Stress, computer-based work monitoring and measurement systems: a conceptual overview

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The design and implementation of computer-based work monitoring systems can result in changes in the organization, job and task. Electronic performance monitoring (EPM) systems are one type of change based on principles of work simplification and work rationalization. In this new work arrangement, control and coordination functions are allocated to the computer. The supervisor becomes a monitor of information and primarily provides negative performance feedback to the employee. The employee is constrained in his/her ability to use either job resources or social resources to meet the greater demands resulting from the system controlling the pace of work. It is proposed that these work arrangements provoke stress responses in employees that can result in short-term illness and potentially long-term changes in health status. Information enriched work environments are proposed as an alternative. These new work arrangements could improve job resources and social resources to manage job demands and reduce the potentially damaging stress responses. To provide a frame of reference we focus on the impact of EPM systems on the organizational and job elements involved in provoking individual stress responses. The impact of EPM systems on individual health is described using a psychosocial stress framework. Ergonomics interventions discussed include: participation in the design process; allocation of control and coordination functions between the computer and the employee; development of feedback systems; and work measurement and the development of performance appraisal systems.

Keywords: Computers, work measurement, performance assessment, electronic monitoring, stress

Introduction

Newspaper claims abound about workers who suffered stress-related maladies because of computer monitoring (Smith *et al*, 1986). Ergonomists are faced with responding to these rising concerns. How do new computer-based work monitoring and measurement systems affect worker health (c.f. Smith, 1988)? Given the current body of knowledge and experience, what ergonomics interventions are applicable? The practitioner must have a frame of reference to understand the potential effects of what has become labelled electronic performance monitoring (EPM) systems. This overview of the role of computer-based work monitoring systems in provoking, and in preventing, stress responses is intended to provide this reference.

Our thesis is that the design and implementation of computer-based work monitoring and measurement systems create new work arrangements with new jobs, tasks and work relationships. Depending on the management and design principles guiding the system development and implementation effort, there are two major consequences. (1) These new working arrangements can enable the employee to cope better with job demands, lowering the risk for stress-related health effects. (2) The new work arrangements can disable the employee from coping in a positive way with the demands, increasing the risk for stress-related health effects.

Because electronic performance monitoring is not a neutral concept and typically denotes the use of information technology to initiate organizational changes that simplify jobs (leading to consequence 2 above) and enhance management control, we shall not attempt to use it in a neutral manner. Instead, we shall introduce the notion of 'information enriched work environments' to act as a counterpose to EPM (leading to

 0003-6870/92/01 0006-11 $03.00

Table 1 Stages in the development of an electronic performance monitoring system

Stage	Management control principles	Engineering measurement practices
1	Standards or specified objectives	Set standards for the time it should take to produce a unit of work
2	Monitoring devices to measure performance	Monitor actual time it takes to produce each unit of work
3	Comparing devices to check the closeness of performance to standards	Analyze variance of actual time it takes to produce each unit of work
4	Action devices to bring deviations from standard into line	Provide data in planning cost estimates, productivity improvements and production control

consequence 1 above). Throughout the remainder of this paper we shall emphasize EPM systems to illustrate the potentially deleterious stress-related health effects.

The change at work, stress and health

EPM systems change the work environment through the integration of management control principles, work measurement concepts and computerized information systems. Management seeks to control the ebb and flow of human activity at work to create a more predictable work process. Modern work measurement systems codify human activity into finite elements which can be captured electronically. This process is accomplished in four stages identified in Table 1. The result is a work process that has been atomized – reduced to the basic elemental acts.

The ability to digitize work at the sub-task level has been a key to rapid integration of information technology into management practice contributing to the field of management information systems. Whereas, in the past, pieces of an individual's work output could be monitored, today every element can be codified and monitored. Non-essential human actions or inappropriate activities can be identified in real-time. Productivity bottlenecks can be eliminated with little downtime. Therefore, the change represents both a change in the organization of work and the technology of work.

These changes can affect an individual's health status by provoking a stress response. Stress is not a discrete consequence of any piece of hardware or software; rather, stress results from conditions in the physical and psychosocial work environment. These conditions, termed stressors, can be identified in the work place and, with appropriate changes, reduced.

The design and implementation of an EPM system creates new work arrangements that exacerbate, intensify or generate psychosocial conditions of work, placing a worker at greater risk for stress-related illness and disease. This process, described below, is depicted in greater detail in Figure 1.[1] Organizational choices are made about how to design the technology for work monitoring. The new technology-driven production system is implemented in the organization creating new work arrangements. Employees interact with each other and within the constraints of the new work arrangements to complete their work. Over time this generates the psychosocial conditions of work. Workers adapt, both mentally and physically, to the psychosocial conditions of work. To the extent that the psychosocial stressors are persistent, the individual can experience mental or psychophysiological illnesses due to chronic emotional and biological arousal. To the extent that the worker is exposed to psychosocial stressors for an extended period of time sufficient to initiate pathological changes or exacerbate underlying biological conditions, then chronic disease may develop (cf Schnall *et al*, 1990).

The role of technology

The model depicted in Figure 1 suggests that technology influences a person's health status indirectly through how it structures the job and the broader psychosocial work environment (cf Turner, 1987; Amick and Ostberg, 1987; Smith and Sainfort, 1989; Amick and Celentano, 1991). The model demonstrates how the effect of an EPM system on the individual can be mediated by the design of the job and social opportunities in the work environment. In a test of this model, Amick and Celentano (1991) found technology more strongly influences the job dimensions than the social dimensions. They also found support for the indirect influence of technology on psychosomatic symptoms through how the technological system was related to the psychosocial conditions. Anchoring the stress process to structural conditions of work makes engineering control strategies more practical since engineers can modify these structural conditions. This is in concert with ergonomics approaches to eliminating hazards and developing engineering controls to reduce risks in the work environment, rather than focusing on worker behaviour.

It suggests technology indirectly influences a person's health status through how it structures the job, but depending on the influence of technology on the resources (social support and job control) available, workers may be differentially vulnerable to the stressor (cf Amick and Ostberg, 1987). This key point will be expanded upon in later sections. For the designer and manager, information systems change the job and

[1] The framework reflects the use of the basic arousal theory of stress as the transitional mental and biological internalization of the psychosocial risk factors that contributes to the natural history of diseases. See Karasek and Theorell (1990) for a discussion of this topic.

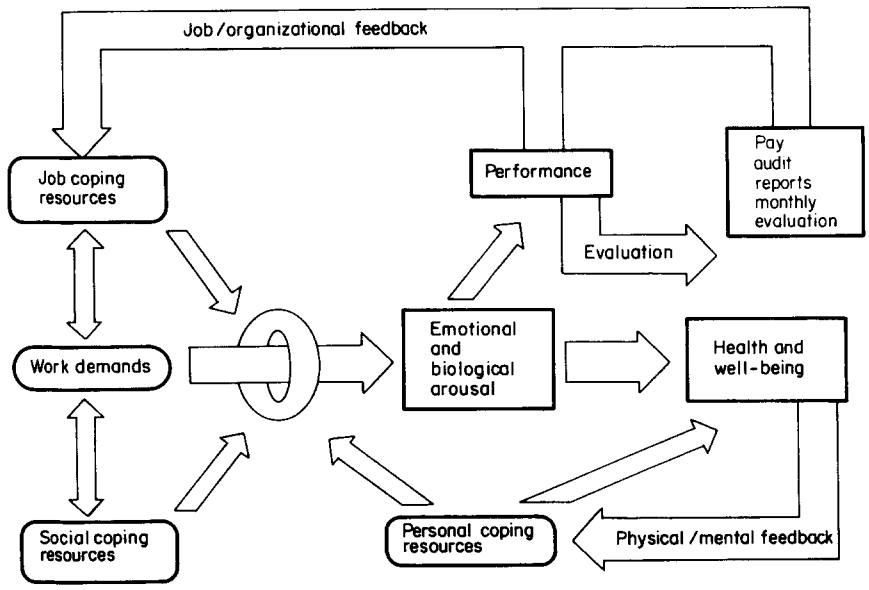

Figure 1 Psychosocial work environment and stress-related well-being and health

social conditions of work, and both must be managed along with the technological conditions of work to avoid adverse stress consequences and to create a high performing system.

This offers the ergonomist the opportunity to intervene at three different levels: the organizational–technology interface; the job-technology interface; and the human–technology interface. The individual psychosocial work environment is a consequence of all three levels. It is a cascade of changes from the organizational level down to the individual worker that must be considered. What follows is a review of the key organizational and job characteristics affected by EPM within this general technology/stress paradigm. Organizing the review in this manner identifies key intervention points.

Organizational system of production

The implementation of electronic performance monitoring systems results in organizational change, either planned or unplanned. Two broad organizational areas[2] are discussed in relation to stress: (1) human resource management – performance evaluation systems, pay systems (incentive systems), career ladders and job security; (2) communication systems – supervisor–employee patterns of interaction/leadership style.

Human resource management

Many human resource systems are designed for the purpose of accounting. An EPM system can be considered an electronic accounting system. As such, an EPM system is one form of human accounting designed to coordinate and control human activities at work, and thus can become a central organizational tool for human resource management. The allocation of coordination and control functions between the technology, employee or supervisor are organizational decisions that affect the design of the job, and thus are central to a consideration of how EPM systems can create stressors in the work place.

Performance evaluation

Evaluating the performance of employees is a central aspect of both determining advancement, job security and compensation (see Figure 2). Performance evaluation is the primary element of any EPM system. In general, performance evaluation involves the assessment of a variety of employee behaviours and accomplishments considered relevant for organizational performance. The feedback given to the worker is intended to act as a guidance aid and reinforcement for worker behaviours. Performance systems are intentionally designed to hold employees accountable for their performance. When the performance appraisal system is considered judgmental and not based on performance, anxiety or fear of reprisal can be elicited with an attendant sensitivity to feedback.

Because of computerized performance monitoring, the supervisor can be removed from the monitoring process and the computer can become the supervisor by providing the feedback automatically. This is a critical intervention point for the ergonomist. To the extent that the worker has some control over the type of performance information collected and the way it is presented, the result can be a positive effect on employee motivation and performance (Earley, 1988). It can lead to a feeling of mastery over the task and a greater sense of control in the work environment. Information received in a timely manner can assist the employee in planning work. This can contribute to a greater sense of control over work by providing opportunities to modify work strategies. However, a balance must be sought in the design of performance evaluation systems to use the information collected electronically to complement other less-tangible elements of work.

[2] A third area, organizational information policy, especially individual information privacy policy, is not discussed here. For further information on this topic the reader should refer to OTA (1987).

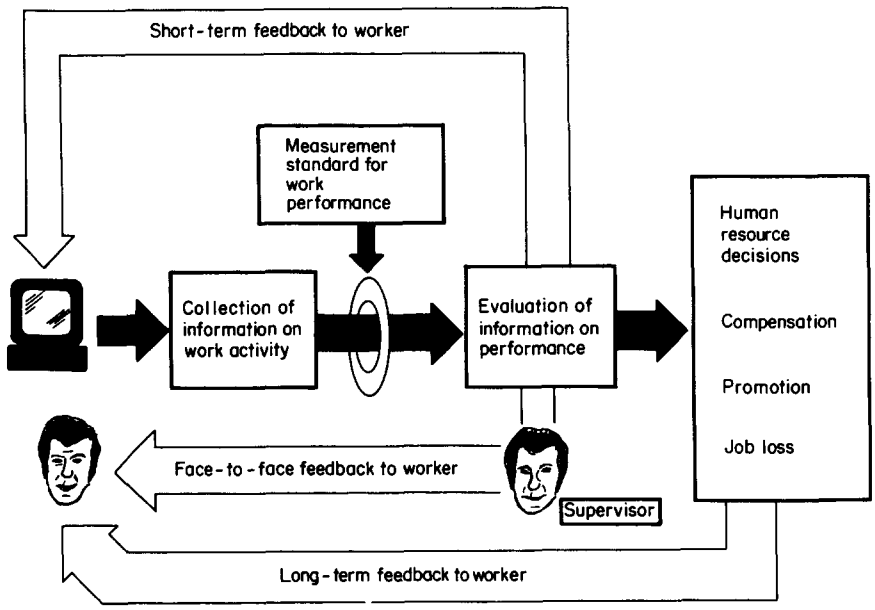

Figure 2 Typical components of a performance evaluation system in an electronic workplace

The ability of an individual to work as a team member in work groups can be just as critical in performance evaluation as the raw output. Information should be used to enrich the performance evaluation process.

Pay system

Computerization of work may promote incentive pay schemes, given the computer system's ability to tally and process individual performance information continuously. Piece-rate pay systems are one example of an incentive pay plan. Electronic performance monitoring takes advantage of rationalized and standardized production approaches to enable piece-rate pay systems. Computers can be programmed to count output, analyze performance, store performance information and provide information to employees about their performances. This facilitates implementing piece-rate pay systems.

The motivational advantages of piece-rate pay systems (cf Locke *et al* (1980) and Rothe (1960)) might be offset by the potential health costs. These computer-administered pay practices may lead to increased workload and time pressures with diminished opportunities to exert control or to seek social resources to meet the demands. Moreover, the worker may be compelled to suppress feelings of tension and fatigue in an effort to earn higher pay. Levi (1964) found, among a group of invoicing clerks, that self-reported feelings of 'rush,' 'physical discomfort,' and 'fatigue' increased significantly from salaried to piece-wage conditions. Froberg *et al* (1970) found adrenaline and noradrenaline levels rose 27–40% on days when invoicing clerks were under piece-rate conditions compared with a time-based pay system. Cakir *et al* (1979) found VDT typists under piece-work conditions experienced more mood disturbance and 'strain' than VDT typists under non-piece-work conditions.

Piece-rate systems are one aspect of the work structure that can contribute directly to chronic stress because they persist day after day. Schleifer and Amick (1989), in laboratory studies of incentive pay, found that workers in incentive pay conditions, compared with non-incentive pay conditions, experienced greater rush and tension. Further analyses demonstrated a consistent pattern of cardiovascular reactivity as a result of incentive pay. Heart rate variability decreased and blood pressure increased with an incentive pay plan compared with a non-incentive pay plan (Schleifer and Okogbaa, 1990).

Career ladders

When new computer technologies are introduced into the work environment, they can either diminish or enhance career advancement opportunities (OTA, 1985). In general, work simplification associated with EPM has eliminated steps on a career ladder through the standardization and rationalization of work activities which do not allow workers the opportunity to acquire the necessary skills to advance. Concerns over chances for promotion have been shown to be a stressor for office workers (Smith *et al*, 1981), while being passed over for promotion has been related to a decrease in job satisfaction and an increase in psychiatric illness in a military work environment (Arthur and Gunderson, 1965).

EPM systems are not likely to change the career ladder as dramatically as other technological innovations. However, the use of an EPM system could change the organizational basis for denying or awarding a promotion. When a performance monitoring system is established to collect information which workers consider relevant and pertinent to the evaluation of their capabilities and skills, then the system creates a more objective mechanism for promotion decisions from the worker's perspective. This type of monitoring system can be a more objective assessment of a person's performance than supervisor ratings.

Job security

The threat of job loss is a potent source of stress (Jick, 1984). It has been associated with ulcers, colitis

and patchy baldness in one study of factory workers (Cobb and Kasl, 1977), and with muscular and emotional complaints in a study of office workers (Smith *et al*, 1981). Organizations seeking to justify their work-force reductions may use performance monitoring to dismiss an employee for unsatisfactory performance. The fear of such a use of employee monitoring can be very stressful. Smith *et al* (1986), in their study of electronic monitoring, found this to be the major reason that employees feared monitoring.

One area where the implementation of an EPM system can directly impact job security is the first-line supervisor or foreman. Historically, these workers monitored the work activities on the floor to maintain a level of control over the production process. As EPM systems evolve, there is less and less need for the supervisor as a monitor of the employee behaviour. The supervisor can be replaced by the computer.

The practitioner must consider the broad labour–management implications of designing an EPM system, given the heightened social visibility of job security as a bargaining issue. In the organizational design of the EPM system, attention must be paid to communicating with employees about layoffs and job security.

Communication systems

Since a fundamental aspect of any EPM system is the feedback of information to supervisors and/or workers about performance, any implementation can impact the communication system of an organization. To the extent that new types of information are collected and analysed, the meaning of work and the relationship between workers can change. While many discussions of stress do not consider leadership style, it is an important determinant of the supervisor–employee interaction, and may represent what is being changed in implementing an EPM system.

Supervisor–employer interaction leadership style

Implementing an EPM system can change the relationship between the supervisor and the employee and the substance of the feedback or interaction. Where once the supervisor was important for ensuring that a worker completed a work quota or maintained the appropriate level of service, the computer can now be programmed to monitor this. EPM systems can reduce the supervisory function to checking data to ensure that the employee is not at variance with current production norms. As an example, in the US Postal Service of the past, a supervisor had to motivate the employees through human cajoling and leadership. Today, a computer monitors and evaluates each worker. When the supervisor and the employee interact, it almost always involves a negative action due to an employee's failure to meet production standards. Seldom are such interactions supportive.

Supervisor support can moderate the impact of stress on the health of the factory worker (House and Wells, 1978). Griffin (1983) has shown that when supervisors provide cues to workers about their performance, this changes the way workers evaluate other task components of the job. Supervisor support can be an essential social resource for coping with the demands of work. Good relationships between supervisors and workers have been shown to lead to decreased labour turnover, improved mental well-being and increased productivity (Coch and French, 1948).

Smith *et al* (1981, 1986) found that computer automation with monitoring produced a more coercive stricter number-counting supervisory style that replaced a more helpful less performance-oriented supervisory approach. Amick (1986) found similar supervisory influences in a study of the US Postal Service. By changing the nature of the feedback, the supervisor adopts an authoritarian leadership style. The feedback is nothing more than the figures collected by the electronic monitoring system. Each person becomes a faceless stream of information for the supervisor. Irving *et al* (1986) found in their study of EPM systems that monitored workers felt there was an over-emphasis on quantity as opposed to quality.

This type of leadership leads to a sense of depersonalization among the workers (Pearlin, 1985). The worker does not feel she/he is being recognized for uniqueness. Rather, the worker has a sense of facelessness. When supervisors no longer provide support, this loss of identity and lack of social resources can become a stressor. Being the constant bearer of negative news or the enforcer of remedial action may be as stressful as being the receiver of the action. To perform these duties, the supervisor may have to disengage from the work process, becoming a passive actor.

Alternatively, organizations could allow the supervisor to use the information created by the EPM system for greater decision-making at the production level (Burns and Fitter, 1987). This provides the supervisor greater flexibility in improving quality and production control through positive feedback and team-based decision-making. This type of work organization empowers the supervisor to create job and social opportunities to manage excessive job demands.

Finally, receiving supervisor feedback may not always be the most desirable channel. As noted above, an advantage of EPM is that the information can become less judgmental and more objective. Earley (1988) found that workers preferred receiving feedback from the computer system more than from their supervisor. He concluded that the reason for this was a greater sense of control over the planning of their work. Therefore, in situations where feedback from the computer replaces a more authoritarian leadership style (and perhaps judgmental feedback and evaluation), and allows the worker to use the information to control the work, the implementation may have a positive influence (Smith and Amick, 1989).

Jobs – Psychosocial work environment

We shall consider three general categories of job dimensions involved in producing individual stress responses related to stress-related diseases: job (work) demands – job content, workload and role conflict; job resources – performance feedback, instrumental and discretionary control; and social resources – co-worker

support. These three classes of work environment dimensions have been related to the health of a worker. Each of these can be influenced by the implementation of an EPM system (Smith *et al*, 1986; Smith and Amick, 1989). Currently, there is little empirical research on the effects of EPM systems on the psychosocial work environment, but, based on how EPM systems will change the work structure and current evidence from the work stress literature, the relevant job elements can be identified.

Job demands

Job demands are the environmental challenges the individual must engage in daily to produce value-added labour. These factors have been associated with chronic biological arousal as measured by catecholamine levels (Frankenhaeuser and Johansson, 1986) and changes in heart rate (Salvendy and Smith, 1981). In many epidemiological studies, these factors are collapsed into a single risk factor[3] to facilitate risk analysis (cf Theorell and Floderus-Myrhed, 1977; Karasek *et al*, 1981; Alfredsson and Theorell, 1984; Johnson and Hall, 1987). The job-demands dimension has been expanded to allow for a more refined conceptual analysis of the possible effects of EPM systems on job demands.

Job content

Any job requires a set of skills to complete the work. The content of a job reflects the level of skill use. As tasks become automated with advanced information technology and the job is not supplemented with new activities, job content tends to be diminished. In the design process, work simplification has a tendency to reduce the content of jobs by reducing cognitive content, task complexity and responsibility. This is accomplished by lowering the skill level required to complete the work, leading to the phrase 'de-skilling of work'. The process of de-skilling involves work standardization and work rationalization. Smith and Amick (1989) postulated elsewhere that work standardization and rationalization within a 'control organization' may be the most serious job stress aspect of electronic monitoring.

When work is fragmented into specified work elements, the purpose is to reduce uncertainty in production, to limit environmental dynamics, eliminate technical interdependence, and to make the work procedure as simple and easy to accomplish as possible (Cummings and Blumberg, 1987). This results in work whose variety, challenge, growth potential and social opportunities have been eliminated. Responsibility for making decisions about performance is embedded in the information system. This is most likely to occur when the EPM system is implemented to reduce the human variability in the work process and to increase the production levels by the division of labour. The result is typically simple repetitive work, easily monitored and controlled by management. Many times, the reductions in job content are accompanied by increases in workload as a result of the new repetitive nature of the job.

Jobs depleted of meaningful content result in monotonous work and boredom. O'Hanlon (1981) found that employees maintain a level of neurohormonal arousal for coping with the problems of habituation to the work activity caused by boredom. One purpose of work simplification is to reduce errors, yet jobs depleted of meaningful content have been associated with more accidents and injuries, an increase in the level of errors and decreased quality in performance. This can be more of a problem in an EPM system where errors are immediately identified and feedback is likely to be remedial (Grant *et al*, 1988).

Workload

Monitoring is often accompanied by the establishment of work standards to assess employee performance and to establish minimum performance levels. To the extent that EPM increases the work pace or the time pressure, it can increase the chances of the employee experiencing stress-related problems as a result of increased workload. In the work stress literature, workload is the most commonly measured element of the work environment and has demonstrated the most consistent relationship with health outcomes (cf Theorell and Floderus-Myrhed, 1977; Rose *et al*, 1978; House, 1980; French *et al*, 1982). This finding has persisted for industry-wide job-specific studies (cf Cooper and Marshall, 1976; Rose *et al*, 1978; Smith *et al*, 1981) and community studies (cf House *et al*, 1986).

Continuous electronic monitoring that provides feedback to an employee about performance below acceptable levels may lead to workload pressure. Early stress studies demonstrated increases in stress level as difficult deadlines drew near (Friedman *et al*, 1958). Constant pressure from EPM feedback may be more damaging than the intermittent deadlines of the accountants studied by Friedman in 1958. The pressure results from the fear of making a mistake and the potential negative reprimand (eg the letter-sorting-clerk job). Tied to the fear of reprimand for not meeting standards is the pressure to perform above average while not making mistakes. This is encouraged by managers since it produces higher production levels. But such workload pressure can bring about adverse health consequences (Smith, 1987).

Increased workload demands resulting from implementation of an EPM system can have adverse consequences for employee behaviour. Employees can limit their performance to cope with the excessive demands as they have under incentive pay systems (Rothe, 1960). For the organization seeking to use an EPM system to control employee behaviour, this can result in stabilizing performance below optimal individual levels which defeats the purpose of EPM systems based on individual performance. Employees who adapt by

[3] In epidemiological analyses, the job demands measure is often combined with a measure of job control to create a term measuring job strain. Researchers argue that job demands are only important in producing stress-related illness when the employee has no ability to control them. The evidence is still accumulating on this model (cf Karasek and Theorell, 1990). To understand the role of EPM systems more fully and identify points of intervention we have chosen to keep the two measures distinct.

performing below their optimal level may find it necessary to depersonalize their work. This can lead to a reduced sense of self-esteem, well-being and poorer mental health. Removal of the individual self from the production process results in less individual concern for quality or service.

A key factor in the development of a computer-based work monitoring system is the establishment of the work standards. If they are based on sound scientific considerations, they can help establish performance at a level acceptable to both management and labour. (The article by Schleifer in this issue elaborates on this.) To the extent that knowledge of the stress consequences of performing at a particular workload level can be specified, healthful work practices might be developed by the practitioner.

Role conflict

Role conflict exists when there is ambiguity over who is responsible for a certain set of duties or the individual is presented with conflicting demands. New forms of role conflict emerge when EPM systems cause the redesign of work, or eliminate the monitoring responsibilities of the supervisor. The EPM system may be designed to provide feedback to the workers about their performance. This type of feedback may have been the responsibility of the supervisor in the old work system. Walton and Schlesinger (1979) found difficult transitional problems associated with the change to work teams and new forms of information exchange evoking strain in the supervisor, and between the supervisor and subordinates. If roles remain ambiguous there may be role conflict emerging over who has the right to the information and who makes decisions about production based on the feedback provided by EPM. Unless clear organizational responsibilities are tied to the information generated by an EPM system, it can create conflicting roles due to the uncertainty of who is to use the information.

A service employee can experience stress from role conflict when confronted with having to comply with the differing expectations of the customer and the demands of the production standard. The goal in many telephone sales or telephone assistance jobs is to maximize the number of transactions. Work standards are typically established to force compliance with a specified set of goals for performance. This can sometimes conflict with the needs of the customer. The operator who knows she/he is continuously monitored can experience conflict in meeting the needs of the system over the needs of the customer.

Job resources

Job resources are those psychosocial dimensions of work which provide the worker with the opportunity to modify or cope with the job demands. To the extent that workers directly participate in the decisions about the nature and level of job demands, or the design of the EPM system, they have some influence on job stress (Gardell, 1988). One job opportunity is the ability of the worker to exercise instrumental control and discretionary control in the job (cf Sauter *et al* (1990) for a complete review of the evidence relating job control to health). A major design decision affecting psychosocial well-being is whether to codify control in the computerized information system or to provide the worker with greater control (Sheridan, 1980).

Instrumental control

Instrumental control is the ability of the employee to use the tools available to change the environment. Instrumental control occurs at the level of the human–technology interface. The ability of the worker to specify the nature of the feedback (eg, tactile, auditory or visual) to be generated or to modify the way the information is presented on the screen are examples of instrumental control. An important type of instrumental control may be the timing of the feedback. Individuals may vary in their desire to have feedback. The ability to control the presentation of information could be one mechanism used to cope with the workload pressures in regulating work activity (Sainfort, 1990). Earley (1988) found that the ability of the worker to specify the nature of the feedback on the computer terminal was associated with increased employee performance and engagement in task-planning strategies.

In most cases, the design decisions about the extent of control are made early in the design process, and control is most often embedded in the computer by the system designers. Workers seek mastery over their tools, and this is not allowed when opportunities for instrumental control are limited. This can affect the ability of the person to develop and learn new skills in work. The work system becomes a black box and the worker is unable to modify the system in an exercise of instrumental control. The worker becomes disengaged in this work process leading to problems of self-esteem and psychological well-being (Zuboff, 1988).

Discretionary control

Discretionary control is the ability of the employee to decide the task schedule to meet performance needs and how the tasks are to be carried out. Analysis of American and Swedish data support the importance of discretionary control in the etiology of heart disease (Karasek *et al*, 1981; Johnson and Hall, 1987). An EPM system is by definition providing feedback to the worker about performance. Provision of such information in concert with the ability to use discretionary control makes the design of EPM systems extremely significant in the development of job opportunities to manage job demands. Feedback from the environment, about meeting performance goals, is essential for effective accurate performance. A vast literature on human performance has demonstrated that failure to provide the proper feedback produces diminished performance and frustration (Smith *et al*, 1986). All theories of human performance at work identify the significance of having up-to-date accurate information about individual performance so aspects of personal motivation can be applied to increase productivity. Kalimo and Leppanen (1985) found the implementation of a computerized information system resulted in greater feedback to the worker and reduced stress.

When performance feedback is used to control the

worker, opportunities to modify work activities will be constrained and stress increased. This is accomplished by embedding discretionary control in the computer application system. The computer acts as both supervisor and pacer of the work process. Electronic monitoring can mimic paced work systems by using current performance information to feed messages to workers to speed-up production. Some systems add a new dimension to work pacing since they do not operate on a fixed work rate, but control performance variability through evaluation of monitored performance, automated work scheduling and performance feedback. As EPM systems are used to create computer-paced work, discretionary control which is necessary to cope with the attendant increase in job demands is removed.

The example of the automatic call router for long-distance operators shows how EPM can augment and intensify a current monitoring system, transforming it into a continuous or real-time worker performance tracking system (OTA, 1985). In this system, the computer keeps track when an operator is connected with a customer and automatically directs a new customer to the operator when the previous connection has been completed. The system keeps track of the time it takes to complete each call and develops an average for each operator. Operators must keep their average within a standard set by the company or be subject to disciplinary action. Operators can disconnect from the system for personal needs, but the number and amount of time taken for these disconnects is also recorded. It, too, can be the basis for disciplinary action. (For examples of how these conditions lead to stress-related outcomes see articles by Smith *et al* and DeTeccio *et al* in this special issue.)

Alternatively, feedback from an information enriched work environment system may reduce stress by providing information on a timely basis to the worker about the effectiveness of coping strategies. Computer-based work monitoring can provide feedback and knowledge of results about performance that helps the employee to exercise control in the work process. This information can be used in task planning and goal setting. Feedback can be critical to an individual's self-esteem. It enhances the employee's sense of mastery over the work environment leading to greater psychosocial well-being (Turner and Noh; 1988). If the discretionary control exercised was effective and efficient, then self-esteem should be increased. This will certainly enhance the person's ability to solve problems in the future and to manage job demands more effectively. Discretionary control also enables co-workers to interact and provide feedback and support. The ability to develop, maintain and use social resources can be essential in meeting the demands of work and in managing the potential threats to health.

Social resources

There is a broad and lively debate in the work stress literature on the mechanisms by which social relations at work influence a worker's health status. Johnson and Hall (1987) found that employees who had little control and little support were at a 68% greater risk for heart disease. There is general agreement that social resources are important for coping with the demands of work. Generally, two types of social resources are discussed: supervisor support and co-worker support. We have discussed supervisor support earlier in the context of the organizational communication system. Here we shall restrict our discussion to worker relationships.

Co-worker support

There is a growing literature on the importance of co-worker support in moderating the effects of job demands on a worker's health (cf House, 1981; Cohen and Syme, 1985). House and Wells (1978) found, in a study of factory workers, that there was no moderating effect of co-worker support on health. They attributed this to the design of the work process. Amick and Celentano (1991) demonstrated how technology can influence the level of co-worker support, reducing the opportunity of workers to use social strategies to deal with work demands. Smith *et al* (1981) found that the introduction of VDTs into the workplace reduced the sense of peer cohesion. Thus, the implementation of new technologies into the workplace can change the level of co-worker support.

EPM systems can change the ways in which workers interact and the ease of assistance provided to fellow workers. Socialization and talking can be reduced when work is monitored and performance feedback is comparative. When EPM systems are used as a primary form of supervision and the computer paces the worker, social isolation can be the norm. This can lead to depression. Monitoring adds to a worker's concern about being watched on a frequent basis. Thus, workers may be afraid to socialize. In a recent study, all workers interviewed commented on the importance of the workplace as a place to socialize and to interact with others (Smith *et al*, 1986). When social interaction is eliminated, worker feelings of isolation and loneliness occur which leads to stress.

EPM systems, stress and applied ergonomics

We have called attention to the importance of both the design of the EPM system and the attendant changes in the organization of work, emphasizing that there are organizational choices to be made. Throughout our conceptual overview there are four common themes: (1) participation in the design process; (2) allocation of control and coordination functions between the computer, employee and supervisor; (3) development of the feedback system; and (4) work measurement and the development of the performance appraisal system. Each of these is inter-related and design decisions regarding one generally are concordant with decisions regarding the other three. Each has been addressed in the conceptual overview. All but participation in the design process are discussed in other articles in this issue. From an applied perspective, participation is essential to the development of an ergonomically designed performance monitoring information system, while from a stress perspective, participation can lead to a sense of involvement in the job. Lack of involvement has been associated with physical and psychological health complaints (cf French *et al*, 1982; Gardell, 1988). Therefore, the ability of the

worker to participate or become involved in the design of the system can directly influence the level of stress through a sense of involvement in the organization (cf Jackson, 1983). It can also lead to the consideration of how best to design the system for the worker, creating an information enriched work environment.

There is a large literature that discusses the importance of participation in work system design based on socio-technical principles (Smith, 1986). A smaller literature has focused on participation in information system design (Amick, 1987). When the worker participates in the design of the EPM system, a variety of system design questions relevant to the worker and his or her work are likely to be addressed. Alternatively, when information system designers build systems, they will make a broad array of assumptions about the employee and typically build a system that is more likely to meet the employer's needs than the employee's needs.

The codification of human work by system designers is central to the process discussed. Table 2 shows the choices and the range of information processing activities that can be codified (cf Ostberg *et al* (1988) for a more complete discussion of ergonomics codification practices in software design). EPM systems can automate the workplace, creating machine-paced cognitive work. The attendant stress consequences have been discussed. Alternatively, the new systems can informate/support the production process and possibly lead to an information-enriched work environment. In many design activities these codification practices have been invisible. For the practitioner, the type of chart shown in Table 2 can be useful to enjoin managers and employees in a participative design process.

Table 2 The correspondence between types of work system design approaches and human information processing activities and in ergonomics codification practice

System design choice	Information processing activity
Automate (Relegate the task to a machine)	*Transportation* Physically relocate data (eg moving diskettes)
	Translation Change data storage medium (retrieval)
	Correlation/Matching Data manipulations based on the surface features of the data (pattern matching)
	Algorithmic processing Deterministic work using set of prescribed procedures (sorting, numerical programs)
Informate/Support (Provide the human with pertinent task information and automated tools)	*Heuristic processing* Nondeterministic judgements involving complex pieces of information; decisionmaking (expertise)
	Pragmatic processing Application of meta-knowledge for planning & goal achievement (strategy, negotiation)
Humanize (Assign the work process entirely to a human, etc.)	*Creation* Generating novel data (art, innovation)

Conclusions

Today, several million workers have their performance monitored electronically. The emphasis on cost containment in many industries and the opportunities to monitor people via their use of computer terminals will encourage more widespread use of automated work measurement and work monitoring techniques. The population at risk for stress-related maladies is expanding and the opportunity to impact the decision making process is today.

EPM systems have the potential to influence the design of jobs adversely, and in so doing creating significant occupational stressors. Alternatively, the integration of work measurement and information systems can influence jobs in positive ways that may be effective in reducing occupational stress. Positive interventions have been identified throughout the conceptual overview. There is no one single best solution. Ergonomists must use the full range of tools in their professional bag from interface design to organizational design to facilitate the development of an information-enriched work environment.

Acknowledgements

The authors would like to thank Larry Schleifer, Thomas Glass, Nigel Corlett and three anonymous reviewers for comments on earlier versions of this paper.

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