

Technological stress: psychophysiological aspects of working with modern information technology

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There is rapid technological transformation occurring in both work and social life. The results of information technology, such as mobile telephones, computers, and electronic networks, have been looked upon as the key to solving several of the most pressing problems of the Western world. At the same time, numerous studies have shown that the great majority of computerization projects fail to meet their deadlines with the originally specified functionality mainly because human factors are not sufficiently taken into account during the planning and implementation phase of the project. In a study of the bodily, mental, and psychophysiological reactions of employees involved in the design of advanced telecommunications systems and of office employees using regular video display technology, several stress-related psychosomatic disorders have been identified. They include sleep disturbances, psychophysiological stress and somatic complaints. Controlled intervention programs aimed at enhancing organizational structures and individual coping strategies have been proved effective in counteracting the negative effects of working with information technology. The two-way interaction between the external information technology environment and bodily and mental reactions needs to be taken more into account in the design and use of modern information technology. There appears to be an increased awareness of human aspects when the risks and benefits of the rapid spread of information technologies are discussed.

Key terms computer, coping, psychophysiology, telecommunication, video display units.

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The use of modern information technology (IT), including the use of computers, is spreading rapidly in today's working world, as well as in life in general. Along with these trends, there is an ever increasing concern about the possible health effects of working with information technology or exposure to electromagnetic fields generated from the equipment involved. Originally, the concern about the possible health effects of information technology was focused on the possible impact on the musculoskeletal system, (eg, repetitive strain injuries, eye discomfort, headache, threats to the fetus, skin diseases, hypersensitivity to

electricity and video display units, and psychosocial aspects) (1—11). More recently, the term "techno-stress" was suggested to describe the psychophysiological consequences of a poor man-IT-machine fit (12). This term was originally introduced in 1988 by Brod in his book *Techno-Stress — the Human Cost of the Computer Revolution*.

Five of the 10 fastest growing occupations involve nonmanufacturing applications of computer technology. In the United States, more money is spent on computing and communication gear than on industrial, mining, farm, and construction machines (13). Many corporations expect productivity and efficiency to soar as they introduce new and more sophisticated forms of information technology, and therefore lay off large numbers of employees. However, computers per se are not a guarantee of enhanced efficiency. More important determinants are traditional factors such as the way professional work should be done and the organization of work processes (14). Only eye discomfort

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and possible headache have been repeatedly shown to be linked with computer use (12, 15). Other alleged health effects, including skin diseases, birth defects, spontaneous abortions, musculoskeletal disorders (including repetitive strain disorders), and hypersensitivity to electricity and video display terminals have yet to be convincingly linked to the actual computer per se (1–10). A World Health Organization (WHO) working group (5) states that “psychosocial factors are at least as important as the physical ergonomics of work stations and the working environment [p. 957]”.

Little, if no, previously reported controlled research on IT-work has assessed the impact on highly skilled professionals, such as designers of telecommunication systems. This group of professionals is of interest for many reasons. First, they are experts in the use of computers and therefore are unlikely to suffer from stress related to the pure novelty of computer ware. Second, they work with hardware and software in the forefront of computer ware development, which, as yet, has not reached the traditional working world. These circumstances should enhance our chances to detect, and possibly prevent, health effects related to technology before the introduction of a product. Finally, this group of highly skilled professionals represents a rapidly growing and economically very important group of workers for the continuous economic development of countries in the age of information technology (16).

Since the early 1990s, my colleagues and I have been involved in a number of occupational health studies carried out in Ericsson laboratories (17) where advanced telecommunication systems are designed.

The purpose of the present study was to evaluate prospectively the impact of a controlled prospective stress-management program on psychosocial well-being, efficiency, and physiological stress indicators.

Subjects and methods

To qualify for the study, an employee had to be permanently employed at Ericsson and assigned to one of two selected departments or be on a temporary assignment scheduled to last for at least another year. With these criteria, there were 138 potential participants in department L, later to be selected as the intervention group, and 130 potential participants in department F, which became the reference group.

Subsequently, a total of 66 (10 women) of 138 potential participants in department L and 50 (15 women) of a total of 130 in department F decided to participate in the study. There were no significant differences regarding age, gender, job classification, educational background, or tenure at the company between those who chose to participate and those who declined.

The questionnaire, distributed to all the participants, covered the following broad areas: socioeconomics, marital status and family situation, education, work conditions, psychosocial and physical work environment, social support at work, perception of one's immediate and senior superior, clarity of mission and short-term goals, and specific questions on the functionality and reliability of the computer hardware and software (12, 17, 18). In addition, other questions covered coping style (19), type A behavior (20), physical and mental well-being (21), earlier health history, and quality of sleep. All told, the 39-page base-line questionnaire consisted of 470 distinct questions. Scales were further revised or developed to measure intellectual exhaustion, project pressure, intellectual discretion, occupational mental load or strain, intellectual discretion in one's work (22), organizational efficiency, perception of one's immediate superior, job satisfaction, organizational commitment, coping style, social support, clarity of mission and immediate goals for the work section, the department and the company in general, and the quality of information given. Scales measuring perceived indoor environment, mood, fatigue, and work-family conflicts were also developed. Participants in the intervention group were also asked in what way, if any, the stress-reduction program had an impact on their stress resilience and daily stress level, and how often they participated in the formal training sessions and used the techniques after the formal training sessions ended.

The initial questionnaire was distributed to all the participants before the initiation of the stress-reduction training sessions. At this time, all the participants were also subjected to blood sampling, which was done in the morning between 0800 and 1000 on fasting donors. Blood pressure and heart rate were determined at the time of the blood sampling after 5 minutes of rest in a reclining chair. (For details on the biochemical analysis, see reference 23.) Immediately after the completion of the stress-reduction training sessions (about 3 months after the initiation of the study), all the subjects were again asked to respond to a revised questionnaire and to provide another blood sample (within ± 15 minutes of the first sample). Five to six months after the second sample, after which all formal training had ceased, the final questionnaire was administered and blood samples were collected. The second and third questionnaire consisted of 30 pages encompassing 348 separate questions.

Only distinctly abnormal values for cardiovascular risk indicators, according to guidelines set forth in the National Cholesterol Education Program (NCEP) (23), were reported to the participants. Otherwise, no comments on the biochemical analysis were offered until the completion of the entire study. Then each participant was given his or her individual values for all three times, along with the appropriate reference values. The subjects with values out of range were informed in writing, offered a free telephone

consultation with the author, and advised to discuss their results further with their personal physician.

The participants in the intervention department were given an opportunity to participate in one of three partly different stress-reduction programs. These were (i) progressive relaxation according to the method described by Benson (24, 25), (ii) applied relaxation as described by Öst et al (25, 26), and (iii) Tai Chi combined with progressive relaxation.

The statistical program STATA was used to develop the psychosocial instrument (27). This work was done in collaboration with the Department of Sociology, University of Stockholm, Sweden. All the other statistical analyses were done using the BMDP statistical software (28). Statistical significance was set at a two-tailed P-value of less than 0.05.

The study was approved by the regional ethics committee of the Karolinska Institute. All the participants had given their informed consent. They were free to withdraw at any time during the study without any explanation or further consequences. In addition, they were allowed to continue the stress-reduction sessions, should they so decide, without having to fill out any additional questionnaire. Both the management and the unions at the laboratories approved the study.

Results

We compared those who participated in all three assessments with those with only partial participation regarding some key background and outcome variables. There were no systematic differences between the compliers and the partial non-respondents.

Immediately at the end of the formal training program, as well as 5–6 months later, we asked the participants in the intervention group how often they had participated in the formal training. There were no statistically significant differences over time in the recollection of the participants. Most of the subjects participated in between half and three quarters of all the training sessions.

In response to the questions on whether the stress-reduction program had any effect on their stress-management technique immediately following the end of the formal training sessions, 6.9% stated that it had significantly improved their technique, 70.7% believed that it had somewhat improved their technique, and the remaining 22.4% felt that it had had no impact whatsoever. When the questions were repeated 6 months later, there was no significant difference in the responses (McNemar's test for symmetry, $P = 0.10$).

In response to the question on whether the stress-reduction program had any impact on the participants' daily stress levels, 6.9% stated that the program had had a very

positive effect, 37.9% mentioned a rather positive effect, and the remaining 55.2% stated that the program had had no perceived effect. The response to this question was stable over time (McNemar's test of symmetry $P = 0.53$).

The instrument measuring perceived project pressure, with a minimum score of 3 and a maximum of 15, increased significantly over time regardless of the group or department [analysis of variance (ANOVA), time-effect, P -value = 0.02]. However, no significant interaction was found between time and group, and, therefore, a lack of effect from the stress-reduction program per se was suggested.

Perceived mental work load (figure 1), with a minimum value of 4 and a maximum of 16, increased significantly over time regardless of group ($P < 0.001$). Overall, the mental strain scores were significantly higher for the reference group ($P = 0.02$). There was a nonsignificant tendency for an increase in the mental strain scores related to time in the reference group as compared with the results of the intervention group (ANOVA for interaction between time and group, $P = 0.08$, with or without covariance for initial scores).

Intellectual discretion, that is, whether a person learns new skills and perceives his or her job as challenging, did not change over the 9-month study period. Both departments scored rather high on a scale from 4 to 16. They averaged 14.10 (SEM 0.15) points.

Job satisfaction did not change significantly over time. The participants were all rather satisfied—with a mean score of 7.74 (SEM 0.16) points on a scale ranging from 2 to 10.

The index measuring perceived organizational efficiency decreased significantly over time ($P < 0.001$). However, there were no significant interactions between the groups or between group and time.

There was a significant deterioration in the clarity of the overall mission and immediate goals, both for the company as a whole and for one's own department (P for time

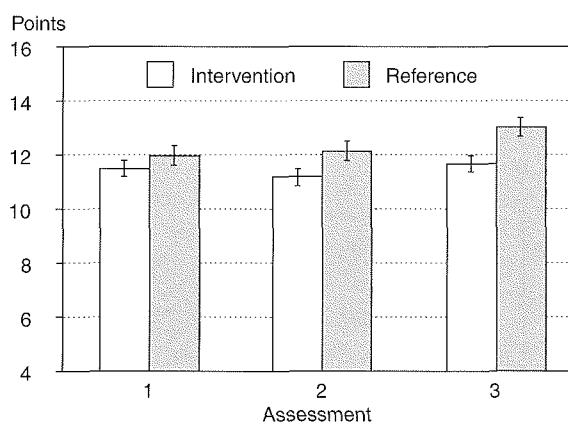


Figure 1. Perceived mental work load by study group (mean and SEM). (ANOVA, time-effect, $P = 0.02$, for interaction between time and group, $P = 0.08$).

< 0.01), but no interactions were found between the groups or between group and time.

Both groups reported an improvement related to time in their overall rating of the computer functioning from an initial mean value of 3.73 (SEM 0.09) to 4.01 (SEM 0.07) in the final assessment ($P < 0.001$).

Regarding social support at work, there was a significant deterioration over time ($P < 0.001$) (figure 2). There was also a significant interaction between time and group with a more accentuated deterioration for the reference group ($P < 0.05$).

There were no significant differences between the groups concerning priority conflicts between work and family. However, there were more such conflicts at the time of the second measurement ($P < 0.0001$).

The program had no impact on the instrument measuring intellectual exhaustion. The mean score was 20.34 (SEM 0.76) on a scale ranging from 8 to 48. There were no changes over time or between the two departments in the degree of intellectual exhaustion. Coping style was unaffected by the stress-reduction program during the study.

Finally, on the scale assessing the perceived quality of the indoor environment, the subjects rated the environment as being of high quality [mean 16.67 (SEM 0.28); minimum 12, maximum 24 points]. Over time, the positive rating even improved somewhat ($P < 0.01$ for time). The number of subjects stating that they were affected by the indoor environment also decreased over time from an initially low base line of 12.45 (SEM 0.44, $P < 0.001$ for time). There was a nonsignificant tendency for the subjects in the stress-management group to perceive their improvement in indoor-air environment to a greater extent over time than the reference group.

Regarding the biological measures, the serum levels of prolactin decreased significantly over time in the intervention group with a significant decrease observed in the last measurement (figure 3). The effect-time interaction and

the interaction between time and group was significant ($P < 0.01$ and $P = 0.03$ respectively).

The serum levels of testosterone decreased significantly over time with the lowest levels occurring in the final assessment ($P < 0.001$). There was a tendency for a significantly higher mean level of testosterone for the intervention group ($P = 0.08$).

The serum levels of total cholesterol decreased over time ($P < 0.001$) with a tendency for a more accentuated decrease in the intervention group ($P = 0.06$).

The ratio between the apolipoproteins B and A1 increased significantly over time ($P < 0.001$), as shown in figure 4. Between the first and second measurements, both groups increased their levels. Between the second and final measurement, the values of the intervention group decreased significantly. There was a significant interaction between time and group ($P < 0.001$).

There was a significant increase over time in the total number of circulating thrombocytes ($P < 0.01$). The interaction between time and group was also significant ($P < 0.05$) with a relative decrease in the intervention group as compared with that of the reference group.

Systolic blood pressure increased an average of 4 mm Hg during the study period from an initial mean of 122.5 (SEM 1.1) to 126.1 (SEM 1.4) mm Hg ($P < 0.001$). There were, however, no significant interactions between the groups or between time and group.

Using multiple linear regression techniques, we tested various models to predict the selected effect or dependent variables. As dependent variables we used changes over time, from the initial to the final measurement, in the key psychosocial and biological variables. The change was calculated in such a way that a positive value was considered a desirable change, for example, a decrease in mental stress. Thus, in the case of mental stress, we subtracted levels at the final measurement from those at the initial one with the hypothesis that a decrease would occur in the intervention group.

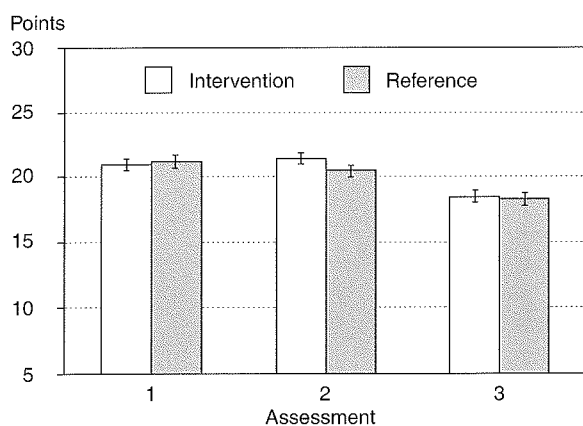


Figure 2. Social support at work by study group (mean and SEM). (ANOVA, time-effect, $P < 0.01$, for interaction between time and group, $P < 0.05$).

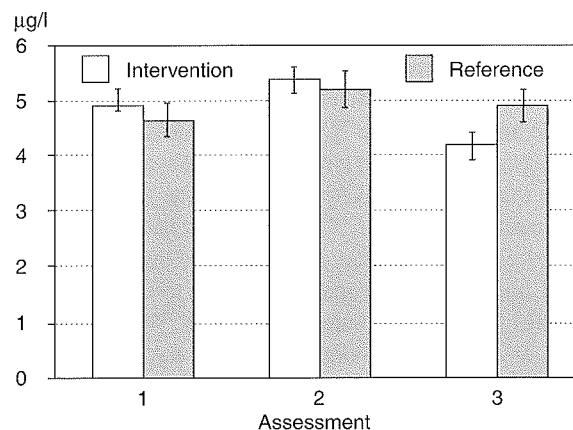


Figure 3. Serum prolactin levels by study group (mean and SEM). (ANOVA, time-effect, $P < 0.001$, for interaction between time and group, $P = 0.03$).

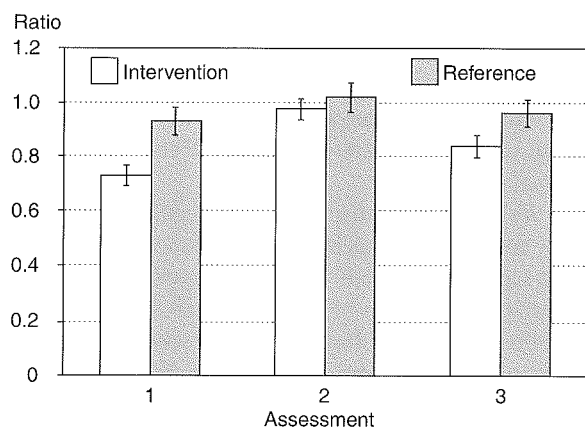


Figure 4. Ratio of Apolipoprotein B/A1 by study group (mean and SEM). (ANOVA, time-effect, $P < 0.001$, for interaction between time and group, $P < 0.001$).

Improved job satisfaction was positively associated with improvement in perceived control over one's work and the work processes (7.2% of the explained variance). Improvement in mental work load was positively associated with company loyalty (5.8% of the explained variance) and being part of the intervention group (5.6%).

Decreased levels of serum prolactin were positively related to belonging to the intervention group (6.0%), a decrease in mental work load (6.1%), and male gender (4.3%).

Improvement, that is a decrease, in the ratio of apolipoprotein B to apolipoprotein A1 was related to higher scores on the type A scale and decreasing scores on the job satisfaction scale.

Discussion

The intervention and reference groups were similar regarding the number of background factors and psychophysiological variables. Of a total of about 268 potential participants in the two selected departments, 116 employees decided to participate in our prospective study. We compared this population, as far as possible, with results from previously administered questionnaires at the telecommunication systems laboratories. We found no systematic differences between the present study group and those administered questionnaires earlier.

The stress-reduction program attenuated the time-associated increase in mental strain as compared with that of the reference group. Stress is one of the dominant concerns in work with modern information technology (17). Thus our program, based on improving personal stress-management skills, had at least a palliative effect on mental strain. Mental work load, in contrast, increased continuously in both groups. Of interest is the finding that both groups

reported a time-related improvement in the feeling of being in control of one's own work and work conditions. It has been suggested that enhanced control protects against the negative effects of a stressful work environment characterized by high mental strain (22, 29, 30).

The stress-reduction program had no significant impact on intellectual discretion, that is, whether a person perceives that he or she learns new skills and views the job as challenging. However, both departments viewed their work as highly intellectually stimulating with a mean of 14.1 out of a maximum of 16 points.

Social support at work, an important factor attenuating stress, deteriorated significantly faster during the study period in the reference group. Thus the stress-management program apparently had a beneficial and lasting effect on social interactions and support. Rather than withdrawing into oneself and the work, when under increased work pressure, the intervention group used their colleagues as resources to manage their stress.

The stress-reduction program did not measurably affect organizational commitment, the rating of one's immediate supervisor or the perceived clarity of the mission statement, and the objectives of the overall company or one's own department. However, the intervention group perceived the business objectives to be better defined for their own section.

Concerning psychophysiological measures, the stress-reduction program had a significant and beneficial impact on the circulating levels of prolactin. Prolactin levels have been reported to increase in situations of high mental demands with feelings of not being in complete control, as well as during negative events (12, 31). The stress reduction program thus had beneficial effects on mental stress load and social support, as well as on psychophysiological stress markers. The most accentuated effect was observed after the initial training session. This finding suggests that there is a learning curve or, alternatively, that it takes some time to reset the neurocortical-hypothalamic-pituitary axis. The multiple linear regression models, using changes in serum prolactin between the initial and the final assessments as the dependent variable, showed that departmental changes in mental stress load over the study period and male gender explained 16.4% of the overall variance in changes in prolactin levels. This finding could be interpreted to indicate that decreased mental work stress, along with the stress-reduction program, attenuated the psychophysiological stress response.

However, they may be parallel phenomena and changes in neurotransmitters as well as altered activation of cytokines in the central nervous system. Such changes will have an impact on peripheral prolactin levels, as well as on cognitive and behavioral changes. Elevated prolactin levels, known to influence established or putative autoimmune disease, may also partly contribute to symptoms such as neurobehavioral changes, dermatological symp-

toms, and repetitive strain disorders in workers using video display units (5, 7, 12, 32–34).

Stroke, as well as other forms of cardiovascular disease, has been linked to certain forms of mental stress (35, 36). No firm theory has held up concerning mechanisms by which stress might contribute to stroke. In their classical work, Selye et al (37) suggested enhanced coagulatory tendencies in stressed animals. The increased circulating levels of thrombocytes in stressed engineers may be one of a cascade of factors contributing to stroke. The stress-reduction program attenuated this increase in thrombocytes.

In our study, a lowered level of total cholesterol was associated with the scoring on the type A scale and with decreased job satisfaction. There was no association with the stress-reduction program per se. Changes in blood lipid levels have been reported in some previous studies, in which dietary changes were mixed with stress-reduction programs (37).

We found decreased mental work load to be positively associated with increased cortisol levels. In some previous studies, blood cortisol levels have been used as an indicator of psychophysiological stress levels. However, apart from animal studies, there is no convincing evidence that serum cortisol is a nonspecific indicator of stress in humans (12, 31, 38, 39). Rather, increased serum cortisol levels in humans appear to be related to situations characterized by hopelessness and depressed mood (40, 41).

We found significant changes in the ratio between the apolipoproteins B and A1. The stress-reduction program resulted in a decreased ratio of apolipoproteins. This finding indicates an overall improvement in an important cardiovascular risk indicator (22, 42). However, decreased job satisfaction over time was also related to an improved ratio of apolipoproteins. This finding indicates a rather complex association between psychophysiological measures and work characteristics.

Fructosamine decreased significantly after the initial 3-month training period with a significantly faster attenuation in the intervention group. We have previously reported an association between mental strain load and serum fructosamine levels and hemoglobin A_{1c} (29, 43). This finding further supports the notion that the stress-reduction program decreased the overall psychophysiological arousal levels. In the multiple linear regression assessment, both decreased project pressure over the 9-month study period and female gender were positively associated with decreasing levels of serum fructosamine.

In summary, the studied laboratories, where high-tech telecommunication systems are designed and developed, provide a work environment that is highly intellectually stimulating and provides a high degree of control over work processes. At the same time, employees and managers point out stress as a major concern. The stress stems from the constant development of new software tools, a rapidly changing technical and business environment, and

increased focus on shortening the time-to-customer period. Moreover, poor response to performance, suboptimal organizational efficiency, and a partial mismatch between the skills and competence available in the work force and those required for new product development add to the mental strain.

We have shown that such a work environment, however correct from a technical-ergonomic point of view, will have a significant impact on psychophysiological arousal levels. Stress-reduction programs apparently alleviate some of the stress. However, structural changes need to be considered as well. Our findings warrant serious consideration, as new developments in the area of information technology are rapidly transcending into everyday workplaces. When correctly designed and implemented, along with proper organizational adaptations, such technology will significantly enhance work and business opportunities (17). However, if due consideration is not given to human factor needs, we will continue to see health consequences. As the use of modern information technology is rapidly spreading, we are likely to see more psychosomatic complaints purported to be elicited from the information technology environment. It is important not to forget old knowledge concerning the basic human needs that must be satisfied to create healthy work and social environments. The information technology sector may develop rapidly, but our genes may not be quite as fast to adapt to these changes. However, information technology per se is not good or bad from the human point of view. The human applications of such technology (ie, how we use it) decide how we are going to react psychosomatically. Individual differences in the relationship to information technology also need to be taken into account.

Acknowledgments

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