Ergonomic aspects of the health and safety of VDT work in Japan: a review

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Following the IEA Congress held in Japan in 1982, many researches of the effect of VDT work on health have appeared. This paper reviews critically the field surveys and experimental studies on eye problems associated with VDT work in Japan. The following trends were discerned:

- Many field surveys and medical check-ups suggest that the visual load of VDT work is heavy, and that complaints and subsequent medical diagnoses relate to the user of VDTs. However, very few surveys were epidemiologically well designed.
- Some clinical cases were diagnosed as relating to VDT work; however, the pathogeny was not disclosed.
- The most commonly measured and examined physiological response to evaluate objectively the load and fatigue in VDT work was visual accommodation. There are other indices, such as eye movement, pupil size, critical flicker frequency, ocular tension, tears, surface temperature of cornea, electroencephalogram, but they lack consistency and strength in their relation with VDT work. There is no index that can help to evaluate the load and fatigue caused by VDT work alone. There are also few physiological indices which are compatible with the subjective symptoms often observed in VDT work.
- Many studies show that the workload is greater in VDT work than in paper work. Many experimental evaluations of the photometric characteristics of VDT screens support the contention that positive presentation (bright characters on a dark background) is better than the negative presentation (dark characters on a light background).
- With regard to environmental factors, there are some experimental studies on the effect of static electricity or magnetic field on eyesight.
- In comparison with VDT work in Europe and America, some experimental studies show that VDT work in Japan additionally increases visual load because of text processing of Japanese characters.
- Some experimental studies aim to obtain evidence to establish rules regulating continuously working minutes or daily working hours spent on VDT work. However, these are not so systematic and extensive.
- It is suggested that astigmatism increases visual load as well as presbyopia.
- There is no special legislation regulating VDT work in Japan.

1. Introduction

In Japan computers play an increasingly important role in all matters of business, and non-commercial life: and VDTs become inevitable interfaces where people use computers. Figure 1 shows the rapid spread of VDTs in Japan; it is the use of VDTs for wordprocessing that shows the most remarkable spread.

This process prompted a growing interest in the health hazards posed by VDT work in Japan (Nishiyama 1987). the problem creating greatest interest focused on the adverse effect of VDTs on the eyes.
Figure 1. Production of VDT hardware in the Japanese domestic market, 1978–1988. ---: Personal computers, ---: Japanese character word processors (total for 1983 and 1984 include European language processors).

The Japanese Association of Office Automation (1987) investigated 119 companies. The results of this survey showed that the numbers of employees per office automation device were 10.2 for online terminals, 11.7 for personal computers, 26.3 for facsimile transmission machines, 40.1 for word processors, 96.9 for office computers, and 329.6 for general purpose computers. In 1987 10.3 million workers were engaged in clerical occupations in Japan. By adding the number of the employees of professional, managerial, or sales status, the total number grows to 27.6 million. This corresponds to 47% of the total number of employees. This may increase absolutely and relatively in the future, and is far larger than the number of workers engaged in mechanized office work such as key-punchers who suffered from occupational cervicobrachial disorders under the first era of computerization of office work in the early 1960s (Nishiyama 1987).

The history of the studies about the effect of VDT work on health in Japan is now discussed. Table 1 shows the growth of VDT-related presentations at the annual conferences of the Japanese Association of Industrial Health (JAIH) and the Japanese Ergonomic Research Society (JERS) in the past decade. The JAIH organizes around 4000 occupational health professionals, such as researchers in the related departments of universities and doctors in industrial enterprises. The JERS organizes around 1500 ergonomics specialists or engineers. This table suggests that Congress of the International Ergonomics Association (IEA) held in Japan in 1982 created a stimulus for the study of VDT problems in the field of occupational health and ergonomics.

The Annual Meeting of the JAIH in 1983 decided to establish a committee to examine VDT work. The committee subsequently issued a recommendation on VDT work (1985). Since the 1984 Annual Meeting a session devoted to VDT work has been held. In the journal of the JAIH, the first original paper about VDT work in Japan was published in 1984. Up until May 1989, five original papers and one short letter had been published.

In the Japanese Journal of Ergonomics published by the JERS in 1980, ergonomic factors as discussed today were summarized in a special edition entitled 'The Life Extending Computer'. It included a commentary entitled 'Human factors in computer
Table 1. The number of papers relating to VDT problems and associated visual factors presented in annual meetings of major academic associations in Japan.

<table>
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<tr>
<th>Year</th>
<th>Association of industrial health</th>
<th>Association of Ergonomics</th>
<th>Remarks</th>
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<tr>
<td>1989</td>
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JERS: Japan Ergonomic Research Society.
%: ratio accounted for all papers.

terminal usage' (Yazu 1980), and reference was made to research by Cakir et al. (1978) and others. In 1983, a second special edition, 'Ergonomics of Visual Display Terminals Work' was published. However, it is in the edition of April 1984 that the first original paper appeared. From that year, original papers have been published annually. Since the annual meeting of the JERS in 1983, sessions on VDTs have been held. In 1987, a session entitled 'VDTs interface' and in 1988, a session on computer interface were held.

The Japanese Association of Traumatology and Occupational Medicine (JATOM) organizes physicians concerned with labour accidents. In 1982 the JATOM Annual Conference heard a presentation on VDT work for the first time; the theme was related to eye problems. Thereafter this tendency has strengthened. From 1983, except for 1984, presentations about VDT work had been done at the session on ophthalmology. In 1984, a session on VDT work was held, and four presentations were made. In 1985, a symposium on VDT work and visual function was held. Four presentations were made as plenary addresses; however, since then, only one or two presentations have been done. In 1989, a seminar on education and training entitled 'Health Hazards Caused by VDTs' was held. The Japanese Journal of Traumatology & Occupational Medicine (JJTOM) published an original paper in 1981. Thereafter one to three papers were published every year.

Turning to academic ophthalmology, the Societas Ophthalmologica Japonica (SOJ) first addressed VDTs in 1985. In 1986, a symposium on VDT work and visual fatigue was held. In 1988, a science exhibition on 'Refraction and Accommodation' was held and three presentations were made. In the 1988 edition of the SOJ's journal an original paper which included the keyword 'VDT' was published. Previously there had been no
original paper relating to VDT work. The *Folia Ophthalmologica Japonica* first published a report about VDTs for the first time in 1982. Thereafter from one to three presentations have been done, except in 1987 when five subjects were addressed.

The Japanese Association of Ophthalmologists (JAO) is mainly concerned with clinical ophthalmology. It established a three-year project on VDTs in 1986 (Arizawa 1986). The group characterized the effect of VDTs on health as ‘VDT Syndrome’. Its activities have been reported in the journal of the JAO, *Japanese Ophthalmology* (Ishikawa and Aoki 1986). In the past there were several studies that statistically analysed subjective symptoms collected by clinical questionnaires. It was a weak point that in those results there was no standardization of diagnosis for asthenopia between researchers. However, many researches were done which had a good command of many kinds of objective examination methods.

Other organizations dealing with the visual aspects of VDTs are the Illumination Engineering Institute of Japan, the Institute of Television Engineers of Japan, the Japanese Association of Oculo-optics, and so on.

Some researchers have tended to present similar topics at several annual meetings of different societies. On the whole, however, the number of original presentations has increased since 1982.

This paper investigates the effects of VDT work on workers’ health through reviewing critically Japanese research. The reviewed materials are mainly original papers published in the journals mentioned above; and the papers address those visual problems in VDT work such as the increase of workload, fatigue, or discomfort, decrease of comfort, and pathological findings. In addition certain proceedings of meetings are reviewed, as these cannot be ignored, as they are valuable in terms of promptness and scarcity. Reports which evaluate VDT work only through its performance are excluded.

2. Field surveys and clinical studies

2.1. Questionnaire studies

Sugita *et al.* (1986) analyzed complaints of subjective symptoms of 285 VDT office workers through data gleaned from a medical check-up. The number of controls was 60. In female subjects, they noted significant differences in complaints of decreasing visual acuity and the score of subjective symptoms for eyes between the VDT workers’ group \(n = 156\) and the control group \(n = 30\). Furthermore, in female subjects, they noted the relationship between hours of VDT work and the score of subjective symptoms for eyes. In both sexes, the group characterizing VDT work as excessive showed a considerably higher score of subjective symptoms for eyes than the group not expressing such sentiments. The subjective symptoms were also related to the degree of self-control evaluated by VDT workers.

Shimai *et al.* (1986) carried out a questionnaire investigation of symptoms and working conditions for all employees \(n = 300\) of a company manufacturing computer peripherals who worked with VDTs. The results showed that the prevalence of subjective symptoms tended to increase with the number of years worked with VDTs. The correlation coefficients of eye fatigue, poor long range vision, shoulder and/or neck stiffness, and dullness of whole body with the number of hours worked were from 0.23 to 0.34, with a degree of significance. They concluded that the ill effects of VDT work might accumulate chronically, because the correlation coefficients between subjective symptom and age were negative. As hours of VDT work per day increased, the prevalence of subjective symptoms tended to be higher. However, a
group working with VDTs for more than 3 h showed a slight decrease in this prevalence. Only the correlation coefficient between shoulder and/or neck stiffness and the daily hours of VDT work was significant, at 0.31. Shimai et al. concluded that there are differences in VDT workload dependent on the work procedure and the content of the work. Their results and conclusions can only be suggestive, because the correlation coefficients, although significant, are small.

Yamada et al. (1986) circulated a questionnaire based on the 'Inventory for the Subjective Symptoms of Fatigue' standardized by the Research Committee of the JAIH (Fatigue Scale of Industrial Fatigue Research Committee 1970, Kogi et al. 1970, Saito et al. 1970). They investigated fatigue in VDT workers (n = 80) and office workers (n = 45) in two enterprises. They noted the need to add certain items related to visual function to the three components used to assess industrial fatigue to understand the fatigue symptoms and situation of VDT workers.

Matsui et al. (1986) carried out a questionnaire study of the health condition of 9684 VDT workers in 389 enterprises randomly sampled from all enterprises using computers in the whole country. The number of responses was 5097 and the rate was 52.6%. The highest prevalence of subjective symptoms was for whole body fatigue, the second was for eyes, and thereafter mental or nervous symptoms, musculoskeletal symptoms, and intestine function, in that order. A statistical quantification analysis was done. The external criterion variables were the subjective symptoms. The explanatory variables were sex, age, occupation, type of business, years worked with VDTs, length of continuous VDT work, type of VDT work, working environment, work motivation, working posture, and characteristics of the VDT screen. They concluded that the most influential factor for all symptoms, except intestine function, was complaints about the VDT screen; this was especially remarkable for eye symptoms. From this they suggested that the removal of the cause of complaints about the VDT screen would promote occupational hygiene measures for VDT work. However, there was no examination nor discussion on the bias probably introduced by low response rates to the questionnaire.

The Inventory for Subjective Symptoms of Fatigue mentioned above is used very often to investigate fatigue. However, it does not include a sufficient number of items to assess eye fatigue satisfactorily. To investigate eye symptoms, the 'Checklist of ophthalmological symptoms for a VDT worker', with 17 items (Suzumura 1985) exists, as do others: however, these have not yet been standardized, as the above Inventory has.

2.2. Medical check-up
Shinosaki (1985) carried out a medical check-up for 19 VDT workers among 43 managerial staff in one company. He recognized many cases with lowered visual acuity, and especially with anisometropia. He felt these might cause asthenopia. He also recognized many eye diseases, such as four cases of diffuse superficial keratitis, four cases of opacity of lens, and 17 cases of retinal disease. However he did no more than indicate that the ageing factor might contribute to those suffering, because they were middle aged, in their 30s to 50s.

Karai et al. (1986) checked up ophthalmologically on 281 VDT workers from three insurance companies and one newspaper. They reported there was no relation between eye fatigue and age (for those under 30), working hours with VDTs (between under 4 h), exophoria (between under 10 diopters), and disorders of refraction or accommodation.
Nakagawa et al. (1987) examined ten male workers who were engaged in tasks such as viewing screens, mainly for editing programs, 5 h per diem; and 16 female workers who were engaged in tasks such as inputting numerals or letters, looking more at documents than at screens, 6-1 h everyday. The checked items before and after the work were far and near visual acuities, distance of near and far points, accommodation time, critical flicker frequency, ocular tension, slit-lamp microscopy, position of eyes, stereopsis, lacrimation reflex, and small rapid eye movement during fixation. They found two cases with decrease of accommodating power and nine cases with increase of frequency of visual fixation. Eight subjects suffered from both symptoms.

Yamada et al. (1986) did precise ophthalmological check-ups. The indices were: power of accommodation; accommodation time; refraction disorders; heterophoria; strabismus; lacrimation reflex; corneal disorders; and suitability of glasses (if worn), as well as identifying subjective symptoms, by questionnaire. The subjects were 80 VDT workers and 45 non-VDT office workers in two enterprises. The comparison between both groups disclosed that a prevalence of subjective symptoms for visual organ or function, prolongation of relaxation time for accommodation, unsuitableness of glasses (if worn), and poor tear flow were significantly more observed in VDT workers than in the other group. However, a decrease of the power of accommodation and prolongation of constricting time for accommodation were more prevalent in non-VDT office workers. A higher ratio of VDT-group subjects were diagnosed as having asthenopia. However, Yamada et al. speculated that the asthenopia in VDT workers was mainly due to mental fatigue, because the frequency of disorders for accommodation was similar in both groups.

Tokoro (1987) noted the absence of a correlation between near vision and working hours per day or years with VDTs for 528 eyes/266 men and 338 eyes/171 women. Furthermore he (and colleagues) observed a change of refraction through one year by using the same method with auto refractometer (Tokoro et al. 1988). The subjects were 705 VDT workers of both sexes, 18-59 years. The control group consisted of 721 men and women, 20-54 years, who worked with VDTs for less than 150 min per week. From the results they recognized that some people in their 20s of both sexes developed myopia. However, the degree of development did not differ among the groups. Therefore, they concluded that it was not possible to say VDT work is a cause of myopia.

Ibi et al. (1988) checked ophthalmologically 68 workers before and at one year after the introduction of VDTs in a newspaper company. The items checked were visual acuity (5 m and 50 cm, with and without their own glasses), colour vision, eye position, eye movement, camera anterior or bulbi, optic media, retina, ocular tension, and far and near point distance. They compared the data before and after the introduction for 61 workers who took part in both medical check-ups. The results showed that visual acuity at 50 cm significantly decreased after the introduction in comparison with before. They noted abnormal position of eyes, convergence disorder, corneal erosion, conjunctivitis and cataracts after the introduction of VDTs. They did not examine these finding statistically, and did not note an increase of ocular tension or a decrease of power of accommodation. However, they did note a significant decrease of the power of accommodation for subjects who worked with VDTs for more than 2 h before the check-up, and postulated that this decrease might have been caused acutely. They concluded that to allow VDT work just before a health examination was problematic.
Harim et al. (1988) carried out ophthalmological examinations on 246 VDT and 534 non-VDT workers in 43 printing companies in Osaka, Japan. As working hours with VDTs increased, subjective eye symptoms increased. However, after 3 h the increase reached a ceiling. Nevertheless, subjective symptoms for eyes decreased with age. The correlation coefficients between subjective symptoms and ophthalmological factors like the difference of visual acuity between right and left or between far and near, red/green test, astigmatism, power of accommodation, heterophoria, and stereopsis were less than 0.2. Therefore Harima et al. speculated that these factors hardly affect eye fatigue. The correlation coefficients between the subjective symptoms and symptoms of autonomic nerves, mental symptoms or whole body symptoms were more than 0.5. Harima et al. postulated that eye fatigue could be understood as a part of whole body symptoms. In the female workers, the correlation coefficients between subjective symptoms for eyes and working hours with VDTs per day was 0.30, and that for the length of continuous VDT work was 0.39.

Kojima et al. (1988) examined near reaction of 24 hospital workers who spent more than 2 h per day and had no ophthalmological disorders, except refractory disorders. The age range was 20–40 years, and the mean was 27.4 years. A control group consisted of 16 clerical non-VDT workers, whose age range was 21–34 years, and the mean 25.8 years. They studied the ratio of accommodative response versus accommodative stimulus \( A_r / A_s \). For the control, \( A_r / A_s \) was normal. There was no difference of accommodative response between right and left, and nobody had paralysis or spasms. For VDT workers without asthenopia, 12 out of 14 eyes showed normal \( A_r / A_s \). Even if \( A_r / A_s \) was normal, 6 out of 12 eyes showed abnormal pupil function: thus they recognized the need to observe these processes. On the other hand, among VDT workers with asthenopia \((n = 16)\), they noted only one normal eye in all three functions of near reaction. From these results they suggested that VDT work might have some effect on pupils or convergence system.

Aizawa (1988) analyzed by questionnaire 133 VDT workers less than 40 years (mean = 28.3, s.d. = 5.8) for the relationship between subjective symptoms and working environment. He compared the prevalence of eye disease symptoms between a group \((n = 33)\) who complained of glare, or that rooms were too bright or dark, and another group \((n = 97)\) who felt no glare, nor had any problems with room brightness. The results showed a significantly higher rate of symptoms in the former than latter. The prevalence of 'a perceived decrease of visual acuity' and 'eyes fatigued' were significantly higher when correlated with the length of working hours with VDTs. Groups studied were (a) working more than 5 days per week with more than 5 h per day \((n = 44)\); (b) working more than 5 days per week with more than 3 h per day; and (c) working less than 4 days per week with less than 3 h per day. Furthermore they noted eye symptoms were related to irritation with noise.

2.3. Clinical cases of visual dysfunction
Komoike (1979) reported a case where an individual suffered with abnormal colour vision after VDT work for the first time in Japan. This female worker had worked for six months with a VDT for 35 h a week from 0900 to 1700, undergoing special training for VDT work to promote office automation in the company. She was surprised to experience abnormal colour vision, so she consulted a doctor. The physician did not find any ophthalmological abnormality in visual acuity, colour vision, and so on. She
finally consulted Komoike. She complained of severe abnormality when the luminance of the screen was increased. Komoike speculated that this phenomenon might be caused by the McCullough Effect (McCollough 1965).

Kitayama et al. (1986) analyzed the eye movement of a VDT worker through an ‘eye-mark’ recorder, because she suffered from considerable eye fatigue without any ophthalmological abnormality except myopia. She was engaged in Chinese word processing using a Japanese word processor. Kitayama et al. reported that they were almost convinced that the eye fatigue was caused by this Chinese word processing work.

Ooishi et al. (1988) studied daily outpatients working with VDTs who seemed to suffer from a predisposition for glaucoma. He reported that some of them improved after they left VDT work.

Yoshikawa (1989) reported a 19-year-old VDT worker suffering from rapid increase of myopia during a two-year stint in a printing company, where he had been examined ophthalmologically before the introduction of VDTs, and twice a year afterwards. Given a stepwise distance change of a visual target from $-2$D to $-6$D with a period of 5s, he failed gradually to follow the target year-by-year and finally he was completely unable to follow it. Yoshikawa reported that a decrease of the accommodative function before working with a VDT might be a cause of the rapid progress of myopia. The progress slowed after stopping VDT work. Thereafter triggered by VDT work, it is possible to say that the tendency towards myopia becomes marked if accompanied by a failure to wear glasses. He suggested that a worker with such a decrease of the accommodative function should be barred from VDT work by an aptitude test.

The JAIH special interest group for VDT work began to collect and examine cases of illness in VDT workers in earnest from 1989.

2.5. Image quality, lighting, and reflection

There were very few investigations and researches measuring image quality or brightness.

Takahashi et al. (1987) measured direct and reflected glare at 834 workplaces, and work surface brightness and luminance characteristics of VDT screens at 659 workplaces. They asked 388 VDT workers at 160 workplaces to evaluate the brightness of characters. Being independent of a character luminance ratio at more than 5.0, the majority of VDT workers characterized it as ‘optimal’. There was a 41.2% ratio subjectively assessing characters ‘dark’ with the character luminance set at less than 4.9, but was less than 30.2% when it was more than 5.0. Most of VDTs were covered with screen filters. The background luminance ratio ranged from 1–3 cd/m². Takahashi et al. suggested that under these conditions character luminance ratio should be set at more than 5.

At a further 167 workplaces they asked 391 VDT workers to evaluate work surface brightness. Being independent of a work surface illumination level, the majority of workers evaluated it at their workplace ‘optimum’. However, Takahashi et al. noted that as the illumination level decreased, the percentage of workers assessing work surfaces as ‘dark’ increased, and those assessing them ‘bright’ decreased. Below the range 100–299 lx, 38.0% of workers assessed keyboards or documents as ‘dark’. The authors felt this result suggested that the illumination level of work surface should be kept at more than 300 lx.
2.6. Behavioural analyses
There were also very few investigations and researches analyzing or examining actual behaviour.

Kubota et al. (1986) analyzed objects habitually viewed by 34 VDT workers through video-taped records of nine workstations in three companies. They classified the viewed objects as: VDT screen; keyboard; printer; input document; and ‘other’. They sampled the viewed objects every 5 s by the snap reading method. In the case of non-professional KANA data (customer's name and address) entry operators, about 30% of work time was spent looking at the screen regardless of the length of time spent looking at the keyboard. In operators doing word-processing or programming, the time spent looking at the screen accounted for 30-70% of work time. In the case of professional numerical data entry, the time spent looking at the screen accounted for less than 10% of the work time, because the eyes concentrated mainly on the invoice slips.

3. Experimental research
3.1. Measuring methods of workload and fatigue in VDT work
3.1.1. Accommodative eye function. Many researches have been carried out to gauge the causes of eye fatigue in VDT work. Amongst these the change in accommodative eye function has been considered promising, and studied frequently.

Kurimoto et al. (1984) and Iwasaki et al. (1984a, 1986) mentioned that the low frequency component of accommodative fluctuation increased from 0.5 to 1.0 Hz through VDT work, using an infrared optometer. By utilizing the scale method, Tanahashi et al. (1986) evaluated a similar low frequency component. Tamura (1984) noted that the average controlling time for accommodation was prolonged by VDT work. Additionally he mentioned that this prolongation coincided with the increase of low frequency component. However, these experiments were based on only about 1-2 h VDT work, and in some experiments the increase of the low frequency component was rather small. Takeda et al. (1987) identified some cases that showed a fair increase of accommodative fluctuation after 1 h continuous VDT work, by using a 3D infrared optometer developed by Takeda (1988). This enabled them to measure the accommodation when the eyes move in real work for 40° in the horizontal and 30° degrees in the vertical. This result contradicts the above mentioned.

Takeda et al. (1986a, 1986b) used this method to examine step response of different accommodations. They underlined the problem that large individual differences disturbed the effect of VDT work. The usual measuring method using an infrared optometer requires subjects to view the target after VDT work. By thus interrupting the work a temporary recovery from possible fatigue may be caused. Furthermore, there might be an effect of myopia induced from the machine. These problems are not resolved. Takeda (1988) claimed that the increase of the low frequency component showed up in the central nervous system. However, this was not demonstrated by experimental evidence.

Takahashi (1987) mentioned that it took a long time to measure dark focus by using laser optometer and the variance was large. Ukai (1986b), Iida et al. (1987) showed there might be dark focus certainly measured by infrared optometer, but was rather variable and strongly affected by the accommodative condition before the measurement. Measurement by three dimensional optometer mentioned above which made possible the vision line to be free also showed different result. As Jaschinski-
Kruza (1986) mentioned it is necessary to bring to light whether dark focus is really resting point of accommodation or not.

Tokoro et al. (1986) and Takeda et al. (1987) developed an open front infrared optometer. This enabled the measurement of accommodation, eye movement, and pupil response simultaneously with VDT work. The progress of the study by using it is awaited. A device which enables the measurement of 'free' VDT work has not yet been developed.

3.1.2. \( A_r/A_s \)  Kabayama et al. (1987) compared \( A_r/A_s \) when loaded by 0.2 D/s accommodative stimulation between 3 h continuous VDT work and non-VDT office work for a 25-year-old male. Non-VDT office work hardly showed any effect. However, the accommodative response velocity decreased after 2 h VDT work. After 3 h near point lengthened and depth of accommodation decreased. They inferred that eye fatigue was apparent.

Ishikawa et al. (1986, 1987) measured \( A_r/A_s \) curve (Ukai 1983, 1986 a) when loaded by 0.25 D/s accommodative stimulation. Some subjects complaining of asthenopia showed \( A_r/A_s \) unequal to one. Other similar subjects showed as extreme differentiation for accommodative amplitude or velocity between the right and left eyes. Ishikawa et al. (1987) compared the pupil response by accommodative response (P/A) as well as \( A_r/A_s \), between hospital patients working with VDTs and a healthy control group working without VDTs. They found the process of pupil size changing at the phases between decrease and increase. They suggested this difference correlated with a feeling of fatigue. Kojima et al. (1988) mentioned that near reactions such as \( A_r/A_s \), \( P/A_s \) and \( C/A_s \) (convergence response by accommodative response) were useful to judge abnormality of VDT workers objectively. That is, abnormal \( A_r/A_s \) accompanied with poor pupil function or convergence.

3.1.3. Critical flicker frequency (CCF). Osaka (1985 a) showed that VDT fatigue as measured by CFF changed as VDT colour, eccentricity, and adaptation changed in the visual field. The CFF decreased as the distance from the fovea increased when measured by red flicker. On the other hand, it increased up to a 10' periphery, and then decreased when measured by blue flicker, except for white. Osaka mentioned that the rod-and-cone local flicker procedure is an useful index for measuring visual fatigue.

Oohira (1986) measured CFF by excluding the effect of change in pupil size and accommodation. He found that the change in CFF through VDT work became small. He warned researchers to be careful in using CFF as in index of asthenopia following VDT work.

Iwasaki et al. (1987 b) measured coloured CFF every 15 min during the two kinds of experimental tasks differing in work speed and workload. The displayed colour was white, and the energy ratio of red, green and blue was 1:1:1. They did not find changes of coloured CFF between the tasks. In the time course of the changes, however, they noted that green and yellow CFF deteriorated significantly only 30 min after loading. However, the red CFF value decreased significantly from the 15 min after starting the task, continuing until its end. They suggested that the decrease of CFF, in particular in work observing light directly, such as often using a VDT display screen, indicated deterioration of retinal function, rather than one of brain function such as mental or psychological fatigue.
3.1.4. **Eye movement.** Iwasaki *et al.* (1984 b, 1987 c) evaluated fatigued eye movement by measuring vergent eye movement using the jumping method. The eye movement was elicited by watching far or near target, which alternated every 5 s on the accommodo-polyrecorder. The time for convergence or divergence was recorded objectively. The authors found that divergence time was prolonged after VDT work, with high significance.

Saito (1986, 1987, 1988) and Saito *et al.* (1987) compared workload from the viewpoint of eye movement using the distribution of fixation points and saccadic velocity as indices measured by an eye mark recorder. They argued there was a negative correlation between amplitude and frequency of saccades in VDT work. However, the amplitude and frequency during VDT work is very much larger for other work. Eye movement velocity expressed by the product between amplitude and frequency was from 20 to 25°/s during VDT work. They showed that these were 2.5 times faster than other many usual visual tasks and correspond to that of a pilot when landing or taking off in a civil aircraft.

3.1.5. **Ocular tension.** Suzumara (1985) and Atsumi *et al.* (1986) reported that ocular tension significantly increased after VDT work. However Nakamura *et al.* (1985) did not recognize a significant difference in change for VDT work. Atsumi *et al.* (1986) noted that VDT workers suffered an increase in ocular tension even if they had good accommodative function. They suggested that the close relation generally noted between accommodative function and the increase in ocular tension was not necessarily absolute. Furthermore they speculated that such ocular tension increase might be not so high as to cause pathological change, because they could not perceive a decrease in the visual field.

Tanijima *et al.* (1988) did not record a significant change in ocular tension after 3 h word processing work in which the subjects were classified as from normal vision to myopia less than –3D. They suggested that about 3 h VDT work did not affect the movement of humor aquosus. However, they mentioned that ocular tension in middle-aged or elderly people should be further studied.

Nanba (1987) measured the change in ocular tension when eight healthy subjects with normal refraction aged 18–25 years worked for 2 h with or without VDTs. He observed a slight but significant increase in ocular tension after VDT work. By using eye drops of pilocarpine after VDT work, he found a significant decrease in ocular tension in comparison with the control task. He suggested that VDT work caused a slight relaxation of ciliary muscle.

3.1.6. **Surface temperature of cornea.** Atsumi *et al.* (1988) used a radiant thermometer and measured the surface temperature of corneal centre before and after VDT work, 5 times, 30 s after blinking. They noted a significant increase of the temperature after 1 h VDT work, but no significant increase for paperwork.

3.1.7. **Electroencephalograph (EEG).** Iwasaki *et al.* (1986) studied visual-evoked potential (VEP) as well as accommodation, performance, and subjective symptoms of nine female subjects with normal vision without ophthalmological diseases, aged 22. They conducted VEP from occipital area by a flash method before and after 1 h of calculation/discrimination tasks using VDTs. As a result, the accommodative relaxation time was prolonged significantly, and the latency of the positive wave of VEP elicited in about 100 ms delayed significantly after the task, in proportion to the
amount of the visual load. Glumann et al. (1979) and Regan et al. (1984) reported that the amplitude of the most prominent component was reduced with asthenopia and visual fatigue. Iwasaki et al. (1986), however, found a significantly reduced amplitude when a small visual load was applied.

Kotani et al. (1988) studied EEG and topographs in 10 min VDT work under monocular and binocular visual conditions. They found that the alpha-blocking under monocular conditions was stronger than that under binocular conditions. Moreover, they noted that the inhibitory state of right and left hemispheres of the brain under binocular conditions overturned in comparison with that under monocular conditions. However, they implied nothing about visual load by this phenomenon.

3.1.8. Subjective symptoms. Ishikawa et al. (1988) reported a high correlation ($r = 0.81$) between subjective legibility of displayed stimuli on various VDT screens and accommodative constricting velocities. They mentioned that the velocity might be an objective index for subjective symptoms.

3.1.9. Channel capacity. Ito et al. (1989) proposed a measurement method for general fatigue based on the attenuation of channel capacity, and applied it to VDT work. They displayed for 10 ms 11 pairs of alphabetic letters with $5 \times 7, 7 \times 13$ or $16 \times 16$ dots at foveal vision or parafoveal vision with visual angles of $4.6, 5.3, 6.1, 6.8$ and $7.6^\circ$. Subjects had to identify paired letters displayed. They used the ratio difference of the correct answers before and after VDT work as an index for evaluating general fatigue. They found that $5 \times 7$ or $7 \times 13$ dots and parafoveal position with $7.6^\circ$ were the optimal display to measure fatigue. They studied the effect of noise on various VDT work using this method. They noted that noise affected word processing work particularly badly. The result obtained by the proposed method corresponded with that of performance. However, they could not always detect changes of accommodative time, near point, and CFF. They concluded that accommodative time, near point distance, and CFF were problematic measurement methods to ascertain fatigue.

3.2. Display characteristics and readability of VDT text

3.2.1. Polarity. Misawa et al. (1986a) studied the effect of polarity on CFF, near point distance, accommodation time, subjective fatigue symptoms, heart rate, electromyography in the upper limbs, and performance score. The subjects were eight healthy male college students aged 21–23, having a naked binocular vision of not less than 0.7, and no astigmatism nor hyperopia. For the experiment four types of VDT screen image, that is, positive and negative screens, and green and white coloured displays, were used. Each operation took 2 h. The authors observed a greater decrease in CFF and more frequent complaints of subjective fatigue in subjects using a negative (bright characters on dark background) screen than those using a positive screen. They suggested that the visual load using negative screens is larger than positive screens.

Using an infrared video pupilograph, Ishihara et al. (1987) noted that pupil area was $28.6 \pm 8.8 \text{mm}^2$ (mean $\pm$ standard deviation) in case of negative display, and $7.6 \pm 2.1 \text{mm}^2$ in case of the positive, which favoured the latter.

Ishikawa et al. (1988) examined accommodation under different polarities for five people in their 20s and five in their 30s. The accommodative stimulus was disc visual target with diameter of 17.5 mm, which was displayed at 0.5 D of 2.0 D alternatively for different polarities. The authors reported that the positive display showed an accelerated velocity for accommodative constriction, though this claim was made without statistical analysis.
Kubota et al. (1988) concluded that the superiority of the positive VDT display was not as clearcut from the viewpoint of pupil size as previous studies had suggested. They investigated experimentally the relationship between display luminance conditions and pupillary response. For example, for a negative display, a character had 25 cd/m², the background had 1 cd/m², and that average luminance was 3 cd/m²; in another case, a character had 70 cd/m², the background had 25 cd/m², and the average luminance was 21 cd/m². In the case of a positive display, characters had 1 cd/m², the background had 25 cd/m², and the average luminance was 21 cd/m². The results indicated that pupil diameter response to an irregular luminance field is biased significantly in the direction of the peak luminance. Furthermore, the difference between pupil diameter and source document and screen luminance had more to do with the peak luminance of the screen than with the integrated luminance. Such a difference, even in the case a negative display, was not very large. The authors suggested that neither the proposed lighting differences based on image polarity nor the recommendations favouring positive VDT image polarity did not appear to be warranted. They concluded from the results of a subjective evaluation of brightness, ease of work, and eye fatigue that an appropriate luminance for documents was more important than the contrast ratio between the screen and documents.

3.2.2. Oscillation and stability. Sato (1984a, 1984b) described subjective symptoms such as 'feeling violent trembling when viewing or staring' and 'feeling a trembling under my eyelids when I touched my closed eyes' were peculiar to VDT work. She speculated that the causal factors were an inhibition of involuntary small rapid eye movement when gazing at the flickering figure on the surface of a VDT screen, and compensatory exasperation after such eye movement.

Takeichi et al. (1985) reported an apparent increase of pupillary diameter and a decreased response against light after 1 h work with a VDT flickering at 30 Hz, in comparison with 60 or 90 Hz. They suggested there might be a limit to flickering frequency beyond which pupillary response was badly affected.

Saida (1985) investigated saccadic eye movement in relation to the frequency of movement of a vertically moving point on a CRT screen. From these results he noted it might be possible to explain (a) the feeling that the displayed text was swaying or flickering and (b) the accompanied discomfort after saccadic eye movement during text reading.

Takeda et al. (1986b) disclosed that a small accommodation area was caused under negative polarity (bright characters on dark background) in case of low flickering frequency, but in case of higher rates it was created under positive polarity.

3.2.3. Colour. Tainaka (1985) required subjects to discriminate between numerals during 30 min of numerical sequences displayed at the centre of different stripe patterns in green on a VDT screen. He reported that the prevalence of a colour after-effect was about 70% horizontal stripes and about 7% for vertical stripes. The difference was statistically significant. In case of horizontal stripes the colour after-effect appeared already 10 min after the task started, continued for at least another 20 min and longer after task completion.

Ishikawa et al. (1985) investigated the colour after-effect by using Lagorio's colour chart, as well as accommodation and near point distance for 2 h VDT work (inputting or correcting text) at intervals of 30 min. The luminance of characters was 25 and 65 cd/m², and horizontal illumination was 300, 700 and 1000 lx. Colour after-effect
was more marked in green than in amber, and increased during 2 h green screen VDT work. However, with an amber screen it saturated after about 1 h. The authors noted that a higher luminance strengthened colour after-effect, and a rather high environmental luminance weakened it. However, the number of subjects was only four, the experimental task was not clearly described, and no statistical examination was done.

Osaka (1985a) investigated the decrease of CFF after 30 min of a simple addition task with a VDT displayed with red, yellow, green, blue or white. He recognized the significant difference depending on the colours displayed. That is, the decrease of CFF was 4.5–7.5 under red or blue, but was 3.5–5.5 under green or yellow.

Misawa et al. (1986a) observed greater extent of near point distance and larger complaints of subjective fatigue in subjects using the green coloured display than for those using the white coloured display by the method mentioned above in § 3.2.1.

3.2.4. Brightness and contrast. Ishikawa et al. (1988) investigated accommodative function by alternatively displaying a disc target with diameter of 17.5 mm at a visual distance of 0.5 D and 2.0 D. With an increase of disc luminance, the velocity of accommodative constriction and accommodative depth were improved and saturated at around 1.06 cd/m², for subjects in their 20s and 30s (n = 5, respectively). However, they reported there was no target luminance effect for a group in their 50s (n = 5).

3.2.5. Reflection. Tabuchi et al. (1987) carried out an experimental study using subjective appraisal (n = 12) to ascertain the permissible range of reflected luminance related to character luminance and the background with vertical illuminance from 30–400 lx. The display used was 12 ft, the mirror's reflective ratio was 0.045, and coefficient of diffuse reflection was 0.062 cd/m²/1x. They expressed their results as empirical formulae:

\[ L_c = 16 \times L_b^{0.71} \]

where

- \( L_c \) : preferred luminance of the character;
- \( L_b \) : background illuminance on the screen in the dark.

\[ L_r = 1.9 \times L_b^{0.91} \]

where

\( L_r \) : permissible value of the reflected luminance.

Furthermore, for the practical range of the \( L_r \), this contrast (\( L_r/L_b \)) was nearly constant, at about 1.2. The authors noted that to avoid reflected luminance, \( L_r \) should be kept under 1.2 \( \times L_b \).

3.2.6. Size and shape. Ishikawa et al. (1988) investigated accommodative function when negatively displaying disc targets with five different diameters, from 8.58–35.0 mm, with a visual distance of 0.5 D and 2.0 D alternatively. They reported that subjects in their 50s showed better accommodative response to the larger target.

3.2.7. Windowing, scrolling and paging. Saito et al. (1988) measured small rapid eye movement at fixation following a visual load of scrolling on a VDT display screen. They noted the change of frequency and amplitude of flicker as equal to that for a load of
saccadic eye movement. They concluded that scrolling was a stimulus causing, for example, optokinetic after nystagmus (OKN). Increased colour and light fluctuation accompanied scrolling, as well as the change in accommodation: scrolling created a visual load which led to the greatest eye fatigue. In this experiment, however, they investigated only three subjects, normal except for refraction disorder.

Takeda (1988) stimulated two female subjects (20 and 23 years, with normal vision) with random dot patterns, oscillated to the right and left on a display screen. He observed accommodation through a 3D optometer. He found that the farthest position of accommodation was 10 cm backward from the display screen surface, at \(-4\) D. He was convinced that accommodative function responds to stimuli of depth perceived by the motion parallax.

3.2.8. Display flatness. Sakamoto et al. (1989) compared different type of VDT display, such as CRT(TOE1, FTC-1455H), non-luminant LCD(NEC, N5914), plasma display (NEC, N5195), as well as polarity, by observing accommodative time, subjective symptoms, and correct response rate. Fifteen male subjects aged 21–23 years verified numerals for two 55 min sessions, with a 5 min interval. Displays were ranked CRT, PDP and LCD, in that order. Positive presentation was perceived to be 'good': the optimum display was positive presentation of CRT, and the worst negative presentation of LCD.

3.2.9. Comparison between VDT displays and paper. Kumashiro et al. (1984) carried out a comparative experiment between a VDT (Tandy Radio Shack, TRS-80) and paper, using seven healthy male students aged 21–22 years. The subjects did a 90 min task, multiplying two numbers of one figure (for every 30 min of the task, an 8 min measurement was done). Near point distance lengthened with the increase of working time with the VDT. The difference of accommodation after 60 min and 90 min from that before the task was significant. On the other hand, there was no marked change in the paper work. CFF and performance of sight adjustment decreased in a way similar to near point distance in VDT work; it also decreased with working time, but significant difference was shown only after 90 min. The peak frequency of an electroencephalograph band moved to slow a band with working time with VDT. However it was not significant. Thirty minutes after work the peak frequency returned to the band before work started.

Osaka (1985b) reported that the decrease of CFF was significantly larger in VDT work than in paper work, in a study where eight subjects did a 30 min task adding numbers. Furthermore the decrease of CFF was greater in the fovea and 10° periphery than the 20° periphery. However, it did not depend on the visual field in paper work. Prevalence of eye fatigue after work was 95% for the VDT, but was only 15% for paper.

Yoon et al. (1987) showed that visual load was greater in VDT work than hard copy/paper work by measuring ocular fixation time and near point distance, in a study where subject did a 90 min task twice, with a 5 min interval.

Atsumi (1988) compared temperature of cornea surface before and after reference work of 100 material names with colour VDT display and paper respectively. The paper was A4 size and the contrast ratio of the bright background to dark characters was 5. Subjects were seven males and one female, normal except for abnormal refraction, aged 27–41 years. The results showed that VDT work showed a significant increase of temperature, at \(0.37^\circ C\), but paper work showed no significant change. He
noted blinking had no influence, as measurements were done 30 s after blink. He concluded that congestion of the conjunctiva in case of VDT work might affect the surface temperature of the cornea.

3.2.10. Other factors. There were no studies carried out into information layout and format, coding, and labelling, and heading, in relation to eye fatigue.

3.3. Illumination level
Osaka (1985 a) found that the decrease in CFF was significantly larger under a dark screen adaptation than under a light adaptation. Subjects did a 30 min adding task. Osaka concluded that a bright adaptation causes less visual fatigue in VDT work.

Iwasaki et al. (1987 a) reported that the low frequency component of minor accommodative fluctuation increased under low illuminance or short visual distance. However they measured only three subjects for illuminance condition, while measuring fourteen subjects for visual distance. Furthermore they did not describe repetition times and did not statistically examine the data obtained.

Yamada et al. (1988) investigated the effect of illuminances of 10, 32, 100, 320 and 1000 lx with green display character luminance from 58.3 to 67.1 cd/m², and background luminance from 0.0 to 9.9 cd/m². They measured CFF, heart rate, subjective fatigue symptoms, and performance of eleven male subjects who did the Kanji correction test. As a result, at 10, 32 and 100 lx, the awakening level (CFF) decreased in relation to illumination and character luminance, as did working accuracy. At 1000 lx, the awakening level decreased, but accuracy did not decrease. At 320 lx, both the awakening level and accuracy did not decrease. At 320 lx, both the awakening level and accuracy did not decrease. They concluded that an illuminance of around 320 should be recommended.

There were no studies on the effect on eye fatigue of illumination quality, layout of illumination, and design of illumination, and so on.

3.4. Other office environments
Atsumi et al. (1987) investigated the effect of static electricity on CRT display screen. Ten subjects with no ophthalmological disease except abnormal refraction, aged 24–35 were tested for 2 h. When static electricity voltage was from 6–10 kv, a decrease in blinking and tear volume and a high prevalence of complaints such as extraneous substances in eyes, dry eyes, tearing eyes, and bloodshot eyes were noted. Furthermore, inflammation of the cornea in four out of ten subjects was discovered. The inflammation was measured after one night's sleep. On the other hand, when using filtered anti-static electricity, voltage was 0.0 kv and no cornea disorder and fewer subjective symptoms were found.

Edakawa et al. (1989) investigated the effect of magnetic radiation on accommodation and pupillary diameter. They generated magnetic radiation of 800 gauss coinciding with visual line at 10 cm in front of the subjects' eyes. The twenty subjects were patients working with VDTs who complained of eye fatigue; 20 controls were healthy people. The age range was from 20–35. No remarkable change of $A_e/A_s$ and $P/A_e$ for the eyes of the control group was found. However, in patient group a 20% clear improvement in, e.g., an increase of accommodative power and the slope of $A_e/A_s$ was found. A 30% improvement, in e.g., decrease of spasm at accommodative response was also found. In contrast 20% of patients suffered worse symptoms. A 20% (slight) improvement of $P/A_e$, that is, pupillary response, was found.
3.5. Tasks
Misawa et al. (1986b) studied the effect of different input devices on VDT task workload. They deduced from the significant differences of CFF, accommodative constricting time, pupil size, blinking counts and subjective fatigue symptoms that visual load was larger when using lightpens than when using keyboards. No significant differences between near point distance and accommodative relaxation time was found. However, significantly more speed and a higher error rate in performance under lightpen condition was noted. It is problematic that, in this experiment a difference in work output (use of a lightpen improved output 1-9 times) was considerable.

Sato et al. (1986) observed that with the increase of ratio of viewing a VDT (33, 50, 82 and 100%) for 1 h, blinking counts, frequency of subjects' closing eyes for more than 1 s, near point distance, and subjective fatigue symptoms increased, and visual acuity of near distance decreased. However, no remarkable change in CFF, heart rate, breathing counts and eye movement was noted. In spite of inconclusive data because of only one subject, it was argued that visual workload increases with an increase of ratio of viewing a VDT.

Ishihara et al. (1987) disclosed that the faster the presentation speed of figures on a CRT screen was, the more the pupil area increased significantly. The authors speculated that such a phenomenon occurred because emotional fluctuations in VDT work affects pupil area. They noted that such an increase of pupil area adversely affects depth of focus.

Tainaka et al. (1988) observed eye movement by use of an eye mark recorder in one skilled and two unskilled subjects for a Japanese work processing task. They analyzed 3 min out of the recorded task. The ratios of viewing the VDT screen and keyboard when inputting Japanese were from 22-48% and from 15-20% respectively. These ratios were higher than for an alphanumerics input task (Elias et al. 1980). Each fixation period for each visual object was short, although major eye movements from one object to another occurred very frequently. The efficiency of taking information in through major eye movements might be small; though skilled workers showed eye movement more frequently than unskilled workers. The former also moved the visual line to the keyboard, but the fixation period was very short as opposed to that of the unskilled. A frequent, major eye movement with a very short fixation time might be necessary for the subject to look at keyboard for the purpose of conversion and reconversion for katakana and kanji, for function key operation, and to view a display screen to determine synonyms during kanji conversion. Major eye movements increased with speed of the task. In order to decrease such eye movement, the authors proposed the following measures: a decrease in excess key operation, an improvement of distribution and layout of function keys, the alignment of display and keyboard so as to decrease the need for eye movement, and obtain a high rate of information intake for each fixation time.

3.6. Working hours and rest periods
Misawa et al. (1984) compared workloads in three work regimes. Subjects were nine male students, aged 19–23. The actual working time was 120 min. One regime had no rest period another had a 10 min break every 60 min, and the third had a 5 min break every 30 min. The VDT task was a simulated correction of preserved English documents on a VDT screen, in which the subject had to replace the letter 'e' with the number 5. A decrease of CFF, a lengthening of near point distance, an increase of subjective symptoms, the slow wave component in electromyography, and an increased error rate in performance was correlated with working time. However, the effect of third regime, that is, a 5 min break every 30 min showed the least incidence of the above
characteristics. From these results it was felt visually intensive VDT work required breaks. The duration of continuous VDT work should be less than 60 min and breaks should be frequent.

Iwasaki et al. (1984 b) investigated the effect of 2 h VDT work. Convergence time was unchanged before and after the task. However, divergence time prolonged significantly. The amplitude of vergence significantly decreased after the task.

Saito (1987, 1988) investigated eye movement. Six healthy male subjects aged 20-1-21:2 did 5 h of VDT tasks. For one task subjects tracked targets on a display screen in a clockwise direction. For another, instead of targets, figures were displayed, which had to be discriminated as quickly as possible, as above. No remarkable change in eye movement was found; only a significant difference between tasks. An extreme decrease of CFF that is, $-8.4\%$ in comparison with that before the task without clear change of heart rate and breathing was discovered.

Kabayama et al. (1987) investigated types of work breaks. The subject was a 27 year old female with no ophthalmological disease except $-3D$ myopia. She had to refer to randomly arranged figures on a display screen for 1 h. Recovery of decrease of accommodative function was faster when the subject did specific eye rest exercises such as far vision, fogging method, or lying down with eyes closed than recovery was when no special behaviour, with free vision, was allowed. Therefore it was concluded that for the purpose of health management it was better to guide VDT workers as to how to rest their eyes during the rest period.

Tanijima et al. (1987) measured blinking counts, break up time of tear layer and tear volume for six subjects aged 22-39 doing a 1 h VDT task. They found decrease of blinking counts, but no change for tears.

Horie (1937) made the subjects refer/add two numbers of a figure for 3 h with various combinations of continuous VDT work and break. The ratio of combinations between a period of work and a break was 30 min: 4 min, 60 min: 10 min and 90 min: 20 min, or 60 min: 5 min, 60 min: 10 min and 60 min: 15 min. Heart rate, CFF, performance, subsidiary behaviour, signal sound detection, subjective symptoms, and degree of impression of the task were measured. From the results obtained, the author concluded that 60 min work with 10 min rest was the optimum. In addition, those working with VDTs over 2 h per day should take at least 15 min rest for every 60 min work.

Yamano et al. (1988) compared step and lump response of accommodation, secretion of tear (by the cotton thread method) and ocular tension. They investigated 23 VDT workers aged less than 30 and with corrected visual acuity of more than 0.8; the control group was comprised of eight non-VDT office workers. The VDT group showed significantly more decrease of step response and secretion, and shortening of break-up time of the tear layer. Furthermore the subjects working more than 4 h per day consecutively or intermittently showed a much more remarkable change than those subjects working intermittently less than 4 h per day. From the results obtained it was concluded that intermittent VDT work for less than 4 h per day, with an appropriate level of resting time was advisable.

Sato et al. (1988) investigated the visual workload of VDT operators engaged in seat reservation work (Multi-Access Seat Reservation System) at railway booking offices for 3-4 h on average per day. CFF, near point distance, time for character reading, subjective symptoms, polygram (performance, illuminance, eye movement, blinking, respiration, and heart rate) and visual line distribution were measured on video tape records. From the results, the visual load of the work was thought to be small. However,
subjects did not work for the same periods, and data were not examined statistically: thus the result of this study could not be generalized.

3.7. Individual factors
The decrease of accommodative power with ageing is well known. Ishikawa et al. (1988) investigated accommodative response and pupillary diameter using various type of displays set up at the distance of 0.5 and 2.0 diopters. Accommodative response decreased with ageing on average with all types of VDT, and a decrease of pupillary diameter might increase the depth of focus so that visual load decreased.

Ibi et al. (1989) studied the influence of astigmatism on accommodation system of five subjects for each age class, that is, 20–24, 30–37, and 46–52. Artificial astigmatism over 1 diopter was induced on the accommodative system of subjects 20–24. The effect was a decrease of contraction velocity of accommodation, a prolongation of the settling time of accommodation, and an increase of accommodative fluctuation. From the results it was concluded that even if visual acuity was fairly good with mild astigmatism, the astigmatism needed to be corrected to achieve the preservation of accommodation for VDT work in the youngest age groups.

4. Legislation
Japan has lagged far behind Europe and North America in legislating for health problems associated with VDTs. The JAIM Investigative Committee on VDT Work and Occupational Health issued recommendations regarding VDT work and occupational health in July 1985 (Nishiyama et al. 1986). At the end of that year, and during the following, the Japanese Ministry of Labour (Directorate of Labour Standards Bureau, Ministry of Labour, 1985, and 1986) issued notifications. The Japanese Industrial Standards Committee (1987) established ‘CRT Display and Keyboard Units for Business Use’; however these were not mandatory. JERS made no particular response to the problem.

The Labour Ministry notifications referred to management of the working environment, maintenance of environment, maintenance of environment and devices, operation, health and education/training.

The typical worker to whom all of the above apply is, however, a person who is obliged to devote her or himself to continuous VDT work through every working day. Such continuous VDT work may be characterized as follows. Every working day is spent almost continuously with eyes fixed on a CRT display screen, or operating keys, save for associated administrative tasks such as the preliminary meeting at the beginning of the work day, delivery of documents, arrangement of VDT devices, a report of work done at the close of business, making notes as the occasion demands, perhaps some business contact as necessary, or waiting for answers and responses to queries. Many problems arise such that the upper limit of working hours with VDTs per day has not been determined. However few workplaces fulfill the requirements of these notifications (Ministry of Labour 1989).

A few cases of eye disease referred under the labour accident compensation system were claimed to have been caused by VDT work. There was no case which was recognized as due for compensation. Furthermore, the details as to why cases were not judged to be worthy of compensation were not publicized. In Watanabe et al. (1984), one of the claimants explained the process. This person’s eye disease compensation claim was rejected, so that he appealed to the Labour Insurance Jury Committee.
reasons for the initial claim dismissal were recounted to him by the Director of the Labour Standard Inspection Bureau Office, as follows: a causal relation between VDT work and disease symptoms was not recognized medically; no recognized precedent existed, nor were any similar claims pending. Watanabe felt that such reasoning was unfair.

5. General discussion and conclusions

It was only after the IEA Congress held in Japan in 1982 that any research into the effect of VDTs on health appeared; yet that computerization of office work began in Japan in the 1950s. Why was Japan so backward in the study of the VDT health problem? It is not possible to judge how far the computerization of office work related to occupational diseases in Japan during that time. Around 1960, the introduction of 'mechanized' office work began; this included a new kind of occupation, called a keypuncher. Soon after many workers engaged in such work suffered from occupational cervicobrachial disorder. It was highlighted as a major social problem by the Japanese labour unions. Nevertheless, the relevant academic and administrative groups failed to recognize the disorder. One of the reasons was that they could find no examples outside Japan (Nishiyama 1987). The prevalence of occupational cervicobrachial disorder suggested that, in the field of office work, new technology might cause serious occupational disease, therefore indicating that the development and introduction of new technology relating to office work should be examined from the viewpoint of occupational health and safety.

If a lesson from this experience had been learned well, Japan might possibly have been at the forefront of research into VDT work and health: VDTs had been used in Japan for office work from the beginning of the 1970s, as in Europe and North America. Moreover, at that time several enterprises discovered health problems related to VDTs, and coped with them. However, they were not publicized until the 1980s, when public interest grew. At the same time the labour unions began to express concern. Personal computers able to process Japanese characters came onto the market, and began to spread rapidly. In this situation, non-Japanese research on the effects of VDT work on health attracted greater interest. In this context the IEA Congress held in Japan strongly stimulated Japanese researchers. Unfortunately, what research there was did not match the social expectations towards researchers. In view of this, the JAIM Investigative Committee or VDT work and Occupational Health (1985) issued recommendations for VDT work. These were based mainly on general knowledge about occupational health and ergonomics, and on results obtained by non-Japanese research. Keeping up with this pace, domestic research gradually began to increase.

To conclude this critical review of the field surveys and experimental studies on eyesight and VDT work, the following observations are pertinent.

First, many field surveys and medical check-ups suggested that the visual load of VDT work is heavy, and that complaints and medical subsequent diagnosis relate to the use of VDTs. Some of these studies were unsatisfactory, in terms of epidemiological design and statistical analysis of data obtained.

There are few clinical cases reported as relating to VDT work. Moreover the pathogeny was not disclosed completely. There was no case recognized as appropriate for compensation by the labour accident insurance system. It does not follow, however, that the eye disease symptoms are not caused by VDT work. Occupational health measures in Japan tend not be be effected until the rate of medically-treatable occupational disease is observed to be high. As a result measures tend to lag behind
disease. The number of workers engaged in VDT work is, however, very large, so that the potentially-affected population cohort might be too large to compare with previous cases of non-VDT occupational disease. In this sense we should not remain idle simply because there is only a small number of clinical cases. People should take a serious view of the VDT risk, and work to secure comfortable working conditions, a reduction of working hours, and a decrease of load and fatigue.

Visual accommodation has been the most frequently measured physiological response to objectively evaluate visual load and fatigue in VDT work. There are other indices, such as eye movement, pupil size, critical flicker frequency, ocular tension, tears, surface temperature of cornea, electroencephalogram, but many of them lack the consistency and strength in their relation with VDT work. Furthermore these do not always depend on the length of working hours with VDT. There is no index that can help to evaluate the load and fatigue caused by VDT work alone. The best way to handle the interaction of vergence and pupillary response in evaluating accommodation remains an area needing research. There are also few physiological indices which are compatible with the subjective symptoms often observed in VDT work.

Many studies show that the workload is greater in VDT work than in paper work. Many experimental evaluations of the photometric characteristics of VDT screens supported the contention that positive presentation (bright characters on a dark background) is better than negative presentation (dark characters on a bright background. Although colour VDTs are widely used in Japan, CRT-type VDTs with good positive presentation are not common. For this reason it is difficult to do field surveys on positive presentation, so that any associated problems in the workplace may not have been recognized.

With regard to environmental factors, there are some experimental studies on the effect of static electricity or magnetic field on eyesight. Especially in the case of static electricity, this review shows measures are necessary not only for skin disorders but also effect on eyesight.

Many experimental studies deal with VDT tasks using alphanumerics. It is a noticeable feature in Japan, however, that, in comparison with VDT work in Europe and America, much Japanese VDT work includes processing of Japanese characters. Some experimental studies show that this can increase visual load additionally. Hence it is imperative to further investigate the processing of Japanese in VDT work.

Some experimental studies aim to obtain evidence to establish rules regulating the length of time spent working on VDTs per day. Although these studies suggest a limit, they are not systematic and extensive.

Some studies show that astigmatism increases visual load as well as presbyopia. This suggests the significance of the appropriate correction of astigmatism as an individual measure.

Finally, there is no special mandatory legislation regulating VDT work in Japan.

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A la suite du Congrès de l’IEA tenu au Japon en 1982, on a vu apparaître de nombreuses recherches consacrées aux effets du travail devant les écrans d’ordinateurs sur la santé. Cet article est une revue critique des travaux relatifs aux problèmes visuels posés par le travail sur l’écran. On peut distinguer les tendances suivantes:

- De nombreuses enquêtes médicales suggèrent que la charge visuelle sur l’écran est astreignante et suscite beaucoup de plaintes et de symptômes cliniques. Cependant, peu d’enquêtes épidémiologiques ont été bien conçues.
- Certaines observations cliniques ont été mises en rapport avec le travail sur écran, mais sa pathogenie n’a pas été démontrée.
- La réponse physiologique prise en compte pour évaluer objectivement la charge et la fatigue du travail sur écran était le plus souvent l’accommodation visuelle. Il y a d’autres indicateurs tels que les mouvements oculaires, la dimension pupillaire, la fréquence critique de fusionnement, la tension oculaire, les larmes, la température corneéenne, l’électro-oculogramme; mais ces indicateurs ne sont ni fidèles, ni fortement corrélés avec la charge de travail sur l’écran. Il n’y a pas d’indicateur qui, à lui tout seul, permet d’évaluer cette astreinte. Il y a aussi des indices physiologiques qui peuvent être mis en rapport avec les symptômes subjectifs observés lors de ce type de travail.
- De nombreuses études ont montré que la charge de travail est plus grande lors du travail sur écran que lors du travail sur papier. L’évaluation photométrique des caractéristiques des écrans confirme la supériorité de la présentation positive (caractère lumineux sur fond sombre) sur la présentation négative (caractères sombres sur fonds lumineux).
- En ce qui concerne les facteurs de l’environnement, on possède quelques études sur les effets de l’électricité statique ou du champ magnétique sur la vision.
- Dans les comparaisons avec l’Europe et l’Amérique, on constate que le travail sur écran au Japon entraîne une charge visuelle supplémentaire à cause du traitement de texte en caractère japonais.
- Certaines études se proposent d’établir des normes relatives au temps de travail devant un écran ou au temps de travail journalier. Cependant ces études sont restreintes.
- On pense que l’astigmatisme et l’hypermétrie accroissent la charge visuelle.
- Il n’existe pas de dispositions légales réglementant le travail sur écran au Japon.

Im Anschluß an den IEA Kongreß 1982 in Japan sind viele Forschungsarbeiten über die Wirkung von Bildschirmarbeit auf die Gesundheit erschienen. Dieser Aufsatz setzt sich kritisch mit den Felduntersuchungen und experimentellen Studien bezüglich der Augenprobleme bei Bildschirmarbeit in Japan auseinander. Folgende Trends wurden erkannt:

- Viele Felduntersuchungen und medizinische Untersuchungen deuten darauf hin, daß die visuelle Belastung bei Bildschirmarbeit groß ist und daß Beschwerden und anschließende

- Einige klinische Fälle wurden als Folge von Bildschirmarbeit diagnostiziert, obwohl die pathogenen Ursachen nicht enthüllt wurden.

- Die am meisten gemessene und geprüfte physiologische Wirkung zur objektiven Beurteilung der Beanspruchung und Ermüdung bei Bildschirmarbeit war die visuelle Akkommodation. Es gibt andere Indices, wie Augenbewegung, Pupillengröße, Fliimmerverschmelzungs frequenz, Augenspannung, Tränenmenge, Oberflächen- temperatur der Cornea, Elektroencephalogramm, aber es fehlt ihnen die Konsistenz und Stärke in ihrem Bezug zur Bildschirmarbeit. Es gibt keinen Index, mit dem alleine die Beanspruchung und Ermüdung infolge Bildschirmarbeit beurteilt werden kann. Es gibt ebenfalls einige physiologische Indices, die vereinbar mit den subjektiven Symptomen sind, die bei Bildschirmarbeit oft beobachtet werden können.

- Viele Studien zeigen, daß die Beanspruchung bei Bildschirmarbeit größer ist als bei Papierarbeit. Viele experimentelle Beurteilungen der photometrischen Charakteristiken der Bildschirmoberflächen stützen die Behauptung, daß die positive Darstellung (helle Zeichen auf dunklem Hintergrund) besser ist als die negative Darstellung (dunkle Zeichen auf hellem Hintergrund).

- Im Hinblick auf die Umgebungsbedingungen gibt es einige Untersuchungen über den Effekt der statischen Elektrizität oder der magnetischen Felder auf die Augen.

- Im Vergleich mit der Bildschirmarbeit in Europa und Amerika zeigen einige Untersuchungen, daß die Bildschirmarbeit in Japan die visuelle Belastung aufgrund der Textverarbeitung mit japanischen Zeichen verstärkt.

- Einige Untersuchungen zielen darauf, Regeln anzugeben, die die zeitliche Länge der Bildschirmarbeit oder die tägliche Arbeitszeiten regulieren. Die Untersuchungen sind aber nicht so systematische und umfassend.

- Es wird angedeutet, daß Astigmatismus genauso wie Weitsichtigkeit mit der visuellen Belastung zunimmt.

- Es gibt keine speziellen Vorschriften, die Bildschirmarbeit in Japan regulieren.

1982年に日本で開催された IEA 会議の後に VDT 労働の健康に及ぼす影響に関する研究が日本でも多く見られるようになった。本稿は日本における VDT 作業関連の目立るべき問題に関する現場調査と実験研究を検討した。以下の傾向が見られた。

- 多数の現場調査と健康診断は VDT 作業の視覚負担が高く、症状の訴えと医学的研究者により VDT の使用に関連していることを示唆している。しかし、疫学的によく計画された研究はほとんどなかっ

- VDT 作業に関連すると診断された臨床例が報告されているが、発病機序は解明されていない。

- VDT 作業での負担と疲労を客観的に評価するために最も測定、検討されている生理的反応は視覚調節、眼球動き、瞳孔の大きさ、眼瞼関節、角膜表面温度、脳波などの指標であるが、VDT 作業との関連についての一致率、強度性に欠けるものが多い。VDT 作業だけを生じる負担と疲労を評価できる唯一の指標は、VDT 作業でよく見られる自覚症状に対応する生理的指標もほとんどない。

- VDT 作業の方法や職場環境や作業負担が大きいことを示している結果も多い。VDT 画面の視覚特性の実験的評価では背景表示（暗い背景に明るい文字）が陰極表示（明るい背景に暗い文字）よりも良いという主張を裏付けてもいることが多い。

- 作業環境要因に関しては、視力に及ぼす環境または環境の影響についての実験的研究がある。

- オーストリアの VDT 作業と比較して、日本での VDT 作業が医療的により日本の VDT 作業が視覚負担がさらに高くなることを示す研究がある。

- 一連の VDT 作業時間を一日の VDT 作業時間の極限をもとにする実験的研究もあるが、体験的、全面的でもない。

- 記者としても乱視も視覚負担を増大させると示唆されている。

- 日本では VDT 作業を規制する法律はない。