A REVIEW OF NIOSH ERGONOMICS VDT RESEARCH

Michael J. Smith, Ph.D.

Applied Psychology and Ergonomics Branch
Division of Biomedical and Behavioral Science
National Institute for Occupational Safety and Health
Centers for Disease Control
Public Health Service
Department of Health and Human Services

Cincinnati, Ohio

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7. Author(s) Smith, M. J.

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9. Performing Organization Name and Address Applied Psychology and Ergonomics Branch, NIOSH, U.S. Department of Health and Human Services, Cincinnati, Ohio

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16. Abstract (Limit: 200 words) Recent laboratory and field research into the health and safety issues of work with video display terminals (VDT) by NIOSH was reviewed. Studies have been conducted to determine possible occulomotor and visual function patterns inherent in VDT viewing which may be related to eye strain or visual fatigue and to isolate workstation design, environmental and work regimen factors which are related to VDT operator health complaints and performance. While the studies thus far have not resulted in clear findings, certain areas of greater uncertainty have arisen. Using a variety of indicators of visual acuity, eye movement patterns, and pupillary response for VDT tasks lasting from 1.5 to 3 hours in the laboratory and over a normal work day in field testing, attempts to objectively quantify visual fatigue and strain have not been successful. These same studies have indicated a wide variety of subjective visual complaints including eye fatigue, eye irritation, and blurred vision as well as significant muscular strain. Both laboratory and field studies indicated that VDT operators have more subjective muscular strain than nonoperators and that ergonomically suboptimal workstation features produced increased muscular strain. Studies to date offered mixed results concerning the relative stressfulness of VDT and non VDT work.

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NIOSH has an active research program examining the health consequences of VDT work, including both laboratory and field studies. Findings from field studies generally indicate high levels of subjective health complaints from VDT users concerning visual, muscular and emotional problems. Laboratory investigations confirm these subjective symptoms of visual discomfort, but have been unable to show objective changes in visual functioning using many diverse evaluative methods. This may indicate that these methods are insensitive to the factors causing VDT operator complaints. Musculoskeletal complaints have been shown to be related to postural and other muscular loading factors such as task requirements. Job stress factors have been associated with somatic complaints and may interact with ergonomic features to heighten VDT operator distress and complaint level. A major need in VDT research is to develop methods that are more sensitive appraisors of discomfort and strain reactions. There is also a need to determine the most appropriate objective measures (especially for visual functioning) for assessing the basis of VDT operator subjective complaints.

INTRODUCTION

Interest in the health effects of video display terminal (VDT) use has steadily increased since the mid-1970s as evidenced by the investigative activities of national scientific bodies in the United States (NAS, 1983) and Canada (Canadian Task Force, 1982). There remains a significant amount of controversy about whether VDT use or associated work activities are harmful to worker health. Such controversy is predictable given that large numbers of VDT operators report complaints about visual disturbances, muscular aches and emotional distress, yet evidence for pathological effects, or dysfunction is absent. The abundance of subjective discomfort complaints has been sufficient to prompt calls for regulations and other strictive actions regarding VDT usage. On the other hand, it has been argued that since very little objective evidence for VDT health effects exists, there are no problems. Both positions must be questioned in the absence of adequate research to ascertain whether demonstrable health problems result from using VDTs.

To date there have been no long term evaluations of VDT operators which could serve as the basis for determining chronic pathological or functional effects. Similarly, there has been little laboratory investigation to systematically isolate factors in VDT work that underlie apparent visual and muscular strains, or offer objective characterizations of such effects. Finally, field studies to examine the effects of VDT technology and work processes have not been undertaken in such a way as to assess the potential for stress arising from the interaction of psychosocial, technological, organizational, job design and ergonomic factors. This paper will discuss recent laboratory and field research of the National Institute for Occupational Safety and Health (NIOSH) that addresses some of these issues where ergonomic factors are especially important.

LABORATORY STUDIES

NIOSH supported laboratory research on VDT work has been aimed at: (1) defining occulomotor and visual function patterns inherent in VDT viewing that may be related to eye strain or visual fatigue, and (2) isolating workstation design, environmental and work regimen factors related to VDT operator health complaints and performance. This research program has primarily been collaborative activities and funded research projects, with some inhouse activities. Dr. Helmut Zwahlen at Ohio University (1982; 1983) is conducting collaborative research with NIOSH staff in which the visual behavior of experienced typists is characterized as they work at a VDT workstation in a laboratory. A Gulf and Western Applied Science Laboratory 1998 computer controlled eye monitor system is used to collect and evaluate eye movements and pupillary response. Subjects perform data entry and file maintenance tasks on a DEC VDT100 VDT fitted with a Polaroid CP70 circular polarized glare filter. Adjustable furniture allows subjects to have comfortable screen height, keyboard height and chair height. An Armstrong Tascon lighting fixture is used to illuminate the work area according to NIOSH specifications (NIOSH, 1981).

A first study used 3 subjects who carried-out data entry and file maintenance tasks for 3 continuous hours. The purpose was to examine eye scanning behavior, amount of time looking at specific features of the work environment (e.g., the VDT screen) and the changes in pupil diameter. The results of the study are reported in Table 1. They show a varying eye scanning pattern between tasks but stable pupillary response.

A second set of laboratory studies is being conducted by Dr. Larry Stark at Berkeley University under funding from NIOSH. In these studies, Dr. Stark is evaluating the effects of VDT viewing on "reading eye movements". In a first study, six researchers served as subjects and read material on a VDT continuously for 1 1/2 to 2 hours. Before and after each reading session subjects' eye movements when reading standard textual materials were recorded with an eye tracker. The eye movements were analyzed for progression and regression as well as the duration of fixations. Subjects were asked to report any visual discomfort.

In a follow-up study, Dr. Stark examined 12 employees of the university library who worked on VDTs. The participants had varied jobs consisting of reading, data entry, and transcribing, and used VDTs varying amounts of time during a work day. Participants came to the visual testing laboratory before and after work on a typical day. As with the previous study, reading eye movements were assessed. In both studies, reading rate, regressions/progressions of eye fixations, recognition span and fixation duration were all unchanged from before work to after work. Neither study demonstrated changes in eye movement patterns from before to after work.

Laboratory work is also underway at the NIOSH Human Performance Laboratory and has the aim of defining relationships between environmental and workstation features that influence VDT operator comfort and performance. A paradigm of examining best case ergonomic conditions versus worst case has been employed. This research has been under the direction of Dr. Marvin Dainoff of Miami University of Ohio (Dainoff et al., 1982) in collaboration with NIOSH scientists.

A series of 3 studies have been completed where objective and subjective measures of visual and muscular effects of VDT work have been obtained. In the first study, 13 typists performed data entry and file maintenance tasks continuously for 3 hours for five days. On the first day baseline measures were taken of task performance, visual function and subjective health complaints. This served to familiarize the subjects with the testing procedures and the task to be performed, and to set baseline performance measures for calculating a bonus incentive pay for performance improvement. A battery of objective visual tests were given before and after the daily three hour work period. These included measures of visual acuity, phorias, near point of accommodation, flicker threshold and spatial frequency. Titmus eye testing equipment, a ruler and an Optronix 200 vision tester were used to make these tests. In addition, subjective measures of visual and muscular complaints were obtained before and after each day of work using a scaled ten item checklist displayed on the VDT screen.

Subjects conducted data entry and file maintenance tasks under best and worst case conditions on two days for each condition, with counterbalancing of the conditions to control order effects. Under the best case conditions, subjects worked at fully adjustable workstations in which the heights of the VDT screen, keyboard, seat pan and back rest were appropriately set for each subject. In addition, lighting was optimized using a Armstrong Tascon lighting fixture, and glare was controlled by fitting a DEC VDT100 VDT with a Polaroid CP70 circular polarized glare filter. In the worst case condition VDT height, keyboard height, chair height and backrest height were fixed for all subjects at settings approximating conditions observed and reported in office studies (see Dainoff, 1982).

The results of this study indicated better subject performance under the best case condition in terms of increased incentive pay (approximately 24% higher) which is indicative of improvement over baseline, and in terms of total keystroke rate (approximately 5% higher). None of the objective measures of visual function demonstrated differences between the best case and worst case conditions.

In terms of the subjective checklist responses there were higher levels of visual and muscular complaints under the worst case conditions. However, for visual effects, the differences between best and worst case conditions were not consistent. For example, higher levels for blurred vision, eye irritation and eye fatigue, were noted for the worst condition on the first two days but not on the last two days of testing. This was not true of headache which had a consistently higher level for the worst case condition on all days of testing.

Contradictory musculoskeletal effects were also noted in that the influences of the worst case condition were greatest on the postural muscles, but not on the manipulative muscles of the hands, wrists, and fingers for which lower levels of strain were reported under the worst case condition. The difference in the level of postural muscle complaints between the best and worst case conditions decreased over the days of testing.

In a follow-up study focusing on the musculoskeletal effects, 15 typists performed the same data entry and file maintenance tasks under the same best and worst case conditions for 5 days, with one exception. The visual environment (lighting and glare control) were equated for both best and worst conditions, such that only the adjustable versus fixed workstation and chair features were examined. The results for the muscular complaints differed from the first experiment in one major way. Both the manipulative and the postural muscular complaints were higher under the worst case condition based on subjective checklist measures. As with the postural complaints in Experiment I, this effect was greatest on the first two days of testing and decreased in the last two days of testing. In addition, the results for visual factors were more consistent than in the first experiment. For eye fatigue and eye irritation the worst case condition showed higher levels over all days, although the effect decreased over days. For blurred vision the effect was similar to the first study with the worst case showing higher levels on the first two days of testing and lower levels on the last two days.

The performance effects in this study were similar to those observed in the first study with the incentive rate about 16% higher under the best case condition and the total keystroke rate about 4% higher.

In yet another laboratory study, Dainoff and his associates examined the effect of rest breaks on the level of VDT operator subjective complaints and performance as well as objective measures of visual function as described in Experiment 1. In this study, 11 typists performed the same data entry and file maintenance tasks for 3 hours on five days as in the first two studies, and again received incentive pay for performance over the baseline determined on the first day. The workstation conditions were set to the worst case adjustments of the prior experiments. Under the rest break condition subjects were given 15 minutes of rest after each 60 minutes of work. Under the no break condition the subjects had to work continuously for three hours.

The results indicated no differences between the break and no break conditions in terms of objective measures of visual function. However, as with Experiments 1 and 2 there were differences in subjective health complaints. For visual complaints there were higher levels of eye irritation and eye fatigue for the no break condition, with the irritation effect decreasing over time and the fatigue effect remaining stable. Blurred vision showed lower levels for the no break condition on the first two days of testing and higher levels on the last two days of testing. Headache showed the opposite effect.

The muscular complaints showed higher levels over all days for the no break condition for both manipulative and postural muscles. For the manipulative muscles there was a decrease over the days of testing, while for the postural muscles there was an increase over testing days.

The performance data indicated that the rest break condition provided better performance in terms of higher incentive pay (7%) and a greater rate of keystrokes per minute (3%).

FIELD STUDIES

NIOSH has conducted field investigations of VDT operations using questionnaire and ergonomic observations of workplaces to define health concerns. A first effort was the NIOSH San Francisco evaluation (NIOSH, 1981; Smith et al, 1981) the results of which have served as a major impetus for NIOSH efforts in the VDT area. The questionnaire data provided indicators that VDT operators were reporting high levels of visual, muscular and emotional complaints, and that the levels of these complaints varied by the type of VDT task activities. The ergonomic findings indicated workstation/environmental factors such as too much illumination and improper keyboard height that could have contributed to the reported discomfort. While this evaluation had methodological and procedural shortcomings, it suggested the direction that VDT research could take in addressing worker concerns.

A NIOSH contract study by Sauter and associates (1983) was formulated from the theoretical, methodological and procedural approaches of the San Francisco study (see Smith et al, 1980). In the Sauter study, 248 VDT users and 85 non-users were compared on subjective ratings of stress and strain using a comprehensive questionnaire. In addition, photographic analyses were conducted on each workstation to define relationships between ergonomic conditions and subjective complaints. The questionnaire findings of this study (see Table 2) were notable in that the differences between VDT operators and non-operators were not as striking as in other research studies (see Dainoff 1982 for a review of VDT health studies). High levels of health complaints were reported by both VDT operators and non-operators and indicates that both groups were under stress and strain. This suggests similarities in the job stressors for the two groups.

This was confirmed in that few of the job stress factors showed differences between the VDT operators and the non-operators. One notable exception was that the VDT operators reported fewer job demands than the non-operators. However, the VDT operators did report greater work pressure, more role conflict, greater underutilization of abilities, less job autonomy, and less social support from supervisors than the non-operators. They also reported more supervisory control.

The photographic and ergonomic evaluation data, when correlated with the health complaints data for the VDT operators, indicated that the VDT operator's angle of viewing was positively associated with arm and hand discomfort and neck, back and shoulder strain. Also, non-detachable keyboards were associated with increased arm and hand discomfort and arm and hand strain. Finally, the higher the illumination level of the VDT screen and the surrounding work area, the greater the reported visual strain.

A second field study was a NIOSH evaluation of programmers using VDTs at a government facility (Smith et al, 1982). The evaluation consisted of a questionnaire survey concerning psychosocial stress, workplace design and health complaints, and an ergonomic evaluation of environmental and workstation parameters. In addition a Titmus Vision Tester was used to visually screen a sample of employees to determine the level of uncorrected visual deficits. A total of 198 employees completed the questionnaire (84% response rate), 33 workstations were given an ergonomic assessment, and 32 employees were given visual screening.

The results indicated that the ergonomic conditions were suboptimal when compared to various recommendations cited in the literature (see Cakir et al, 1979; NIOSH, 1981; ANSI, 1973; DIN, 1980). In particular, illumination levels at the keyboard and the document areas were either too high (exceeded 700 lux) or too low (less than 300 lux) at 60% of the workstations. In addition, 30% of the workstations had keyboard heights that were either too high or too low, and only 29% of the VDT keyboards were detachable. Character to screen contrast was less than 3 to 1 for 53% of the VDTs, and 100% of the VDT screens had significant glare.

The results of the questionnaire survey indicated health complaint levels that were consistent with other field studies (see Dainoff, 1982). In terms of vision problems, 81% reported headaches, 77% tearing or itching eyes, 71% burning eyes, and 69% eye strain. For muscular complaints, 60% reported neck pain and 59% back pain. Reported levels of psychological distress included 71% irritability, 62% sleeping problems, 61% depression, 59% tension and 57% fatigue.

The vision examinations indicated that 39% of the 32 employees evaluated had a deficit, the majority of which were acuity problems.

DISCUSSION

Rather than clarifying health issues regarding VDT work, NIOSH VDT research to date appears to have added more uncertainty. Attempts to objectively quantify visual fatigue and strain due to VDT work have not been successful using a variety of indicators of visual acuity, eye movement patterns, and pupillary response for VDT tasks lasting from 1 1/2 to 3 hours in the laboratory, and over a normal work day in field testing. Still, in these same studies large percentages of the VDT operators report a wide variety of subjective visual complaints from eye fatigue to eye irritation to blurred vision as well as significant muscular strain. How can such findings be reconciled? Does the absence of objective measures of what subjectively seems to be visually taxing work mean that the complaints of VDT operators should be written off as merely discomfort? Or, are the objective measures used thus far too insensitive to depict real effects? Assessment of visual fatigue remains a complex and often difficult problem (NAS, 1983). Indeed, attempts to define eyestrain in objective terms remains an enigma, suggesting to some that the term should be dropped. One of the deficiencies of current efforts to measure VDT operator visual function changes may reflect a more basic methodological shortcoming, namely, inadequate quantitative indicators of visual fatigue.

A major missing ingredient in evaluating VDT vision issues is the absence of a longitudinal study that can assess the potential for chronically induced changes in visual function. Until such work is done, there will continue to be controversy over whether VDT work is hazardous to vision (or more hazardous than other visually demanding jobs).

In terms of the musculoskeletal effects of VDT work, both laboratory and field research by NIOSH have shown that VDT operators have more subjective muscular strain than non-operators, and that ergonomically suboptimal VDT workstation features produce increased muscular strain. This finding is consistent with the literature (Dainoff, 1982) and implicates workstation design, task requirements and job design as primary culprits rather than the VDT. It must be recognized that VDT technology dictates the need for new workstation design, and when VDTs are put into traditional workstation configurations musculoskeletal strain is bound to occur. Thus, the VDT plays a role, even though it is an interactive one. Further work is underway at NIOSH to characterize musculoskeletal effects of VDT work on a more objective basis using electromyography.

With regard to stress issues, current NIOSH supported studies show mixed results about the relative stressfulness of VDT and non-VDT work. In one study, the VDT operators reported varied sources of stress as previously identified by Smith et al (1981). These include greater work pressure, more supervisory control and less job autonomy. However, contrary to other NIOSH studies, in terms of overall job demands, the non-VDT operators reported higher levels with associated higher levels of psychological disturbances such as anxiety, depression and irritability. This does not mean that the VDT operators were not stressed; indeed, the percentage reporting anxiety, depression and irritability for the VDT group was very high. In fact, the office worker control subjects may be a poor comparison group due to high stress levels. A second study of programmers using VDTs indicated relatively low levels of self report job demands and job stressors, but a high percentage (over 50 percent) reported anxiety, depression, irritability and fatigue. From these two studies it appears that while the VDT operators reported only moderate levels of job demands and stress, high percentages reported emotional distress, as did other office workers that were control groups. Further research into the VDT/office work as related to stress problems is continuing at NIOSH.

Overall, the results from current NIOSH laboratory and field research on VDT health issues demonstrates the lack of consistency between objective and subjective indications of health problems. This dictates renewal efforts to overcome methodological deficiencies. Such work is underway at NIOSH on a broad range of workplace issues where ergonomic factors are convergent with problems of job stress and strain.

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Table 1. Visual Behavior When Performing Two VDT Tasks*

Viewing Source	Date Entry Task	File Maintenance Task
<u>SCREEN</u>		
% Viewing time	14	34
Fixation per minute	14	23
Pupil diameter (mm)	4.26	4.12
<u>KEYBOARD</u>		
% Viewing time	28	22
Fixation per minute	29	23
Pupil diameter (mm)	4.22	4.16
<u>DOCUMENT</u>		
% Viewing time	—	—
Fixation per minute	38	32
Pupil diameter (mm)	4.15	4.05
<u>OTHER</u>		
% Viewing time	58	44
Fixation per minute	6	6
Pupil diamter (mm)	4.17	4.09

*See Zwahlen and Escantrela (1982)

Table 2. Comparison of Health Complaints of VDT Operators and Non-Operators*

Health Complaint	Percentage Reporting VDT	Percentage Reporting Non-VDT
Eye aches	75	64
Eye strain	75	75
Burning eyes	71	56
Tearing/itching eyes	68	60
Blurred vision	39	41
Backache	81	72
Back pain	79	72
Neck/shoulder ache	79	79
Sore shoulders	59	51
Neck pain	52	53
Arm/leg pain	56	52
Leg cramps	46	39
Swollen muscles/joints	41	42
Sore wrist	26	16
Hand/finger cramps	26	20

*See Sauter et al (1983)