. Increasing luminance leads to 1) decreased pupillary diameter and thus greater depth of field, 2) a decrease in the spherical aberration of the eye and 3) a decrease in the amount of accommodation needed (Bauer et al, 1982; Krueger, 1982).

— Very high luminance ratios may lead to greater incidence of eyestrain (Elias et al, 1979), decreased visual acuity and increased objective and subjective symptoms of eye irritation (Laubli et al, 1981).

— With frequent alternation between objects with different luminance levels, it seems that operators suffer from permanent problems of adaptation (B.I.T., Wisner, 1978).

— Onset of visual fatigue may be faster with longer duration or greater frequency of screen viewing. The amount of time spent looking at the screen depends on the nature of the task (shorter for data entry than for entry and correction) (Roussel et al, 1980). Furthermore, the time operators spend looking at the screen is a function of the complexity of the texts consulted (Wisner, 1978).

— The longer the screen is viewed without interruption, the more operators perceive reflections and flicker. This may explain the increase in subjective feelings of visual fatigue (Elias et al, 1979a).

— The incidence of subjective feelings of eyestrain appears to increase directly with the number of hours at work (especially after 4 hours) (Rey, 1982).

Ergonomic studies can identify the environmental factors that may underlie the prevalence of visual and ocular problems in VDT operators. They can also generate hypotheses to be tested in epidemiological studies.

Finally, it should be noted that these studies do not allow us to decide if flicker perception can lead to long-term visual or ocular problems. We do not even know whether unperceived flicker is harmful to the retina since the possibility has not been investigated. Grandjean (1980) has recommended that attention be turned to this question.

In general, the following conclusions emerge from the scientific literature:

— Rigorous epidemiological studies should be carried out to compare the frequency of visual problems in VDT operators with that in other occupational groups.

— Questions about vision are very closely linked to ergonomic variables and to the organization of work. These factors should be studied. Multivariate statistical analysis is also needed to identify the specific aspects of screen work that may underlie the visual and other symptoms that have been observed.

— Owing to the absence of scientifically valid studies on the effects of VDT use on the visual system, many questions remain unanswered. Nevertheless, the prevalence of oculovisual symptoms in VDT operators has been demonstrated.

— From the available information, we can pinpoint measures that are likely to increase the comfort and improve the performance of VDT operators: use of good-quality screens, control over lighting, application of anthropometric principles in the design of workstations and consideration of workers' needs when tasks are being defined.

3.1.2 The case of cataracts

Several cases of capsular cataracts in VDT users have been reported by Zaret (U.S. Congress House, 1981), but no studies have been conducted to determine if this health problem is more prevalent in this group than in other occupational categories.

Capsular cataracts may be caused by electromagnetic radiation, and, unlike ordinary cataracts, their effects first appear as opacity on the surface of the crystalline lens, rather than in the internal part. The cataractogenic effects of high-intensity infrared radiation are well established, and the results of some studies indicate that microwave radiation may also play a role in cataract formation. Furthermore, Zaret has suggested that radiofrequency waves may also have the same effects, but no studies have made any serious argument in favor of this hypothesis.

Research has shown that the infrared and microwave radiations from VDTs are of a lower intensity than those permitted by the standards. With the exception of Zaret, the investigators unanimously reject the possibility that the cataracts observed in VDT users were caused by exposure to radiation emitted by the equipment. Thus, it is unlikely that VDTs are responsible for cataracts in exposed workers.

3.1.3 Conclusions on visual and ocular problems

A) Frequently reported and strongly suspected problems

Visual fatigue

1) Important and strongly suspected factors
   - Low luminance of characters
   - Poor contrast between the characters and background of the screen
   - High luminance ratios between the screen and objects illuminated by the ambient lighting (especially printed texts).
   - Reflections on the screen and flicker.

2) Secondary and strongly suspected factors
   - Long duration and frequent uninterrupted screen viewing
   - More than four hours of VDT use
   - Oculovisual problems that have gone undetected or have not received proper correction.

B) Rarely reported and unlikely problems

1) Cataracts
   The only radiations suspected were those emitted by VDTs, and this possibility has been ruled out.

2) Other medium- and long-term visual and ocular problems
   None of the factors that might explain the high incidence of visual fatigue are very likely.

3.2 Musculoskeletal Problems

No studies have used a rigorous epidemiological approach to determine whether the incidence of clinical signs in VDT operators is higher than in other occupational groups. Investigators usually employ unvalidated questionnaires to measure the incidence of musculoskeletal symptoms. However, because of methodological problems from an epidemiological point of view and a lack of longitudinal studies, it is impossible to conclude whether there is any relation between the risk factors operators are exposed to and the incidence of musculoskeletal problems.

Just one study has compared the results from clinical examination of the muscles, tendons and joints in the upper limbs of VDT operators with those of other office workers engaged in traditional tasks (Hunting et al, 1981). The sample contained 162 VDT operators: 53 were responsible for entering data and 109 worked with interactive communication terminals. The control group contained 133 subjects, 78 of whom were typists and 55, traditional office workers. The clinical examination involved identification of painful pressure points in the muscles, tendons and tendinous insertions of the neck, shoulders, arms and forearms.

The results suggest that the constrained postures assumed full-time at VDT workstations and desks used by typists often lead to problems in the hands, arms, shoulders and the base of the neck. The authors did not try to identify possible confounding variables, nor did they subject the differences between the groups to statistical analysis. Furthermore, the method used in subject selection was not given.

The within-group analysis of differences in the clinical signs suggests that the frequency of problems in VDT operators is higher when:

- — the keyboard is thick;
- — the distance between the eye and the task is great;
- — there is not enough room on the table to rest the forearm and hands;
- — inclination or torsion of the head is excessive.

Other ergonomic studies have concentrated on the incidence of symptoms of local fatigue or pain. This approach has been used parallel to an analysis of the work and the conditions under which it is performed as well as of the postures adopted by operators. This type of study does not allow us to conclude if the musculoskeletal problems are more severe or more frequent in VDT operators than in other occupational groups. However, they do make it possible to determine the elements of the workstation, task structure and work organization which are inappropriate and might lead to postural problems (unsatisfactory and static posture).

Several recommendations have been proposed to promote the adoption of satisfactory posture in office work. Studies on VDTs have attempted to:

- — determine whether these recommendations could be applied to screen use;
- — identify factors that could explain the postures of VDT operators;
- — evaluate whether satisfactory postures could be adopted.

Table IV summarizes the variables dealt with in the studies consulted.

Table IV: Summary of the variables considered in the ergonomic studies

AUTHORS	**VARIABLES**				
	Nature of the task*	**Complaints**	**Clinical Examination**	**Observation of posture**	**Dimensions ****
Hunting et al (1981)	x	x	x	x	x
Laville (1982)	x			x	
Tisserand et al (1981)	x	x		x	
Stammerjohn et al (1981)	x				x
Elias et al (1982)	x	x			
Brown et al (1982)					x

* Data entry, coding and interpretation, typing
** Includes workstation adjustment strategies

The studies were based on the premise that the posture assumed by VDT operators are associated with two closely-related, but different, factors:

— the dimensions of the workstation;
— the visual and manual characteristics of the task.

With respect to workstation dimensions, the following elements were considered:

- A workstation should have elements providing support (chair, support for the forearm, etc.) arranged in a series of planes that oppose body mass at critical anatomical points where gravitational force can be transferred to the skeletal structure.
- The chair or the support provided for the forearms and feet should be at a suitable height in order to avoid compression of soft tissue and joints.
- The workstation dimensions should be adjustable so that operators can assume satisfactory positions.

Table V Summarizes the main factors determining the characteristics of the visual and manual activities.

Table V: Factors associated with visual and manual activities

Factors	Activities	
	Visual	Manual
Screen characteristics	x	
Keyboard characteristics		x
Workstation dimensions	x	x
Lighting	x	
Types of task	x	x
Work organization	x	x

The visual characteristics of a task define eye and head position, which in turn, determine the posture. The manual characteristics determine the position of the upper limbs.

In general, all the results obtained are in agreement and may be summarized as follows:

1) The nature of a task determines the posture and the resulting complaints. It is impossible to define an ideal posture for all situations.

   Researchers emphasize the importance of a movable keyboard independent of the screen. When the keyboard is fixed and attached to the screen, the manual and visual demands are likely to be incompatible. Furthermore, the equipment should be designed so that the height of the keyboard and the distance between the screen and the source document can be adjusted. The forearm or hands should have a place to rest upon. Finally, Swiss researchers (Zurich school) recommend that the chairs have high backs (see comments on page 67).

2) The postures observed do not seem to present more problems than those assumed at other workstations also involving use of the upper limbs and considerable visual activity. In fact, the back was found to be supported more often and the head was less inclined. This is due to the height of the visual axis at VDT workstations.

3) Far-sighted operators had special problems. Eyeglasses are usually designed for reading distances of from 30 to 40 cm, but the most frequent eye-to-task distance for VDT operators (a necessary one for good posture) is around 50 cm. Furthermore, when bifocal lenses are not adapted for VDT use and the workstation layout is poor, operators have to pull their heads back in order to be able to read through the lower part of their lenses; this can lead to neck and shoulder pain.

4) The major problem seems to be associated with the fact that the position is static, especially at data-entry workstations. This is because the operator is forced to keep his head and hands in the same position more or less permanently.

Conclusions on musculoskeletal problems

Frequently reported and very strongly suspected problems

Muscular fatigue and musculoskeletal pain

1) Important factors that are strongly suspected
   - Constraining postures due to incompatibility between the manual and visual activities; impossibility of adjusting the dimensions and inclination of the equipment; absence of places to rest the forearms.
   - Static position because of: organization of the tasks with specialized VDT work; screen fixed in place; rapid work pace.
2) Secondary factor that is strongly suspected
   - Bifocal lenses inappropriate for the work.

3.3 Problems Associated with Reproduction and Pregnancy

The risk factors in reproduction and pregnancy that will be considered here are ionizing and non-ionizing radiation and what is commonly called "workload". This section will concentrate on the genetic and teratogenic effects of these factors, in particular spontaneous abortion, premature births, low birth weight and birth defects.

Genetic damage includes mutations (modifications in the number or structure of specific chromosomes or genes) in a germ cell (sperm or ovum) which can be transmitted to future generations, or in a somatic cell of the fetus, in which case only cells originating from the first mutant cell are affected. Teratogenicity refers to the processes acting *in utero* on an embryo causing its development to deviate from the normal. The consequences of the abnormal development may be death (spontaneous abortion), malformation, retarded growth or a functional disorder in the fetus or child (Wilson, 1979).

It can be very difficult, if not impossible, to determine whether these occurrences are "spontaneous" or "environmentally induced", or the result of a mutagenic or teratogenic event. The two processes are biologically very distinct, but their effects may not always be so.

This section deals first with the question of x-rays: their emission and the biological effects of low radiation levels. Microwaves and radiofrequency waves will also be discussed along with their thermal and nonthermal effects on biological processes. There will be a brief consideration of the possible effects of workload, and finally, a discussion of the effects of VDT work on reproduction and outcome of pregnancy.

3.3.1 Radiation

X-rays

Emission of x-rays

If a pregnant worker is exposed to a VDT that emits radiation within the regulatory limits (not more than 0.5 mrem/h at a distance of 5 cm) throughout the first three months of pregnancy, the maximum dose absorbed by the fetus is 6 mrad "or about one quarter of the absorbed dose due to background radiation during the same period" (Hirning and Aitken, 1982). During the last six months of pregnancy, the fetus is probably exposed to similar doses. These doses of ionizing radiation are really very low. Since VDTs emit radiation at levels below those set by regulation (which appears to be the case since the most frequent levels measured have been between 0.01 and 0.05 mrem/h) (see Section 2.2.3), the calculation above considerably overestimates the real dose received by workers. Thus, the x-ray levels emitted by VDTs do not constitute a health risk to a pregnant worker or to the fetus.

The biological effects of low radiation levels

Radiation does not lead to new biological phenomena, but rather, may increase the probability of events considered spontaneous, or called natural. This may occur either stochastically[15] (an all-or-none effect such as mutation on a single cell) or non-stochastically (with thresholds). In the second case, there is a level of exposure below which an event will not occur at a higher than "natural" frequency. The teratogenic effects of radiation are generally considered to be of this type. At below-threshold exposure, the number of cells needed for normal development and growth is maintained, and there are no visible or measurable effects. In contrast, above threshold, an increase in the dose a worker is exposed to will increase the frequency and severity of the effects as compared with radiations from natural sources. The effects on pregnancy depend on when the worker is exposed. At lower levels, some effects may occur but could go undetected.

To our knowledge, there are no longitudinal studies on the health of populations exposed to x-rays at levels similar to or lower than those emitted by VDTs. Furthermore, no comprehensive studies have appeared on the reproductive experiences of workers exposed at such levels. The fact is that we have no empirical proof of whether such levels of exposure affect the health of workers and/or their offspring. Despite the many unanswered questions about the biological effects of radiation in general, some general conclusions can be drawn about x-rays and VDTs.

It seems clear that the annual dose of ionizing radiation received by VDT users (or the fetuses) is very much below the lowest levels at which effects have been found above a certain threshold. For effects such as infertility, birth defects and abnormal development, many data suggest a threshold of 10 rads of acute radiation. Furthermore, the possibility that stochastic (all-or-nothing) effects are occurring theoretically cannot be eliminated even though, in practice, it is virtually impossible to distinguish this risk from that present in the natural environment. Therefore, there is no scientific basis for mass media suggestions that certain cases of spontaneous abortion or birth defects observed in VDT users were related to ionizing radiation. Emissions of ionizing radiation by VDTs are lower than the standards and cannot produce such biological effects. Consequently, even if adverse effects on pregnancy were found in these workers, the most improbable explanation would be ionizing radiation emissions from VDTs. However, to ensure that emissions from VDTs remain at or below the current levels (0.01 to 0.05 mrem/h), it might be appropriate to reduce the regulatory limits to these levels.

Microwaves and radiofrequency waves

Microwave and radiofrequency radiation from VDTs at levels of 10 MHz or more are either undetectable or are much lower than the most stringent standards. About 95% of the radiofrequency emissions of the screens are below 10 MHz, ranging from 15 to 125 kHz. There are very few instruments for accurately measuring these emissions.

Biological effects

A) Thermal effects

These waves can excite water molecules (or other molecules) in the body, and the movement may produce heat. At high intensities, this radiation produces heat perceptible to the individual. At low intensities, the temperature increase in cells and tissue may not be noticed.

Lary et al (1982) summarize our knowledge of this subject as follows: "Because of the absence of studies of low-intensity RF radiation below 300 MHz, the difficulty of predicting RF power absorption and heating from a given RF source, and the usual difficulties in extrapolating teratology data from animals to man, an accurate assessment of potential teratogenic effects in human beings cannot be made at this time". When animals *in utero* have experienced growth or developmental problems, it is following exposure that has led to an excessive increase in temperature (Michaelson, 1982). Caution should be exercised in extrapolating these animal findings to humans. While it is feasible that a human embryo or fetus could be exposed to significant heat without the mother perceiving it, the very low intensities associated with VDTs are probably much too low to produce harmful effects on the child.

B) Non-thermal effects

Neither microwaves nor radiofrequency waves can directly damage the DNA[16] in germ cells, and therefore, they cannot cause transmissable mutations. However, it is not known whether they can induce changes in the electrical activity of the heart or brain or lead to the production of hormones or other chemical substances in the body.

15. Stochastic, as used here, refers to the increase in probability of health effects from radiation with increased levels of exposure.

16. DNA (desoxyribonucleic acid) is the substance that makes up genes.

Animal studies on this question are particularly difficult to extrapolate to humans, and there has been debate over the results from studies on humans.

Therefore, although VDTs emit very low frequency electromagnetic waves, there are not enough data to determine the exposure levels and establish whether there are grounds for concern.

To summarize, then, it seems highly unlikely that microwave emissions from VDTs, which are currently undetectable, could have a direct thermal effect on the fetus carried by a pregnant worker or could destroy or damage a critical number of cells through excess heat.

As to the biological effects of very low frequency (VLF) and extremely low frequency (ELF) electromagnetic waves emitted by VDTs, it is more difficult to come to any conclusions. The radiations are in the form of pulses. It seems that a number of studies have been conducted on the biological effects of pulsed radiation. Postow (cited by Marha et al, 1983) concluded that pulsed electromagnetic radiation produces greater effects than continuous radiation. However, little research has been done on the effects of very low frequency and extremely low frequency pulsed radio waves (Marha et al, 1983; Cohen, 1983). Until we have solid data on this subject in humans, it would be wise to support efforts to acquire more information to develop shielding for reducing radiofrequency waves emitted by VDTs and to set standards for frequencies below 10 MHz. Marha (1983) has developed shielding that decreases the electrical field of VDT-emitted radiofrequency waves.

3.3.2 Biological effects of workload

So far, no studies have measured the effects of workload on pregnancy in women working with VDTs. But it can be recommended that future studies, in addition to meeting the methodological requirements of epidemiologic research should include not only a detailed description of the work (place, activities, all exposures, pace, physical demands, intellectual demands, etc.) and of the equipment (e.g., specification of maximum radiation levels the equipment could emit), but also an attempt to quantify these independent variables. Furthermore, the studies should try to assess the proportion of the different problems in pregnancy that can be attributed to each of the risk factors identified.

3.3.3 Findings on reproduction and outcome of pregnancy

As has already been pointed out, most of the environmental factors associated with birth defects and spontaneous abortion probably do not invariably give rise to the effect but rather predispose the individual to it or increase the probability that the effect will occur. It follows that the effect will not be found in everyone who has been exposed, and will be more difficult to identify than an inevitable effect. Moreover, all health problems in reproduction occur at a certain spontaneous frequency, and in many cases, the cause is not known. The spontaneous, or background, frequency is strongly influenced by such factors as the mother's age, reproductive history, smoking, alcohol consumption, etc.; such factors must be considered in any attempt to study the association between an occupation or exposure level and a particular effect.

Furthermore, with widespread exposure and frequent effects, the probability of these elements being associated purely by chance is higher.

But, what exactly is known about reproduction in workers exposed to VDTs, and does it suggest an unusual frequency of undesirable effects?

To our knowledge, only two epidemiological studies have been carried out on this question (Lewis et al, 1982; Centers for Disease Control, 1981). To these should be added the study now being conducted in Montreal by McDonald et al on the effects of any type of work on pregnancy; the results are still not available. A recently begun American study by Rosenberg et al should also help clarify the issue.

In 1981, the Centers for Disease Control in Atlanta investigated a series of spontaneous abortions and neonatal deaths in women using VDTs in a large company in Dallas, Texas (Centers for Disease Control, 1981). This cluster represented an event in time which, in the absence of any other consideration, could not be considered entirely due to chance. However, the investigators examined the sociodemographic characteristics, occupational history, reproductive history, general health of the workers, and found no particular characteristic predominating in women who had suffered spontaneous abortions or whose child had been lost neonatally. There was absolutely no association between the outcome of pregnancy and length of VDT use, nor did the workers' distance from the screen play a role. No causal agent could be identified. The authors suggest that it was an "expected-unexpected" cluster.

If enough groups of pregnant women are studied, it is highly probable that at least one of the samples would show a high incidence of problems in pregnancy. It is estimated that in the United States about 7 million people work with VDTs, and that many are of reproductive age. If this number is divided into groups of 70, it gives 100,000 groups. Assuming an equal fecundity rate in the groups, over a period of three years 2,500 groups would show a high number of unfavorable outcomes of pregnancy ($p = 0.05$) by chance alone.

Lewis et al (1982) examined the relation between spontaneous abortion and VDT use in Australia in a retrospective study of 30 cases of unfavorable outcomes of pregnancy. These cases were compared with controls matched for age of the mother and date of delivery. The cases and the control subjects were chosen from a cross-sectional study in 13 companies where 279 women worked with VDTs and 100 never used this type of equipment. All the subjects were volunteers. The proportion of women working at VDTs did not differ significantly between the cases and controls. The study contains several methodological problems: chronological bias (unfavorable outcomes spread over a long period of time), selection bias (volunteers and elimination of several cases of abortion with no reason given), the study was not conducted blind (the women knew its purpose), and measurement bias (no independent verification of the validity of the information provided by the women on the outcome of their pregnancy).

The few studies on the relation between reproduction and VDT work do not allow us to draw any conclusions about the dangers or safety of exposure. This is not surprising since, overall, there are few studies on the occupational exposure of the mother and its effects on the fetus. Thus, we cannot even make inferences from similar occupational groups.

Despite the paucity of data, there has been much speculation on the harmful effects of VDTs on reproduction. We have already discussed radiation and workload and shall now turn to two other factors: the ergonomic aspects and stress.

Ergonomic factors (e.g., poorly designed workstations and the fact that a VDT operator must remain in the same constrained position for long periods of time with few breaks) can force a pregnant woman to assume positions that may reduce blood supply to the fetus. Inadequate placental blood supply may lead to prematurity and retarded growth. However, such a sequence of events has not been studied in women using VDTs, although it is physiologically plausible.

Finally, no studies have been carried out on the effects stress might have on reproduction and pregnancy in VDT users.

3.3.4 Conclusions on the risks to pregnancy

To date there is not enough information to draw any conclusions about the extent to which VDT work could lead to harmful effects on reproduction. Concern about the effects of ionizing radiation is probably unwarranted. However, the effects of ergonomic factors and low frequency electromagnetic waves on the physiology of pregnancy are poorly understood. While, for the moment, we cannot identify any particular risk factor with certainty, it should not be concluded that there is no possibility of harmful effects. Conversely, anecdotal reports are an insufficient basis on which to conclude that VDTs are dangerous.

3.4 Dermatitis

Facial dermatitis has been reported by a number of researchers (Linden et al, 1981; Olsen, 1981; Tjonn, 1982). Itchiness may appear after a few hours or days of work, generally followed by a rash characterized by erythema and pink papules. These reactions usually disappear if work is stopped for a day or two.

To the best of our knowledge, no epidemiological studies have been conducted to determine the incidence of dermatitis in VDT operators.

There are only two published studies (Linden et al, 1981; Olsen, 1981) on dermatitis in VDT users, both clinical reports. The researchers examined the work environment of the operators in order to identify factors that could account for the problem. From their observations, they suggested that the skin reactions were due to a difference in electrical potential between the operator and the terminal when:

1) relative humidity was low (from about 20% to 30%);
2) the material in the clothing of the workers, the furniture and, especially, the carpets did not have antistatic properties.

Olsen (1981) has hypothesized that static electricity promotes the precipitation of irritating particles in the air. Other factors in the appearance of the rash are length of exposure, individual sensitivity, cosmetic use, etc.

To prevent these dermatological problems, it is recommended that the relative humidity be maintained at about 50% and that antistatic carpeting be installed. The effectiveness of these preventive measures has been demonstrated over a period of four months in two different work settings (Linden et al, 1981).

It has also been suggested that Polychlorinated Biphenyl (PCB) emission by terminals could be responsible for dermatitis in VDT operators (Digernes and Astrup, 1982). This study found that PCB concentration in offices where VDTs were used was 50 to 80 times greater than outside the building. It was, however, lower than the acceptable concentration defined by NIOSH. The authors mentioned that they could not determine the source of the chemical.

It should be noted that Canada, the United States and Japan prohibit the use of PCBs. Even when they are present in electronic circuits, the quantities are low, and it appears that a leak usually causes failure of the apparatus containing the substance.

3.5 Photosensitive epilepsy

The possibility that VDT use could lead to epileptic seizures has been examined from a theoretical point of view (Cakir et al, 1980; Rosenbaum, 1981; Wilkins, 1978). There is nothing in the literature to indicate whether the problem is more common in VDT operators than in other occupational groups. As the figures below show, relatively few people are likely to be affected.

It is estimated that about 0.5% of the population suffers from epilepsy. One form of this pathology, photosensitive epilepsy, in which seizures are induced by flickering light, affects from 1 in 2,500 to 1 in 10,000 people. It is more common in women than in men and primarily affects children from 6 to 12 years of age. There is marked regression after the age of 16 to 18.

Some photosensitive epileptics experience seizures when watching television (about 4% of epileptics). Several researchers have postulated that the sensitivity of epileptics depends on the frequency of luminous fluctuations and the geometric organization or pattern of these fluctuations. Apparently, frequencies of from 10 to 25 Hz very often produce convulsions in photosensitive epileptics. A survey has shown, however, that the sensitivity range expands to anywhere from 10 to 43 Hz when the fluctuations follow a pattern. Furthermore, a number of photosensitive epileptics may be sensitive to geometric designs even in the absence of movement. Their sensitivity doubles if the drawings vibrate.

The epileptic excitation associated with VDT use has not been studied. Investigators assume that it is of the same type as that caused by television, except that a VDT screen would be more apt to produce seizures because it is viewed from a shorter distance. They believe that the flicker of the screens, particularly flicker associated with a low refresh rate of the screen's fluorescent substances, can be epileptogenic. Furthermore, the fact that texts are linear and the frame may be irregular could increase the sensitivity of people subject to epileptic seizures. Finally, it is believed that minor instabilities could produce low-frequency vacillation. All these hypotheses have yet to be tested.

Refresh rates of from 50 to 60 Hz are generally recommended to reduce flicker (Cakir et al, 1980; Rosenbaum, 1981; Wilkins, 1978). These values have, however, been disputed. Fluorescent substances with low persistence should also be used.

3.6 Stress-related Problems

In this document, stress refers to the psychological, somatic or behavioral reactions associated with characteristics of a task and work organization which constitute risk factors for VDT operators.

3.6.1 Sources of stress for VDT operators

A number of studies deal with stress in office workers using VDTs. The following are the main potential sources of stress that have been examined:

1) Intrinsic characteristics of the task content (inherent to the task):
   — qualitative and quantitative demands of the task at the cognitive and psychomotor levels (complexity, monotony, worker under- or over-qualified for the task content, rigid tasks, etc.).
2) Characteristics extrinsic to task content:
   — pace;
   — no identification with the work;
   — no initiative;
   — over specialization of the workers;
   — electronic monitoring of the work;
   — no job security;
   — fear of layoff;
   — absence of interpersonal relations.
3) Certain sociodemographic factors (age, sex, education, etc.) may help explain differences in reactions to stress.

The mental workload resulting from an interaction of the three groups of variables listed above may also be a source of stress.

Finally, the seriousness of possible health problems associated with VDT use and the attention given them by the media have frightened many workers, and this has contributed to an increase in the amount of stress they experience.

3.6.2 The effects of stress on health

Indices used

Many indices can be used to identify the existence of a stress situation. The most frequently cited effects are listed below:

— Psychological symptoms:
depressive state, anxiety, fatigue, dissatisfaction with work, etc.

— Somatic symptoms:
musculoskeletal pain, gastrointestinal disturbances, cardiovascular problems, etc.

— Behavioral signs:
problems with appetite, excessive weight gain or loss, alcoholism, deterioration in performance, absenteeism and frequent lateness.

— Physiological signs:
increased blood pressure and heart rate, migraines, headaches, elevated catecholamine levels.

Study results

Studies designed to measure the incidence of stress in VDT operators usually have major methodological defects that, for the most part, invalidate their findings:

1) Problems with subject selection:
   — Low response rate (under 50% of people surveyed) (Smith, 1982; 1981);
   — use of volunteers.
2) Absence of appropriate controls for certain variables
3) No analysis of the work.

Furthermore, some of the interpretations are not supported by the results: Ghiringhelli (1982), for example, compared the results of interviews with VDT operators in two companies and concluded that "VDTs seem to add their own troubles and emphasize the usual problems of employees and we suggest that they could become a symbolic focus of discomfort". This interpretation does not take into account the modifications in tasks that accompany screen introduction and the effect of new phenomena, such as active waiting between two displays (Ostberg, 1980).

Only one study has used a physiological index of stress (Johansson, 1979). This author compared catecholamine levels in urine, heart rate and blood pressure in data-entry operators with the same measures in secretaries, and found a higher average catecholamine excretion level in the VDT operators. There was also a statistically significant increase in these indices during computer failure, as well as greater irritability, fatigue and boredom. In the VDT operators, these high values were probably due to stress from a lack of control over the computer.

Studies on the incidence of subjective symptoms of stress generally find that they are more frequent in VDT operators than in other office workers.

The questionnaire method is used. In the studies conducted by Smith (1982, 1981), the questions were specific and the questionnaire had been validated. This, however, was not the case in other studies (CTC, 1981; Ghiringhelli, 1982; Mallette, 1983). Furthermore, the studies are biased from the very outset, since the purpose of the questionnaire was explained to the subjects. These studies also have the methodological problems mentioned above.

Investigators attribute the prevalence of subjective symptoms of stress in VDT operators to the following factors:

1) The types of tasks: most sources of stress are in data entry and acquisition, in terms of both their intrinsic and extrinsic characteristics. There are far fewer sources of stress associated with VDT use for operators in word processing and interactive communication. There are practically no such sources for professional workers using VDTs (CTC, 1982; Smith, 1981).
2) Monotony: this aspect is associated with task content (Cakir et al, 1982; Gunnarson, 1977).

3) Repetitivity in the tasks (Gunnarson et al, 1977). It should be noted that monotonous and repetitive tasks may involve many psychomotor and psychological activities (e.g., short-term memory, coding), and these may be sources of stress.

4) Remuneration: subjective stress may be felt more frequently in operators paid by the unit (Cakir et al, 1980).

5) Frequent contact with the public (Gunnarson et al, 1977).
   The main factor is the nature of the exchanges between the operator and the public. The public's expectations about services that can be obtained may conflict with the administrative guidelines the operator has to respect.

6) Frequent failure or delays in the computer: rather than giving operators an opportunity to rest, the active waiting between two displays is an additional source of stress (Ostberg, 1980). These problems especially affect operators paid by the unit and those in contact with the public (Brown et al, 1982).

7) Number of hours working with the VDT (CTC, 1982). Dainoff (1982) did not, however, observe any relation between the amount of stress felt and time spent working on the screen per day.

3.6.3 Conclusions on stress

Because of methodological problems in the stress studies and the absence of any longitudinal work on the pathological effects of stress in VDT operators, the prevalence of stress and the possible relation between task content, work organization and incidence of specific health problems cannot be established with any certainty.

It does, however, seem plausible that stress could predispose workers to oculovisual, musculoskeletal and obstetrical problems. This implies that future studies on the effects of VDT use should approach the health and environmental problems of work from a more global perspective.

4. Conclusions on the Health Problems

Overall, the health problems of VDT operators do not seem to be restricted to this group of workers. The most strongly suspected risk factors relate to work-station dimensions, characteristics of the task and work organization. These variables may also affect the health of workers in other fields.

Furthermore, according to available ergonomic data, it is plausible that the frequency and seriousness of health problems in VDT users vary according to the types of tasks performed.

The most frequently reported problems in VDT operators are ocular and visual, with visual fatigue tending to predominate. Although the research findings do not allow us to conclude that there is a definite relation between VDT use and the occurrence of these problems, it is likely that ergonomic factors could explain the symptoms.

On the question of cataracts, there is little probability that they are due to exposure to radiation emitted by VDTs.

Musculoskeletal problems are also frequently reported in VDT operators. There seems to be a logical and plausible relation between these problems and certain ergonomic factors, such as maintenance of a stationary posture, as has been shown in a number of ergonomic studies.

Of all the health problems encountered in VDT users, the most important in terms of their consequences are probably those associated with complications of pregnancy.

There is ample evidence that apart from low frequency waves, radiation does not constitute a potential risk factor. However, the question is not fully answered since too few studies have been conducted to allow us to reject the possibility. Nevertheless, it is not very likely that radiation puts the fetus at risk.

The factors most likely to be associated with complications of pregnancy are, rather, those relating to how the work is organized, the workload, the static position and stress. These aspects should receive special attention if abnormally high rates of complications of pregnancy were to be demonstrated.

Few reports of dermatitis appear in scientific literature. The suggestion by some authors that static electricity is at the root of the problem is logical and plausible. It is also likely that the number of clinical cases has been underestimated. because relatively little information has circulated about the relation between dermatitis and working with VDTs.

Photosensitive epilepsy appears to be of minor importance. Although no studies have succeeded in clearly documenting this phenomenon in VDT users, it does seem plausible that flicker constitutes a risk for susceptible individuals.

Problems of stress in VDT operators have been frequently noted by researchers. The modifications in the work environment that accompany the introduction of VDTs are a source of worker stress. However, stress is not restricted to this occupational group.

Health, as defined by the WHO, may be affected by stress. In the case of VDT work, it is possible that the psychological and social strains constitute a stress for operators which predisposes them to oculovisual, musculoskeletal and obstetrical problems. However, studies on stress at the workplace have failed to establish any direct links between stress and the development of pathology. Thus, despite the possible amplitude of the problem, we do not have the scientific evidence we need to determine with any certainty the health risks from exposure to these psychological and social stresses.

5. Task Force Recommendations

Introduction

The concern over the health problems reported in VDT operators is related to the following factors:

— VDT use is spreading rapidly, and a high and ever-growing number of workers are involved.

— Operators have been sensitized to the health problems potentially linked to VDT use, and their sensitization can be attributed to four factors:

- The introduction of VDTs entails changes in tasks and in work organization. Unlike conventional office work, the tasks performed by most VDT operators are fragmented and as a rule require fewer skills. They are often rigid and repetitive, leaving little room for initiative. There is then an incompatibility between the operator's training and the task requirements.
- In certain cases, the work is monitored electronically and, to boost productivity, workers are paid by the unit. Such conditions used to be rare in the service sector.
- VDTs are found mainly in the service sector, which has better educated and more unionized workers than the industrial sector.
- Introduction of computer systems often creates fear of layoff among workers since one of the objectives in introducing VDTs is to rationalize operations and optimize production.

Considering the number of workers now affected, the increasing rate at which computer systems are being introduced in various sectors of the economy and the fears about the health of VDT operators, the task force believes that steps must be taken as soon as possible to prevent the problems that have been identified.

It seems, however, that most of the health problems reported in VDT operators are not specific to this occupational group.

In fact, the task structure, work organization, unsatisfactory workstation design leading to poor posture and a static position over long periods seem to be the principal risk factors in musculoskeletal disorders, problems related to reproduction and pregnancy and other, non-specific, problems such as stress.

As for visual disorders, certain VDT characteristics (they are light-emitting visual objects), as well as workstation layout and the tasks are under suspicion but little research has been done on this subject. As for dermatitis, it may be due to a difference in electric potential between the operator and the VDT.

All of these elements can be found in other work environments where they are likely to produce similar health problems.

When a problem is suspected, preventive measures, if they exist, must be applied. The best means of intervention is to eliminate problems at their source. In the absence of means of primary prevention, other measures such as protective reassignment for pregnant workers and medical supervision can be adopted. But these are no more than temporary solutions to be applied under particular conditions. These aspects are dealt with in detail in the pages that follow.

Research is needed to identify means of primary prevention. The task force is aware of the rapid pace at which new technologies are developing. But defining the avenues of research depends on which technologies are chosen. Consequently, studies on means of prevention at the technical level must take this choice into account and, depending on the state of technological development, must be oriented toward existing equipment or techniques now being developed. The medium and long-term effectiveness of any means of intervention developed will have to be evaluated.

But whatever the technological developments, any problems due to the work reorganization accompanying the introduction of VDTs must be prevented.

Given the diversity of the risk factors and health problems, and their complex interaction, research on VDTs will have to be multidisciplinary.

5.1 Recommendations on Means of Prevention

5.1.1 Radiation emitted by VDTs

A) General considerations

Results of studies in which radiation emitted by VDTs has been measured show that the levels to which workers are exposed are below Canadian standards.

Moreover, the additional annual dose of ionizing radiation received by VDT operators is below the natural level of radiation, which is called "natural background emission", and far lower than the lowest doses of radiation for which the health effects are known.

The task force therefore considers that if pregnancy problems were to be identified in VDT users, the effect of ionizing radiation would be the least probable explanation. The same applies to cataracts.

As for microwaves, ultraviolet, infrared and high radiofrequency waves, the very low intensities associated with VDTs are below the levels at which harmful effects have been produced in children and adults.

The task force nevertheless considers that in the absence of sufficient scientific data on the effects of low frequency electromagnetic waves (< 10 MHz), it cannot entirely reject the possibility that exposure to such radiation may be hazardous to health.

B) Recommendations on radiation

The task force recommends that:

R.1 New VDTs introduced into a work environment be equipped with an efficient shielding system to reduce emissions from the electric field of radiofrequencies below 10 MHz even though their biological effects, if any, are still not known.

R.2 A system of annual or semi-annual monitoring be implemented to check that the levels of ionizing radiation (x-rays), ultraviolet, infrared and radiofrequency waves emitted by VDTs comply with Canadian standards.

R.3 The present standard for ionizing radiation be lowered to the levels observed in the studies of VDTs (between 0.01 and 0.05 mrem/h) in order to guarantee that the x-ray emissions from the equipment are maintained at these or lower levels. It should be pointed out that application of this recommendation would not entail any modification to VDTs now in use.

5.1.2 Visual and ocular problems

A) General considerations

There are indications that certain characteristics of VDTs (mainly negative contrast and luminance problems), workstation layout, tasks (complexity of printed texts and length of uninterrupted screen reading, for example) and work organization may account for the many reported symptoms of visual fatigue. We have means of primary prevention to avoid these problems (see Appendix, Section 3), but the application of certain preventive measures depends on technological developments (see 5.2, Intervention strategies, R.19 and R.20).

The task force also recognizes that it is plausible that undetected or improperly corrected visual disorders lead to oculovisual symptoms in VDT operators. Appropriate optical correction would prevent these problems.

Since visual disorders could be detected and corrected in pre-hiring checkups, such examinations are justified so long as they are not used as a means of hiring discrimination. However, the task force considers that it does not have sufficient data to judge the effectiveness of pre-hiring checkups and cannot formally recommend the practice.

Where long-term oculovisual changes are concerned, neither their incidence nor the risk factors involved can be determined from current epidemiological data. Ergonomic data, on the other hand, make it possible to identify sources of discomfort to VDT users.

B) Recommendations

The task force recommends that:

R.4 The IRSST and/or the CSST distribute information on the technical measures that can be taken to improve visual comfort in VDT operators.

This subject is dealt with in greater detail in the section on intervention strategies (R.15).

R.5 The IRSST conduct or fund studies to measure the incidence of long-term oculovisual problems in VDT operators and the utility of checkups before and after hiring.

5.1.3 Problems associated with reproduction and pregnancy

A) General considerations

Results of studies on the emission of electromagnetic radiation show that the levels are below the standards and that such low levels of x-ray, infrared, ultraviolet and high radiofrequency radiation have no effect on health.

The task force therefore considers that this electromagnetic radiation presents no risk to reproduction and pregnancy. But in view of our current knowledge and the absence of any exhaustive research on low frequency radiation, the group believes that this aspect should be viewed with caution.

Very little is known about the effects a static position and stress have on pregnancy. The theory that prolonged maintenance of an unsatisfactory position constitutes a risk for the fetus by reducing the blood flow is plausible. Another suspected risk factor is stress. These problems seem to vary with the tasks carried out by VDT operators. It should be noted, however, that static postures and stress are not specific to VDT work, but are also found in other occupations.

Because of the absence of scientific evidence to prove or disprove the presence of pregnancy problems in VDT users and, where such problems do exist, to define the risk factors that are indisputably responsible for them, the task force considers that research should be done on the subject.

The studies should focus on the frequencies of the following problems: spontaneous abortion, premature births, low birth weight and birth defects. In addition to establishing whether a danger to pregnancy exists, the studies will also have to determine the nature and extent of such risk. Since a static position and stress are strongly suspected risk factors, they too will have to be evaluated.

Research is now being conducted on reproduction and pregnancy problems in VDT operators, but until the studies are published, the task force cannot give an opinion on their validity.

B) Recommendations

The task force recommends that:

R.6 The IRSST continue to update the list of ongoing research into pregnancy problems, not only in VDT operators, but also in other female workers whose jobs entail static posture and considerable stress.

R.7 The IRSST evaluate whether the methodology of the studies will, as their results become available, provide answers to the questions mentioned earlier.

R.8 The IRSST promote international exchanges between researchers whose studies deal with the possible risks of static posture, of stress and, more particularly, of VDT use on pregnancy.

If the IRSST considers that the findings of studies now under way do not satisfactorily answer the questions raised, **the task force recommends that:**

R.9 The IRSST conduct or fund one or more studies on the subject.

The question of pregnancy risks associated with VDT use is a complex one and has long held the attention of the task force members. Given the seriousness of the problems, the task force considers that temporary measures must be adopted to protect operators until the results of research now under way become available.

The task force recommends that:

R.10 Operators of VDTs not equipped with a shielding system to reduce the electric field of radiofrequency waves below 10 MHz, and for whom length of VDT use, the tasks, work organization and workstation layout may lead to static posture and/or considerable stress, have the right to protective pregnancy reassignment; this same right should be available to all women whose work has similar characteristics.

R.11 The CSST provide doctors with data on all the risk factors for pregnancy associated with VDT use as well as criteria on which protective reassignment can be based.

Protective reassignment of a pregnant worker is no more than a temporary solution. It has two shortcomings: the most critical period for teratogenic effects is between the second and twelfth week of intra-uterine life, and it is during this period that pregnancy is confirmed. Therefore, the work environment may have affected the development of the fetus before the worker is reassigned. It should also be noted that pregnancy may be affected after the twelfth week. In another connection, protective reassignment opens the door to hiring discrimination, and it is essential that this side effect be avoided.

5.1.4 Problems associated with the tasks and work organization

This section brings together the musculoskeletal problems, fatigue and stress since there is evidence that these are mainly associated with the tasks performed by VDT operators and with the reorganization of work which accompanies introduction of VDTs.

A) General considerations

1) Musculoskeletal problems

Musculoskeletal problems can be linked to poor posture due to poor workstation design and strain brought on by the requirements of the tasks. They may also be due to constrained posture resulting from prolonged maintenance of one position.

It would not be very difficult to design workstations that could be adjusted for good posture. The problem could be solved by distributing information about the principles that should be respected in planning a workstation (see R.14).

The same holds true for static posture, which is related to the structuring of tasks. In this case, the information should emphasize the importance of eliminating tasks involving prolonged static positions.

2) Fatigue

A number of researchers and government bodies have drawn up recommendations as to the maximum length of VDT use and the minimum duration and number of rest periods which should be provided during a workday to lessen worker fatigue.

We still do not have enough data on the details of VDT-user tasks, and such data are indispensable if we are to identify the factors responsible for the fatigue felt by workers and to recommend means of primary prevention.

The task force considers it essential that rest periods be provided during the working day. But it is doubtful that a blanket rule on the duration of rest and work periods for VDT users could be adopted. In fact, the duration of the work and rest periods recommended would have to vary according to the tasks performed, but they too are very variable in nature.

3) Mental workload and stress

The consequences of the introduction of VDTs on work activities and the resulting mental workload, are often underestimated. Also overlooked are the secondary effects of VDT use on work organization (stricter control of output by electronic monitoring, changes in interpersonal relations, etc.). The suggestion that these aspects constitute a source of stress for operators is very plausible.

In general, little research has been done on the effects of work on mental health or on the physiological manifestations of stress. This type of study runs into difficulties in finding tools to analyze work situations and methods of evaluating the health problems of workers exposed to stress.

B) Recommendations

Since prevention of the musculoskeletal problems, stress and fatigue experienced by VDT operators calls for further scientific data on the tasks performed, and because it would be very helpful to ascertain the possible impact of the introduction of new technologies on the health of workers, **the task force recommends that:**

R.12 The IRSST conduct or fund studies to analyze the work of VDT operators with emphasis on the structuring of tasks and on the musculoskeletal problems, fatigue and stress. The studies should also try to identify measures likely to prevent these health problems.

5.1.5 Dermatitis

A) General considerations

Several clinical cases of dermatitis in VDT operators have been reported. The difference in the electrical charge between the operator and the VDT when relative humidity is low and the floor-covering has no antistatic properties is strongly suspected as a risk factor.

B) Recommendations

The task force recommends that:

R.13 Adequate relative humidity be maintained in work areas where VDTs are used. The relative humidity values usually recommended for heated areas (between 40% and 50%) to prevent drying of ocular and respiratory mucous membranes (Grandjean, 1969) have also proven effective in preventing dermatitis (Linden et al, 1981).

R.14 Antistatic materials be used in floorcoverings in areas where VDTs are used.

5.2 Recommendations on Intervention Strategies

5.2.1 Information distribution

A) General considerations

Computerization of tasks and introduction of screens are now taking place at a rapid pace. While all the elements of the problem are not known, there is a whole body of knowledge that could be applied. Several organizations have issued recommendations which, despite a few differences, are in complete agreement over choice of screens and the rules to be followed for VDT introduction (Appendix, Section 3).

These recommendations are often ignored because buyers and managers do not have or do not know how to use the information. Several general documents are available but they do not meet the specific needs of each of the groups concerned. A printed guide or other means of distributing information (video, conferences, etc.) is urgently needed to help those whose positions give them a strong voice in the choice and introduction of VDTs.

This information should also be made available to health and safety committees and to workers who use VDTs so that they can carry out the functions and duties required of them under the Québec Act respecting occupational health and safety.

B) Recommendations

The task force recommends that:

R.15 Printed guides relating to the specific needs of each of the following target groups be prepared and distributed: company managers, engineers, architects and lighting engineers responsible for planning work areas, programmers, health and safety committees, VDT operators and health professionals.

R.15.1 The guide to purchasing VDTs should indicate, among other things, screen characteristics to be considered, their role and their importance, as well as list the recommendations that have been made. The buyer would then be able to draw up specifications before ordering any equipment.

R.15.2 The guide to VDT introduction should describe the procedure to be followed and the instruments that can be used to help determine the needs and work characteristics to be considered. The guide would be addressed to managers who order development plans (inside or outside their companies) and to those who draw up the plans.

R.15.3. The task force recognizes that data display formats should be flexible so that operators can choose the best format for themselves. The fact remains that the development of display formats must be based on ergonomic criteria, and a guide to the subject should be prepared for programmers.

R.15.4 The guide for potential users should be addressed to the health and safety committees of companies and to unions.

The task force recommends that:

R.16 A representative from each of the target groups participate actively in the preparation of the guide for his particular group.

In view of the rapid pace of technological change, the task force recommends that:

R.17 The file on VDTs be regularly updated by the IRSST and that any information on the subject be made readily accessible to the working world.

Public and parapublic organizations are major users of VDTs. Their purchasing power allows them to demand that certain design standards be respected by VDT manufacturers. They therefore have a major influence in determining the characteristics of VDTs on the market. **The task force therefore recommends that:**

R.18 The CSST propose purchasing standards to these organizations.

5.2.2 Standardization

A) General considerations

The task force considers that short-term means of intervention can be applied in:

— layout of workroom;
— ambient lighting;
— choice of VDT based on best design characteristics (luminance and character contrast, refresh rate, keyboard size, etc.);
— presentation of information on screen;
— dimensions of workstation;
— use of document-stand and footrest.

In view of our current state of knowledge and the rapid rate at which technology is developing, the task force considers that standards cannot be applied to these aspects and that it would be preferable by far to set guidelines.

B) Recommendations

The task force recommends that:

R.19 A multidisciplinary technical committee be given the task of drawing up more detailed guidelines for the aspects mentioned above. The committee could use the information contained in this report. Since the needs associated with the various contexts in which VDTs are used differ, the committee should in general promote adjustable equipment.

It should also define the conditions that must be respected in order to ensure the effectiveness of the guidelines recommended and should establish the relative importance of each one. The guidelines should be revised as new technological developments take place.

5.2.3 Technological choices concerning image polarity

A) General considerations

Given the characteristics of positive-contrast display, the following advantages would seem to flow logically from its use:

- greater uniformity of luminance in the elements of the work situation. This reduces the load imposed by pupillary readjustments and successive retinal adaptations and contributes to solving the lighting problem;
- improved contrast between characters and screen background;
- similarity to scotopic reading conditions and therefore greater visual comfort;
- fewer problems with screen reflection.

Positive contrast does however have one inconvenience: since the background luminance is higher than character luminance, flicker is perceived at rates lower than those that cause flicker perception in a negative-contrast screen.

In view of these considerations, the group favors the use of positive-contrast screens provided that the flicker problem is solved. But, because very few studies have been devoted to this technology, **the task force recommends that:**

R.20 Priority be given to studies evaluating the advantages of positive as opposed to negative contrast and which could serve as a guide for choosing technologies.

5.2.4 Technological choices with regard to display

A) General considerations

The legibility of the characters displayed on a screen is less than perfect, and we do not have enough scientific information about visual work on light-emitting objects.

Liquid crystal display offers the double advantage of being a light-reflecting object producing a positive-contrast display. This suggests that it might eliminate some of the oculovisual problems associated with conventional VDTs. But, as far as we know, such a system is not yet available, and the task force cannot predict whether the next few years will see widespread use of this or some other technology which will alleviate the problems associated with the use of current systems.

B) Recommendations

Given the advantages that a liquid crystal display seems to offer, **the task force recommends that:**

R.21 Efforts be made to explore the design and utilization possibilities of this type of system or of any other new technology offering similar advantages.

Appendix

Means of intervention recommended in the documents consulted

This section is divided into three parts. The first two parts summarize in table form the principal government standards and researchers' recommendations on the material environment and work organization of VDT operators. The question of periodic medical examinations is also dealt with. Our comments on these recommendations appear in the third part of this section.

1. Government recommendations

At the outset, it should be noted that:

1) The following recommendations serve as laws:

   — United States: Maine, since March 1981
   Massachusetts, since 1982
   Illinois, since February 1983

   — West Germany, since January 1981
   — Norway, since January 1982
   — Sweden, since January 1979

   } The original version of the texts was not available. The information was taken from *Newsletter* NBOSH 1978 (Sweden) ILO (Germany, Norway)

2) The Ontario recommendations (Bills 149 and 169) come from bills defeated in 1982.

3) The Saskatchewan recommendations are from a study by the provincial Department of Labour but do not constitute a law or bill.

Taking the recommendations as a whole, Sweden and Norway appear to be very flexible when it comes to such considerations as equipment characteristics, workstation dimensions, ambient lighting (although Sweden seems to attach great importance to this) and work organization (in terms of training, making information available to employees, rest periods). Medical examinations are less rigorous than those of the American states.

West Germany is flexible about work organization and ambient lighting. It is not very strict about medical examinations but is more specific about standards for workstation dimensions and equipment characteristics.

U.S. standards and Ontario's Bill 149 (the latter available in the original version) seem very flexible about ambient lighting and workstation dimensions but are much stricter when it comes to terminal maintenance (compulsory every 6 months), work organization and medical supervision.

The Saskatchewan recommendations are similar to the U.S. laws except for a few specific standards on presentation of information, workstation dimensions, work organization and pregnant operators.

Ontario's Bill 169 contained a great many requirements for work organization and medical supervision, which, in some instances, are difficult to apply (right to reassignment if employee has health problems that might have been caused by working on a VDT: see Article 8).

It should be noted that only Norway and Massachusetts have ruled on the duration of work and/or rest periods based on more specific work organization and task content.

Lastly, mention should be made of two regulatory French texts (Order-in-Council dated 1977-07-11, Circular dated 1980-04-29) which apply to medical evaluation of people working with VDTs.

The 1977 Order-in-Council includes work with VDTs in its list of jobs that call for special medical supervision (where employees work "regularly" at these jobs). The doctor must schedule one hour of his time each month for every ten employees.

The 1980 Circular defines this special medical supervision which, in addition to pre-hiring and annual medical check-ups, involves more frequent examinations, preventive measures and "observation" or "study" of work locations or stations.

The importance of setting specific standards (even if they are empirical) rather than adopting a more flexible attitude was discussed at a symposium on work with VDTs (Brown et al, 1982). It seems that the disagreements that arose over the need to make specific recommendations were due mainly to the researchers' perceptions of the objectives that regulations should pursue and the social means of intervention in their respective countries.

The following tables summarize the standards recommended, and sometimes adopted, in the countries, states and provinces mentioned above.

I. Environment
A) Room

	CANADA			
	ONTARIO *(Bill 149)*	**ONTARIO** *(Bill 169)*	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Windows				
2. Temperature			Adequate	
3. Humidity			Adequate	
4. Noise		No printer in the same room as a VDT unless it is equipped with an acoustical shield.		
5. Static electricity			As low as possible: controlled by adequate humidity, for example.	

I. Environment
B) Ambient lighting

	CANADA			
	ONTARIO *(Bill 149)*	**ONTARIO** *(Bill 169)*	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. General lighting a. quantitative			500 lux	
b. qualitative	Same as Maine	Same as Maine		Aim must be to reduce glare and reflection: • indirect general lighting • if lighting is direct or indirect add anti-reflective device
2. Individual lighting		Individual lighting that can be adjusted by the operator.	If work involves use of written documents: individual ligthing required.	
3. Reflection		Provide anti-reflective filters.	— Provide anti-reflective filter or coating on screen. — Use divided mask when a direct light source throws light on screen.	Anti-reflective filter on screen
4. Luminance-contrast a. Characters and screen background	Adjustable at screen	Adjustable at screen	Adjustable	Adjustable at screen

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
— Install drapes or blinds that can be closed completely — Place VDT so that operator does not face windows				No window within operator's field of vision
Adequate				
Adequate				
Minimum				
			As low as possible: all textiles and carpets must be given anti-static treatment	

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
				200-300 lux when work on VDT is continuous
Same as Maine	Same as Maine			
				When general lighting is dim, provide adjustable individual lighting and anti-reflective device
	Same as Maine			Reflection on screen to be avoided
	Adjustable by operator	Positive contrast suggested		Background luminance must be at appropriate level

I. Environment
B) Ambient lighting (cont'd)

	CANADA			
	ONTARIO *(Bill 149)*	**ONTARIO** *(Bill 169)*	**SASKATCHEWAN**	**MAINE (U.S.A.)**
b. screen and workstation elements			No highly reflective elements	
c. screen and room			Walls and ceilings must be mat	Reflection index ≤ 16 for room
5. Chromaticity		Color of characters must conform to regulations (established by the Lieutenant-Governor)		

I. Environment
C) Presentation of information

	CANADA			
	ONTARIO *(Bill 149)*	**ONTARIO** *(Bill 169)*	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Character size		Character size must conform to regulations (established by the Lieutenant-Governor)	— Character height: Min: 3 mm — Spacing: 1.5 × height	

I. Environment
D) Equipment characteristics

	CANADA			
	ONTARIO *(Bill 149)*	**ONTARIO** *(Bill 169)*	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Terminal a) Heat	Same as Maine	Same as Maine		No source of excessive heat (without centralizing duct, insulation) within a 4-foot radius of the operator
b) Maintenance	Every 6 months	Every 6 months		Every 6 months
2. Screen — flicker		Refresh rate must conform to regulations		

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
		Mat-surface desk		
		Screen lighting must be adequate relative to general lighting		No windows or light source within field of vision
		— Orange, yellow or green recommended — Red and blue to be avoided		

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
		— Character width and height defined by law — Screen must be large enough to allow for diffusion of large amounts of information at the same time — No geometric distorsion of characters — Uppercase used only when small amount of information to be transmitted or when emphasis to be place on portion of text	Image must be clear	

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
Avoid excessive heat coming from VDT	Same as Maine if the operator remains in this area for more than one hour			
— Often enough to keep the equipment in good working order — A file must be kept for each unit	Every 6 months		Annual inspection	
		No flicker		

I. Environment
D) Equipment characteristics (cont'd)

	CANADA			
	ONTARIO ***(Bill 149)***	**ONTARIO** ***(Bill 169)***	**SASKATCHEWAN**	**MAINE (U.S.A.)**
3. Keyboard		Mobile (not attached to screen)	— Mobile (not attached to screen) — Thin as possible	Mobile (not attached to screen)
4. Keys			Black or grey concave keys with legible white symbols	
5. Paper				
6. Radiation	None	— None, except visible light — Provide anti-radiation protection on VDT		

I. Environment
E) Dimensions of workstation

	CANADA			
	ONTARIO ***(Bill 149)***	**ONTARIO** ***(Bill 169)***	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Viewing distance			45-70 cm	
2. Viewing angle relative to the horizontal			20° (between 10° and 40°C)	
3. Position of screen a) tilt of screen				
b. height				
4. Keyboard			Wrist must not be bent	
5. Desk: a. height	Adjustable	Adjustable	Adjustable	Adjustable
b. width-length			Adequate depth	
6. Chair: a. seat (height)	Adjustable	Adjustable	Adjustable	Adjustable
b. backrest	Adjustable height and pressure	Adjustable height and pressure	— Adjustable height and pressure — Support at small of back only	Adjustable height and pressure
7. Document stand		Angle adjustable	Angle adjustable	
8. Footrest			Adjustable	

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
	Mobile (not attached to screen)	— Mobile (not attached to screen) — Maximum height (tickness): 3 cm — Tilt angle: 15°		
		— Clear contrast between screen and paper — No plastic-covered texts		

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
		— Screen legible at 50 cm — Provide for possibility of raising eyes 35°, lowering eyes 25° without moving head	Adapted so that head need not be bent over (45-70 cm)	Adjustable
10°		25° maximum	15°-20°	
Adjustable		Adjustable	If screen is tilted, check lighting arrangement	Adjustable
		Adjustable if VDT used by more than one operator		
— Height adjustable — Must be at elbow level				
Adjustable	Adjustable	— Adjustable — 72 cm recommended		
		— 120 cm depth (length) — 160 cm width		
Adjustable	Adjustable	— Adjustable — Leg-floor distance: 60 cm		
Must be adjustable to the small of back	Adjustable height and pressure			
		15°-17° angle		
		Recommended		

II. Work organization

	CANADA			
	ONTARIO ***(Bill 149)***	**ONTARIO** ***(Bill 169)***	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Rest periods	15 minutes / 2 hours	— 15 minutes / 2 hours — not to be taken near VDT	Same as Massachusetts	15 minutes / hour: scheduled at convenience of employee but work time must not exceed two consecutive hours
2. Duration of work on VDT (per day)		Maximum of 4 hours / day		
3. Employee training			Pre-job training	
4. Employee organizations		Formation of committee of two or more members (50% of whom employees) to analyze problems of work on VDTs		
5. Information	Same as Bill 169	— Allow employee to consult Bill 169 — Inform employees of risks associated with VDT use and of precautions to be taken		— Allow all employees to consult this law — Inform employees of risks associated with VDTs (visual acuity, ocular and musculoskeletal symptoms) — Inform employees of precautions to take to reduce these problems
6. Tasks				
7. Monitoring of employees		No performance measurement by computer		

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
— 15 minutes / 2 hours, if work is continuous and visual and workloads are moderate — 15 minutes / hour if the work is continuous and the visual load high and / or if the work is repetitive	Same as Maine		Short rest period every 2 hours	Arranged according to visual fatigue
			— For data-entry (transcription of texts), work on VDT: 50% of the day at most — The other half of the day to be devoted to tasks of a different nature	
			Training prior to any work on VDT	
Employees notified 6 months prior to introduction of VDT	Same as Maine	— Information on the various operations involved in the work — Information on ergonomic aspects in order to reduce constraint and fatigue	Complete information given before VDTs introduced	
Consideration by employer to ways of increasing motivation and reducing fragmentation				
Operator must be first to see results of performance measurement	Where performance is measured, employee is advised and given the results		Avoid measurement of performance as much as possible	

III. Medical examination

	CANADA			
	ONTARIO ***(Bill 149)***	**ONTARIO** ***(Bill 169)***	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Examination before starting work			Complete ophthalmological examination	Compulsory examination for all employees before or within 30 days of starting work
2. Periodic examination	Compulsory annual examination	— Compulsory every six months — Report to be given to employee		— Compulsory once a year — Cost of lenses to be met by employer

IV. Individual differences

	CANADA			
	ONTARIO ***(Bill 149)***	**ONTARIO** ***(Bill 169)***	**SASKATCHEWAN**	**MAINE (U.S.A.)**
1. Corrective lenses			Visual correction adapted to work	
2. Pregnancy		Employee whose pregnancy is confirm by a doctor's certificate can be reassigned without loss of wages or benefits	Pregnant employee can be relocated	
3. Physical aliments		If an employee shows symptoms or signs of problems that may be due to VDT use, he has the right to ask to be relocated without loss of wages or benefits		

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
Eye test before starting work	Ophthalmological examination compulsory before, or within 30 days of starting work	— Eye examination for every employee — If treatment required, employee referred to an ophthalmologist	Eye examination compulsory before starting work	
— Compulsory annual examination — Details of examinations appear in the law	Same as Maine	After the age of 45, compulsory examination every 3 years; up to age 45, examination every 5 years	Annual examination compulsory after age 45	

UNITED STATES		EUROPE		
MASSACHUSETTS (U.S.A.)	**ILLINOIS (U.S.A.)**	**WEST GERMANY**	**NORWAY**	**SWEDEN**
Employees who wear glasses must not work full-time on VDTs (no loss of wages or benefits involved)				— Bifocal glasses cannot be used — Visual correction adapted to work distance, and paid by employer

2. Recommendations by Scientists

The recommendations in the following tables come from non governmental associations (trade-unions or associations of scientists) and authors, and mainly apply to quantitative aspects of VDTs.

The many recommendations are rarely based on actual studies, and even more rarely are they warranted by the studies. (Justified recommendations are indicated by an asterisk (*) following the name of the author or association).

There are many differences in the quantitative recommendations for several variables, such as:

— Ambient lighting: general lighting, luminance of characters;

— Scheduling of rest periods: length and frequency of breaks;

— Medical evaluation: periodic examinations.

There is greater consensus, however, about workstation reflections, mobility and adjusting the equipment.

"Écrans cathodiques — guide d'aménagement des postes de travail" (CSST, 1982) was based largely on the recommendations of Cakir et al (1980) concerning ambient lighting, equipment characteristics and workstation dimensions. However, the recommendations on workstation dimensions (furniture, etc) proposed by those authors are based on European anthropometric data, which are not applicable here.

Furthermore, there is no consensus in Québec over work organization and medical evaluations.

N.B.: 1. Where the sources (column on right) propose different recommendations (column on left) in a given range, the recommendations of each source are presented in the same order as the sources. (See example below).

2. Where the authors are affiliated with an organization, its name (abbreviated) is given in parenthesis. The meaning of the abbreviations is given on page 65.

Environment	Recommendations	Sources
Luminance/contrast	Screen background luminance (range of the recommendations)	
a) character vs screen background	5-20 cd/m^2 (≤ 10 cd/m^2; ≥ 10 preferable 15-20 cd/m^2; 5-15 cd/mm^2	(V.T. conference; Elias (INRSS); (ECOTRA)

I. Environment	Recommendations	Sources
A. Room		
1. Window	— No window in front of or behind operator	Birnbaum (TUC C.I.), Pardon (OMS), (ECOTRA), (CTNIL), Stewart, (ASTMS).
	— Avoid placing operator in front of windows without drapes or blinds	Desnoyers (IRAT).
	— Position screen so that the line of sight is parallel to the windows	Elias (INRS), (ANACT).
	— Windows on only one side of room	(ANACT).
	— Use blinds or drapes that can be closed completely	(NIOSH), (ANACT), (SKANDIA).
2. Temperature	— 21 ± 1°C (average), 26-28°C in summer.	Cakir, (V.T. conference).
3. Humidity	— 50%	Cakir.
	— 60%-65%	(ANACT), (V.T. conference).
	— 65%-70%	APEX [Cited by J. Purdham]).
4. Noise	— ≤ 60 dBa	Pardon (OMS).
	— ≤ 65 dBa	(V.T. conference), (ANACT), (CTC).
5. Static electricity	— Use antistatic material or material treated for static (floor, carpets, furniture)	(ECOTRA), (ASTMS), Olson (The C.M.I.)*.

* Olson: recommendation justified based on study of work environment of workers with skin rashes.

Environment	Recommendations	Sources
B) Ambient lighting		
1. General lighting		
a. quantitative	— ≤ 150 lux (50 lux; 50-100 lux)	(TUB [cited by Rupp]); (DCIEM [cited by Rupp]
	— 150-300 lux (150-300 lux; 200-300 lux; ≤ 300 lux)	(ECOTRA); (ANACT), (ASTMS), Birnbaum (TUC C.I.), Elias (INRS).
	— 300-500 lux (300-400 lux; 300-450 lux; 300-500 lux)	Cail (INRS); (V.T. conference); Stewart, Cakir, (VDT [cited by Rupp]).
	— 300-500 lux (if negative contrast), 500 lux minimum (if positive contrast, 200 lux if screen is angled at 20°	(DIN [cited by Rupp]).
	— 500-750 lux (500-700 lux; 500-750 lux)	(NIOSH, (U. of L. [cited by Rupp]).
b. qualitative	— Place lamps parallel to windows and in direction of operator's line of sight (if direct or semi-direct lighting)	(CTNIL), (ECOTRA).
	— If lighting is mainly direct, mask every glare source with diffusers or filters	(CTNIL), (ANACT), Cakir, Desnoyers (IRAT).
	— Give preference to indirect lighting	(CTNIL), (ECOTRA).
	— Lighting should be uniform in the entire visual field	Elias (INRS).
2. Individual lighting		
a. quantitative	— 500 lux	Birnbaum (TUC C.I.), Elias (INRS).
b. qualitative	— Must be adjustable by operator	(NIOSH), (CTNIL), (ECOTRA), (CTC), Desnoyers (IRAT).
	— Use direct lighting and/or anti-reflection device	(NIOSH), (ECOTRA).
3. Relative lighting values	— Equal for floor and workstation, walls: 0.5 to 0.8 of workstation lighting level, ceiling: 0.3 to 0.9 of workstation lighting level	Cakir.
	— Comfortable level for workers	Desnoyers (IRAT).
4. Reflection		
a. reflection factors	— Avoid placing operator facing windows without drapes or blinds, facing shiny objects or annoying lamps	Desnoyers (IRAT).
	— Floor: 0.2-0.4 (0.2-0.3; 0.2-0.4)	Cakir; (ANACT).
	— Wall: 0.3-0.8 (0.4 [if direct lighting], 0.6 [if indirect lighting]; 0.3-0.8)	(ANACT); Cakir.
	— Ceiling: 0.6 to 0.9 (0.6; 0.8 to 0.9)	Cakir; (ANACT).
	— Work surface: 0.4	(TUB [cited by Rupp]).
	— Keyboard: 0.15 to 0.7 (0.15-0.7; 0.4-0.5)	(TUB [cited by Rupp]); (DIN [cited by Rupp]).
	— Keys: 0.2 to 0.7	(DIN [cited by Rupp]).
b. reflection index	— 16 preferable, 19 accepted.	Ostberg (IES).
c. work surface	— Avoid shiny coverings or paint.	Elias (INRS), (ECOTRA), Desnoyers (IRAT).

d. screen	— Screen must be mat and have an anti-reflection filter.	(ECOTRA); Elias (INRS), (NIOSH), Stewart, (DCIEM [cited by Rupp]).
	— Anti-reflection technique must include: diffusing surface, micromesh filter, ultrathin antireflection film, aerosol, divided mask, polarizing filter.	(TUB [cited by Rupp]), (VDT [cited by Rupp]).
	— Add side and top anti-reflection hoods	(V.T. conference).
	— Use anti-reflection treatments or filters if workstation rearrangement does not eliminate reflection (in descending order of preference: thin quarter-wavelength films, dulling of surface, treated nylon polarized filter).	Desnoyers (IRAT).
5. Luminance contrast		
a. character vs screen background — qualitative	— Must be operator-adjustable and have a control independent of luminance contrast	(ECOTRA), Pardon (OMS), Elias (INRS), (NIOSH), (ASTMS), Desnoyers (IRAT).
	— Positive contrast	(TUB [cited by Rupp]), Elias (INRS), Cakir, Santucci, Radl, Desnoyers (IRAT).
— quantitative	— Screen background luminance: 5-20 cd/m^2 (≤ 10 cd/m^2; ≥ 10 cd/m^2 preferable 15-20 cd/m^2; 5-15 cd/m^2).	(V.T. conference); Elias (INRS); (ECOTRA).
	— Character luminance: 20-100 cd/m^2 (20-60 cd/m^2; 85 cd/m^2; 45-100 cd/m^2)	(ANACT); (DCIEM [cited by Rupp]); Elias (INRS), Stewart.
	80-160 cd/m^2 (75-150 cd/m^2; 80-160 cd/m^2)	(ASTMS); (VDT [cited by Rupp]),
	50-400 cd/m^2, but the ideal is between 100-200 cd/m^2	(V.T. conference).
	— If two luminances are used: maximum difference between the two must be from 1 to 2 cd/m^2.	(ANACT).
	— Luminance ratio between the two surfaces: 3:1 to 5:1 (3:1; 3:1 min; 4:1 min; 3:1 to 5:1)	Elias (INRS), Stewart, Cakir; (TUB [cited by Rupp]); (DIN [cited by Rupp]); (V.T. conference).
	— Luminance ratio: 6:1 to 20:1 (6:1 to 10:1, 15:1 max; 8:1 to 10:1; 15:1; 20:1).	(DIN [cited by Rupp]); VDT [cited by Rupp]; Snyder, Maddox; Gould.
b. screen vs workstation elements	— Avoid shiny coatings; surfaces must be mat.	Elias (INRS); (ECOTRA).
c. screen vs room		
— qualitative	— Avoid shiny coatings or paint	(ECOTRA)
— quantitative	— Luminance ratio: 1:3:10	Stewart, Cakir, Elias (INRS).
6. Chromaticity: color of characters	— Yellow — Yellow-green	Haider (I.E.H.A.)*, Taylor [cited by Birnbaum], Elias (INRS), Cakir, (V.T. conference), (ANACT), (ASTMS).
	— Yellow-green (symbols and screen background must be the same color but of different intensities)	(TUB [cited by Rupp]).
	— Green to orange	(DIN [cited by Rupp]).
	— Personal preference	(VDT [cited by Rupp]).
	— Avoid red	(GREV [cited by Rupp]), (ASTMS).

* Haider: recommendation justified on the basis of performance standards.

I. Environment	Recommendations	Sources
C. Presentation of information		
1. Presentation of information	— Long texts: use upper & lower case	(V.T. conferennce)
	— Short texts: use upper & lower case	(V.T. conference)
	— Do not use screen extremities	(ASTMS).
	— Number of characters/line: 20-80;	(ANACT), (ECOTRA), Desnoyers (IRAT).
	— Number of lines: 6-80; 25-30 maximum	(ANACT), (ECOTRA), Desnoyers (IRAT).
	— Very clear characters	Desnoyers (IRAT).
2. Characters		
a. character height based on viewing distance (diameter in minutes)	— Best possible definition	(CTNIL).
	— 16′-20′	Stewart, Grandjean (I.F.T.), (TUB [cited by Rupp]), (VDT [cited by Rupp]), (DIN [cited by Rupp]).
	— from 50 cm: 16′-20′ (16′-20′; 18′ minimum; 20′ minimum)	Cakir, (DIN [cited by Rupp]); (ECOTRA).
	— from 70 cm: 15′-20′ maximum 22′	Cakir.
b. height (mm)	— 3.1 mm to 4.2 mm (3.1 to 4.2 mm; 3.3 to 4.1 mm; 4 mm)	Stewart, (VDT [cited by Rupp]), Cakir, (ANACT); (ASTMS); Grandjean (I.F.T.); Desnoyers (IRAT).
	— 4 to 5 mm	(V.T. conference).
	— For distance of 50 mm: 2.3 to 2.9 mm (2.6; 2.3 to 2.9)	Grandjean (I.F.T.); (DIN [cited by Rupp]).
	— For distance of 70 cm: 3.1 to 4.2 mm	(U. of L. [cited by Rupp], Grandjean (I.F.T.).
	— 4.5 mm maximum	(ASTMS).
c. width	— 2-3 mm	(V.T. conference).
	— 50% to 75% character height	Fellman (I.F.T.), Bouma.
	— 75% to 80% character height	Laubli (I.F.T.), (ASTMS), (ECOTRA), Desnoyers (IRAT).
	— 65% to 100% character height	Wisner [cited by Pardon].
d. line width	— 12% to 17% of character	Stewart, (ANACT), (ASTMS).
e. space between two characters	— 20% to 50% character height (> 10%; 20-50%)	Stewart, (VDT [cited by Rupp]); (DIN [cited by Rupp]).
	— 50% character height	(ANACT), (ECOTRA), (V.T. conference), Desnoyers (IRAT).
	— 15% to 20% character width	Bruton.
	— 50% character width	(TUB [cited by Rupp], (U. of L. [cited by Rupp]).
f. space between two words	— 66% character height	Wisner.
g. space between two lines	— 50% to 100% character height	(V.T. conference).
	— 100% character height	(U. of L. [cited by Rupp]), (ANACT), (ECOTRA); Desnoyers (IRAT).
	— 100%-150% character height	(VDT [cited by Rupp]), Stewart, Grandjean (I.F.T.).
3. Matrix	— 5 × 7 minimum	(DIN [cited by Rupp], (DCIEM [cited by Rupp]).
	— 7 × 9 preferable	(VDT [cited by Rupp], Desnoyers (IRAT).

I. Environment	Recommendations	Sources
D. Equipment characteristics		
1. Terminal: maintenance:	— Periodic check	(ASTMS), (ECOTRA).
	— Check every 3 months	(CTC).
2. Screen		
a. persistence-refresh rate	— 35 Hz if persistence high.	(ANACT).
	— 50 Hz if persistence average	Stewart, Elias (INRS), Birnbaum (TUC C.I.).
	— 50 Hz if persistence average or low	Cakir.
	— ⩾ 50 Hz	(ANACT), (ASTMS), (TUB [cited by Rupp]),
	— 50-60 Hz if persistence average	(DIN [cited by Rupp]) (U. of L. [cited by Rupp]), (ANACT).
	— At least 60 Hz if persistence rather weak	Desnoyers (IRAT).
b. color of console	— Grey	(ECOTRA).
3. Keyboard		
a. mobility	— Mobile (not attached to screen)	(ASTMS), (ECOTRA), (NIOSH), Elias (INRS), Pardon (OMS), Desnoyers (IRAT).
b. type	— QWERTY type	Cakir, (ASTMS).
	alphabetic keyboard	(V.T. conference).
	— AZERTY type	(V.T. conference), VDT [cited by Rupp]).
	— Telephonic type	
	numerical keyboard	Tisserand, (TUB [cited by Rupp]).
	— Calculator type	
c. shape	— Slightly concave at top	(V.T. conference).
d. height	— ⩽ 30 mm from top of desk	(DIN [cited by Rupp]).
	— 30-50 mm of height between start and center keys	Grandjean (I.F.T.), (VDT [cited by Rupp]), (ECOTRA).
	— 40-70 mm	Tisserand (INRS).
e. depth	— 400 mm between desk edge and back row of keys	Cakir.
f. width	— 420 mm maximum	(V.T. conference).
g. tilt	— ⩽ 5°	(TUB [cited by Rupp]).
	— 5°-15° (7°-9°, 8°-13°, 5°-15°)	(V.T. conference); (ANACT); Grandjean (I.F.T.), (VDT [cited by Rupp]).
h. color	— Avoid black	Stewart.
4. Keys		
a. shape	— Concave	(V.T. conference).
b. color	— Neutral, light with dark letters and numbers. Groups of keys with different functions must be in different colors.	(V.T. conference), Stewart.
	— Mat surface	Pardon (OMS), Elias (INRS), Stewart, (V.T. conference), Cakir.
c. size	— If square: 12-55 mm each side (13 mm; 12 to 15 mm)	(TUB [cited by Rupp]); (VDT [cited by Rupp]), (V.T. conference), (ANACT).
	— If round: 12.7 mm	V.T. conference).

d. distance between two keys	— Between the two centers:	
	16-19 mm	(ASTMS).
	18-20 mm	(VDT [cited by Rupp]), Stewart, (V.T.
	(18-20 mm; 20 mm)	conference); (TUB [cited by Rupp]).
	— Between the two edges of two keys: 3-6 mm	(ASTMS), (ANACT).
e. distance between two rows	— 1-4 mm	(ANACT).
f. displacement	— 0.8 to 4.8 mm (0.8 to 4.8 mm); 1-4 mm; 4 mm)	(VDT [cited by Rupp]), Stewart, (ASTMS), (V.T. conference).
	— 3 to 6 mm	Grandjean (I.F.T.)
	— 5 to 8 mm	(TUB [cited by Rupp]).
g. force	— 25 to 150 g	(V.T. conference), (ANACT).
	— 0.25 to 1.5 N	(TUB [cited by Rupp], (VDT [cited by Rupp]), Cakir.
	— 0.8 to 4.8 N	Stewart.
5. Documents	— Legible, colored paper and light ink to be avoided	(ECOTRA).
	— Must be non-reflecting	Elias (INRS).
6. Work surface	— For manual transcription of data: place sheets on an adjustable tilted surface.	Desnoyers (IRAT).
7. Radiation	— No radiation (x-ray)	(ASTMS).
	— 1 mw/cm^2 (microwave)	(ASTMS).

I. Environment	**Recommendations**	**Sources**
E. Dimensions of workstation		
1. Workstation	— Must be completely adjustable	(NIOSH), (CTC).
2. Viewing distance from screen	— 400-500 mm (450-500 mm; 500 mm if document or keyboard used)	(NIOSH); (TUB [cited by Rupp]), (DIN [cited by Rupp]).
	— 400-800 mm (400-600 mm; 400-600 mm, 700 maximum, 400-800 mm; 500-700 mm, 700 mm maximum; about 700 mm)	(CTNIL); Desnoyers (IRAT); Hunting (I.F.T.)*; (DIN [cited by Rupp]); (VDIT [cited by Rupp]); (VDT [cited by Rupp]), Cakir, (ASTMS).
	— Eye height: 1000 mm-1150 mm (= 1 m-1 m 15)	Stewart, Cakir.
3. Visual angle relative to the horizontal	— 10°-20° (10°-15°; 10°-20°; 15°-20°; 20°)	Cole (U.M.); (ANACT); (DCIEM [cited by Rupp]); (TUB [cited by Rupp]).
	10°-20°, with upper edge of screen no higher than eyes, and lower edge ≤ 40° from level of eyes	(NIOSH).
	— 15°-30° (15°-30°; 20°-30°)	(V.T. conference), (CTNIL); Elias (INRS).
	— 30°-45°	Stewart.
4. Position of screen		
a. tilt	— Adjustable	(NIOSH), Stewart, (DIN [cited by Rupp]), (ECOTRA), Desnoyers (IRAT).
	— Screen must be rotatable	Elias (INRS), (ANACT), (ECOTRA).
	— 5° forward; 20° backward	(DIN [cited by Rupp]).
	— 10°-30° backward	(ECOTRA).
	— Must be vertical if not adjustable	(TUB [cited by Rupp]), (DIN [cited by Rupp]).
	— To be at right angles to operator's visual angle	Cakir, Stewart.
	— Slightly backward	Desnoyers (IRAT).

* Hunting: recommendation justified on the basis of the incidence of physical signs and symptoms (manual palpation, examination of tendons and joints) as a function of dimensions of workstation.

b. height	— Adjustable	(NIOSH), (ECOTRA), Desnoyers (IRAT). (DIN [cited by Rupp]).
	— Upper edge should be 370-520 mm above work surface	Pardon (OMS).
	— Height from base of screen: 740 mm	Desnoyers (IRAT).
	— Top of screen below height of eyes	Desnoyers (IRAT).
	— On desks whose height can be adjusted	
5. Keyboard		
a. height	— 700 mm	Elias (INRS).
	— Center row of keys: 720-750 mm	Cakir, Stewart.
	— 740-750 mm	(NIOSH).
	— ≤ 750 mm	(TUB [cited by Rupp]).
b. distance from operator (depth)	— Start of keyboard 60 mm from front edge of desk	Cakir.
	— Back row of keys 600 mm from front edge	Cakir.
c. position	— With data entry, slightly to the right of operator	Grandjean (I.F.T.)
6. Desk		
a. height	— 720 mm if fixed	(TUB [cited by Rupp], (DIN [cited by Rupp]).
	— 650 mm-750 mm if adjustable (650 mm-750 mm); 720-750 mm	(TUB [cited by Rupp]), (DIN [cited by Rupp]).
	— Clerical work: 750 mm	(V.T. conference).
	— Keyboard work: 650-690 mm (650; 650-690 mm)	(V.T. conference); Pardon (OMS).
	— Take keyboard height and desk thickness into account	Tisserand (INRS).
	— Easily adjustable for height	Tisserand (INRS).
b. width	— 800-1200 mm with space provided for support of forearms, hands.	Hunting (I.F.T.)*, (ANACT).
	— 1500-2000 mm	(ECOTRA).
	— 1200-1600 mm	DIN [cited by Rupp]).
c. depth	— 1000-1500 mm, 800 mm under desk	(ECOTRA).
7. Chair		
a. Seat	— Upholdstered	Desnoyers (IRAT).
— height	— Adjustable	Cakir, Elias (INRS), Stewart, Tisserand (INRS), (NIOSH), (ASTMS), (SKANDIA), Desnoyers (IRAT).
	— 400 mm-550 mm (400 mm; 400-500 mm; 429-550 mm; 450-520 mm)	Elias (INRS); (V.T. conference); Grandjean (I.F.T.), (ECOTRA); Cakir.
	— If desk height fixed: 420-500 mm	Tisserand (INRS).
	— If height adjustable: 350-500 mm	
— depth	— 350-450 mm (400 mm; 350-450 mm)	(ANACT), Tisserand; (V.T. conference).
— width	— 380-400 mm (380 mm-400 mm; 400 mm)	Tisserand (INRS); (ANACT).
— base	— Firm base (5 legs)	Tisserand (INRS), Elias, Stewart, (V.T. conference).
b. Backrest	— Adjustable for tilt and height	Cakir, (ECOTRA), Hunting (I.F.T.)*, (V.T. conference).
	— Sufficiently wide, easily adjustable, forward or backward	Desnoyers (IRAT).

* Hunting: recommendations justified on the basis of the incidence of physical signs and symptoms (manual palpation, examination of tendons and joints) as a function of dimensions of workstation.

— height	— 100-300 mm (100-300 mm; 200-250 mm)	(V.T. conference); Tisserand (INRS).
	— 480-500 mm	(ECOTRA), Grandjean (IFT).
— width	— 280-320 mm	Tisserand (INRS).
— tilt	— Adjustable	Hunting (I.F.T.)*, Tisserand (INRS), Elias (INRS).
	— 2° forward, 15° backward	Tisserand (INRS), (ECOTRA).
	— Curved inward at top, curved outward at lumbar area	Elias (INRS).
8. Document-stand	— Provided at all workstations	Stewart, (ASTMS).
a. position	— Slightly to left	Grandjean (I.F.T.)
	— Never above screen	(ANACT).
	— Positioned so that documents are at screen height	(ASTMS), Desnoyers (IRAT).
	— Viewing distance: 450-500 mm; same as for screen	Cakir, Desnoyers (IRAT).
b. tilt	—In relation ot the horizontal: 30°-70° (30°-70°; 45°; 70°)	(ECOTRA); Stewart; Cakir.
	— Same as for screen	Desnoyers (IRAT).
9. Footrest	— Stationary and adjustable for height and tilt	(ANACT), (CTNIL), Cakir, (ASTMS).
	— Adjustable for height of tilt	Desnoyers (IRAT).
	— Provided for all workstations	Elias (INRS).
a. height	— Adjustable 0-50 mm	Cakir.
	40-150 mm	Tisserand (INRS).
b. width-depth	— 400 mm; 300 mm minimum	Tisserand (INRS).
c. tilt	— 10°-30° (10°-15°; 0° to 30°)	Cakir; Tisserand (INRS).
10. Work surface		
a. work level	— 220-250 mm	Cakir, Elias (INRS), Stewart.
b. height of clearance space for lower limbs	— 650-690 mm (650-690 mm; 690 mm)	Cakir, (DIN [cited by Rupp]); (TUB [cited by Rupp]).
c. width of clearance space for lower limbs	— For knees: 450 mm	Tisserand (INRS).
	— For feet: 700 mm	
d. Angulation	— Trunk-axis angle relative to head-neck axis ≤ 20°	Grandjean (I.F.T.).
	— Elbow angle: 80°-100° (80°-100°; ≥ 90°)	Grandjean (I.F.T.); (ECOTRA), Cakir.
	— Wrist-hand angle: 0°	Cakir, Grandjean (I.F.T.).
	— Thigh-leg angle: ≥ 90° (≥ 90°; 95°)	Cakir, (ECOTRA); Tisserand (INRS).
	— Femur-trunk angle: 100°-105°	Tisserand (INRS).

* Hunting: recommendation justified on the basis of the incidence of physical signs and symptoms (manual palpation, examination of tendon and joints) in relation to dimensions of workstation.

II. Work organization	**Recommendations**	**Sources**
1. Introduction of VDTs	— Provide for trial period of a few months. Reject VDTs that cause health problems during trial period	Desnoyers (IRAT).
2. Rest periods	— Hourly: 10 min/50 min; 5 min/55 min; 10 min/h; 15 min/h	(I.W.C.); (M.B.B.), (W.G.T.U.C.); (S.G.W.U.), (H.A.U.); (C.F.D.T. [cited by Pérusse]), (CTC).
	— Every two hours: 15 min/1h30 min; 15 min/1h45 min; 15 min/2h; 15-20 min/2h; 20 min/2h; 30 min/2h; variable after 2 hours of work; no more than 2½ hours of work	(ECOTRA); (M.B.B.); (A.T.U.); Rosenbaum (H.A.U.); Bose [cited by Rey, Gilet [cited by Pérusse]; Green [cited by Pérusse].
	— At least 15 min/1h30 min	Desnoyers (IRAT).
	— At discretion of operators	(IRACT).
	— Before symptoms are felt, about 5%-10% of total working time	Cakir.
3. Rest periods based on work	— Heavy visual demand (data entry: 10 min/50 min; 15/60 min)	(M.T.A.S.); (NIOSH).
	— Dialogue (interactive communication): 10/80 min	(M.T.A.S.).
	— Monotonous task 10/1h40 min	(V.T. conference).
	— Moderate visual demands: 15 min/2h	(NIOSH).
	— More enriched tasks: 10-20 min/2h	(V.T. conference).
	— Take rest periods away from workstation	(ASTMS).
4. Duration of work on screen	— 1h/2h of work	(A.T.U.).
	— 2h/4h	Ostberg [cited by C.L.S.C.C.V.].
	— 4 consecutive hours per day	(W.G.T.U.C.), (ASTMS), (ECOTRA), (CTC).
	— 4½ hours per day	(V.T. conference), Bélanger, Bose [cited by Pérusse].
	— No more than 7 hours per day	Green [cited by Arnaud].
	— Alternation between work and office work	(V.T. conference).
	— Less than half the normal working day	Desnoyers (IRAT).
5. Training-information	— Inform employees six months prior to introduction of VDTs	(ASTMS).
	— Prepare workers before introduction of VDTs	Gilet, Elias (INRS), Pardon (OMS), Rosenbaum (HAU).
	— Continue training after introduction of VDTs	Rosenbaum (HAU), Pardon (OMS).
6. Work organization	— Character presentation speed: 10-15/s. If greater memory or understanding required; 10/s.	Bevan*. Hunting (IFT)*, Elias (INRS)*.
	— Reduce repetitiveness of tasks	(CTC).
	— No electronic monitoring of work	

* Bevan: recommendation justified based on comparative analysis of symptoms felt by employees with or without visual problems.

* Hunting: recommendation justified based on results of subjective questionnaire concerning work satisfaction (office workers compared with VDT users)

* Elias: recommendation justified based on evaluation of visual function, posture and psychosomatic problems for two types of tasks.

III. Medical evaluation	**Recommendations**	**Sources**
1. Pre-hiring examination	— Complete oculo-visual examination before VDT system introduced, then a few months later, followed by annual examinations	Desnoyers (IRAT).
	— Examination of every employee (optician)	(ASTMS), (V.T. conference), Anderson.
	— Examination of every employee (ophthalmologist)	(CTNIL); Dubé, Gilet, Grall* (CTC).
2. Periodic examination	— Every six months (optometrist)	Crépeau.
	— Annual and more frequently if symptoms present	(CTC).
	— Annual: refraction, accommodation, visual acuity	(NIOSH), (MBB).
	— Annual: if heavy visual strain	(ASTMS), (ECOTRA).
	— Annual: if over 40	(ASTMS).
	— Annual: employees who wear glasses	Anderson.
	— Every two years: by an ophthalmologist	Dubé.
	— If complaints.	Anderson.
3. Tests	— Visual acuity without correction, refraction, corrected visual acuity, accommodation, neutralization, muscular balance at a distance, at one metre, close	(VET [cited by Cakir]).
	— Carry out specific tests adapted to the work: refraction rate, visual acuity, accommodation, visual function, examination of cornea and crystalline lens	(ECOTRA), Elias (INRS), (NIOSH).
	— Measure diopter and field of vision	(NIOSH).

IV. Individual differences	**Recommendations**	**Sources**
1. Epileptics	— No work with VDTs	Anderson.
	— No work with VDTs without pre-hiring examination	(ASTMS).
	— No work with VDTs in the case of photosensitive epileptics	(ASTMS).
2. Migraine sufferers	— Follow-up at close intervals, any increase in migraines must be reported to the doctor	(ASTMS).
	— No work with VDT	Anderson.
3. Wearers of bifocal lenses	— No work with VDT	Ostberg [cited by Birnbaum].
	— Adapt lenses	(V.T. conference).
4. Far-sighted people	— Adapt glasses to suit eye-screen distance	(V.T. conference).
	— Provide suitable glasses for VDT use	Desnoyers (IRAT).
5. Persons over 45 or under doctor's care	— Follow advice of doctor	Anderson.
6. Persons with nystagmus	— No work on VDT.	Anderson.

* Grall: recommendation justified based on comparative analysis of symptoms felt by employees with or without visual problems.

Organizations and associations cited

1. A.N.A.C.T.: Agence nationale pour l'amélioration des conditions de travail (France).
2. A.S.T.M.S.: Association of Scientific, Technical and Managerial Staff (England).
3. A.T.U.: Austrian Trade Union (Austria).
4. C.F.D.T.: Confédération française démocratique du travail.
5. C.L.S.C.C.V.: Centre local de services communautaires du centre-ville.
6. C.M.I.: Christian Michelson Institute Department of Science and Technology (Norway).
7. V.T. conference Colloque vision travail (France), Bureau international du travail.
8. C.T.C.: Congrès du travail du Canada. (Canadian Labour Congress)
9. C.T.N.I.L.: Comité technique national des unités du livre (France).
10. D.C.I.E.M.: Defense and Civil Institute of Environmental Medicine (Canada).
11. D.I.N.: Deutsche Industrie Norm. (Germany).
12. E.C.O.T.R.A.: Centre d'études des problèmes d'écologie du travail; Unité de médecine du travail et d'ergonomie (Switzerland).
13. G.R.E.V.: Groupe de recherche sur les écrans de visualisation (France).
14. H.A.U.: Health Advocacy Unit; Department of Public Health (Canada).
15. I.E.H.A.: Institute of Environmental Hygiene (Austria).
16. I.E.S.: Illuminating Engineering Society (Germany).
17. I.F.T.: Institut fédéral de technologie (Switzerland).
18. I.N.R.S.: Institut national de recherche scientifique (France).
19. I.R.A.C.T.: Institut de recherche pour l'amélioration des conditions de travail (France).
20. I.R.A.T.: Institut de recherche appliquée sur le travail (Québec).
21. I.W.C.: Industrial Welfare Commission (California).
22. M.B.B.: Messerschmitt-Boelkow-Blohm (West German aviation company).
23. "M.T.A.S.": Department of labor and social affairs (Germany).
24. N.I.O.S.H.: National Institute for Occupational Safety and Health (U.S.A.).
25. O.M.S.: World Health Organization.
26. SKANDIA: Swedish insurance company.
27. S.G.W.U.: Swedish Graphics Workers Union.
28. T.U.B.: Technical University (Berlin).
29. T.U.C.C.I.: TUC Centenary Institute of Occupational Health (England).
30. U. of L.: University of London (England).
31. U.M.: University of Melbourne (Australia).
32. V.D.T.: Visual Display Terminals (the VDT manual) (Germany).
33. V.E.T.: VDT Eye Test Advisory Group (England).
34. W.G.T.U.C.: Western Germany Trade Union Confederation (England).

3. Critical review of the recommendations

As described in this report, discomfort or health problems in VDT operators can be linked to an interaction between different environmental variables (intensity and placement of light sources, for example, which interact with the texture and color of the walls of the room, the VDT and the workstation furniture) and to an incompatibility between the characteristics of the workstation and of the tasks performed by the operators.

Consequently, any recommendation concerning the majority of environmental features, particularly those of the workstation, must take into account all the elements mentioned above.

But the fragmented nature of the recommendations formulated by government bodies and researchers and the absence of clear statements about other factors that must be taken into account when a recommended means of intervention is implemented limits the effectiveness of the preventive measures.

Moreover, no weight has been given to the relative importance of each means of intervention.

Despite these drawbacks, we have tried to provide a succinct assessment of the principal recommendations in the tables contained in this chapter. It should be mentioned that most of the recommendations relate to the use of negative-contrast screens and must therefore be revised if positive-contrast screens come into general use. This confirms the importance of establishing the technological choices a priori.

A) Room and ambient lighting

The recommendations on room environment and lighting apply to office work in general (except where they concern the elimination of static electricity). There is a greater need to implement these means of intervention where the work involves VDT use, since the reflection and lighting problems are even more acute.

As for the lighting near VDTs, levels below those for conventional offices are generally favored but the recommendations vary from country to country and are as unsystematic as the overall standards on lighting.

We prefer not to rule on this factor since it also depends on the characteristics of the screen work, the importance of the other tasks and screen design.

As for individual lighting, it should be adjustable. There are few adjustable lamps on the market although this feature would pose no problems from the manufacturing standpoint.

B) Luminance and contrast

The recommended luminance and contrast values are quite varied and are based on few studies. Since optimal values depend on a number of environmental factors, such as general lighting and character size, equipment must be designed so that it can be adjusted by the operator.

C) Chromaticity

The recommendations on chromaticity are based on a limited number of studies, and there is insufficient evidence to justify any particular color choice.

D) Equipment characteristics

1) Screen

Recent research shows that flicker is perceptible at 60 Hz. Current recommendations are based on the characteristics of the power distribution system (50 Hz a.c. in Europe and 60 Hz a.c. in North America). It would be advisable to conduct a feasibility study on the utilization of equipment that operates at higher frequencies.

2) Filters

The main function of filters is to reduce reflection. They are also used to eliminate low wavelengths and permit the emission of a single color. Most filters reduce screen luminance and thereby aggravate the frequent problem of insufficent contrast. Furthermore, filters quickly become dirty. An evaluation of these specific aspects would help define the best choice of filters even though they should not be considered an ideal solution to the problem.

3) Keyboard

The only recommendation relating specifically to VDTs states that the keyboard must be movable. This is an important recommendation and merits adoption.

E) Workstation

1) Eye-task distance

This varies with the characteristics of the furniture, the VDT, the tasks performed, etc. It seems that the most frequently observed distance is 500 mm but few studies have specifically measured this distance. In this case, an observation has become a recommendation!

2) Position of screen

The tilt of the screen is an important variable since it determines the angle of the head and the viewing angle, which in turn affect the operator's posture and the trunk-thigh angle.

A trunk-thigh angle greater than 90° is preferable since it reduces pressure on the spinal discs. This position is rarely observed for it is often incompatible with other aspects of the task (reading of printed texts placed on a horizontal surface, for example). Here, the screen presents one advantage that can be put to use, and in this case, an upright screen is preferable.

However, when the angle is equal to or less than 90°, a screen with a slight backward tilt may be more comfortable.

Finally, what is most important is that screens be adjustable for height and tilt and that they can be rotated.

3) Desk and chair

Little information is available on the anthropometric characteristics of workers, particularly of female Québec workers. We therefore cannot define the best dimensions for VDT workstations. Equipment that can be adjusted for size partially compensates for the lack of precise dimensions.

The recommendations on furniture, and chairs in particular, are essentially the same as those for conventional office workstations. The VDT operator's station allows for a wider trunk-thigh angle and more frequent use of the backrest because of a higher visual axis. This is an advantage since the wider this angle, the lower the pressure on the discs. For conventional workstations, the possibility of widening this angle is limited by the need to maintain the head in line with the chest in order to minimize fatigue in the neck muscles. This axis is determined by the characteristics of the visual task. Therefore, from the point of view of posture, the VDT operator's station may have the advantage. This is why Grandjean recommends a high backrest. This would be a useful feature since operators often complain of pain in the cervical area. We think this recommendation is valid and merits consideration.

Backrests are, however, usually fixed and do not allow for adjustment for support of the small of the back. More detailed studies are needed on this aspect, especially since there is a tendency to generalize recommendations intended for stations with different characteristics from those built for VDTs.

Lastly, a surface should be provided on which the forearms can be rested.

4) Document stand

This is an important element since it helps to prevent postural and visual problems resulting from alternation between horizontal and vertical surfaces.

5) Footrests

This element is recommended for both VDT and conventional office tasks.

Bibliography

1. ABENHAIM, L.L. and DAB, W. *Recherche et prévention en santé et en sécurité du travail. Développement d'un modèle basé sur des algorithmes décisionnels.* Montreal, IRSST, 1983, 38 p. ("Notes et rapports scientifiques et techniques" Collection), E-004.
2. AGENCE NATIONALE POUR L'AMÉLIORATION DES CONDITIONS DE TRAVAIL. *Terminaux à écran cathodique: fiches documentaires.* France, A.N.A.C.T., 1981, 12 p.
3. AGENCE NATIONALE POUR L'AMÉLIORATION DES CONDITIONS DE TRAVAIL. *Informatique et travail de bureau: que devient l'employé?* France, A.N.A.C.T., 1982, 62 p. ("Expériences et réalisations" Collection).
4. ARNAUD, B. et al. "Écran cathodique et tâche visuelle. Étude à propos de 243 observations", *Bulletins et mémoires. Société française d'ophtalmologie,* Vol. 93, (1982), pp. 397-400.
5. ARTIOLA, I.; FORTUNY, L. and HIORNS, R.W. "Recovery curves in a visual search task", *International Rehabilitation Medicine,* Vol. 1, No. 4, (1979), pp. 177-181.
6. ASSOCIATION OF SCIENTIFIC, TECHNICAL AND MANAGERIAL STAFF. *Guide to Health Hazards of Visual Display Units,* policy document, London, A.S.T.M.S., 1980, 29 p.
7. AUNASSON, E. *À propos de la fatigue au poste de terminal d'ordinateur.* Doctoral thesis in medicine, Faculté de Kremlin-Bicêtre, 1976.
8. BAGNARA, S. "Error detection at visual display units", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 143-146.
9. BAINBRIDGE, L. "Problems in the assessment of mental load", *Le travail humain,* Vol. 37, No. 2, (1974), pp. 279-302.
10. BAUER, D. and CAVONIUS, C.R. "Improving the legibility of visual display units through contrast reversal", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 137-142.
11. BEAULIEU, E. *An Act to Provide Occupational Safeguards for Operators of Video Display Terminals.* Legislative Document 1049, State of Maine, House of Representatives, 1981.
12. BÉLANGER, S. and BELLEMARRE, M. *Le travail de bureau incluant le travail devant l'écran cathodique et ses conséquences sur la santé des travailleuses,* report presented to the Ministère des Affaires sociales, Québec, 1982, 71 p.
13. BENSAID-SINGERY, J. and SINGERY, J. "Les incidences de l'information sur l'évolution du travail administratif", *Le travail humain,* Vol. 42, No. 2, (1979), pp. 193-200.
14. BEREST, N.; GILBERT, A.P. and PERDRIEL, G. "Prévention de la fatigue visuelle chez les lecteurs de scope radar", *Médecine aéronautique,* Vol. 11, No. 4, (1956), pp. 403-412.
15. BEREST, N.; CURVEILLE, J. and PERDRIEL, G. "Les normes d'aptitude visuelle des lecteurs de scope", *Médecine aéronautique,* Vol. 3., (1958a), pp. 197-213.
16. BEREST, N.; GILBERT, A.P. and PERDRIEL, G. "Étude analytique des facteurs d'asthénopie chez les lecteurs de scope radar", *Médecine aéronautique,* Vol. 13 No. 2, (1958b), pp. 135-139.
17. BEVAN, N. "Is there an optimum speed for presenting text on a VDU?" *International Journal of Man-Machine Studies,* Vol. 14, No. 1, (1981), pp. 59-76.
18. BINASCHI, S. et al. "Study on subjective symptomatology of fatigue in VDU operators", in *Ergonomic Aspects of Video Display Terminals.* London, Taylor and Francis, 1982, pp. 219-226.
19. BIRNBAUM, R. *Health Hazards of Visual Display Units with Particular Reference to Office Environments.* Information and Advisory Service TUC, Centenary Institute of Occupational Health, London School of Hygiene & Tropical Medicine, [n. d.], 10 p.
20. BJORSET, H.-H. and BREKKE, B. "The concept of contrast. A short note and a proposal", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 23-24.
21. BOLSEN, B. "VDTs still beleaguered by worker complaints", *Journal of the American Medical Association,* Vol. 246, No. 15, (1981), pp. 1634 and 1639.
22. BOUMA, H. "Visual reading processes and the quality of text displays", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 101-114.
23. BOURJOT, F. "The benefits of implementing. What is known about VDT'S." 14th annual congress, *Human Factors Association of Canada,* (1981), pp. 43-44.
24. BRENT, R.L. "Cancer risks following diagnostic radiation exposure", *Pediatrics,* Vol. 71, (1983), pp. 288-289.
25. BROWN, C.R. and SCHAUM, D.L. "User-adjusted VDU parameters", in *Ergonomic Aspects of Video Display terminals.* London, Taylor and Francis, 1982, pp. 195-200.
26. BROWN, L.D. *Health Effects of Working with Video Display Terminals.* Saskatchewan Department of Labour, Radiation Safety Unit, Report RSU 28/OG/1281, 1981.
27. BROWN, B.S. et al. "Video display terminals and vision of workers. Summary and overview of a symposium", *Behaviour & Information Technology,* Vol. 1, No. 2, (1982), pp. 121-140.
28. BRUTON, D.M. "Medical aspects of cathode ray tube display systems", *Transactions of the Society of Occupational Medicine,* Vol. 22, No. 2, (1972) pp. 56-57.

29. BUCHANAN, D.A. and BODDY, D. "Advanced technology and the quality of working life: the effects of word processing on video typist", *Journal of Occupational Psychology,* Vol. 55, (1982), pp. 1-11.

30. BUREAU INTERNATIONAL DU TRAVAIL; ORGANISATION MONDIALE DE LA SANTÉ ET PRÉVENTION ROUTIÈRE INTERNATIONALE. *Actes du Colloque international vision-travail.* Toulouse, B.I.T., November 1978.

31. CAISSE NATIONALE DE L'ASSURANCE MALADIE. "Travaux devant écran cathodique", *Cahiers de notes documentaires,* No. 1359-105-81, (1981), pp. 619-620.

32. ÇAKIR, A. et al. *Les terminaux à écran.* Paris, Édition d'organisation, 1980, 291 p.

33. CANADIAN LABOUR CONGRESS. *Vers une nouvelle technologie plus humaine: étude des effets des terminaux à écran cathodique sur la santé et les conditions de travail des employés de bureau au Canada,* Ottawa, Centre d'éducation et d'études syndicales du C.T.C., 1982.

34. CASARETT, G.W. *Biological Effects of Low Levels of Radiation Exposure,* report presented to the School of Medicine and Dentistry, Report UR-3490-1072, Rochester, University of Rochester, 1977, 29 p.

35. CENTERS FOR DISEASE CONTROL. *Cluster of Spontaneous Abortions.* Dallas, Texas, 1981.

36. CHARLES, M.W. and BROWN, N. "Dimensions of the human eyes relevant to radiation protection", *Physics in Medicine and Biology,* Vol. 20, No. 2, (1975), pp. 202-218.

37. CHOWN, P. "VDT'S regulated by union agreements in England", *Labor Occupational Health Program Monitor,* Vol. 7, No. 6, (1979), p. 3.

38. CLSC CENTRE-VILLE. *Les écrans cathodiques: risques pour la santé.* Montréal, 1980, 17 p.

39. COHEN, M. *Radiation Emissions from Video Display Terminals.* Montréal, 1983, 17 p.

40. CONOVER, D.L. "R.F. radiation measurements: instrumentation, techniques and occupational data. Non-ionizing radiation", *Proceedings of a Topical Symposium,* (1979), pp. 55-62.

41. CRÉPEAU, F. *Revue de la problématique des écrans de visualisation,* Montréal, 198l, 56 p.

42. COMMISSION DE LA SANTÉ ET DE LA SÉCURITÉ DU TRAVAIL, Direction des programmes et des normes, Direction des systèmes. *Guide d'aménagement de postes de travail à écrans cathodiques.* Montréal, CSST, 1981.

43. CUNNINGHAM-DUNLOP, S. et al. *Carcinogenic Properties of Ionizing and Nonionizing Radiation,* Technical Report No. 78-122, [n. p.], NIOSH, 1977.

44. DAINOFF, M.J. "Visual fatigue in VDT operators", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 95-100.

45. DAINOFF, M.J. "Occupational stress factors in visual display terminal operation: a review of empirical research", *Behaviour and Information Technology,* Vol. 1, No. 2, (1982), pp. 141-176.

46. DELAHAYE, R. "Problèmes biologiques et médicaux posés par l'utilisation des ondes ultracourtes du radar, I. Rappel physique, Problèmes biologiques (Expérimentations animales)", *Radioprotection,* Vol. 12, No. 13, (1977), pp. 199-216.

47. DESNOYERS, L. and LEBORGNE, D. *Vision et travail. Les tâches visuelles.* Montréal, IRAT, 1982.

48. DESRIAUX, F. "Travail sur écran et charge mentale", *Revue de la sécurité,* (juillet-août 1982), pp. 6-12.

49. DESSORS, D. et al. "Conditions de travail des opératrices de renseignements téléphoniques et leur vie personnelle et sociale", *Archives des maladies professionnelles de médecine du travail et de sécurité sociale,* Vol. 40, (1979), pp. 469-500.

50. DIGERNES, V. and ASTRUP, E.G. "Are datascreen terminals a source of increased PCB-concentrations in the working atmosphere?", *International Archives of Occupational Environmental Health,* Vol. 49, (1982), pp. 193-197.

51. DOLAN, S. and ARSENAULT, A. *Stress, santé et rendement au travail.* École de relations industrielles, Université de Montréal, Montréal, 1980, 176 p.

52. DRISCOLL, J. *House Bill 2910, VDT Safety.* Commonwealth of Massachusetts, 1982.

53. DUBÉ, I. and MICHAUD, R. *Les écrans cathodiques et leurs effets sur la santé oculaire.* Montréal, Association des ophtalmologistes du Québec, 1982.

54. DUBOIS-POULSEN, A. "Les yeux et la télévision", *Annales d'oculistique,* Vol. 204, No. 4, (1971), pp. 371-386.

55. DURAFFOURG, J. et al. "Analyse des activités de saisie-correction de données dans l'industrie de la presse", *Travail humain,* Vol. 42, No. 2, (1979), pp. 232-243.

56. DWYER, M.J. and LEEPER, D.B. *Carcinogenic Properties of Ionizing and Non-ionizing Radiation, Volume II: Microwave and Radiofrequency radiation,* Technical Report No. 78-134, [s. l.], NIOSH, 1978.

57. ELIAS, R. "Une approche médico-biologique de l'étude du travail", *Cahiers de notes documentaires,* No. 91, (1978), pp. 293-306.

58. ELIAS, R. et al. "Conditions de travail devant les écrans cathodiques: problèmes liés à la charge visuelle", *Cahiers de notes documentaires,* No. 1216-97-79, (1979a) pp. 577-592

59. ELIAS R. et al. "Conditions de travail devant les écrans cathodiques: questionnaire d'évaluation", *Cahiers de notes documentaires,* No. 1217-97-79, (1979b), pp. 577-592.

60. ELIAS R. et al. "Conditions de travail devant les écrans cathodiques: organisation des tâches et astreintes de l'organisme", *Cahiers de notes documentaires,* No. 1282-101-80, (1980a), pp. 499-504.

61. ELIAS, R. et al. "Investigations in operators working with CRT display terminals; relationships between task content and psychophysiological alterations", in *Ergonomic Aspects of Video Display Terminals.* London, Taylor and Francis, 1980b, pp. 211-219.

62. ELIAS, R. and CAIL, F. "Contraintes et astreintes devant les terminaux à écran cathodique", *Travail et sécurité,* Vol. 10, (1982), pp. 498-511.

63. ELINSON, L. et al. *Health Effects of Video Display Terminals,* report presented to the Health Advocacy Unit, Toronto, 1980.

64. EMARAH, M.H.M., "Occupational cataract review of literature: report of a case of thermal cataract in the printing industry", *Bulletin of Ophthalmological Society of Egypt,* Vol. 66, No. 70, (1973), pp. 159-166.

65. ENGEL, F.L. "Information selection from visual display units", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 121-126.

66. FELLMAN, TH. et al. "An ergonomic evaluation of VDTs", *Behaviour and Information Technology,* Vol. 1, No. 1 (1982), pp. 69-80.

67. FRIEDELL, H.L. *Radiation Protection — Concepts and Trade Offs.* Lauriston S. Taylor Lecture Series, Radiation Protection and Measurements, Lecture No. 3, NCRP, 1979.

68. GANTHI, Om.P. "Dosimetry — the absorption properties of man and experimental animals", *Bulletin of the New York Academy of Medicine,* Vol. 55, No. 11, (1979), pp. 999-1020.

69. GHIRINGHELLI, L. "Collection of subjective opinions on use of VDUs" in *Ergonomic Aspects of Video Display Terminals.* London, Taylor and Francis, 1982, pp. 227-233.

70. GHYS, C. and LEFEBVRE-PRINEAU, L. *Étude ergonomique d'un poste à écran cathodique.* École polytechnique, Département de génie industriel, Montréal, 1979, 208 p.

71. GILBERT, P. "Visual display units: are they safe?", *Occupational Health,* (1978), pp. 357-362.

72. GILBERT, P.R. *Telecomms on Line Data (Told): Controlled Eyesight Experiment Stage Summary,* British Telecom, 1981.

73. GILET, A et al. "Le travail sur terminal à écran: aspects médicaux et ergonomiques. À propos d'une étude sur la fréquence critique de fusion et les potentiels évoqués", *Archives des maladies professionnelles, de médecine et de sécurité sociale,* Vol. 39, No. 6, (1978), pp. 357-373.

74. GORRELL, E.L. "Visual fatigue, legibility and electronic displays", 14th Annual Congress, *Human Factors Association of Canada,* 1981.

75. GOULD, J. "Visual factors in the design of computer-controlled CRT displays", *Human Factors,* Vol. 10, No. 4, (1968), pp. 359-376.

76. GOVERNMENT OF ONTARIO, *An act to Safeguard Terminal Operators,* Bill 149, 1981a.

77. GOVERNMENT OF ONTARIO, *An Act for the Protection of Video Display Terminal Operators,* Bill 169, 1981b.

78. GRANDJEAN, E. *Précis d'ergonomie. Organisation physiologique du travail.* Presses académiques européennes, Brussels, Dunod, Paris, 1969, 275 p.

79. GRANDJEAN, E. "Ergonomic and medical aspects of VDU workplaces", *Displays,* Vol. 2, No. 2, (1980), pp. 76-80.

80. GRANDJEAN, E. "Ergonomics of VDUs: review of present knowledge", in *Ergonomic Aspects of Visual Display Terminals,* London, Taylor and Francis, 1982a, pp. 1-12.

81. GRANDJEAN, E. and VIGLIANI, E. *Ergonomic Aspects of Visual Display Terminals,* London, Taylor and Francis, 1982b, 300 p.

82. GRIECO, A. et al. "Field study in newspaper printing: a systematic approach to the VDU operator strain", in *Ergonomic Aspects of Video Display Terminals.* London, Taylor and Francis, 1982.

83. GUNNARSON, E. and OSTBERG, O. *Physical and Mental Working Environment in a Terminal — Based Data System,* report presented to the Industrial Welfare Council, Industrial Medical Division, Industrial Hygiene Section, Stockholm, 1977.

84. GUNNARSON, E. and SODERBERG, I. *Eye-Strain Resulting from VDT Work at the Swedish Telecommunications Administration: Eye Changes and Visual Strain during Various Working Procedures,* report presented to the National Board of Occupational Safety and Health, Stockholm, 1980.

85. GUSTAVSEN, B. "Improving the work environment: a choice of strategy", *International Labour Review,* Vol. 119, No. 3, (1980), pp. 271-286.

86. HAIDER, M. et al. "Work strain related to VDUs with differently coloured characters", in *Ergonomic Aspects of Visual Display Terminals,* London, Taylor and Francis, 1982, pp. 53-64.

87. HALLORAN, T.O. et al. "Reaction time to accelerating lines and dots on a cathode-ray tube", *Perceptual and Motor Skills,* Vol. 46, No. 2, (1978), pp. 611-623.

88. HEALTH AND WELFARE CANADA, *Investigation of radiation emissions from video display terminals,* report presented to the Environmental Health Directorate, Health Protection Branch, Ottawa, 1983, 44 p.

89. HEWIT, P.J. "Radiation hazard of demonstration cathode ray tubes", *Radiological Protection Bulletin,* Vol. 30, No. 21, (1979).

90. ILEMAN, B. "Radiofrequency and microwave radiation", *Environmental Science and Technology,* Vol. 16, No. 8, (1982), pp. 442A-444A.

91. HIRNING, C.R. and AITKEN, J.H. "Cathode ray tube x ray emission standard for video display terminals", *Health Physics,* Vol. 43, No. 5, (1982), pp. 727-731.

92. HULTGREN, G.V. *Discomfort Glare and Disturbances from Light Reflection in an Office: Environment with CRT Displays Terminals.* Stockholm, 1973, 16 p.

93. HUNTING, W. et al. "Constrained postures of VDU operators", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 175-184.

94. HUNTING, W. et al. "Postural and visual loads at VDT workplaces. I. constrained postures", *Ergonomics,* Vol. 24, No. 12, (1981). p. 917-931.

95. HUNTING W. et al. "Constrained postures at VDTs", *Ergonomics,* Vol. 25, No. 6, (1982), pp. 556-557.

96. HUSAT RESEARCH GROUP. "Stressless use of VDUs", *Health and Safety at Work,* (1980), pp. 34-39.

97. HUTCHINGSON, R.D. "Formatting, message load, sequency method, and presentation rate for computer-generated displays", *Human Factors,* Vol. 23, No. 5, (1981), pp. 551-559.

98. INTERNATIONAL BUSINESS MACHINES CORPORATION. *Human Factors of Workstations with Display Terminals.* [n. p.], 1979, 59 p.

99. INTERNATIONAL LABOUR OFFICE (ILO), "Netherlands. FNV's call for regulations on work with visual display terminals", *Social and Labour Bulletin* (ILO), No. 1, (1979a), p.84.

100. INTERNATIONAL LABOUR OFFICE (ILO). "Norway. New technology agreement reflects four years' experience", *Social and Labour Bulletin* (ILO), No. 4, (1979b), pp. 326-327.

101. INTERNATIONAL LABOUR OFFICE (ILO). "France. Employee access to information on data processing systems", *Social and Labour Bulletin* (ILO), No. 3, (1980), pp. 376-377.

102. INTERNATIONAL LABOUR OFFICE (ILO). "Denmark central agreement on new technology", *Social and Labour Bulletin* (ILO), No. 2, (1981a), pp. 133-134.

103. INTERNATIONAL LABOUR OFFICE (ILO). "Federal Republic of Germany. Safety regulations on the use of VDUs at the workplace", *Social and Labour Bulletin* (ILO), No. 2, (1981b), p. 203-204.

104. INTERNATIONAL LABOUR OFFICE (ILO). "Switzerland. Ergonomic study of visual display units", *Social and Labour Bulletin* (ILO), No. 2, (1981c), pp. 206-208.

105. INTERNATIONAL ORGANISATION FOR STANDARDISATION. "Ergonomic principles in the design of work systems", *International Standard* ISO 6385, (1981d).

106. JOHANSSON, G. "Psychoneuroendocrine reactions to mechanized and computerized work routines", in *Response to Stress. Occupational Aspects.* I.P.C. Science and Technology Press, 1979, p.142-149.

107. KALLEN, B. et al. "Delivery outcome among physiotherapists: non- ionizing radiation a fetal hazard?", *Archives of Environmental Health,* Vol. 37, (1982), pp. 81-84.

108. KALSBEEK, J.H.W. and UMBACH, F.W. "Tasks involving contrast resolution, spatial and temporal resolution presented on VDU screen as a measuring technique of visual fatigue", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 71-76.

109. KENTZ, R.T. and BOWKER, D.O. "Accommodation response during a prolonged visual search task", *Applied Ergonomics,* Vol. 13, No. 1, (1982), pp. 55-59.

110. KNOWLES, W.B. and WULFECK, J.W. "Visual performance with high-contrast cathode-ray tubes at high levels of ambient illumination", *Human Factors,* Vol. 14, No. 6, (1972), pp. 521-532.

111. KOLERS, P.A. et al. "Eye movement measurement of readability of CRT displays", *Human Factors,* Vol. 23, No. 5, (1981), pp. 517-527.

112. KOSUGI, Y. et al. "Quantitative evaluation of saccadic eye movement disorders under random visual stimuli on CRT", *IEEE Trans-Biomedical Engineering,* Vol. 29, No. 3, pp. 184-192, 1981.

113. KRAMER, G. "Positive-mode dichroic Lc display", *Displays,* (January 1982), pp. 30-32.

114. KRUEGER, H. "Ophthalmological aspects of work with display work-stations", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 31-41.

115. LABOUR CANADA. In the chips: opportunities, people, partnerships. Report of the Labour Canada Task Force on Microelectronics and Employment, Supply and Services Canada, 1982, 104 p.

116. LARY, J.M. et al. "Teratogenic effects of 27.12 mHz radiofrequency radiation in rats", *Teratology,* Vol. 26, (1982), pp. 299-309.

117. LAUBLI, TH. et al. "Visual impairments in VDU operators related to environmental conditions", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 85-94.

118. LAUBLI, TH. et al. "Postural and visual loads at VDT workplaces II. Lighting conditions and visual impairments", *Ergonomics,* Vol. 24, No. 12, (1981), pp. 933-944.

119. LAUBLI, TH. et al. "Visual loads at VDT workplaces", *Ergonomics,* Vol. 25, No. 6, (1982), p. 554.

120. LAUREC, M. "L'utilisation des systèmes interactifs couleur en salle de contrôle", *Technique moderne,* Vol. 72, No. 12, (1980), pp. 43-44.

121. LAVILLE, A. "Postural reactions related to activities on VDU", in *Ergonomic Aspects of Visual Display Terminals,* London, Taylor and Francis, 1982, pp. 167-174.

122. LAZARUS, M.G. and BOURKE, J.A. "Problems associated with use of visual display units by bank clerical staff", *Medical Journal Australia,* Vol. 2, No. 4, (1982), p. 186.

123. LE GRANDE, D. "CRT — VDT: problems and solutions", *Communications Workers of America,* Vol. 39, No. 1, (1980), p. 12.

124. LEPLAT, J. "Les facteurs déterminant la charge de travail", *Le travail humain,* Vol. 40, No. 2, (1977), pp. 195-202.

125. LÉTOURNEAU, G. "Are video display terminals safe?" *C.M.A. Journal,* Vol. 125, (1981), pp. 533-534.

126. LEWIS, M.J. et al. "A survey of the health consequences to females of operating visual display units", *Community Health Studies,* Vol. 6, (1982), pp. 130-134.

127. LINDEN, V. and ROLFSEN, S. "Video computer terminals and occupational dermatitis", *Scandinavian Journal of Work Environmental Health,* Vol. 7, No. 1, (1981), pp. 62-67.

128. LUBART, N.D. "Resolution model for a VDU-based person/machine interface: an overview", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 25-30.

129. LUCAS, Y. "Charge mentale et composantes intellectuelles du travail ouvrier", *Les composantes mentales du travail ouvrier,* Rapport de l'A.N.A.C.T. France, 1980, pp. 7-10, ("Études et recherches" Collection).

130. LUCKETT, L.W. "Radiation exposure from a cathode ray tube display device", *(Abstract) Health Physics,* Vol. 29, No. 6, (1975), p. 925.

131. MALLETTE, R. *A survey of attitudes and perceptions of video display operators in Ontario Hydro,* Prepared for Health Assessment of Video Display Units Project, Personnel Applied Research, Human Resources, Planning Department, MR & D., 1983, 17 p.

132. MAMELLE, N. "Activité professionnelle et grossesse", *Concours médical,* Suppl. 47, (1981), pp. 82-86.

133. MAMELLE, N. et al, "Prématurité en milieu professionnel — appréciation du risque et évaluation des mesures de prévention". *Actes du colloque "Conceptions, mesures et actions en santé publique".* Paris, Institut national de la santé et de la recherche médicale, 1981, Vol. 108, pp. 285-294.

134. MAMELLE, N. "Prematurity and occupational activity during pregnancy", *American Journal of Epidemiology,* in Press, (1984).

135. MARHA, KAREL et al. *The Case for Concern about very Low Frequency Fields from Visual Display Terminals: The Need for further Research and Shielding of VDTs.* Hamilton, Canadian Centre for Occupational Health and Safety, 1983, 22 p.

136. MARHA, KAREL. *VLF — Very low Frequency Fields Near VDTs and an Example of their Removal.* Hamilton, Canadian Centre for Occupational Health and Safety, 1983, 11 p.

137. MARHA, Karel. *The State of Knowledge Concerning Radiations from Video Display Terminals.* Hamilton, The Canadian Centre for Occupational Health and Safety, 1982, 31 p.

138. MARSHALL, E. "FDA sees no radiation risk in VDT screens", *Science,* Vol. 212, (1981), pp. 1120-1121.

139. MATIJEVICH, *An Act to Provide Occupational Safeguards for Operators of Video Display Terminals.* (Video Display Terminals Safeguard Act), State of Illinois, House Bill 1725, 1983.

140. MATULA, R.A. "Effects of visual display units on the eyes: a bibliography (1972-1980)", *Human Factors,* Vol. 23, No. 5, (1981), pp. 581-586.

141. MAYER, A. and BARLIER, A. "Conditions de travail devant les écrans cathodiques: étude de l'environnement lumineux", *Cahiers des notes documentaires,* No. 1332-104-81, (1981), pp. 373-385.

142. MC PHEE, HAWIE A. "Ergonomics and visual display units", *Proceedings of the Ergonomics Society of Australia and New Zealand Symposium,* Australia, 1979, 18 p.

143. MC REE, D.I. et al, "Effects of nonionizing radiation on the central nervous system behavior and blood: a progress report", *Environmental Health Perspectives,* Vol. 30, (1979), pp. 123-131, 1979.

144. MELANÇON, C. "L'écran cathodique, outil de travail", *L'Optométriste,* Vol. 2, No. 2, (1980), pp. 23-26.

145. MERCIER, A. and PERDRIEL, G. "La protection oculaire du personnel non navigant chargé de la sécurité aérienne", *Revue de médecine aéronautique,* Vol. 1, No. 1, (1961), pp. 97-111.

146. MEYER, J.J. et al. "Exploration fonctionnelle des régions rétiniennes maculaires et périmaculaires au moyen de l'ERG de papillotement et détermination des seuils de fusion perceptive d'une lumière intermittente", *Archives d'ophtalmologie,* Vol. 35, No. 3, (1975), pp. 253-264.

147. MEYER, J.J. et al. "Psychophysical flicker thresholds and ERG flicker responses in congenital and acquired vision deficiencies", *Modern Problems in Ophthalmology,* Vol. 19, (1978), pp. 33-49.

148. MEYER, J.J. et al. "Plaintes visuelles, déficits fonctionnels et carences vitaminiques", *Médecine sociale et préventive,* Vol. 24, (1979a), pp. 244-246.

149. MEYER, J.J. et al. "Quelques aspects de la charge visuelle aux postes de travail impliquant un écran de visualisation", *Travail humain,* special issue on display screens. Vol. 42, (1979b), pp. 275-301.

150. MEYER J.J. et al. *L'analyse ergonomique des postes de travail avec écran de visualisation: recommandations concernant la conception, l'aménagement, l'utilisation des écrans et l'adaptation visuelle des opérateurs.* Université de Genève, Centre d'étude des problèmes d'écologie du travail, 1980, 49 p.

151. MICHAELSON, S.M. "Standards for protection of personnel against nonionizing radiation", *American Industrial Hygiene Association Journal,* Vol. 35, No. 12, (1974), pp. 766-784.

152. MICHAELSON, S.M. "Health implications of exposure to radiofrequency/microwave energies", *British Journal of Industrial Medicine,* Vol. 39, No. 2, (1982), pp. 105-119.

153. MOLE, R.H. "Radiation dose limits for embryo and fetus in occupationally exposed women", *British Journal of Radiology,* Vol. 53, No. 630, (1980), p. 608.

154. MORAY, N. "Mental workload: its theory and measurement", *Human factors,* [n. p.]. 1979, 500 p. ("Nato Conference Series" Collection).

155. MOSS, E.C. et al. *A Report on Electromagnetic Radiation Surveys on Video Display Terminals,* report presented to the U.S. Department of Health, Education and Welfare Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, [n. p.], 1977, pp. 652-662.

156. MOURANT, R.R. et al. "Visual fatigue and cathode ray tube display terminals", *Human Factors,* Vol. 23, No. 5, (1981), pp. 529-540.

157. MUC, A.M. "Video display terminals: a radiation hazard?" 14th Annual Congress, *Human Factors Association of Canada,* 1981.

158. MURRAY, W.E. et al. "A radiation and industrial hygiene survey of video display terminal operators", *Human Factors,* Vol. 23, No. 4, (1981), pp. 413-420.

159. NAEYE, R.L. and PETERS, E.C. "Working during pregnancy: effects on the fetus", *Pediatrics,* Vol. 69, (1982), pp. 724-727.

160. NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH, Division of Biomedical and Behavioral Sciences and Division of Surveillance, Hazard Evaluations and Field Studies. *Working with Video Display Terminals: A Preliminary Health-Risk Evaluation.* NIOSH, 1980, pp. 307-308.

161. NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH. *Potential Health Hazards of Video Display Terminals.* Research report, [n. p.], DHHS (NIOSH) Publication No. 81-129, 1981, 75 p.

162. "NIOSH recommendations for video display teminals", *Occupational Hazards,* Vol. 44, No. 10, (1982), p. 63.

163. "Norway draft rules on new technology", *European Industrial Relations Review,* No. 93, (1981), pp. 22-23.

164. OLMEDO, E.L. and KIRK, R.E. "Maintenance of vigilance by non-task-related stimulation in the monitoring environment", *Perceptual and Motor Skills,* Vol. 44, No. 3.1, (1977) pp. 715-723.

165. OLSEN, W.C. *Electric Field Enhanced Aerosol Exposure in Visual Display Unit Environments.* The Christian Michelsen Institute, Department of Science and Technology, (1981), 40 p.

166. ONTARIO PUBLIC SERVICE EMPLOYEES UNION. *The Hazard of VDT'S.* Department of Special Operations, [n. p.], 1981, 57 p.

167. OSTBERG, O. "CRTS pose health problems for operators", *International Journal of Occupational Health and Safety,* Vol. 44, No. 6, (1975), pp. 24-26, 46, 50, 52.

168. OSTBERG, M.O. "Les terminaux d'ordinateur à écran cathodique. Problèmes de santé chez les opérateurs", *Cahier de notes documentaires,* No. 1049-86-77, (1977), pp. 55-63.

169. OSTBERG, O. "Towards standards and threshold limit values for visual work. Current concepts in ergophthalmology", *Societas Ergophtalmologica Internationalis,* (1978), pp. 359-382.

170. OSTBERG, O. "The health debate", *Reprographics Quarterly,* Vol. 12, No. 3, (1979), pp. 80-83.

171. OSTBERG, O. "Accommodation and visual fatigue in display work", *Displays,* Vol. 2, No. 2, (1980), pp. 81-85.

172. OSTBERT, O. "Accommodation of visual fatigue in display work", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 41-53.

173. OH, C.S. and KRAMER, G. "Positive-mode dichroic Lc display", *Displays Technology and Applications,* Vol. 3, No. 1, (1982), pp. 30-32.

174. ONTARIO ADVISORY COUNCIL ON OCCUPATIONAL HEALTH AND OCCUPATIONAL SAFETY. "Task force on the possible health hazards of visual display units", *Fifth Annual Report April 1, 1982 to March 31, 1983.* Vol. 1.

175. PARDON, N. "Ergonomic optimisation of work at computer terminals", *Cahiers de médecine interprofessionnelle,* No. 77, (1980), pp. 29-49.

176. PAVLASEK, T. and MISHRA, S. "The E.M. environment, its simulation and measurement", *Canadian Electronics Engineering Journal,* Vol. 6, No. 2, (1981), pp. 3-8.

177. PETERSON, R.C. et coll. *Nonionizing Electromagnetic Radiation Associated with Video Display Terminals. Ocular Effects on Nonionizing Radiation.* Belligham, Society of Photo-optical Instrumentation Engineers, 1980.

178. PETERSON, R.C. "Bioeffects of microwaves: a review of current knowledge", *Journal of Occupational Medicine,* Vol. 25, (1983), pp. 103-110.

179. PINSKY, L. et al. *Le travail de saisie-chiffrement sur terminal d'ordinateur.* Centre national des arts et métiers, Paris, 1979, 413 p.

180. PINSKY, L. et al. *Dialogue homme-ordinateur: rationalité et divination.* Actes du 18[e] Congrès de la S.E.L.F., 1982.

181. POCHIN, E.E. *Why be Quantitative about Radiation Risk Estimates,* Lauriston S. Taylor Lecture Series, Radiation, Protection and Measurements, Lecture No. 2, 1978.

182. POLEDNAK, A.P. "Fertility of women after exposure to internal and external radiation", *Journal of Environmental Pathology and Toxicology,* Vol. 4, No. 1, (1980), pp. 457-470.

183. PROPERZIO, W.S. "Radiation emissions from demonstration type cold cathode gas discharge tubes", *Electronic Product Radiation and the Health Physicist,* 4[th] Annual Topical Symposium, Health Physics Society, U.S. Public Health Service, Publication BRH/DEP70-26, 1970, pp. 197-213.

184. PURDHAM, J.T. *A Review of the Literature on Health Hazards of Video Display Terminals.* Hamilton, Centre canadien d'hygiène et de sécurité au travail, 1980, 18 p.

185. RADL, G.W. "Experimental investigations for optimal presentation-mode and colours of symbols on the CRT-Screen", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 127-136.

186. REY, P. et al. "Les problèmes visuels des opérateurs utilisant des écrans de visualisation", *Les écrans de visualisation,* A.N.A.C.T., 1977.

187. REY and P. MEYER J.J. "Visual impairments and their objective correlates", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 77-84.

188. ROBINSON, G.H. et al. "Eye and head movements during visual search", in *Ergonomics,* Vol. 19, No. 6, (1976), pp. 691-709.

189. RONCHI, L.R. and CICCHELLA, G. "Dioptric problems in connection with luminance brightness relationship on VDUs", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 65-70.

190. ROSENBAUM, L. *Health Effects of Video Display Terminals: The Non-Radiation Problems,* report presented to the Health Advocacy Unit, Department of Public Health, Toronto, 1981.

191. ROUSSEL, C. et al. "Peut-on quantifier et diminuer la charge de travail sur terminal à écran?", *Archives des maladies professionnelles de médecine du travail et de sécurité sociale,* Vol. 41, No. 4, (1980), pp. 177-182.

192. RUPP, B.A. "Visual display standards: a review of issues", *Proceedings of the Society for Information Display,* Vol. 22, No. 1, (1981), pp. 63-72.

193. SALVENDY, G. "Human-computer communications with special reference to technological developments, occupational stress and educational needs", *Ergonomics,* Vol. 25, No. 6, (1982), pp. 435-447.

194. SANTUCCI, G.F. and PERDIEL, G. "L'ophtalmologiste face au tube cathodique", *Bulletin des sociétés d'ophtalmologie de France,* Vol. 78, (1978), pp. 8-9.

195. SANTUCCI, G. et al. "Visual acuity in colour contrast on cathode ray tubes: role of luminance, hue and saturation contrasts", *Aviation Space and Environmental Medicine,* Vol. 53, No. 5, Paris, France, Centre d'études et de recherches de médecine aérospatiale, (1982a), pp. 478-484.

196. SANTUCCI, G. "Les écrans de visualisation", *Année thérapeutique et clinique en ophtalmologie,* Vol. 32, (1982b), pp. 313-328.

197. SCHOENBERGER, R.W. "Stress effects of whole-body vibration on visual display tasks", *Aerospace Medicine,* Vol. 45, No. 2, (1974), pp. 143-153.

198. SHAHNAVAZ, H. "Lighting conditions and workplace dimensions of VDU-operators", *Ergonomics,* Vol. 25, No. 12, (1982), pp. 1165-1173.

199. SMIALOWICZ, R.J. et al. "Chronic exposure of rats to 100-MHz(CW) radiofrequency radiation: assessment of biological effects", *Radiation Research,* (U.S.A.), Vol. 86, No. 3, (1981), pp. 448-505.

200. SMITH, M.J. *Select Research Reports on Health Issues in Video Display Terminal Operations,* report presented to the Division of Biomedical and Behavioral Science, NIOSH, [n. p.], 1981.

201. SMITH, M.J. "A review of literature relating to visual fatigue", *Proceedings of the Human Factors Society 23[rd] Annual Meeting,* Boston, 1979, pp. 362-366.

202. SMITH, M.J. et al. "Job stress in video display operations", in *Ergonomic Aspects of Video Display Terminals.* London, Taylor and Francis, 1982, pp. 201-210.

203. SMITH, M.J. et al. "An investigation of health complaints and job stress in video display operations", *Human Factors,* Vol. 23, No. 4, (1981), pp. 387-400, 1981.

204. SNYDER, H. and MADDOX, M. *Information transfer from computer-generated dot-matrix displays,* report presented to the U.S. Army Research Office, No. HFL-78-3/ARO78-1, North Carolina, 1978.

205. SOLON, L.R. "A local health agency approach to a permissible environmental level for microwave and radiofrequency radiation", *Bulletin of the New York Academy of Medicine,* Vol. 55, No. 11, (1979), pp. 1251-1266.

206. SPÉRANDIO, J.-C. "Les activités mentales dans les tâches de service", *Le travail humain,* Vol. 45, No. 2, (1982), pp. 357-363.

207. SPÉRANDIO, J.-C. *La psychologie en ergonomie.* Presses Universitaires de France, Paris, 1980.

208. STAMMERJOHN, L.W. Jr. et al. "Evaluation of work station design factors in VDT operations", *Human Factors,* Vol. 23, No. 4, (1981), pp. 401-412.

209. STARR, S.J. et al. "Effects of video display terminals on telephone operators", *Human Factors,* Vol. 42, No. 6, (1982), pp. 699-711.

210. STARR, S.J. "A study of video display terminal workers", *Journal of Occupational Medicine,* Vol. 25, No. 2, (1983), pp. 95-98.

211. STEWART, T.F.M. "Eyestrain and visual display units: a review", *Displays,* Vol. 1, (1979), pp. 25-32.

212. STEWART, T. "Problems caused by the continuous use of visual display units", *Lighting Research and Technology,* Vol. 12, No. 1, (1980a), pp. 26-36.

213. STEWART, T. "VDU ergonomics — a review of the last two years", *Proceedings of the HUSAT Research Group,* One Day Conference on Health Hazards of VDUs, Loughborough University, (1980b), pp. 39-47.

214. STUCHLY, M.A. "Interaction of radiofrequency and microwave radiation with living systems: a review of mechanisms", *Radiation and Environmental Biophysics,* Vol. 16, No. 1, (1979), pp. 1-14.

215. SWEDISH NATIONAL BOARD OF OCCUPATIONAL HEALTH AND SAFETY. *Reading of Display Screens.* Directives No. 136, 1978.

216. SZEKELY, J. *Évaluation de la charge mentale dans le cadre de l'étude et de l'aménagement des conditions de travail: théorie, mesure, application.* Paris, I.N.R.S., 1975, 64 p. ("Notes scientifiques et techniques" Collection).

217. TA-FU-HUANG, A. and MOLD, N.G. "Immunologic and hematopoietic alterations by 2,450 MHz electromagnetic radiation", *Bioelectromagnetics,* Vol. 1, No. 1, (1980), pp. 77-87.

218. TERRANA, T. et al. "Electromagnetic radiations emitted by visual display units", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 13-22.

219. TIEFENBACH, W.P. *Video Display Terminals and Possible Radiation Hazards,* report presented to the Saskatchewan Department of Labour, Radiation Safety Unit, No. RSU 24/OE/1081, 1981.

220. TIMMERS, H. et al. "Visual work recognition as a function of contrast", in *Ergonomic Aspects of Visual Display Terminals.* London, Taylor and Francis, 1982, pp. 115-120.

221. TISSERAND, M. and SCHOULLER, J.F. "Dimensionnement des postes de travail: application au poste sur terminal écran-clavier: 1. Le Diagnostic", *Cahier de notes documentaires,* No. 105, (1981), pp. 535-558.

222. TISSERAND, M. and SAULNIER, H. "Dimensionnement des postes de travail: application au poste sur terminal écran-clavier: 2. Conception du poste", *Cahier de notes documentaires,* No. 1389-108-82, (1982), pp. 377-395.

223. TJOHN, H. "Can VDU operation cause dermatitis?", in *Ergonomic Aspects of Video Display Terminals.* London, Taylor and Francis, 1982, pp. 263-264.

224. TOBIS, J.S. et al. "Visual perception of verticality and horizontality among elderly fallers", *Archives of Physical Medicine and Rehabilitation,* Vol. 62, No. 12, (1981), pp. 619-622.

225. TUBIANA, M. "Effets sanitaires des faibles doses", *Revue d'épidémiologie et de santé publique,* Vol. 30, (1982), pp. 131-149.

226. TULLIS, T.S. "An evaluation of alphanumeric, graphic, and color information displays", *Human Factors,* Vol. 23, No. 5, (1981), pp. 541-550.

227. U.S. BUREAU OF RADIOLOGICAL HEALTH DIVISION OF COMPLIANCE. *X-Radiation and Identification Characteristics of CRTs of Foreign Manufacture.* DHEW/PUBI FDA-79 8081, FDA/BRH — 79/69, NTIS Report PB-293 459, 1979, 80 p.

228. U.S. CONGRESS HOUSE. *Potential Health Effects on Video Display Terminals and Radio Frequency Heaters and Sealers.* Committee on Science and Technology, Subcommittee on Investigations and Oversight, 1981, 764 p.

229. U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES. *An Evaluation of Radiation Emission from Video Display Terminals.* Public Health Service, Food and Drug Administration, HHS Publication FDA 81-8153, 1981.

230. UNIVERSITY OF CALIFORNIA. *Resource Packet: Hazards Associated with Video Display Terminals.* Labor Occupational Health Program, 1979.

231. UPTON, A.C. "Low dose radiation: risks vs benefits", *Postgraduate Medicine,* Vol. 70, No. 6, (1981), pp. 34-37, pp. 40-41, pp. 45-47.

232. VARTABEDIAN, A. "The effects of letter size, case and generation method on CRT display search time", *Human factors,* Vol. 13, No. 4, (1971), pp. 363-368.

233. VERHAGEN, L.H.J.M. "Experiments with bar graph process supervision displays on VDUs", *Applied Ergonomics,* Vol. 12, No. 1, (1981), pp. 39-45.

234. VILLEDIEU, Y. "Des écrans plein les yeux", *Québec science,* (1981), pp. 32-37.

235. WAHLSTROM, R. et al. *Working conditions* at VDUs (Conditions de travail devant les écrans de visualisation). Luxo France, Lyon France, 1980, 62 p.

236. WARR, A. "VDUs — the outcome of a screen test", *Occupational Health,* Vol. 33, No. 6, (1981a), pp. 324-326.

237. WARR, A. "Operating VDUs: work organization and subjective effects on operator health and psychology", *Journal of Physics,* Vol. 14, No. 5, (1981b), pp. 530-540.

238. WEBER, A. et al. "Psychophysiological effects of repetitive tasks", *Ergonomics,* Vol. 23, No. 11, (1980), pp. 1033-1046.

239. WEISS, M.M. and PETERSEN, R.C. "Electromagnetic radiation emitted from video computer terminals", *American Industrial Hygiene Association Journal,* Vol. 40, (1979), pp. 300-309.

240. WEISS, M.M. "The video display terminals: is there a radiation hazard?" *Journal of Occupational Medicine,* Vol. 25, (1983), pp. 98-100.

241. WELFORD, A. "La charge mentale de travail comme fonction des exigences, de la capacité, de la stratégie et de l'habileté", *Le travail humain,* Vol. 40, No. 2, (1977), pp. 283-304.

242. WEST, D. et al. "Radiofrequency (RF) sealers and heaters: potential health hazards and their prevention", *American Industrial Hygiene Association Journal,* Vol. 41, (1980), pp. 22-38.

243. "West Germany. Joint new technology rules on the use of visual display units (VDUs)", *European Industrial Relations Review,* No. 86, (1981), pp. 17-18.

244. "WILKINS, A.J. "Epileptogenic attributes of TV and VDUs", *Ergonomics Society Meeting,* Eyestrain and VDUs, Loughborough, (1978), pp. 27-35.

245. WILKINS, R., *Health and Safety Aspects Associated with the Use of Microelectronics Technology in the Workplace: An Overview of the Current Debate Concerning Video Display Terminals* (VDTs), report presented to the Labour Canada Task Force on Microelectronics and Employment, Institute for Research Policy, [n. p.], 1982, 123 p.

246. WILSON, J.G. and FRASER, F.C. "Principles of Teratology", *Handbook of Teratology,* Vol. 1, (1979), 476 p.

247. WISNER, A. "Contenu des tâches et charge de travail", *Sociologie du travail,* Vol. 16, No. 4, (1974), pp. 339-357.

248. WISNER, A. *Ergonomie, travail mental et anthropotechnologie,* Report 68 of the Laboratoire de physiologie et d'ergonomie, Paris, C.N.A.M., 198l.

249. WOLBARSHT, M.L. et al. *Electromagnetic Emission from Visual Display Units: a Non-Hazard. Ocular Effects of Nonionizing Radiation,* Bellingham, Society of Photo-Optical Instrumentation Engineers, 1980.

250. WRIGHT, G.R. "Overview of VDT ergonomics", *14th Annual Congress. Human Factors Association of Canada,* (1981), pp. 38-42.

251. *L'examen médical périodique,* l'Union médicale du Canada, Supplement to Vol. 108, No. 12, 1979.