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Visual Fatigue and Occupational Stress in VDT Operators

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In this study, 121 office workers whose jobs required the use of video display terminals for varying proportions of their workdays were interviewed. A semistructured interview technique was used to determine the attitudes of the workers toward their work and toward office automation. A smaller subset of this group was examined more intensively for 1 workweek, during which time optometric measurements were taken and a mood/physical symptom checklist was administered. Results indicated a relatively high level of incidence of eye fatigue symptoms, as well as complaints regarding glare and lighting. However, the patterning of these complaints appeared to be relatively independent of job pressure and hostility toward office computerization. No consistent pattern of optometric measurements was found to be related to subjective complaints.

INTRODUCTION

In recent years, considerable attention has been focused upon certain health-related problems and issues associated with the occupational use of video display terminals (VDTs). These terminals are becoming an increasingly familiar sight in the modern office workplace. Together with the large or small computer systems to which they are linked, the appearance of VDTs is indicative of a growing trend toward automation of office procedure. Concurrently, there are relatively large numbers of individuals involved with VDT operation who have had little or no training in, or familiarity with, the basic operation of computer systems (Galitz, 1980; Östberg, 1975). Waldholtz (1979) describes a recent "epidemic" of complaints from unions representing newspaper reporters and clerical workers who are required to interact with VDTs on an extensive daily basis. These complaints typically involve problems of visual fatigue accompanied by other physical symptoms such as arm, shoulder, and back pain and headache.

Documentation of such complaints can be seen in a variety of field investigations which are literally global in scope. In the following discussion, primary focus will be on visual system issues; however, a parallel set of evidence exists for musculoskeletal/somatic complaints.

Hultgren and Knave (1973) report that, of a group of Swedish insurance company employees who used VDTs, 47% complained of general eye discomfort and 59% indicated difficulty in seeing their screens because of reflected glare. Gunnarson and Östberg (1977) conducted a survey of 48 VDT operators who worked in a Scandinavian air-

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line reservation center. Seventy-five percent of the respondents indicated some visual discomfort at work, 46% reporting severe discomfort.

Results from a large-scale investigation of over 1000 German office workers (Cakir, Reuter, Schmude, and Armbruster, 1978) indicated that, of a group of high-speed data acquisition operators on piece work incentive schedules, 85% responded that, at least sometimes, their eyes were excessively strained at work. A second group of operators with similar task demands but not on incentive pay schedules showed a 68% response rate to the above eye-strain item; it was reported that the comparable response rate of the entire sample of VDT operators was 64%.

Two recent studies in which control groups of clerical workers who were non-VDT users were employed provides additional corroboration. Coe, Cuttle, McClellan, Warden, and Turner (1980) found that 50% of a group of 257 VDT operators in New Zealand reported symptoms of eye fatigue at work; this was compared with a figure of 33% among a group of 129 non-VDT office workers. In a Swiss investigation, Laübli, Hünting, and Grandjean (1980) found that among a group of 109 VDT operators whose work was interactive in nature, 24% reported an almost daily incidence of eye fatigue. Comparable response rates of 20% from a group of 53 data entry operators were, however, approximately equal to those of a group of 78 non-VDT typists. The lowest rate, 9%, was seen for a group of 55 traditional office workers. (These overall percentages are lower than in previous studies; however, the wording of the question indicates a more stringent criterion.)

In attempting to understand the possible bases for such an extensive range of complaints, it seems useful to consider the ergonomic characteristics of VDT equipment. There is some evidence that VDTs may potentially generate visual problems of a different magnitude and kind than are usually found with traditional hard-copy machines such as typewriters. A summary of these findings follows; more extensive details can be found in Gould (1968) and Cakir et al. (1978).

In most equipment examined by the above researchers, the dot-matrix method of creating characters on a VDT screen often resulted in a slight blurring of these characters. As a result, the automatic focusing mechanisms of the operators' eyes tend to be continually operating in a futile attempt to produce a clear image. The contrast between symbol and screen background is typically lower than that normally required; this condition may be exacerbated by the presence of a bright light source in the immediate surrounding area. Such sources often produce glare in the form of reflected light off the face of the screen, further degrading the contrast between symbol and background. Excessive light levels in the surrounding environment may present an additional problem in that the contrast between a relatively dark screen and a relative bright adjacent work area is much *greater* than recommended for comfortable vision. This may be of particular concern if the eyes must continually move between these light and dark areas, as when copying text. Software and hardware problems associated with particular pieces of equipment may cause disturbing flicker of individual letters or entire lines. (It must, of course, be pointed out that the extent and severity of these problems may vary depending on the particular equipment and lighting environment.)

The above conditions can, in general, be said to result in operation of the internal and external muscles of the eye in excess of that required of normal levels of focusing and eye movement. Such excess muscular activity may be perceived as visual fatigue or "eye strain" by the operator (Weston, 1962). At the same time, precise experimental evidence which might link specific characteristics of the VDT/workplace environment to specific symptoms of visual fatigue is not available. Moreover, as Hopkinson and Collins (1970) point out, many years of research on the general problem of visual fatigue have failed to find objective (psychophysical/psychophysiological) measures which are more valid than direct subjective assessment. Nevertheless, efforts in this direction continue.

In an experimental comparison of visual performance using both VDT and printed materials, Mourant, Lakshmanan, and Herman (1979) found patterns of eye movements which took longer for VDT tasks than for printed copy. On the other hand, Kintz and Bowker (1980) were not able to detect changes in the dark (resting) focus of accommodation between microfiche and print displays. No subjective indicators of fatigue were reported in either of the above experiments.

Haider and his colleagues (Haider, Slezak, Höller, Kundi, Schmid, Stidl, Thaler, and Winter, 1975, and Haider, Kundi, and Weissenböck, 1980) conducted an extensive field experiment in which experienced VDT operators were asked to work for varying lengths of time on screen-intensive tasks. Their VDT screens had either green or yellow characters. A battery of psychophysical and subjective measures was administered before and after each work session to each VDT operator as well as to a control group of conventional typists.

Of primary interest were the results of acuity measurements and subjective reports. After 3 h of continuous VDT work, those operators working at screens with green characters showed drops in acuity almost to the level of 20:25, requiring 16 min to recover to prework levels of 20:18. On the other hand, operators at screens with yellow characters demonstrated an average drop of less than 20:22, with a parallel rate of recovery. The control group showed no change at all.

The effects of work breaks on changes in acuity were examined by a combination of several studies utilizing screens with green characters. For those operators working for either 1 h or for 2 h with an interspersed break, drops in acuity were minimal. Three hours of work without break yielded an acuity drop of almost 20:23; however, operators on a 4-h work schedule which included a break showed an acuity deficit of almost 20:22 and required 16 min to recover to prework levels.

With regard to subjective measures, significant differences were found between VDT operators and control group responses to questions about eye strain, musculoskeletal complaints, and general fatigue. However, no differences were seen between green and yellow screen users.

Given the preceding patterns of evidence, it would seem reasonable to conclude that, despite a lack of understanding concerning the locus of specific psychophysical/psychophysiological mechanisms, visual fatigue is an important problem for VDT operators. Moreover, it is likely that such problems result from ergonomic shortcomings of typical machine/workplace environments. On the other hand, several additional considerations which might modify the above conclusions must be considered.

It is possible, for example, that the high incidence of complaints is reflective of a more generalized stress response to certain nonvisual aspects of the work environment. This could include, but not be limited to, factors such as work pressure resulting from demands for increased productivity, feelings of loss of individual control and autonomy in a computerized work environment, fears of loss of jobs due to automation, etc. (see Östberg, 1975; Shepard, 1971; and Galitz, 1980). Thus, it is possible that employees may use visual complaints as a more socially acceptable mechanism to express their dissatisfaction with office computerization.

Finally, it is worth pointing out that the severity of symptoms of visual fatigue may be exacerbated by a general state of debilitation or deterioration of the body (Weston, 1962, Ch. 2). Consider, for example, a hypothetical VDT operator who experiences a generalized stress response to some of the social-psychological stressors perceived to be part of the automated work environment. It is at least possible that the resulting physical debilitation, coupled with the necessity to perform in a visually demanding situation, will cause the operator's reaction to the entire situation to be expressed in the form of visual complaints.

The following is a field investigation of VDT operation, approached from a relatively broad perspective. A two-phase methodology was used. The first phase made use of a relatively unstructured interview procedure, allowing some indication of the priorities operators themselves assigned to health complaints relative to other aspects of their jobs. The second phase, which was more like previous field studies, constituted an in-depth examination of a smaller group of operators and used objective (optometric) and formal questionnaire measures along with the unstructured interview.

METHOD

Subjects

Two groups of subjects were studied. Group I consisted of 90 clerical workers from 15 different offices and organizations in southwest ern Ohio. Their median age was 23, and all but seven were female. The median length of time spent working at their present job was 8.5 mo. Of the total number of participants, 19% worked in word-processing installations, 21.5% with financial operations, 29% with record use, maintenance, and retrieval, and 30.5% in data entry applications. Although all installations studied had some VDT equipment in regular use, not all of the respondents used the equipment equally often. When respondents were asked to estimate the percentage of their working day which they spent actually looking at the VDT, the responses ranged from 0 to 100%, with the mean response at 47%. Arrangements for subjects' participation was accomplished by contact with various office managers and supervisors of organizations which were large users of VDTs. Within each organizational unit, all workers present on a given day participated in the study.

Group II participants consisted of 31 employees of a centralized library cataloging service whose daily work activities primarily consisted of data entry tasks. Twenty-five were female, six were male. They reported that, on the average, 75% of their working day was spent looking at the VDT.

Interview Technique

A standardized interview format was developed following the "funnel" technique suggested by Bouchard (1976), in which the investigator approaches the domain of interest with a series of broad, general questions and then proceeds to more specific followup items. In the present investigation, each subject was asked the following sequence of questions:

(1) Briefly, what is your job here?
(2) How long have you been in this job?
(3) I'd like you to tell me the things you *most* like and *least* like about your job. Mention the things you most like first.
(4) What are your feelings about the use of computer technology in the office? What do you most like and least like about computers?
(5) How satisfied are you with the physical surroundings of your workplace? I mean by this things such as furniture, office equipment, storage space, lighting, and so on.
(6) What would you change in your physical surroundings if you could?

(7) How do you feel, physically, at the end of a typical work day? Please be as specific as possible.
(8) Do you usually wear glasses or contact lenses at work? (If answer is Yes): Do you find them satisfactory? (If answer is No): Do you ever think that you might need glasses at work?
(9) Do you find the lighting at work satisfactory?
(10) Can you give me an estimate of what percentage of your working hours are spent looking at a video display screen?
(11) Can you give me an estimate of what percentage of your working hours are spent doing what you would consider close visual work?
(12) Do you think your job has had any effect on your health?
(13) Would you mind telling me your age?

Each interview took approximately 15 min and was tape recorded. (Seven of the subjects did not agree to the use of tape-recorded interviews; their responses were taken down by hand.) It will be noted that although visual and lighting issues are clearly a focus of questioning in the middle and ends of the question sequence, no specific mention is ever made, by interviewer, of eye strain or eye fatigue.

Optometric Screening Procedure

An industrial visual screening device was used to obtain measures of acuity, lateral phoria, and vertical phoria, at both near (0.35 m) and far (6.1 m) optical distances. Measures were taken binocularly, and corrective lenses were worn if used during work. Subjects were trained to take their own measurements under supervision.

Mood and Physical Symptom Checklist

Subjective reports of mood states and VDT-related physical symptoms were assessed using a 37-item checklist derived from two sources. Twenty-four items were taken from the Profile of Mood States (POMS); these items comprised the "vigor," fatigue," and "tension" scales of that profile (McNair, Lorr, and Droppleman, 1971). The profile was designed to be sensitive to relatively short-term fluctuations of mood and feeling rather than to reflect stable personality traits. An additional 13 items consisted of physical symptom descriptions. These were selected on the basis of reports in the literature as being particularly characteristic of VDT operators; they are listed in Table 5 in the Results section.

For each of the two groups of items discussed above, subjects were asked to rate how they felt regarding that item during the previous hour. A 5-point rating scale was utilized, 0 meaning "not at all," and 4 meaning "extremely."

Procedure—Group I

All subjects in Group I were interviewed using the standardized format just described. Prior to the interview itself, the subject was introduced to the interviewer, who described the study as an attempt to gain information about the feelings toward their work of office workers who use some form of computer technology. Participants were assured of the confidentiality of their responses as well as their right to refuse to participate. At the conclusion of the interview, subjects were debriefed, given an opportunity for questions, and informed that copies of the final report would be available to them.

The equipment used by the study participants included IBM System 6, Telex 227B, Honeywell, NCR Century 100, NCR 7200, Four Phase, and Xerox 850. Some of the computer systems in larger organizations were designed especially for those organizations. Unfortunately, in order to ensure confidentiality of responses, it was not possible to link specific pieces of equipment to specific operators in the data analysis.

Procedure—Group II

Data collection from Group II subjects required 8 workdays and took place in the following three stages:

Orientation. Potential subjects were initially contacted on a Friday. Cooperation was solicited from approximately 50 data entry operators who worked in two shifts in a single, large room containing 25 VDTs. Their work involved transferring bibliographic data from index cards onto a computer system. The nature and aims of the research were explained, and the operation of the visual screening device was demonstrated. It was emphasized that participation was voluntary and that subjects could drop out at any time. Individuals who chose to participate were asked to sign a consent form.

Visual performance, mood, and symptom assessment. Data collection took place during the next work week, Monday through Friday. On each day, subjects completed the following routine. Upon arrival at work subjects tested their own vision with the visual screening device for acuity and vertical and horizontal phoria at near and far distances. Immediately after the vision test, subjects filled out the POMS and physical symptoms checklist. They then proceeded to their normal work activities. Subjects repeated the visual screening device tests just before and again after lunch. At the end of the working day, subjects again filled out a POMS/physical-symptom checklist and tested their vision with the visual screening device. On Monday and Tuesday, an experimenter was present to aid subjects in using the visual screening device; during the remainder of the week, subjects were unsupervised.

Post-assessment interview. On the following Monday, each subject was interviewed using the funnel technique described above for Group I subjects. It will be noted that, for the Group II responses to be considered strictly equivalent to those of Group I, the interview should have *preceded* the more detailed visual testing and checklist administration phase. This was, unfortunately, impossible for a variety of practical reasons. As will be discussed, attempts were made in the data analysis to correct for the possible sensitization of the Group II subjects to the purpose of the study.

RESULTS

Interview—Coding and Description of Responses

Response classification system. Once the primary interviews had been completed, a classification system was developed into which individual responses to each of the interview questions could be coded. Thirty-two separate response categories were used, these being divided into four major classifications: Primary Health-Related Symptoms; Ergonomic Comments; Computer System Comments; and Job Comments. Table 1 indicates the list of response categories and descriptions.

Recall that one of the purposes of using the funnel sequence in designing the interview format was to obtain some assessment of the relative importance of perceived visual problems relative to other aspects of their jobs which might have been bothering the respondents. Accordingly, an attempt was made to define a set of response categories which would be specific enough to allow potentially important distinctions to be made, yet at the same time be broad enough to encompass most of the comments made by the respondents. It is felt that the list indicated in Table 1 meets these goals. Although it was not possible to exhaustively classify each respondent's comments, very little was said which could not be coded into one of the categories.

Categories III and IV contain several similar items, the inclusion of which resulted from attempts to distinguish among those comments related to the job itself. Note particularly Categories III-G and IV-I—both dealing with local operational problems. An example of a III-G response might be that the current computer program structure is ineffi-

TABLE 1

Interview Coding Classifications

I.	*Primary Symptoms*	
	I-A	Physical/mental stress: headaches, tension, mental strain
	I-B	Visual strain/fatigue: eye strain, blurred vision
	I-C	Lighting complaints: glare as a general workplace problem
	I-CC	Lighting complaints: lighting problems specifically related to VDT screen
	I-D	General fatigue: very tired, exhausted, drained after work
	I-E	Needs new glasses
II.	*Ergonomic Comments*	
	II-A	Cramped work space: poor workplace arrangement
	II-B	Noise
	II-C	Privacy needs
	II-D	Esthetic considerations: need for windows, cleanliness, color
	II-E	Uncomfortable furniture: chair/table heights and dimensions
	II-F	Keyboard problems
	II-G	Temperature/ventilation problems
	II-H	Positive environmental comments: pleasant surroundings
III.	*Computer System Comments*	
	III-A	Efficient: makes job easier, error corrections easier, speed
	III-B	Challenge: enjoyable, fun, interesting
	III-C	Down time: losing documents, other problems which result
	III-D	Slow response time
	III-E	Training problems: difficulties in understanding and working with system
	III-F	Hostility to computers in general: fears of unemployment
	III-G	Specific local operational problems
IV.	*Job Comments*	
	IV-A	Enjoyable: challenging, interesting
	IV-B	Pressure
	IV-C	Management complaints: ignore employee suggestions
	IV-D	Management complaints: other
	IV-E	Boring: lack of challenge
	IV-F	Excessive distractions: interruptions
	IV-G	Like atmosphere: coworkers, customers, supervisors
	IV-I	Specific local operational problems
	IV-J	Security/safety needs
	IV-K+	Good pay, benefits
	IV-K−	Poor pay, benefits

cient in performing a particular task. On the other hand, a IV-I response might be that the currently used business forms are poorly laid out and difficult to understand. Both are local in the sense that they refer to a particular problem which needs attention; however, III-G refers to the computer system per se, whereas IV-I refers to aspects of the job not directly related to the computer.

In addition, if Categories I-A and I-D are compared, it can be seen that an attempt has been made to separate specific symptoms of mental or physical stress from the related, but clearly different, perceptions of fatigue and exhaustion. This distinction was felt to be important in classifying those responses in which a general positive feeling of well-being at the end of a workday coincides with feelings of great fatigue. This would be similar to feelings experienced after jogging, playing tennis, etc.

Reliability of coding. The initial coding of responses from all 121 interviews using the above system was accomplished by one of the researchers. As a reliability check, a second researcher independently coded two samples of records. The first sample consisted of seven records from Group II on which one researcher had been the initial interviewer; the second sample consisted of 10 records from Group I on which the second had been the initial interviewer. In order to assess reliability of coding, the percentage of agreement between raters was computed. The number of agreements between judges was obtained by subtracting the number of disagreements from the total number of responses coded across the set of records. A disagreement could be either an omission or a difference in classification.

In the first sample, 67 coded responses produced seven disagreements, yielding an agreement rate of 89.25%. In the second sample, 102 coded responses produced 17 disagreements, yielding an 83.33% agreement rate. In both samples, virtually all disagreements comprised differences in classifications across categories with very similar content (e.g., III-B vs. IV-A: III-G vs. IV-I). In view of the nature of the planned analysis, it was felt that the reliability was sufficiently high.

Weighting of selected coded responses. Once the initial coding and description of the data had been achieved, a secondary stage of data analysis was undertaken to make use of the funnel sequence aspect of the interview format. This involved the application of a weighting system to selected response categories in such a way that the occurrence of a particular coded category of response early in the interview sequence (when questions were more general) would receive a higher weight than that response to a later, more specific, question. The response categories selected for this analysis included all of Category I (Primary Health-Related Symptoms) plus Category IV-B (Job Pressure). These categories were seen as most directly applicable to the primary purposes of the overall study.

Thus, all responses coded as I-A through I-E and IV-B were weighted as follows:

(a) If a given coded response occurred in reaction to an early, general question (Questions 3 or 4), that response received a weight of 3.
(b) If a given coded response occurred in reaction to a somewhat more specific question (Questions 5 or 6), that response received a weight of 2.
(c) If a given coded response occurred in reaction to a very specific question (Questions 7 through 12), that response received a weight of 1.

There were two exceptions to the above set of rules:

(1) For any particular coded response category, the appearance of that response subsequent to its final appearance received a weight of 1.
(2) For the Group II participants who were, as discussed earlier, potentially knowledgeable regarding the purpose of the study, all coded responses were assigned a weight of 1.

Accordingly, any participant who made at least one response coded as Category I-A through I-E or IV-B received a weighted category score for that category. This score was simply the sum of the weighted responses per category for each participant.

Interview—Primary Analysis

Table 2 provides the initial tabulation of response frequencies across the 32 response categories for all 121 participants. For each response category, the table indicates: (a) the number and percentage of participants who responded at least once within that category; (b) the number and percentage of total responses within that category; and (c) the rank orders of the 10 highest category percentages for both of the above methods of analysis.

Examination of Table 2 indicates that 9 out of the 10 categories appearing in this group of 10 highest percentages are the same for both methods of analysis. In fact, the rank order correlation coefficient (Spearman rho) between all corresponding 32 ranks was 0.98. This very high correlation between number of responses to a given category and number of

TABLE 2

Number, Percentage, and Rank Order of Number of People Responding Per Category and Total Number of Responses Per Category

		Number of People Responding			Number of Responses		
	Category	Number	Percent	Rank	Number	Percent	Rank
I. Primary Health-Related Comments	A	51	42.15	6	72	5.96	4.5
	B	55	45.45	4	86	7.12	2
	C	45	37.19	8	68	5.63	6
	CC	45	37.19	9	63	5.22	7
	D	35	28.93		36	2.98	
	E	41	33.88		41	3.39	
II. Ergonomic Comments	A	52	42.98	5	74	6.13	3
	B	19	15.7		23	1.9	
	C	12	9.92		14	1.16	
	D	41	33.88		59	4.88	9
	E	15	12.4		22	1.82	
	F	2	1.65		2	0.17	
	G	17	14.05		24	1.99	
	H	27	22.31		30	2.48	
III. Computer System Comments	A	98	80.99	1	111	9.19	1
	B	44	36.36	10	54	4.47	10
	C	59	48.76	3	60	4.97	8
	D	21	17.36		23	1.9	
	E	8	6.61		9	0.75	
	F	8	6.61		8	0.66	
	G	31	25.62		36	2.98	
IV. Job Comments	A	68	56.2	2	72	5.96	4.5
	B	29	23.97		32	2.65	
	C	9	7.44		11	0.91	
	D	15	12.4		17	1.41	
	E	32	26.45		39	3.23	
	F	10	8.26		10	0.83	
	G	46	38.02	7	47	3.89	
	I	32	26.45		40	3.31	
	J	6	4.96		7	0.58	
	K+	5	4.13		5	0.41	
	K−	7	5.79		7	0.58	
	Total	121			1208		

people responding to that category indicates that resulting data represented a consensus and were not due to a relatively small number of people making a relatively large number of repetitive comments.

Note that four of the six Category I response frequencies (Primary Health-Related Symptoms) appear on the top 10 list. In particular, reports of visual fatigue are given by 45% of the respondents; this comprises the second most frequent number of responses. In addition, symptoms of physical or mental stress (I-A) are reported by 42% of the participants, and lighting complaints (I-C, I-CC) are made by 37% of the participants.

Moving out of Category I, one of the major concerns has to do with crowding and/or poor arrangement of workspace (Category II-A). This response category is mentioned by 43% of participants and is third most frequent in terms of number of responses. Esthetic considerations (II-D) are mentioned as well by 34% of the participants.

The most frequently coded response category is III-A, reported by 81% of the participants. This high frequency of response, indicating positive comments concerning the operational efficiency of office computerization, is not surprising since Question 4 specifically asks what the participants like about computers. In fact, the only alternative response to the question would be either to make a Category III-B response (computers are challenging/fun)—which was made by 36% of the participants—or to say nothing.

Likewise, 56% of the participants find their jobs enjoyable (Category IV-A). Here again, participants were directly asked—in Question 3—what they liked about their jobs. The only viable alternative was response category IV-G (liking the atmosphere) or to say nothing. Category IV-G was, in fact, used by 38% of the participants.

With regard to concerns about office computerization (Category III), it can be observed that the major problem seems to be with work interruptions caused by the computer's being down (III-C). Forty-nine percent of the respondents mentioned this as an issue—the third most frequent category. On the other hand, only 6% of the respondents expressed hostility toward the computer or indicated fears that its use would result in unemployment (III-F).

Finally, note that none of the responses involving concerns about the job itself (Category IV) was frequent enough to be included on the top 10 list. (Categories IV-A and IV-G both indicate *positive* comments about the job.) It is interesting that issues of salary and benefits (IV-K) were mentioned by very few people, either positively (4%) or negatively (6%).

Interview—Secondary Analysis

Combination of selected categories. As has been discussed earlier, the pattern of results coded into Categories I-A through I-E as well as Category IV-B is of particular interest in this study. Therefore, additional analyses will be concentrated on these categories. One approach which appears to provide useful information has been to derive a set of a priori factor scores. Initially, in establishing the original set of 32 response classification categories, an attempt was made to define categories rather narrowly and specifically. For the present analysis, however, certain of these categories were combined. This combination was done on a logical basis prior to data analysis; thus, the combined scores are called a priori factors. (Traditional factor analytic techniques result in similar kinds of factors, but these are extracted from the data after correlational analysis.)

Three factors were defined from the selected categories discussed above: Fatigue-Stress 1 resulted from the additive combination of Category I-A (Physical/Mental Stress) and Category I-D (General Fatigue), encompassing those physical and mental symptoms which were seen as stressful or fatiguing, but were not attributed to visual aspects of the VDT task. Fatigue-Stress 2 was defined by adding Category IV-B (Job Pressure) responses to the Fatigue-Stress 1 factor. Thus, the constellation of stress symptoms then included comments specifically attributed to time and work pressures. Finally, factor Light combined those categories specifically dealing with visual effects: Category I-B (Visual Fatigue), Category I-C (Lighting Complaints), Category I-CC (VDT Lighting Complaints), and Category I-E (Needs Glasses).

The initial use of these factors was to ascertain the relative percentages of participants who made at least one response in at least one of the categories making up a factor. These percentages are 55.37% for Fatigue-Stress 1, 60.33% for Fatigue-Stress 2, and 75.21% for Light. Thus, over half the total group of respondents mentioned some aspects of general stress/fatigue associated with their work, whereas three-quarters of the participants reported visual problems. Adding the Job Pressure category to factor Fatigue-Stress 1 in order to produce factor Fatigue-Stress 2 only increases the percentage of respondents by five percentage points; thus, the two groups presumably overlap. Furthermore, if factors Fatigue-Stress 1 and Light are themselves combined, the increase in persons responding with at least one of the above (that is, with any Category I response) is 83.47%. This is an increase of only about 8% above the Light alone results and indicates that most of the people making Light responses were also making Fatigue-Stress responses. This conclusion will be further amplified in the correlational analyses found in the next section.

Correlational analyses of weighted responses. The final stage of data analysis utilized the weighted category response scores, discussed earlier, which were applied to Categories I-A through I-E and IV-B. Table 3 indicates, for each of the above categories, the sum (across participants) of weighted category scores. For comparative purposes, the percentages of people responding in a given category (from Table 2) are also included.

These weighted scores give some indication of the relative importance or priority of the responses to the individual respondents, since they reflect the relative order in the interview sequence with which responses occurred. These data are generally consistent with results so far obtained. Visual Fatigue responses (I-B) were given often and early, resulting in the highest combined weighted score; Lighting complaints (I-C) were next, and General Fatigue (I-D) was least important. Of some interest is the relatively high score obtained for the Job Pressure responses (IV-B) compared with the low percentage of persons making that response. It seems that, for those individuals who did complain of job pressures, the complaints were of consider-

TABLE 3

Sum of Weighted Category Scores and Percentages of Participants Responding

Category	Sum	Percentage
I-B (Visual Fatigue)	101.03	45.45
I-C (Lighting Complaints)	83.97	37.19
I-A (Physical/Mental Stress)	76.97	42.15
I-CC (VDT Lighting Complaints)	75.02	37.19
IV-B (Job Pressure)	62.92	23.97
I-E (Needs Glasses)	40.08	33.88
I-D (General Fatigue)	35.09	28.93

able importance, thereby receiving high weights.

The last, and in many ways most important, analysis involved correlating the percentage of estimated time spent looking at the VDT screen (Percent VDT Time) with: (a) the weighted scores on each of the selected response categories described above and (b) the weighted scores on each of the three factors discussed earlier. Note that these factors are now defined in terms of weighted score totals, rather than frequencies, as had been done earlier. Table 4 lists the correlation coefficients. It should be pointed out that these coefficients have been selected from an overall correlation matrix of each variable with every other variable. Furthermore, since examination of the scatter plots revealed that the resulting relationships would be unlikely to meet the assumption of homoscedasticity, a rank order correlation procedure (Spearman rho) was used.

Examining the factor score correlations, a clear-cut picture emerges. The correlation between time spent looking at the VDT screen and extent of general stress/fatigue complaints is low and not statistically significant. This is in spite of the finding that over 50% of the participants made these responses. If one adds the Job Pressure category (Fatigue-Stress Factor 2), the correlation drops to 0. However, the correlation between VDT time and the Light factor is moderately large and highly significant. Thus, complaints about visual fatigue and lighting increase with the amount of time spent looking at the VDT screen.

These conclusions may be amplified by examining the individual category correlations. Of the categories making up the Light factor, only two are significant: I-B (r = 0.28) and I-CC (r = 0.39). Thus, complaints about general lighting (I-C) and the need for glasses (I-D) do not appear to relate to exposure to VDTs in this study. (Note, however, that general lighting complaints occur somewhat more frequently than VDT-related lighting complaints—I-C vs. I-CC in Table 2—and are also seen as more important—Table 3.)

Furthermore, it is of considerable interest that the Job Pressure category (IV-B) has a statistically significant negative correlation with VDT time. Those who complain most about job pressure apparently have job demands which require the least amount of looking at the screen.

Two possible sources of bias exist in these data. First, it is possible that the significant

TABLE 4

Correlations of Weighted Response Category and Factor Scores with Percentage of VDT Looking Time

Factor/Category	*r (Spearman's rho)—VDT Time*
Fatigue-Stress 1	0.15
Fatigue-Stress 2	0.00
Light	0.30**
I-A (Physical/Mental Stress)	0.19
I-B (Visual Fatigue)	0.28**
I-C (Lighting Complaints)	−0.02
I-CC (VDT Lighting Complaints)	0.39**
I-D (General Fatigue)	−0.07
I-E (Needs Glasses)	0.09
IV-B (Job Pressure)	−0.19*

Statistical significance level: * $p < 0.05$.
** $p < 0.01$.

correlations with Categories I-B and I-CC are due to the fact that the job requirements of those individuals who have high VDT time values are inherently more visually demanding. Thus, it is the task itself—independent of the VDT pressure—which results in the complaints. Some evidence against this hypothesis can be obtained by noting that the correlations between I-B, I-CC, and the estimated percentage of close visual work required by the job are low and nonsignificant ($r = 0.1$ and $r = 0.15$).

Secondly, upon recalling that 31 of the participants (those in Group II) clearly knew, at the time of the interview, that issues of stress and visual fatigue were involved in the study, it might be argued that these participants had a bias toward answering with Category I responses. Even if one takes into account the reduced weights assigned to their responses, the fact that this group had exceptionally high average percent VDT times (75.2% as opposed to 36.0% for Group I) might have spuriously inflated the correlations. Accordingly, the above analyses were rerun without the Group II participants.

Results were dramatic. The correlation of VDT time and visual fatigue (I-B) remained exactly the same; however, the correlation with I-CC increased to 0.50. This boosted the overall correlation with the Light factor to 0.32. Thus, far from inflating the obtained correlations, the Group II data seem to have lowered them.

Finally, the presence of two different models of VDT equipment within the same organization (Group II) allowed the possibility of a comparative analysis. An older VDT, used by 20 operators, had only a clear glass faceplate, with no glare-control treatment, while the newer model, used by 11 operators, contained an etched faceplate as an antiglare device. Both units had identical phosphors and keyboards, but the newer unit also had slightly larger characters and better contrast. Of the operators using the nontreated faceplates, 80% indicated complaints about lighting and/or glare (Categories I-C, I-CC), and 60% indicated complaints of eye strain (Category I-B). Comparable percentages for those operators using the etched glass faceplates were 45% and 36%. These differences are suggestive. However, they failed to reach statistical significance.

Optometric Screening

Due to subject attrition, complete or partial data were collected for 23 individuals. Six different tests of visual performance were examined: acuity (both eyes), vertical phoria, and horizontal phoria for far distances (optical distance = 6 m); and acuity (both eyes), vertical phoria, and horizontal phoria for near distances (optical distance = 35.5 cm). Since subject responses fell, in general, within population norms provided in the visual screening device manual and correlations across daily sessions ranged from $r = 0.69$ to $r = 0.95$, it was assumed that the self-administration procedure was sufficiently reliable. Linear regression analysis, however, revealed no significant effects in any of the six vision tests due to time of day or day of the week; on the average, visual performance remained unchanged regardless of the time that the measures were taken.

Individual subject records were examined in detail. Although occasional individuals showed suggestive patterns of changes in visual function as a function of time of day, such patterns were highly idiosyncratic, allowing few or no generalizable conclusions.

POMS/Physical Symptom Data

POMS/physical symptom data consisted of two administrations per day (arrival at work and quitting time) of the 37-item adjective checklist. The 37 items composed four scales:

vigor, fatigue, and tension, plus the physical symptom scale. The data were scored by obtaining the sum of the adjectives for each factor. A higher score, therefore, indicates either nonzero responses for several items or high ratings on a few items. Data from the four scales were analyzed to discover any differences in scores due to day of the week or time of day. Linear regression analysis revealed no significant differences in rated vigor, fatigue, tension, or physical symptoms due to day of the week; subjects reported no more tension, fatigue, physical symptoms, or less vigor later in the week than earlier. Significant differences, however, were indicated for the time of day the measures were taken for three of the four measures. Subjects reported no change in vigor at quitting time compared to arrival at work, $t(22) = 0.215$, n.s.; however, subjects reported significantly more fatigue, $t(22) = 2.22, p < 0.05$, more tension $t(22) = 4.46, p < 0.05$, and more physical symptoms, $t(22) = 2.79, p < 0.05$, after work than before.

Further analysis of the physical symptom data, illustrated in Table 5, indicates that the largest increases in physical symptom complaints over the course of the workday were caused by eye strain, blurry vision, neck and shoulder problems, focus problems, and lower back problems.

DISCUSSION

The pattern of results obtained from the analysis of unweighted interview response scores presents a clear picture of concern among the participants about the visual aspects of working with VDTs. Almost half (45%) of the sample reported specific symptoms of visual fatigue. If these people are combined with those concerned about poor lighting or who need glasses (Factor Light), the total reaches 75%. These figures are clearly within the range of those obtained in the field studies discussed previously and would seem to confirm the existence of visual problems among operators of VDTs. Given that the visual fatigue symptoms comprise the largest component, by far, of the visual factor, it is important to recall that the phrase "visual fatigue" was never actually mentioned by the interviewer as part of the questions he was asking.

Symptoms of physical and/or mental stress seem also to be on the minds of the members of the sample group. Reports of such symptoms were mentioned by 42% of the partici-

TABLE 5

Percent of Subjects Reporting Physical Symptoms (Response > 0) for Ratings at Arrival (Test 1) and at Quitting Time (Test 2)

Physical Symptoms	*Test 1*	*Test 2*	*Increase*
Colored fringes around objects	2.1	3.3	1.2
Upset stomach	8.4	11.0	2.6
Colors don't seem right	0.0	4.4	4.4
Dizzy	4.2	8.8	4.6
Headache	22.1	28.6	6.5
Wrists and fingers cramped	8.4	18.7	10.3
Arms hurt	4.2	17.6	13.4
Eyes uncomfortable (dry, irritated, burning)	35.8	49.5	13.7
Lower back hurts	7.4	26.4	19.0
Hard to focus your vision	16.8	38.5	21.7
Neck and shoulders hurt	18.9	41.8	22.9
Blurry vision	14.7	39.4	24.9
Eye strain	30.1	62.2	32.1

pants; this percentage goes to 60.33% when persons who mention fatigue or job pressure are included (Fatigue-Stress Factor 2). These comments were not directly linked to the visual aspects of VDT work by the participants, although there may obviously be underlying causal connections.

These results are confirmed by the POMS/physical symptom data obtained from Group II over a 5-d period. These data indicate that the workers were more fatigued and tense at the end of the day than upon arrival at work; moreover, specific symptoms relating to eye strain and neck, shoulder, and back pain showed considerable increase across the course of the day. In this regard, it is interesting that the interview data did not reflect a great deal of concern with musculoskeletal complaints. Although the primary focus in the interview was on lighting and vision, a specific mention of problems with furniture (Question 3) and health (Question 12) would have allowed this problem to emerge. However, specific indications, in interview protocols, of musculoskeletal complaints were so rare that it was not deemed appropriate to provide a separate category. It is not clear why respondents who did not spontaneously complain of musculoskeletal problems in the interview were quite willing to indicate their presence on the checklist.

Looking at the remainder of the unweighted interview data, one sees a group of individuals who, by and large, like their jobs (56%) and find the computer technology in their offices to be efficient (81%) and fun to work with (36%). Their major concerns, in addition to those just discussed, are with crowded and/or poorly arranged work areas (43%) and with interruptions caused by failure of the computer system (49%). With respect to the latter, these data cannot reflect the vehemence with which a large proportion of the respondents expressed their concern at the frequency with which their systems would go down. A great deal of frustration was expressed over being unable to complete the work they were expected to do. This was particularly true for those who used VDTs for file access in answer to telephone inquiries; these people then had the additional problem of dealing with irate clients/customers for whom the failure of a computer system was not a reasonable explanation for failure to deliver information or service.

When the responses are weighted as to the priority of their appearance in the interview sequence, the summed weighted category scores give a clear indication of the relative importance of visual fatigue and inadequate lighting as problems perceived by VDT operators. This conclusion is reinforced by the pattern of correlations of weighted category scores with the percentage of time operators spent actually looking at their VDT screens. Visual fatigue and lighting complaints showed a moderate but highly significant correlation with percent of time at the VDT. However, reported symptoms of physical and/or mental stress revealed a small and nonsignificant correlation with this variable, whereas comments about job pressure revealed a significant negative correlation.

It is reasonably clear from the analysis cited above that the more time a VDT operator spends looking at the screen, the more likely it is that the operator will experience symptoms of visual fatigue or be aware of the inadequacy of lighting. Moreover, the frequency of these complaints is sufficiently high to be a matter of general concern for supervisors and purchasers of office computer equipment. What is not quite clear, however, is the nature of the nonvisually related reports of physical/mental stress. These could, of course, be a reaction to the pressure of job demands which are independent of the visual aspects of the equipment used. On the other hand, it is possible that such symptoms may, at least in part, reflect nonspecific responses of the body to the visual demands and problems associated with VDT work. Since many people are not particularly conscious of their visual environments, symptoms of eye fatigue may be translated into general symptoms of headache, lowered energy level, etc.

The correlation of Job Pressure (IV-B) with Physical/Mental Stress (I-A) yields a correlation which is low but statistically significant ($r = 0.19$; $p < 0.05$). However, the correlation of Job Pressure with Fatigue (I-D) is relatively large and highly significant ($r = 0.43$; $p < 0.01$). Thus, reports of pressure on the job seem to be more related to fatigue than to stress. At the same time, the stress measure (I-A) has a low but significant correlation with the percentage of VDT time ($r = 0.19$; $p < 0.05$); this is not, however, the case for the correlation of fatigue (I-D) and VDT time ($r = -0.07$). Finally, there is a relatively large and significant correlation of stress (I-A) with visual fatigue ($r = 0.31$; $p < 0.01$) and VDT-related lighting problems ($r = 0.30$; $p < 0.01$), but not with general lighting problems ($r = 0$).

Thus, there appear to be two essentially separate groups of individuals. One group tends to report relatively high levels of job pressure and job fatigue. The second group (who seem to spend a relatively larger portion of their workday looking at the VDT screen) reports high levels of visual fatigue and VDT-related lighting problems. General symptoms of physical and mental stress appear in each of these groups, as suggested above, but probably more in the second group. The second group is also larger than the first.

The pattern of results is complex, with several possible alternative explanations. It does, however, seem to be fairly clear that the preponderance of visual symptoms among VDT operators in this sample cannot be explained by nonvisual aspects of the job, such as pressure and employee hostility toward the computer. At the same time, it must be recalled that access to the worksites investigated in this study was with the agreement and cooperation of management. It is possible that a self-selection effect was operating in this study, since other literature does indicate relationships between VDT work and job stress (Cakir et al., 1978; Smith, Stammerjohn, Cohen, and Lalich, 1980).

Finally, there were no indications whatsoever of any pre-post changes in optometric measures as a function of VDT work. This does not confirm the results of Haider et al. (1975, 1980), who found decreases in acuity after VDT work, nor does this result support the suggestion of Östberg (1975) that problems of convergence (phorias) may result from VDT use. Haider (personal communication) has indicated that the lack of optometric results may have been due to the fact that the Group II subjects were permitted to take informal work breaks on their own initiative. Presumably, the presence of such breaks acted to minimize any optometric effects; however, subjective symptoms of eye strain were still present. This assertion deserves further investigation.

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