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Automation and the Design of Work: Stress Problems and Research Needs

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Automation and the Design of Work: Stress Problems and Research Needs

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The dissemination of automation in manufacturing and service industries has changed how work is done, organized, rewarded and compensated. The effects of automation on the design of work include increased cognitive demands and performance pressure, but also changes in supervision, work structure and social interaction. Technology has been invading offices, factories, hospitals, banks and other work places at an increasing pace. Numerous papers have summarized stress issues related to automation. For a review of stress issues in automated offices, see for example Briner and Hockey (1988) or Smith et al. (1987), and for a review of stress issues in manufacturing, see for example Smith and Carayon (1994). This paper will not review existing stress issues of automation, but will propose a new conceptualization of technology-related stressors.

In this paper, a model is proposed to examine the direct and indirect effects of automation on stress. The focus of this paper is on identifying the characteristics of work design that can be influenced or changed by automation and that can be considered as stressors. Understanding the role of technology in the design of work is important because it provides insight on ways to design or redesign work systems. The focus of this approach is on the "objective" characteristics of work systems that can be manipulated by, for instance, engineering changes. At the same time, the importance of individual characteristics in the stress process is recognized. The aim of this paper is on developing a sociotechnical engineering approach to the design of work systems that incorporates work organization, technology and personal features.

The paper will highlight some of the challenges of automation for stress researchers. The theoretical framework and discussion of automation and work design can provide directions for research studies and organizational interventions. Time factors in the design of work and the stress process will be examined. Both conceptual and methodological issues related to time

factors will be discussed. Research done by the author will be described to illustrate the effects of automation in offices and the time factors in the stress process.

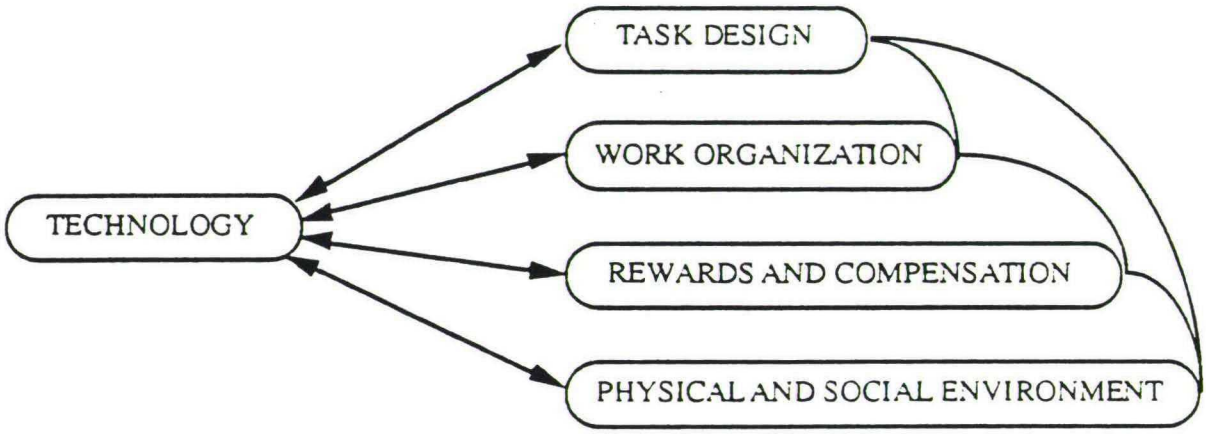
Theoretical Framework: Adaptation of the Balance Theory

The implementation of automation in manufacturing and service industries is likely to create or influence systemic changes in the design of work, and a holistic framework is necessary to examine these effects. The balance theory of job design and stress (Smith and Carayon-Sainfort, 1989) can provide a useful theoretical framework for examining the relationships and interactions between automation, the design of work, and strain and health problems. It is a systems approach that includes a range of factors as potential sources of stress and health problems. Smith and Carayon (1993) show how the balance theory can be used to examine psychological job stress in VDU work.

According to the balance theory developed by Smith and Carayon-Sainfort (1989), stress is a result of an imbalance between elements of the work system. This imbalance produces a load on the human response mechanisms that can produce adverse reactions, both psychological and physiological. The human response mechanisms, which include behaviour, physiological reactions and cognition, act to bring control over the environmental factors that are creating an imbalance. These efforts, coupled with an inability to achieve balance, produce overloading of the response mechanisms that lead to mental and physical strain. Prolonged exposure and strain leads to health problems and disease. This model emphasizes the definition of sources of occupational stress (stressors) that can produce an imbalance in the work system. These stressors can be categorized into one of the following elements: (1) task design, (2) the organizational context, (3) technology, (4) physical and social environment, and (5) the individual. Each element has positive and negative aspects. For instance, repetitive tasks over which the individual cannot exercise control are stressors that can influence the stress load and produce strain and health problems. On the other hand, meaningful tasks with support from supervisors and colleagues have been related to low levels of strain and better health. For a review of the positive and negative aspects of each element of the work system, see Cooper and Marshall (1976), Caplan et al. (1975), Smith (1987), Smith and Carayon-Sainfort (1989) and Landy (1992).

In this paper, the focus is on the technology element of the work system. According to the balance theory, technology can influence or be influenced by any of the elements or combinations of elements of the work system. The influences of technology can be categorized into effects on: (1) how work is done (task design), (2) how work is organized (organizational factors), (3) how work is rewarded and compensated (organizational factors), and (4) where work is performed (physical and social environment). Figure 1 shows a graphic representation of the proposed theoretical framework of the influences of technology on the design of work.

FIGURE 1
INFLUENCES OF TECHNOLOGY ON THE DESIGN OF WORK:
A THEORETICAL FRAMEWORK



The proposed model of technology and work design is not deterministic: the influences of technology are multiple and diverse. Technology can have direct and indirect influences on the design of work and strain and health problems. For instance, the introduction of computer technology has been accompanied by the emergence of "new" stressors, such as computer breakdowns and misfunctions (Johansson and Aronsson, 1984; Carayon-Sainfort, 1992), cognitive demands (Frese, 1987) and electronic performance monitoring (Smith et al., 1992). Therefore the technology is not completely neutral (Smith et al., 1987). However, the effects of technology on the design of work depend on a range of factors, including organizational culture, management style, and regulations and laws. The positive and negative influences of technology on the design of work need to be examined to improve our understanding of the potential strain and health problems associated with automation. In order to understand the

effects of technology on the design of work, one has to define the characteristics of the technology (see for example, Carayon-Sainfort, 1992, and Carayon, 1993a). In the next section, recent technological developments and the potential stress effects of these technologies will be examined.

Technological Developments

Advanced automation has the potential to improve the competitive status of manufacturing, assembly and office operations. New technology may provide the following economic benefits: (1) lowered production costs through the use of more efficient machines, (2) reduced workforce, (3) a cheaper, less skilled workforce, (4) improved product or service quality and conformity, (5) increased "up-time" or productive time, (6) enhanced flexibility of the production system to meet customer needs, and (7) lowered insurance costs by reducing worker risks (Smith, 1986). While there is no guarantee that automation and advanced technology can achieve any or all of these benefits, the evidence from applications research indicates that many are realized (OTA, 1985). However, there is also emerging evidence that inappropriate application and design of technology can be detrimental to the production process and to the employees in an industry (OTA, 1984, 1985, 1987). The goal of automation is to improve productivity. However, there is often confusion between effectiveness and efficiency, and between short-term and long-term views. Effectiveness is doing the right things, while efficiency is doing things right. Automation often brings efficiency gains, but not necessarily increases in effectiveness, or short-term gains but long-term losses. Examples of this confusion will be given later in the discussion of image processing technology. In this section, the discussion will focus on technologies in offices and service industries.

Computer-based technologies have been invading offices and service industries. Many of these technologies are aimed at "improving" or "facilitating" communication. For instance, FAX, e-mail, network, teleconferencing, cellular phones, and voice mail are technologies that change the way people communicate and interact. They change expectations regarding the speed of work and communication. For instance, messages left on an electronic or voice mail box are expected to be received fast and replied quickly. These communication technologies also affect the time structure. For instance, with technologies such as e-mail, cellular phones and voice

mail, people are constantly in touch with the rest of the world. The perception of time also changes: it is OK to contact someone at 3:00 am with technologies such as FAX, e-mail, and voice mail. In return, a quick response is expected. In general, these communication technologies have affected how time is used, organized and perceived. McGrath (1990) discusses how some of these communication technologies might aid or hinder the temporal flow of communication and work in groups. However, he does not discuss how the temporal effects of communication technologies can affect strain and health problems.

The development of fast computers with multiple functions and capabilities can affect the design of work, and result in strain and health problems. Fujigaki (1991) surveyed a total of 1,203 software engineers in Japan. Data was analyzed for the young engineers (20-30 years old) who had been on their job for less than 5 years and who were not project leaders (N=528). Engineers who used high-speed and -function computers reported higher levels of strain than engineers who used less "sophisticated" technologies. Fujigaki speculated that the increases in strain could be due to increased quantitative and qualitative/mental workload. With faster computers, more things can get done (quantitative workload), and the speed for thinking is increased (qualitative/mental workload). High-speed computers can change the way time is used and organized. In fact, time is compressed because more things can get done, while simultaneously the time for thinking and making decisions is reduced.

Other new technologies have been introduced in organizations that process large amounts of information and paper. Image processing is a technology aimed at reducing the amount of paper used in offices. The recent introduction of image processing technology might enable businesses to reduce the amount of paper processed, leading the way to more productive work places. With image processing, paper documents are transformed into computer code, through a device resembling a copying machine. Image processing technology allows employees to retrieve documents very easily and fast. With this technology, a document can be viewed simultaneously by employees in offices far apart that are connected by a computer network.

Carayon and Smith (1993) describe a case study of the introduction of image processing into a public service organization in the United States. The main reason for investing into image processing was for this organization to increase the processing time of transactions in order to deal with the increasing workload. Interviews conducted with the system developer and some

users indicate that, in general, users had mixed reactions toward imaging technology. Some were resistant to changes in the work process or were intimidated by the technology, while others were very positive about the new technology. The positive effects of the use of imaging technology on efficiency included: saving of time to process simple transactions, easy access to information, saving of storage space, and possibility for many people to work on the same case simultaneously.

There were negative aspects of the use of imaging technology, such as technological problems (e.g., computer breakdowns which result in the user losing the work he/she has been doing). Computer breakdowns and slowdown of the computer system occurred frequently enough to bother the users. Such events were particularly bothersome to the imaging users who were highly dependent on the technology to get their job done. The effect of image processing on cognitive workload was obvious, given the users' complaint about phone interruptions. Phone calls were very disturbing when work was in progress with the imaging system because the users had to remember things while processing a case. Users felt that they were able to process a greater variety of transactions with imaging technology, but that they had no control in terms of what document to process (documents are automatically fed to the processor by the computer according to a set of priorities) and how to process the document (the work flow is designed in the image processing system, and there is no possibility to change the sequence in which tasks are performed). The supervisor selected which types of document were processed by the employees. On the positive side, with the increased variety of documents processed, workers perceived their job as more meaningful. Employees got a sense of completion because any case that they processed came back to them if needed. The task completeness gave workers an increased sense of meaningfulness. Users had opportunities to give inputs regarding problems with the use of the imaging system. They could talk to the lead workers. Employees could also give suggestions regarding problem areas at monthly meetings. This gave users some sense of participation. These meetings allowed supervisors to inform employees of changes to the imaging system.

Overall, the image processing technology had many positive effects on the work system and workers. For instance, task variety and completeness increased with the use of image processing technology because boring, repetitive tasks of creating file folders and searching for folders disappeared. However, the image processing technology had also negative effects, such as

decreased control over task sequence and order, and ergonomic problems, such as increased time spent at computer (static job). Open communication with the supervisors and technical staff and employee involvement balanced some of the negative effects. Other negative effects had a major influence on workers. For instance, technology misfunctions were particularly bothersome because of the high dependency on computers to get the job done. Table 1 summarizes the potential effects of image processing technology on the design of work. At the University of Wisconsin-Madison, we are conducting other studies of the effects of image processing technology on the design of work. Studies of this technology are important given the increasing number of office workers affected by it. Recent technical innovation in hardware has contributed to the diffusion of image processing technology into American businesses. The number of image processing systems installed in North America was projected to climb from 1,357 in 1990 to 4,094 in 1992 and 7,241 in 1993 (ComputerWorld, 22 April 1991).

Table 1

Image Processing Technology and the Design of Work

Task/Job Design	increased cognitive demands increased quantitative workload increased variety and task completeness reduced control over task sequence and order
Work Organization	change in employee-supervisor relationships high dependency on computers potential for electronic performance monitoring
Rewards and Compensation	utilization and development of skills
Physical and Social Environment	static job increased social opportunities with technical experts (workers, supervisors and computer staff)

Many of the stressors associated with automation are related to the conceptualization, use and structure of time (McGrath and Kelly, 1986). For example, following the introduction of new technologies, expectations regarding speed of work and communication change: people expect work to get done much faster and communication to be more efficient. Automation changes the conceptualization of time of workers, supervisors and managers. This change can create new stressors, such as time pressure and increased work pace. An example of how automation affects the use of time was given in the case study of image processing. With the introduction

of image processing, the workload increases because the time to process cases was reduced. High quantitative workload is a well-known stressor (Smith, 1987). The structure of time is also affected by automation. For instance, the use of cellular phones, FAX, e-mail, beepers and portable computers extend the work day beyond the traditional 8-hour work day. People can work or communicate almost all the time, at airports or hotels, home or on vacation. This new structure of time creates additional pressures to work. People are constantly in touch with their work. Computer-based technologies that are run or maintained all the time increase the need for shift work which is a well-known stressor (Smith, 1987). Automation seems to be accompanied by "new" stressors (e.g., increased time pressure) or to make "old" stressors important (e.g., shiftwork). In the following section, a conceptualization of technology-related work stressors is described that focuses on the concept of work pressure.

Technology-related Work Stressors

Stress problems in technological change can develop at different stages. Mankin et al. (1984) identified three stages of the innovation process: initiation, implementation, and routinization. The initiation stage is when the technology is designed. Flaws in the technology design (e.g., technology complicatedness) might hinder the process of technological change and create stressors. Implementation of the technology is an important stage at which stress problems can arise. The process by which management introduces technology at the workplace is crucial for worker experience of stress. Korunka et al. (1993a) have conducted a longitudinal study of the implementation of computer technology. They examined how different implementation styles affected physiological and psychological strain of employees. For a discussion of various implementation strategies, see Smith and Carayon (1994). In this section, the focus is on the use of technology. According to Mankin et al. (1984), this is the stage of routinization.

In the previous section, new work stressors brought about by technological developments in offices and service industries were discussed. In this section, the concept of work pressure is central to the conceptualization of technology-related work stressors. Work pressure can be defined as constant job demands put on the individual. Job demands are those work elements that put physical or mental loads on the individual. These requirements or loads can exceed physiological, sensorimotor, or mental capacities of the individual in question. Work pressure

are job demands that are constant, that never seem to go away, that seem to keep increasing and that never decrease.

Table 2

Types and Sources of Work Pressure

Types of Work Pressure	quantitative workload fast work pace backlog of work time pressure (deadlines) cognitive workload being constantly "in touch" technological obsolescence group pressure customer demands
Sources of Work Pressure	*Technology:* computer misfunctions (breakdown, slowdown) pace of technological development human-computer interface (e.g., error recovery) *Task/Job Design:* job content job control *Work Organization:* job future uncertainty training supervision team work *Rewards and Compensation:* performance requirements, standards incentive pay system performance appraisal electronic monitoring of worker performance *Physical and Social Environment:* social relationships at work relationship and communication with technical staff

In technologically advanced work systems, there are different work pressures. Table 2 lists the different types and sources of work pressure. It is important to understand that sources of work pressure are built into the design of work systems. Therefore, they can be "manipulated" by job or organizational redesign. The categories of sources of work pressure listed in table 2 are the different elements of the theoretical framework presented in figure 1. In the rest of this section,

some of the sources of work pressure shown in table 2 will be described and shown how they can create different types of work pressure.

Computer misfunctions, such as breakdown and slowdown, can create or influence conditions of work that put pressure on the individual. Carayon-Sainfort (1992) has proposed a model of the direct and indirect influences of computer-related problems on strain of office workers. The indirect influences of computer-related problems on strain were through the influences of computer-related problems on worker perceptions of work pressure and lack of job control. Computer misfunctions can put additional pressures on the individual, especially under conditions of high quantitative workload and tight deadlines. When the computer breaks down or slows down, the work pile may go up and backlog increases. When the computer is back to its normal function, then the individual has to catch up with the backlog of work, and the pace of work, time pressure and quantitative workload increase. Johansson and Aronsson (1984) have shown how people re-organize their tasks to prevent negative consequences of computer misfunctions. This work re-organization increased quantitative workload when the computer was functioning. Therefore, computer misfunctions can affect work pressures before and after they occur.

Job future uncertainty can also create pressure to work harder and faster for fear of being fired or losing one's job. Unfavourable economic conditions in many countries have made many workers worried about their future. In addition, technological developments can increase productivity and reduce the number of jobs (Smith, 1986). Possible job loss has been related to increased strain and health problems (Caplan et al., 1975). Job future uncertainty is a major source of strain for computer users (Sauter et al., 1983; Smith et al., 1992; Carayon, 1993b). Given new technological developments and bad economic conditions all over the world, more people are becoming increasingly concerned with their future and career in all kinds of jobs and environments. People who experience job future uncertainty may feel the need to work harder (quantitative workload) or faster (work pace), to keep meeting tight deadlines (time pressure) or to stay constantly in touch with their office. In such conditions, people may not be able to exercise control over workload and work pace or to ask their supervisors to decrease their workload for fear of negative consequences (e.g., reprisal, being passed for promotion). People may have the control to change work stressors, but may not exercise control to avoid negative consequences.

Electronic performance monitoring (EPM) has been defined as "the computerized collection, storage, analysis, and reporting of information about employees' productive activities" (OTA, 1987). The U.S. Office of Technology Assessment (1987) estimated that over 6 million workers in several occupations are electronically monitored. EPM is applied to short-cycle office jobs where a limited number of tasks are performed repeatedly. Most of these jobs are considered "clerical" jobs such as data-entry or customer service. However, EPM can also be applied to professional jobs such as computer programmers. Empirical evidence is building that EPM can have psychological and physical stress effects (Smith et al., 1992; NIOSH, 1992; Aiello and Shao, 1993). A model of EPM was developed that looked at both work stressors and strain and that defined the critical job elements for stress responses in an electronic monitoring context (Carayon, 1993a). This conceptual model states that electronic performance monitoring has both direct and indirect effects on worker strain. The indirect effects go through work stressors. It is assumed that EPM can influence worker perceptions of job design which, in turn, are related to worker stress. EPM is a powerful sociotechnical trigger that can influence different types of work pressure. In a study of telecommunications workers, Smith et al. (1992) have shown that monitored employees reported higher levels of work stressors and more strain than non-monitored employees. Monitored employees experienced higher quantitative workload and time pressure than non-monitored employees. In Europe, individual EPM is forbidden. However, group EPM can also influence work stressors, such as group pressure to perform.

The different types of work pressure described in table 2 are related to the conceptualization, use and structure of time (McGrath and Kelly, 1986). Given that time is an inherently scarce resource, work pressures arise when there is not enough time to complete tasks (quantitative workload, backlog of work, time pressure, group pressure), when different tasks have conflicting time allocations (cognitive demands, customer demands), when time is compressed (fast work pace), when the work time is extended (being constantly in "touch"), or when there is concern for future time (technological obsolescence). According to our definition of work pressure, the concept of time is an underlying theme of the different types of work pressure listed in table 2. In technologically advanced work systems, time is an important resource that is compressed, accelerated, saved, and planned for. Because time is a scarce resource, people may feel that they cannot control the work pressures in their job. This lack of control combined with work pressures will increase strain and health problems (Karasek, 1979).

Time: Conceptual Issues

There are a number of time-related conceptual issues related to work stressors and strain. Carayon (1993c) has reviewed longitudinal studies of job design and VDT use and listed various conceptual and methodological issues related to time. In this paper, some of these issues will be highlighted. The importance conceptual difference between chronic and acute stressors will be discussed first.

One of the time-related conceptual issues concerns the distinction between acute and chronic stressors, or between episodic and chronic stressful events (Bailey and Bhagat, 1987). Acute stressors are the events that are temporary or transitory in nature, but may have a major emotional effect. In the work stress literature, there are many studies of acute stressors, such as computer breakdown (Johansson and Aronsson, 1984), and technological change (Amick and Celentano, 1991). Some of these studies show that acute stressors are often accompanied by chronic stressors, such as increased workload (Amick and Celentano, 1991). Some authors have argued that more attention should be paid to chronic stressors which employees have to face day after day (Lazarus and Cohen, 1977; Bailey and Bhagat, 1987).

Many theories of work stress implicitly assume that job stressors are chronic stressors (P:E fit theory - Caplan et al., 1975; Job Strain model - Karasek, 1979). These theories assume that the effect of job stressors on strain and health is likely to be due to the chronic or lasting exposure of the individual to the job stressors. These job stressors may not be considered as very "strong", but because people are exposed to them day after day, they may create a cumulative effect on strain and health. In this regard, the concept of "daily hassles" proposed by Lazarus and his colleagues provides an interesting framework to understand the effect of chronic job stressors on worker stress (Monat and Lazarus, 1977; Lazarus and Cohen, 1977). This concept was used by Carayon (1992a) to study the chronic effect of lack of job control and social support, and work pressure on strain among computer users, and by Carayon and Hajnal (1993) to study the effect of computer-related problems on strain in office workers.

When studying chronic stressors, it is important to examine the temporal dimension of chronic stressors; that is, to determine the level of exposure of the worker to the stressor. Most studies of work stress examine the intensity or strength of stressors: stressors of higher intensity or

strength are hypothesized to cause higher strain than low-intensity stressors. For instance, studies have shown that high workload and work pressure, and low job control and social support are related to high levels of strain (Karasek, 1979, 1990; Johnson, 1989). However, very few studies have examined the effect of the duration of exposure to stressors, that is the length of time that the individual is exposed to the stressor, in addition to the strength of the stressor (House et al., 1986; Heaney et al., 1992; Johnson et al., 1991; Carayon, 1992a). Different research designs can be (and have been) used to study the effect of chronic stressors on strain and health. They will be discussed in the next section.

It is important to understand that acute and chronic stressors are not independent. For instance, an acute stressor such as technological change can produce chronic stressors such as increased workload and loss of job control (Amick and Celentano, 1991; Lindström, 1991, 1993). In addition, the cumulative effect of acute stressors such as computer slowdown and computer breakdowns can create chronic stressors if they accumulate over time and create negative consequences for the individual. Johansson and Aronsson (1984) have shown that a computer breakdown was related to increases in psychological and physiological strain: computer breakdown was an acute stressor. Carayon and Hajnal (1993) reported results of a 4-week diary study of 38 computer users. Computer-related problems and their consequences were recorded on a daily basis. Cumulative measures of computer-related problems were computed by adding the number of days with computer-related problems and the consequences or effects of the computer-related problems (e.g., increased work pace and working overtime). The cumulative measures of computer-related problems were considered as measures of chronic stressors related to the use of computers. Results showed that the cumulative measures of computer-related problems were related indirectly to long-term strain (as measured at the end of the study period). Cumulative computer-related problems were related to changes in weekly measures of mood states which, in turn, were related to long-term strain.

Other temporal dimensions of work stressors can be considered. For instance, Kelly and McGrath (1988) have proposed different temporal shapes of independent variables. These models could be adapted to examine fluctuations in the strength of work stressors over time. In a pilot study of software engineers, Fujigaki (1993) has shown how quantitative workload could vary over time. Such fluctuations in quantitative workload affected short-term physiological and psychological strain (adrenaline excretion, ratings of business and depression).

However, the long-term strain effects of fluctuations of work stressors are unknown. Are the peaks in work stressors more stressful than the accumulation of work stressors (Fujigaki, 1993)?

The study by Fujigaki (1993) demonstrates the need for considering the temporal dimension of strain, such as short- and long-term strain. Boucsein (1993) reviewed different psychophysiological measures of strain that can be used to study computerized workplaces. This approach has been successfully used in a study of computer system response time (Kuhmann et al., 1987). Boucsein (1993) suggests some important time dimensions of these psychophysiological strain responses, such as variability and frequency. Frese and Zapf (1989) distinguishes between different types of strain: irritation (anger reaction), anxiety (flight and avoidance reaction), depression (passive reaction), psychosomatic complaints and psychosomatic illness (bodily reaction) and reality denial (a defense mechanism). They suggest that these different types of strain have different "reaction times". For instance, irritation and reality denial are strains that react more quickly than depression and psychosomatic complaints. Psychosomatic complaints should develop more quickly than psychosomatic illness. Understanding the time course of strain is as important as examining temporal dimensions of work stressors.

Finally, there are important time dimensions in the relationship between work stressors and strain. Frese and Zapf (1989) have proposed different time models of the relationship between exposure time to stressor and strain: (1) stress reaction model, (2) accumulation model, (3) dynamic accumulation model, (4) adjustment model, and (5) sleeper effect model. These models show different temporal shapes of the relationship between stressors and strain. Another temporal dimension of the relationship between work stressors and strain has been examined by Carayon and her colleagues at the University of Wisconsin-Madison, USA. A longitudinal study of a group of office workers in one public service organization suggests that the relationship between work stressors and strain may not be stable, that is may change over time (Carayon, 1992b; Carayon et al., 1993). Three rounds of questionnaire data were collected on the same group of workers for a period of 3 years. The work stressors related to strain seem to change from time to time. For instance, in the first round of the study, the most important work stressor was job control, while in the second round, job future uncertainty, supervisor social support and task clarity emerged as important work stressors (Carayon, 1992b). A multivariate analysis of the three rounds of data show that the underlying structure of the relationship

between work stressors and strain may be stable over time, but that the individual work stressors related to strain change over time (Carayon et al., 1993). Replication of these results is needed. However, they suggest that results of cross-sectional studies may not be reliable.

Time: Methodological Issues

Kelly and McGrath (1988) have reviewed some of the methodological challenges of studying time issues. In this section, the focus is on two research designs, diary study and longitudinal panel design, which can be powerful to examine technological stressors and the time issues described in the previous section.

Diary studies ask people to keep track of work-related events on a frequent basis. The frequency of measurement varies from hourly and daily to weekly. Carayon and Hajnal (1993) reported on a diary study of computer-related problems. The diary study lasted 4 weeks. Every work day, workers were asked to keep track of computer-related problems (computer breakdown/crash, slowdown, other problems with computers) and their effects. Effects were categorized into negative and positive. Negative effects include: working overtime, more work piling up, and increased work pace. Positive effects include: taking a break and ability to perform non-computer tasks. At the end of every week, workers were asked to report their mood states. At the end of the 4 weeks, workers were asked general questions on computer-related problems, and questions on physical and mental health. Cumulative measures of computer-related problems were computed in the following way. The total number of days with slowdown, the total amount of slowdown time, the total number of negative effects and the total number of positive effects were computed for each of the four weeks. The same measures were computed for computer breakdown. The number of other computer problems (e.g., losing documents, computer virus) was also computed for each week. These weekly measures were summed up over the four weeks. These monthly measures were defined as the cumulative, chronic measures of computer-related problems.

Weekly analyses show that the main predictors of mood disturbances were the total numbers of negative effects of slowdown or breakdown and the total number of other computer problems. None of the direct measures of slowdown or breakdown (e.g., number of days of

slowdown or breakdown and total time of slowdown) influenced mood disturbances. In general, studies of computer-related problems have examined the direct influence of computer-related problems on worker stress without taking into account the potential negative or positive effects of such problems. This study showed the importance of understanding the effects of such computer-related problems. This study shows how diary studies can be used to study the chronic effect of technological stressors on strain and health. Diary studies can also help in improving the quality of measurement of stressors because of the short period of time between the time when the stressor happens and the time of recording the stressor.

Longitudinal research designs are powerful designs to examine the temporal dimensions of work stressors, strain and the relationship between stressors and strain. If data is collected on work stressors and strain several times on the same group of people (longitudinal panel design), the following time issues can be studied:

1. comparison of instantaneous, lagged and chronic effects of stressors on strain and health
2. relationship between change in stressors and change in strain and health
3. stability of the relationship between stressors, and strain and health
4. causal analysis
5. effect of (technological) change on stressors and strain and health.

A longitudinal panel design has been used for studying chronic stressors among blue-collar workers in a single manufacturing facility (Heaney et al., 1992), among a sample of workers in different jobs (House et al., 1982), and among computer users in a single public service organization (Carayon, 1992a). These three studies show that duration and exposure to stressors predict long-term strain (as measured at the last measurement point). Marcelissen et al. (1988) have use a longitudinal panel design with three data-collection points to examine the causality of the relationship between social support, and physiological strain (blood pressure, cholesterol, overweight), psychological strain and health complaints. They used LISREL to assess the nature of the causal relationships between social support and stressors (e.g., role conflict) or strain. There was not much evidence for the causal effect of social on stressors and strain. Actually, strains had a causal effect on co-worker social support. This study shows the important role that longitudinal research designs can play in improving our understanding of the causal relationship between stressors and strain.

Korunka et al. (1993b) have reviewed various methodological problems of longitudinal studies of computer use and strain. A major problem with longitudinal panel design is the duration of data-collection (often between 3-10 years) and the problem of attrition and drop-outs. Retrospective designs where people are asked about past experiences can deal with these two problems. Johnson and his colleagues have examined the exposure to low control over the life-course on cardiovascular disease (Johnson et al., 1991; Johnson and Stewart, 1992). They have developed a methodology to measure work organization exposure over the life course based on cross-sectional data (Johnson and Stewart, 1992). Subjects are asked to recall their past work experiences and the duration of time each job was held. Based on this information and on data from the 1977 and 1979 Swedish Survey of Living Conditions, individuals can be categorized in four quartiles: high control, medium high control, medium low control and low control. Individuals in the "high control" category have held jobs with high control for a long time, while individuals in the "low control" category have had jobs with low control during their entire work history. The "medium high control" and "medium low control" categories include individuals with varying levels of control. Johnson et al. (1991) showed that individuals in the "low control" category have higher probability of dying of cardiovascular disease than individuals in the "high control" category. Karasek (1990) has used retrospective questions to examine the effect of change in job control on strain. One of the problems with retrospective questions is memory errors (under- and over-reporting) due to omission or telescoping (Bradburn, 1983).

Conclusion

A model of technology and work design was proposed that specifies how technology can influence or be influenced by task design, work organization, rewards and compensation, and physical and social environment. The model is based on a systems approach that emphasizes interrelationships between the different elements. Examples of technological developments were given to demonstrate how the model could be used to highlight major work stressors. Then, a conceptualization of technology-related stressors was proposed that highlights the concept of work pressure. Different types of work pressure were listed. Sources of work pressure can be found in the proposed model of technology and work design.

The concept of time is a recurring theme of the paper:

1. relationship between work pressures and the conceptualization, use and structure of time
2. conceptual issues of time: chronic vs. acute stressors, temporal fluctuations of work stressors, temporal dimension of strain, time dimensions in the relationship between work stressors and strain
3. methodological issues of time: research designs based on the collection of data over a period of time (diary study, longitudinal design).

The main concern with time is its inherent scarcity which makes work pressures sources of strain and health problems. This problem seems to be critical in technologically advanced work systems. Automation changes the way time is experienced, used and structured.

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