

# STRESSORS AT THE WORKPLACE: THEORETICAL MODELS

**A HISTORICAL OVERVIEW** *by Lennart Levi, MD, PhD*

To create knowledge about occupational stressors, stress, and health, we need to study: the stressors (at the workplace and elsewhere); the way they are experienced, interpreted, and appraised by the exposed person; the way he or she is "programmed" by genetic factors and earlier environmental influences; resulting pathogenic reactions; various (e.g., cardiovascular) outcomes of these reactions, in terms of morbidity, and their interaction with and feedback to other components of the system; and interacting variables (e.g., coping repertoire, social support) that could modify these processes.

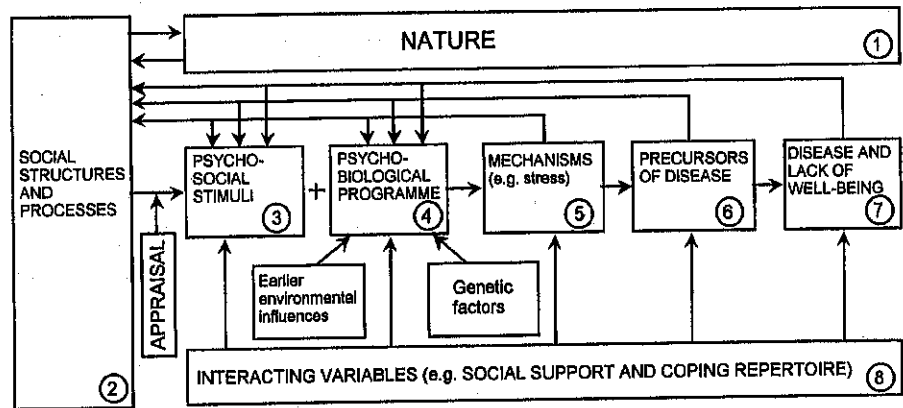
Briefly, then, we need to study over time the whole person interacting with his or her whole environment. A conceptual model of such a worker-workplace ecosystem can serve as a basis for research approaches as well as for therapeutic and preventive interventions<sup>108,137,143</sup> (Fig. 1).

The phenomenon of psychosocially mediated, stress-related ill health is, of course, in no way new to humankind.<sup>264</sup> Our early ancestors no doubt confronted acute and chronic physical and other stressors and attracted some of the diseases we know today. Theological explanations frequently were invoked, such as possession by evil spirits. Rituals were used to rid the body of evil influences.

However, nearly two and a half millennia ago, Socrates came back from army service to report to his Greek countrymen that in one respect the Thracians were ahead of Greek civilization: they knew that the body could not be cured without the mind. "This," he continued, "is the reason why the cure of many diseases is unknown to the physicians of Hellas, because they are ignorant of the whole."<sup>45</sup> And his contemporary Hippocrates, one of the Fathers of Medicine, believed that many diseases were caused by emotions, or passions as they were known, and theorized a mind-body physiology based on combinations of four basic humors (yellow bile, black bile, phlegm, and blood) with the four basic elements (air, earth, fire, and water), i.e., with environmental influences. Various combinations of these building blocks produced different mental states and diseases. To cope with such a complexity and to cure the human body, "it is necessary to have a knowledge of the whole of things."<sup>264</sup> About one millennium later Paracelsus emphasized that "true medicine only arises from the creative knowledge of the last and deepest powers of the whole universe." Perhaps these assertions represent an early, intuitive understanding of what we today refer to as a cybernetic or systems approach.

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**FIGURE 1.** A theoretical model for psychosocially mediated disease. (Adapted from Kagan AR, Levi L: Health and environment—Psychosocial stimuli. A review. In Levi L (ed): Society, Stress, and Disease. Vol. II: Childhood and Adolescence. New York, Oxford University Press, 1975, pp 241–260; with permission.)

During our own century, we often have relinquished as an ideal the mastery of the whole realm of human knowledge by one person, and our training as specialists has made it difficult for us to accept the ideal of intelligent cooperation.<sup>45</sup> This training has tended to keep each of us so closely limited by our own field that we have remained ignorant even of the fundamental principles in the fields outside our own.

### Ecological and Systems Approaches

How is the organism related to itself and to its environment? This is a fundamental problem presenting diverse facets to various specialists. The physician interested in either the maintenance and promotion of health or the cure of illness is working in the dark and by rule of thumb, as a mere technician, unless he or she has grappled with this problem and reviewed his or her practice in terms of it.<sup>45</sup>

#### IMPORTANT STEPS

Work-related stress and stress of other origin and their combined effects on cardiovascular and other morbidity and mortality have been approached by a number of eminent scientists. One of the early pioneers in this field was Bernhardt Ramazzini (1633–1714), Professor of Medicine at the University of Padua. Although his *De morbis artificum diatriba* is more intuitive and impressionistic than scientific, it is a systematic discourse on the maladies of those who practice some 40 different professions, covering possible causes and proposals for ways to prevent or cure them. He exhibited an intuitive understanding of the relationship between conditions of living and working of the poor and the risk of developing a number of work-related diseases.<sup>203</sup>

Alice Hamilton was the first American physician to devote her life to the practice of industrial medicine.<sup>207</sup> She wrote *Industrial Poisons in the United States* in 1925 and *Exploring the Dangerous Trades*, her autobiography, in 1943. In the latter, she lamented the status of occupational medicine in the United States:

“American medical authorities have never taken industrial diseases seriously, the American Medical Association has never held a meeting on the subject, and while European journals were full of articles on industrial

poisonings, the number published in American medical journals up to 1910 could be counted on one's fingers . . . The employers could, if they wished, shut their eyes to the dangers their workmen faced, for nobody held them responsible, while the workers accepted the risks with fatalistic submissiveness as a part of the price one must pay for being poor."<sup>80</sup>

Crucially important contributions to our knowledge of the impact of psychosocially induced psychophysiological reactions were made by Walter Cannon, whose animal studies demonstrated the existence of a complex pattern of bodily reactions preparing the organism for fight or flight under environmental conditions causing pain, hunger, fear, and rage.<sup>30</sup> Ivan P. Pavlov's studies on dogs demonstrated a remarkable ability of the central nervous system to modulate neuroendocrine responses<sup>184</sup> (see Fig. 1, boxes 2-5). Another important contribution to this research field was made by Hans Selye, who demonstrated that a wide variety of physical, chemical, biological, and psychosocial stimuli elicit a reaction pattern, whose non-specific components he termed "stress."<sup>221-223</sup> If prolonged, frequent, or intensive, stress increased "the rate of wear and tear" in the organism and accordingly was of pathogenic significance (see Fig. 1, boxes 2-7).

Franz Alexander presented some evidence indicating that psychosocially induced stress could not only influence but actually produce specific physical diseases.<sup>3</sup> He formulated a "specificity theory," which related specific psychological phenomena to specific somatic diseases (see Fig. 1, boxes 4-7), but had difficulties finding empirical support for it. Harold G. Wolff and Stewart Wolf, in their carefully conducted experiments on human subjects, demonstrated that a variety of bodily functions could be influenced psychosocially (see Fig. 1, boxes 2-5), offering important clues to etiology and pathogenesis of several important somatic diseases.<sup>280,281</sup> Thomas H. Holmes and Richard H. Rahe developed a method for quantifying "life changes," based on the assumption that every such change (e.g., death of a spouse, losing one's job, experiencing marital conflicts) taxed the organism and increased the wear and tear on it, leading to an increased risk of developing a wide variety of diseases, both physical and mental<sup>91</sup> (see Fig. 1, boxes 2-7).

Another important contribution came from Ray H. Rosenman and M. Friedman, based on their observations that many of their upper middle class cardiovascular patients exhibited a behavior pattern (Type A) characterized by a sense of urgency, competition, and hostility.<sup>63</sup> This pattern could be assumed to be accompanied by frequent, pronounced, and prolonged sympathoadrenomedullary responses, secondarily increasing the risk for subsequent ischemic heart disease (IHD). Another reasonable pathogenic mechanism was that such behaviors were causing frequent, prolonged, and/or intensive conflicts with fellow human beings that secondarily led to increases in sympathoadrenomedullary activity and, in a third step, to increased IHD morbidity and mortality (see Fig. 1, boxes 3-7). Although subsequent studies have failed to confirm the pathogenetic significance of the entire Type A behavior pattern, the pathogenic importance of one of its key components, hostility, has been supported by recent evidence.<sup>126</sup>

Richard S. Lazarus added to our knowledge by demonstrating the importance of "appraisal" and "coping" (see Fig. 1, boxes 2, 3, and 7) for the subsequent links in the chain of pathogenic events,<sup>132,133</sup> and James P. Henry and P.M. Stephens demonstrated the importance of subjective and objective control over a noxious situation for the neuroendocrine reaction triggered by the exposure and for subsequent morbidity and mortality.<sup>55,86</sup> Another modifier of the stressor-stress-disease chain of events was described by James S. House, who demonstrated the importance of social

networks (see Fig. 1, box 7) offering emotional, practical, and/or economic support, thereby counteracting morbidity and mortality.<sup>93,94</sup>

I remember Hans Selye once commenting on the abundance of "manufacturers of bricks"—bits and pieces of important information—and the lack of "builders and architects" who were able and willing to put the "bricks" together to produce "buildings." One builder was George L. Engel, who proposed a "biopsychosocial" model of etiology, pathogenesis, therapy, and prevention, as a timely and necessary challenge for biomedicine.<sup>52,53,108,136-139,141,144</sup> This biopsychosocial concept brings us back to the "wholistic" approaches recommended by the ancient Greeks. However, since the times of Socrates and Hippocrates, the amount of knowledge in biology, psychology, and sociology has increased exponentially, making such an approach rather difficult to handle. It follows that we need to *collaborate* across scientific disciplines and societal sectors, but also *simplify*—"as much as possible, but not more." (James Grier Miller, private conversation)

#### MODELS

As pointed out by Gardell, ill effects of "Tayloristic" mass-production methods include *alienation* of the worker, not only during working hours, but with a spillover to leisure time as well.<sup>66</sup> An increase in fatigue, passivity, or apathy may grow out of this disaffection, leading to a decreased willingness of the worker to help change working conditions as well as participate in activities outside work. Further, it seems reasonable that the speed with which a person "unwinds" after work could influence the magnitude of the physiological and psychosocial effects, as well as affect the extent to which stress at work is carried over into leisure time.<sup>56-58</sup>

Promising attempts to include all of these theories have been made by Robert Karasek, Töres Theorell, and Jeffrey V. Johnson in their three-dimensional model of psychosocially induced morbidity and mortality.<sup>99,117</sup> The three dimensions are: environmental demands (Fig. 1, boxes 2 and 3), individual control (boxes 2 and 3), and social support (box 8). The most noxious combination is high demands + low control + low support. This model has been the basis of much research and has found considerable support in empirical studies.

Another basic model is based on the notion of person-environment fit (Fig. 1, boxes 2-4), according to which a misfit in a number of respects acts as a stressor.<sup>61,81</sup> A type of misfit is the basis for a third model by Johannes Siegrist, with his evidence-supported hypothesis of the pathogenic significance of high effort but low reward<sup>228</sup> (Fig. 1, boxes 4-6).

Until recently, virtually all research has focused on pathogenesis. Against this background, Aron Antonovsky asked why we don't all become ill, exposed as we are to "the slings and arrows of outrageous fortune."<sup>6</sup> He formulated his hypothesis about *salutogenesis* and "sense of coherence," with its three dimensions of comprehensibility, manageability, and meaningfulness. High scores in these three respects seem to exercise a protective or even health-promoting influence (Fig. 1, boxes 4-7).

During recent decades, increasing attention has been paid to psychosocially induced, potentially pathogenic *behaviors*, such as alcohol, tobacco, and other substance abuse, risk taking, and other self-destructive behaviors. There is some evidence that work-related stress is one of their determinants. Although not included in Selye's original stress concept, they are probably at least as important for human morbidity and mortality as the more direct psychoneuroendocrinologic mechanisms. An excellent review of the present state-of-the art is found in a recent paper commissioned by the European Heart Network.<sup>48</sup>

Needless to say, the early approaches to stress and health were purely speculative. Subsequent ones were based on scattered clinical observations and anecdotal evidence. The next step comprised studies on mice, rats, and other animals under laboratory conditions and in real life.<sup>55</sup> Subsequently, the favorite experimental animal increasingly chosen was the medical student. Descriptive and observational studies were gradually complemented by hypotheses testing and interventional studies, and experimental studies were used together with epidemiological ones, in "package" approaches. Simple stimulus-response approaches, initially unifactorial, gradually became multifactorial, ecological and, eventually, *systems* oriented.<sup>213</sup> The focus on the individual patient gradually broadened to a *community* approach.<sup>273</sup> There has been a parallel development from therapy to primary and secondary prevention and health promotion.<sup>140,144-146</sup>

**SOCIAL CLASS AND POWER RELATIONS AT THE WORKPLACE** by Mel Bartley, PhD and Michael Marmot, FFPHM—  
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Classical social theories did not concentrate on the effects of the workplace on the individual (in contrast to occupational psychology) but on how the organization of production affects stability and change in norms, values, and other social institutions such as the family and the economy. Social psychology and epidemiology have built on these insights to ask how the position of each individual within the structure of economic relations may influence their psychological makeup and, ultimately, mental and physical health.

Contemporary epidemiologic theories relating work relations and conditions to health have focused on the amount of control exercised over the work process,<sup>84,103</sup> variety and the scope for use of initiative and skill,<sup>156,177</sup> excessive work pressure, and the mismatch between effort and rewards.<sup>191,233,235</sup> All of these concerns have a basis in social theory.<sup>226,227,233</sup>

The classical theories from which our present day approaches to power in the workplace are derived were formulated at a time of great turbulence and change. In Marx's words the new industrialists had "put an end to all feudal, patriarchal, idyllic relations. . . pitilessly torn asunder the motley feudal ties that bound man to his 'natural superiors' . . . resolved personal worth into exchange value . . . Constant revolutionizing of production, uninterrupted disturbance of all social conditions, everlasting uncertainty and agitation distinguish the bourgeois epoch from all earlier ones."<sup>160</sup>

At this time, the very nature of social and economic relationships was in flux. Old certainties based on fixed statuses and associated obligations were being torn down, and it was not at all clear what would take their place. From the perspective of the present day, it is surprising how relevant this work now appears, if we substitute for questions regarding the relationship between lord and serf the more contemporary questions about the relationship between men and women, or parents and children.

### **Divisions of Labor, Anomie, and Alienation**

Marx and Durkheim shared a concern about the changing nature of social bonds that accompanied the development of a modern industrial economy and its

"division of labour," or separation of increasing numbers of different types of work. Although they agreed that the decline of feudal traditions increased the productive capacity of societies and the scope for individual action, their views on the nature of what had replaced these traditions, and of future directions for society, were different. However, for our present purposes, their commonality is more important than their differences, because while each perspective focused on different aspects of the question, both had a major influence on the ways in which we think about the relationship between employment and health.

Durkheim regarded increasing division of labor as a normal phase in the development of societies. "Social pathologies" such as economic crises, mass unemployment, and conflict between factory owners and workers were ascribed to *abnormal forms of the division of labor*. He characterized the course of normal development, as territories became more densely populated and urbanized, as a change from "mechanical" to "organic" forms of solidarity.<sup>46</sup> The ideas behind the different forms of social solidarity are still relevant to social and political debates today. **Mechanical solidarity** is present where collective rules and sanctions are mainly religious in nature, and powerful beliefs tie individuals together so strongly that the idea of the individual is itself problematic. In the mechanically solidaristic society, social bonds are of obligation rather than contract; there is little specialization of work tasks, low levels of individual autonomy, and swift and severely repressive punishment for deviant behavior. As populations grow and come together in larger towns and cities, however, new social divisions arise, based more on the necessary organization of work tasks than on family, tribal, or religious allegiances. Tolerance of differences in beliefs and behavior increases. Social bonds become increasingly a matter of mutually satisfactory arrangements to ensure that productive activity can proceed. In these societies of **organic solidarity**, social relations are based on contracts and agreements rather than religion or sentiment; occupations rather than kinship defines social position. However, in the absence of abnormalities of development, the *conscience collective* ensures that a set of agreed norms underlie the more complex set of social relations.<sup>46,171</sup>

Durkheim did not regard hierarchical differentiation between groups who carry out different tasks within a division of labor as necessary or desirable.<sup>68,154</sup> If one social class becomes too powerful and is in a position to enforce a division of labor on other groups, this results in **anomie**, that is, an enforced specialization that is meaningless and purposeless to those who carry out the specialized tasks. The common values involved in the various branches of the division of labor are lost. Social groups lose track of the larger picture—that all of their different functions are intended to bring about the welfare of the society as a whole. Coordination of different types of work breaks down. Financial crises and industrial conflicts were, for Durkheim, failures of mutual understanding and shared purpose. The welfare of the individual worker and the quality of his or her relations at work were, therefore, central to society's ability to function.

Durkheim's ideas have had a profound influence on the study of social factors in disease. He carried out a study of regional variations in suicide, showing that it was more common in more anomic sections of society where shared norms and social ties were looser.<sup>47</sup> More recently, this finding has been extended to the investigation of the effect of social support and social cohesion on disease.<sup>152,156,200,242</sup> Durkheim's conviction that a society based solely on market relationships was impossible has been carried forward into the investigation of the relationship of social and economic inequality to measures of population health.<sup>121,276-278</sup>

Marx's focus on and concern to explain the social changes of the 18th and 19th centuries was in many respects similar to that of Durkheim. Where Durkheim is relatively vague in dealing with the causes of the social changes he describes as the division of labor, Marx is more explicit in attempting to explain these changes. He attributes them to advances in technology and associated changes in the ownership of a society's most important productive resources. Marx accordingly devoted more attention to the economic aspects of social relations. In feudal societies (which would be regarded as relatively mechanical according to Durkheim's classification), traditional social and legal norms defined legitimate social relationships. The work of producing consumer goods was also heavily regulated by custom and tradition, presided over by the guilds.<sup>95</sup> Land owners also owed certain duties of protection to their serfs, and master craftsmen similarly owed duties to their apprentices. Agriculture and craft were the main forms of work.

During the 18th century, new agricultural and industrial technologies arose that changed the nature of production, both of food and goods. Skilled crafts declined and began to be replaced by fragmented forms of production in factories.<sup>161</sup> During this time, profound legal and political changes took place, including the right to buy and sell land and to lend money at interest. Once this happened, two types of control were lost: (1) Manufacturing workers lost control of the production process when they no longer owned their own tools. (2) Families lost control of the provision of food after the enclosures of common land, when even the most basic foods had to be bought with wages from employment rather than produced at home. We see the importance of this second control today in the former Soviet Union, where access to produce of the land (in the form of extended family members still living in rural areas) can make a major difference in the living conditions of workers who find themselves suddenly in a modern, free-labor market.<sup>32</sup> It also has been pointed out by Amartya Sen that, paradoxically, in the Indian sub continent, the landless laborer is most in need of work and yet least attractive to employers because he starves in between jobs, whereas the laborer with a little land is able to remain fitter and healthier.<sup>43,224</sup>

Whereas Durkheim's central interests have made his work helpful to the study of psychological health and illness, Marx's emphasis on production processes and economic forces are more relevant to the study of industrial causes of disease, the effects of economic deprivation, and issues of control over the work process. We inherit from Durkheim the concept of anomie, the loss of the sense of belonging to a community with common values. Marx's development of the **concept of alienation** is a more economic and less psychological process.<sup>159</sup> All workers are alienated from the things they produce when they have done so under an "over-segmented" and forced division of labor, in a situation where they have no voice in the organization of production. The prices of the goods produced are partly determined by the level of supply: once the market is saturated, demand disappears. Under this division of labor, the harder the worker works, the greater the risk of a glut, with resulting unemployment. As a result: "With the increasing value of the world of things proceeds in direct proportion the devaluation of the world of men. . . the more objects the worker produces the fewer he can possess."<sup>159</sup> Even a worker who responds to a questionnaire by reporting a high level of work satisfaction may therefore be alienated in this objective sense, if his or her high productivity potentially threatens employment prospects.

Alienation has another meaning in Marx's analysis: that of humankind alienated from its "species-being." What distinguishes person from animal is that men and women produce creatively, from previously imagined ideas rather than from instinct,

and they produce far more and far different things than that which is necessary for mere survival. Therefore, to place human beings in a situation where their acts of production are constrained by the will of a controlling group or class, and are undertaken purely for survival, is to deny—or alienate people from—human nature itself.<sup>159,266</sup>

### **Bureaucracy, Hierarchy, and Lifestyle**

Like Durkheim and Marx, Weber was concerned to understand the conflict and change of 19th century Europe. Like Marx, he discussed the role of property ownership in creating wealth and advantage. He differed in four major ways: First, his model of social change put *ideas and beliefs* in the driving seat as the causes rather than the consequences of technological change.<sup>267</sup> Second, he defined a dimension of social division he termed *status*, which is based not on work, production, and the social relationships at work, but on patterns of consumption and lifestyle.<sup>268</sup> The “status group” was defined as a group of individuals who share the same level of prestige or esteem. They express their shared status in terms of common forms of consumption and lifestyle and by limiting their interactions with members of other groups. Third, Weber stressed the role of both status group membership and education in giving a person a better or worse *market position* according to the demand for these attributes. Fourth, Weber paid more attention to the large *bureaucracies* that increasingly presided over both industrial production and government by the time he was writing his major works.

It was not, for Weber, either the forms of material production or of group solidarity that determined individuals’ actions, but individual beliefs themselves, as exemplified in perhaps his best known work on the genesis of capitalism in the religious beliefs of Protestantism.<sup>267</sup> The most important aspect of belief was acceptance of the legitimacy of the prevailing rules of behavior. This aspect is, of course, quite similar to the shared norms of Durkheim’s conscience collective.

Weber’s major contribution to present-day research on the relationship between work and health is his analysis of the labor market, in particular of the differentiation within the newly growing (at the time he was writing, and again today) white-collar labor force of managers, professionals, technicians, supervisors, and clerks. He did not explicitly link labor market position to individual well-being. However, the Austrian sociologist Renner developed the concept of the “service class,” a form of employment characterized by the necessity for the employer to place trust in the employee and to organize the relations of employment to produce loyalty. There is a strong connection between the characteristics of Renner’s “service relationship” between employer and employee, and the concerns of Durkheim and Marx with anomie and alienation. In order to ensure loyalty and the conscientious performance of intricate tasks, the working conditions of professional, managerial, and technical workers developed in a way that minimized feelings of anomie and alienation and maximized perceptions of just reward and of being personally valued. Not least, in Renner’s words, “The payment of a salary is not meant to provide food and shelter from week to week, but to establish a lifestyle . . . which improves as the individual becomes older.”<sup>205</sup> The loyal service worker from a more humble background could therefore be expected, over time, to move into higher-status groups.

### **Relation of Classical Theories to Modern Research on Work and Health**

There are at present two leading alternative interpretations of the relationship of the psychosocial conditions of work to disease risk. The demand-control model



seems to be related more closely to Marx's concept of alienation, and the Effort-Reward Imbalance (ERI) Model to Weber's analysis of the need to regulate and motivate the new service class in emerging large organizations and government bureaucracies. Industrial capitalism resulted in a situation where employees had no control over what they would produce, how they would produce it, or what happened to the goods they made. Continued involvement in work was motivated purely by the need to earn money to be exchanged for food and shelter—devoid of autonomy or creativity. The increasing sophistication of industry gave rise to a need for well-educated workers who could be entrusted with responsibility in large and complex private and public organizations. These workers had to be persuaded of the legitimacy of their employers' demands: mere surveillance was not a guarantee of performance. The solution that developed was that key workers were given more autonomy within the organization and the resources to develop and sustain an elite lifestyle. They acquired power over their status in the wider society: this was accomplished by various combinations of increased pay, incremental pay scales, and conferring of symbolic signs of status as rewards. Taken singly, none of the classical social theories gives us a full picture, but combining them reveals a social structure in which one section of the working population, due to their value on the labor market bestowed by the social status of their families and by their level of education and skills, has access to a form of employment in which anomie and alienation are relatively attenuated.

An example of how the concept of social stratification and its possible effects on health are being operationalized and tested in epidemiologic study can be taken from the Whitehall study of health differences between different levels of a hierarchical organization; the British Civil Service.<sup>157</sup> This research has included measures of psychosocial conditions and relationships at work from its inception. Empirically, as one might expect, work control and ERI have been found to constitute independent dimensions of psychosocial risk.<sup>24</sup> In the "more alienated" groups with low work control, ERI had a large effect on CVD incidence, whereas in those with "less alienated" work (higher levels of job control), the effect of ERI was less strong.

Recent economic developments in some countries have eroded the privileged position of professional and managerial workers. Epidemiologic studies so far have not revealed any narrowing tendency of morbidity or mortality differentials between the service (managerial and professional) and working classes in the U.S.<sup>198,199,279</sup> nor in some European countries.<sup>21,42</sup> However, it may be too soon to see the effects on health of recent deteriorations in the working conditions of white-collar workers.

## Conclusion

The classical theorists were not concerned primarily with the physical well-being of individuals, although it would certainly not have surprised Marx or Durkheim to find that the psychosocial consequences of occupying different positions in society could influence rates of disease and mortality. The points upon which there was broad agreement between the different schools of thought focused on the importance of social relationships, of which employment was the most important. It is possible to trace this theme forward to see the ways in which concepts of anomie, alienation, and status have been used in various combinations to illuminate the processes underlying inequalities in health.

The relationship between work characteristics and health is an example of the unintended consequences of structured social action. In the presence of class division and private ownership of the means of production, much work is undertaken for

financial reasons only, and is neither creative nor self-motivated. Control and autonomy at work vary between occupations and between occupational settings, and have been shown to be associated with CVD<sup>23</sup> and its precursors.<sup>216</sup> Employers offer rewards in terms of material goods and status to ensure the conduct of necessarily self-monitored, highly skilled and responsible work involved in many (mostly white-collar) forms of employment. As well as providing work incentives, these forms of reward also appear to have beneficial effects on health.<sup>120,147</sup> There appears also to be a process that relates the degree of work effort and the perceived fairness and appropriateness of financial and/or status rewards, to the risk of CVD.<sup>189</sup> In these ways the operationalization and measurement of concepts derived from theories of social structures and dynamics have contributed to epidemiologic research.

### THE DEMAND-CONTROL-SUPPORT MODEL AND CVD

*by Robert Karasek, PhD and Töres Theorell, MD, PhD*

The demand-control model (DCM) was introduced by Karasek in his doctoral thesis.<sup>114</sup> It was developed for work environments where stressors are chronic, not initially life threatening, and the product of sophisticated human organizational decision making. In decision making the controllability of the stressor is critical, and it becomes more important as increasingly complex and integrated social organizations develop, with ever more complex limitations on individual behavior. The model is based on psychosocial characteristics of work. It has two components: **psychological demands**, and a combined measure of task control and skill use, or **decision latitude**. The model predicts (1) stress-related illness/risk and (2) active/passive behavioral correlates of jobs. It has been used mainly in epidemiologic studies of chronic disease, such as coronary heart disease.

The health outcome measures in the original studies were mental health variables. The first article with this perspective in an international journal appeared in 1979, on epidemiologic studies of working Swedes.<sup>118</sup> The cardiovascular perspective was introduced in the late 1970s, and the first prospective study appeared in 1981.<sup>115</sup> The latter was based on randomly selected working men in Sweden who were surveyed initially in 1968 and then followed up in 1974. The outcome measures were cardiovascular mortality and a composite measure of cardiovascular symptoms. The study showed a significant association between working in jobs that were psychologically demanding and uncontrollable, and increased likelihood of subsequent development of heart disease symptoms and/or cardiovascular mortality.

The DCM is useful educationally when a worksite is being explored. The model has great face value, and the employees immediately grasp the importance of it in the practical exploration of the psychosocial work environment.

### Historical Context

Kornitzer and his collaborators observed in the 1970s in a retrospective study of two bank groups in Belgium, one private and one state-owned, that employees in the private banks had a higher incidence of myocardial infarction (MI) than employees in the state-owned banks. This study was one of the first to indicate a possible relationship between psychological work demands (which were higher in the private banks) and risk of MI. In the 1960s, an important prospective study demonstrated a higher incidence of MI among lower-level than among higher-level employees in large companies.<sup>187</sup> For the first time, suspicion arose that psychosocial stress may

not be a problem only for people with a lot of responsibility, as researchers had tended to believe previously (see Chapter 2).

The environment's impact on the cardiovascular system via the CNS has been well-appreciated empirically since ancient times. Currently, sociologists and social psychologists have helped to apply theoretically-based models of this dynamic to cardiovascular research.

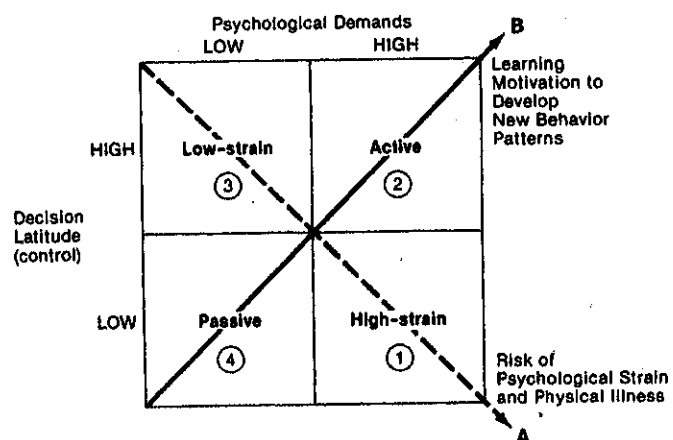
### The Demand-Control Model

Several theoretical models, for instance those of the Michigan school of sociology (Person-Environment Fit)<sup>119</sup> and Cooper's comprehensive model,<sup>36</sup> describe the psychosocial aspects of white-collar work. Karasek's DCM was a synthesis of the *demand* (psychological stress) and the *lack of control* (sociological) research.<sup>118</sup> In generating the concept of lack of control, or "lack of decision latitude" as Karasek labeled it, he had been following sociological traditions on alienation and organizational behavior.

According to the model, there is interaction between high psychological demands and low decision latitude. If demands are regarded as the x-axis and decision latitude as the y-axis in a two-dimensional system, four combinations are recognized (Fig. 2). The high demand-low decision latitude combination is labeled *job strain* (high strain); the high demand-high decision situation *active work*; the low demand-low decision latitude combination *passive work*; and the ideal low demand-high decision latitude combination *low strain work*.

#### JOB STRAIN HYPOTHESIS

The first hypothesis is that the most adverse reactions of psychological strain (fatigue, anxiety, depression, and physical illness) occur when the psychological demands of the job are high and the worker's decision latitude in the task is low. For example, the assembly-line worker has almost every behavior rigidly constrained. In a situation of increased demands ("speed-up"), more than just the constructive response of arousal, the often helpless, long-lasting, and negatively experienced response of residual psychological strain occurs. During a restaurant's lunch-time rush, it is the waiter or waitress who does not know how to "control" the customer's



**FIGURE 2.** Psychological demand/decision latitude model. (From Karasek R, Theorell T: *Healthy Work*. New York, Basic Books, 1990; with permission.)

behavior ("get the jump on the customer") who experiences the greatest strain on the job.<sup>274</sup> Kerckhoff and Back have described garment workers under heavy deadline pressure and the subsequent threat of layoff.<sup>122</sup> They concluded that when the actions normally needed to cope with job pressures cannot be taken, the most severe behavioral symptoms of strain occur (fainting, hysteria, social contagion).

It is not only the freedom to determine how the formal work task is accomplished that relieves strain, but also the freedom to engage in informal rituals such as the coffee break or fidgeting, which serve as supplementary "tension release" mechanisms during the workday.<sup>40</sup> These mechanisms often are social activities with other workers—precisely those activities eliminated as "wasted motions" and "soldiering" by Frederick Taylor's methods from 1911.<sup>249</sup> Thus, the DCM must expand to include social relations and social support for strain relief. According to the theory, prolonged and repeated job strain increases sympathoadrenal arousal and decreases anabolism, the body's ability to restore and repair tissues.

In the DCM, decision latitude refers to the worker's ability to control his or her own activities and skill usage, not to control others. Decision latitude scales have two components: **task authority**—a socially predetermined control over detailed aspects of task performance (also called autonomy), and **skill discretion**—control over use of skills by the individual, also socially determined at work (and often called variety or substantive complexity).<sup>77,123</sup> In modern organizational hierarchies, the highest level of knowledge legitimizes the exercise of the highest levels of authority, and workers undertaking limited, specialized tasks are coordinated by managers with higher authority levels. Skill discretion and authority over decisions are so closely related theoretically and empirically that they often are combined.

Examples of work's psychological demands—"how hard you work"—include the presence of deadlines, the mental arousal or stimulation necessary to accomplish the task, and coordination burdens. The physical demands are not included, although psychological arousal comes with physical exertion, and for some groups of workers responses to questions about working hard may include physical aspects of work.<sup>106</sup> The assessment of psychological job demands has turned out to be methodologically more difficult than was hitherto believed. In particular, the interpretation of questions regarding psychological demands may differ between different groups, e.g., white-collar and blue-collar workers, and men and women. Furthermore, psychological demands may change in nature as information technology and other ongoing working life changes affect working conditions. Assessment difficulties may explain why the psychological demands part of the DCM has less empirical support than the control part.

#### ACTIVE LEARNING HYPOTHESIS

When control on the job is high and psychological demands are also high but not overwhelming, learning and growth are the predicted behavioral outcomes. The combination of high psychological demands-high decision latitude is defined as the active situation; workers experiencing this combination of work environment factors are the most active group outside of work, in leisure and political activities, despite heavy work demands.<sup>117</sup> Only average psychological strain is predicted for the active job because much of the energy mobilized by the job's many stressors ("challenges") are translated into direct action—effective problem solving—with little residual strain to cause disturbance. This hypothesis parallels White's "concept of competence," an environment-based theory of motivation: the psychological state of individuals in challenging circumstances is enhanced by increasing demands. The model also predicts that the growth and learning stimuli of these settings, when they

occur in a job context, are conducive to high productivity. According to the DCM, learning occurs in situations that require both individual psychological energy expenditure and the exercise of decision-making capability.

In an active environment, the worker can cope with high psychological demands because he/she can make relevant decisions, such as planning working hours according to personal biological rhythm and the naturally optimal use of internal physiologic resources. In addition, the worker can improve coping strategies and thereby facilitate a feeling of knowledge and authority, as well as improve access to information in unforeseen situations. These possibilities correspond to psychological growth.

#### PASSIVE WORK AND LOW-STRAIN WORK

The DCM predicts that situations of low demand–low decision latitude (the passive combination) cause an unmotivating job setting that leads to “negative learning,” gradual loss of previously acquired skills. Evidence shows that disengagement from leisure and political activity outside the job appear to increase over time in such jobs.<sup>117</sup> This atrophication may represent “learned helplessness”<sup>220</sup> and may be the result of a sequence of job situations that reject workers’ initiatives. The low demand–high decision latitude situation—low strain—is theoretically ideal from the strain perspective. Low demand in the modern working environment really means no *excessive* demands; it should not be perceived literally, since low demands may be problematic from the perspective of social engagement.<sup>114,117</sup>

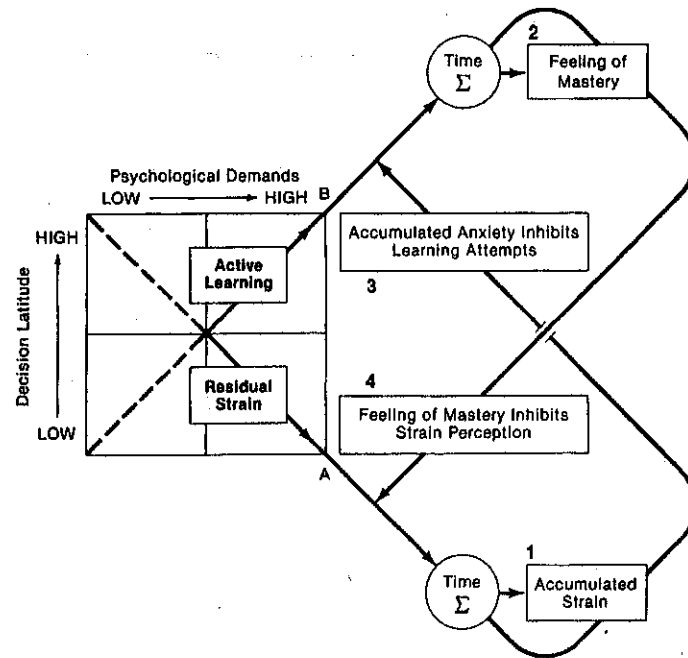
#### DYNAMIC DEMAND/CONTROL HYPOTHESES

Figure 3 shows the dynamic version of the DCM, which integrates environment and personality orientations over the long term. Active learning in the active situation stimulates feelings of mastery. This high mastery personality orientation, in turn, allows more successful coping with the inevitable job stressors, reduces residual job strain, and leaves the individual with extra energy to engage in the challenges of further active learning situations. Overall, this is a feedback spiral with positive consequences, but a “negative” spiral is also possible. High-strain situations lead to withdrawal, reduced mastery, and further reduced coping effectiveness.

Environmental demands can be conceptualized in both positive and negative terms, congruent with the common understanding that there is both “good” and “bad” stress. However, the DCM is not congruent with a model of “demands and resources,” allowing a simple fit with currently common cost-benefit thinking, in which the positive benefits of resources are subtracted from the negative costs of demands. The logic of the DCM cannot be collapsed into a unidimensional form. The distinction between decision latitude and psychological demands must be retained because the model predicts both job strain and active learning associated with psychological demands, depending on the level of control.

#### The Demand-Control-Support Model

It soon became evident that a third component was needed in the DCM: social support. Johnson has pointed out that collective support may be difficult to separate theoretically from collective control.<sup>99</sup> Workers who are exposed to adverse working conditions may join forces and increase their control over the working conditions. The worst hypothesized situation is **iso-strain**—job strain and lack of social support.<sup>100</sup> Several different aspects of social support are relevant. At work the *source* of support is important; the supervisor and colleagues are the main sources for most employees. Customers or patients also can be important sources of social support.



**FIGURE 3.** Dynamic associations linking environmental strain and learning to evolution of personality. (From Karasek R, Theorell T: *Healthy Work*. New York, Basic Books, 1990; with permission.)

Two of the most important types of support are *instrumental* (when there is a lack of material resources, someone should be available to help) and *emotional* (someone to share inner feelings with about job problems).

Social support buffering of psychological strain may depend on the degree of social and emotional integration and trust between coworkers and supervisors, i.e., **socio-emotional support**. Addition of social support also makes the demand-control perspective more useful in job redesigning. Changes in social relations between workers (e.g., autonomous work groups) and changes in decision latitude are almost inseparable in job redesign processes, particularly "participatory" processes.<sup>93</sup>

### Occupation and Psychosocial Job Characteristics

The relationship between occupations and job characteristics has been described by means of national surveys, for instance in Sweden and the U.S. Maps have been published that illustrate the relative positions of different occupations in relation to decision latitude and psychological demands. Typical active jobs are lawyers, judges, engineers, nurses, and managers of all kinds. Examples of passive jobs are clerical workers, such as stock and billing clerks, and service personnel, such as janitors. In the job strain groups, typical occupations are machine-paced, including assemblers, inspectors, and freight handlers, as well as service-based, including waiters and cooks. Examples of low strain jobs are self-paced occupations such as repairmen, foresters, linemen, and natural scientists.

Note, however, that the labor market is changing. In Sweden, for instance, national surveys indicate that there was a long period during the 1970s and 1980s when

the psychosocial job characteristics of most jobs were improving with regard to intellectual discretion and authority over decisions.<sup>214</sup> During the 1990s, risk of unemployment and demands for effectiveness have increased, while decision latitude has decreased markedly for certain groups. One clear example of this labor market evolution is that physicians who belonged to the active group in the late 1970s and early 1980s now belong to the job strain category, according to national surveys.<sup>214</sup> On the whole, workers in the healthcare sector have been disfavored in the societal financial crisis in Sweden. Decision latitude was reported as lower in this sector than in other branches in the Stockholm labor market, and the differences between physicians and others were not as pronounced as expected.<sup>214a</sup>

Aggregation of individual job scores within a work group or occupation is a method for counteracting potential self-report bias in job assessment. This is the basis for the much used occupation-based linkage system. However, subgroups with significantly differing job experiences can be aggregated, leading also to misclassification problems. Thus, adequate operationalization of constructs or objective assessments may be additionally needed. For example, professional bus drivers from inner city areas have a high risk of developing MI in detailed studies, but when all bus drivers (urban and rural) are grouped together and simple questionnaire responses are used, this distinctive inner city bus driving risk is lost.

According to occupational studies, executives and professionals do not belong to the job strain group and, accordingly, they do not record the highest level of stress, as popular belief often holds. While managerial stress certainly exists because of the high psychological demands that come with these jobs, it appears that the frequent occasions for decision making and deciding how to do the job are a significant stress moderator. Of course, at the highest status levels, decision making is the primary psychological demand, and then the demand-control model fails. The implication here is that executives could reduce their stress if they made fewer decisions, and lower-status workers would be better off with a more equal share of decision power. Interestingly, managed care often severely compromises control as well as increases demand among physicians and other healthcare professionals.

Men are more likely than women to have high control over their work process at the task level.<sup>117</sup> Another major gender difference in some U.S. and Swedish samples is the negative correlation between decision latitude and demands for women: women with low control also have higher job demands. This means that women are several times more likely than men to hold high-strain jobs in the general working population. By contrast, men's high-demand jobs generally are accompanied by somewhat higher decision latitude.

### **THE EFFORT-REWARD IMBALANCE MODEL**

*by Johannes Siegrist, PhD and Richard Peter, PhD*

Theoretical work in the field of occupational stress and health is faced with two challenges. A first challenge is defined by scientists who maintain that stressful experience at work is essentially an individual phenomenon determined by a person's psychobiological program, learning history, appraisal, and coping resources, thus precluding any generalization beyond the level of individual variation.<sup>37</sup> Opposite to this approach is a position claiming that the notion of stressful experience at work is amenable to scientific generalization, but that any generalization must reflect the

complexity of a dynamic person-environment transaction operating at the macro-, the meso-, and the micro-social level.<sup>107</sup> In an analytical perspective, the challenge of this latter position consists in a meaningful reduction of complexity, that is in a theory-driven selective emphasis on specific situational and personal characteristics that elicit or enhance stressful experience at work.

The model of effort-reward imbalance (ERI) defines one such theory-driven selective approach. It has been developed to answer the following three questions: (1) Is it possible to identify those dimensions of stressful experience at work that are *typical* for a wide variety of occupations both in the industrial and in the service sector? (2) Can we identify work-related conditions that are likely to elicit recurrent, *chronically stressful* experience? (3) To what extent can we distinguish *situation-specific* versus *person-specific* components of stressful experience at work? Answers to these questions were not obvious from the very beginning.<sup>225</sup> Rather, the theoretical formulations and their adequate operational measurement were elaborated over the years.<sup>228</sup> The following pages summarize what we consider a most updated and valid account of the theoretical model and its contribution toward explaining links between work and cardiovascular (CV) disease.

### Theory and Description of the ERI Model

To determine what kind of stressful experience might be typical for a broad variety of occupations, the focus is put on the centrality of paid employment in adult life. Obviously, having a job is a principal prerequisite for continuous income opportunities and an important means of acquiring social status and social identity. In particular, the **work role** defines a crucial link between self-regulatory needs of a person (e.g., self-esteem, self-efficacy) and the social opportunity structure. Conferment of occupational status is associated with recurrent options of contributing and performing, of being rewarded or esteemed, and of belonging to some significant group (work colleagues). Yet these potentially beneficial effects are contingent on a basic prerequisite of exchange in social life, that is, **reciprocity**. Effort at work is spent as part of a socially organized exchange process to which society at large contributes in terms of rewards. Rewards are distributed by **three transmitter systems**: money, esteem, and career opportunities, including job security.

The ERI model claims that lack of reciprocity between "costs" and "gains" (i.e., high cost/low gain conditions) defines a state of emotional distress that can lead to the arousal of the autonomic nervous system and associated strain reactions. For instance, having a demanding but unstable job or achieving at a high level without being offered any promotion prospects are examples of high cost/low gain conditions at work. In terms of current developments of the labor market in a global economy, the emphasis on occupational rewards reflects the growing importance of fragmented careers, job instability, under-employment, redundancy, and forced occupational mobility, including their financial consequences. The ERI model applies to a wide range of occupational settings, most markedly to groups that suffer from a growing segmentation of the labor market and are exposed to structural unemployment and rapid socioeconomic change. Experience of ERI at work is frequent among service occupations and professions, in particular the ones dealing with client interaction.

But how can we make sure that these widely prevalent high cost/low gain conditions at work elicit chronically stressful experience? The expectancy-value theory of motivation asserts that workers exposed to high effort/low reward conditions escape the situation, or if that is not feasible, reduce their efforts to minimize negative



outcome.<sup>219</sup> Conversely, the ERI model predicts continued high effort and, thus, chronically stressful experience, under the following conditions: (1) **lack of alternative choice** in the labor market may prevent people from giving up even unfavorable jobs, as the anticipated costs of disengagement (e.g., the risk of being laid off or of facing downward mobility) outweigh costs of accepting inadequate benefits; (2) unfair job arrangements may be accepted for a certain period of one's occupational trajectory for **strategic reasons**, perhaps to improve chances for career promotion and related rewards at a later stage; (3) a specific **personal pattern of coping** with demands and of eliciting rewards characterized by *overcommitment* may prevent people from accurately assessing cost-gain relations.<sup>228</sup> "Overcommitment" defines a set of attitudes, behaviors, and emotions reflecting excessive striving in combination with a strong desire of being approved and esteemed. People characterized by overcommitment are exaggerating their efforts beyond levels usually considered appropriate. There is evidence that excessive efforts result from perceptual distortion (in particular an underestimation of challenges and an overestimation of one's coping resources), which in turn may be triggered by an underlying motivation of experiencing recurrent esteem and approval.<sup>162,228</sup> This latter argument points to the third question asked on page 84: it defines a *person-specific component* of the model (overcommitment) in addition to the *situation-specific component* of high extrinsic effort and low reward.

In summary, the model claims that stressful experience is most likely to result from an imbalance between (high) extrinsic effort and (low) extrinsic reward in combination with a high level of overcommitment. But even in the absence of the intrinsic component, high cost/low gain conditions at work evoke stressful experience, given the significance of unmet reciprocity in social exchange. Alternatively, continued excessive efforts in combination with disappointed reward expectancy that is attributable to a high level of overcommitment may produce stressful experience even in the absence of the situation-specific component. Thus, a comprehensive test of the model covers all three conditions mentioned (Fig. 4).

Two final comments on the model are needed. First, while we make a conceptual and methodological distinction between the situation-specific and the person-specific components of the model, we do not claim that overcommitment is considered a personality trait that remains unaffected by social contexts. Rather, this personal pattern of coping with demands and reward expectancies may be reinforced to some extent by specific circumstances in occupational life, most likely at early

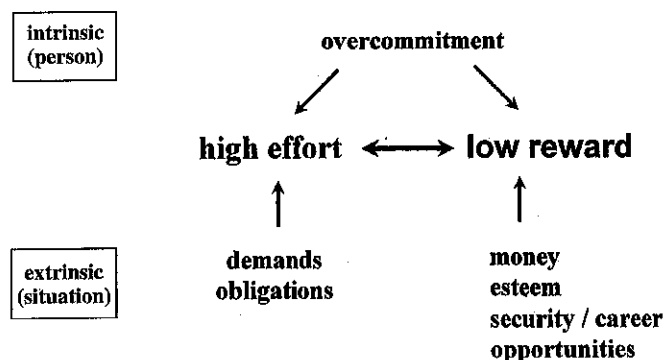


FIGURE 4. The Effort-Reward Imbalance Model

career stages. Although overcommitment was found to be rather stable over time, more research is needed to explore this question. A second comment concerns the significance of the reward dimension. As stated, emphasis in stress-theoretical terms is put on violations of expectancies of reciprocity and fairness underlying exchange in significant social roles (here: the work role). Unmet reward expectancy following effort is likely to provoke strong negative emotional reactions, as this conflicts with a taken-for-granted basic "grammar" of social exchange.<sup>39</sup> All three reward dimensions contribute to this negative experience, although most powerful effects may result from poor rewards related to labor market conditions, such as inadequate wages and salaries, lack of promotion prospects, forced downward mobility, and job loss. In view of this latter observation, ERI at work is likely to be more prevalent among lower socioeconomic status groups.

### Policy Implications

So far, ERI at work was found to predict *new manifestations* of CHD<sup>24,152,236</sup> and to contribute to the explanation of CV risk factors, such as hypertension,<sup>190,193</sup> elevated atherogenic lipids,<sup>229,231</sup> and elevated fibrinogen.<sup>105,234</sup> Further validation of the model is provided by studies that document adverse health effects (e.g., gastrointestinal disorders,<sup>209</sup> psychiatric disorders,<sup>243</sup> poor subjective health<sup>191,242</sup>).

Policy implications of these results in terms of stress prevention and health promotion at work are far-reaching, following the theoretical argument presented on page 84, and they affect both situational and person-specific activities. At the **individual (or interpersonal) level**, specific measures of stress management can be applied, aiming at a reduction of excessive overcommitment and an enhancement of esteem and positive feedback from superiors and work colleagues. One such approach, although supplemented by distinct organizational changes, has been developed and successfully applied in a group of highly stressed, inner-city bus drivers.<sup>12</sup> At the **structural level** of organizational development and, if feasible, of trade union and labor market policy, adequate terms of exchange between extrinsic efforts and rewards should be established. Examples of such measures include developing compensatory wage systems, providing models of gain sharing, and strengthening non-monetary gratifications. Investment in continued training and reskilling programs and collective bargaining over job security and promotional opportunities are important measures in this regard. Clearly, the power structure of economic life and the far-reaching transformations of current work limit the options and impact of workplace health promotion programs that transcend individual risk factor change.

### The Demand-Control-Support Model

Analytical models selectively emphasize specific aspects of the complex psychosocial work environment, thereby enabling us to create new knowledge. At the same time, they point to obvious limitations. The analytical approach underlying the ERI model is based on the stress-theoretical paradigm of social reward.<sup>39</sup> A different analytical approach, the demand-control-support (DCS) model, is mainly based on the stress-theoretical paradigm of personal control.<sup>117</sup> The notions of control and reward may overlap to some extent, but in terms of psychological theory of self, control is more closely related to the notion of self-efficacy,<sup>241</sup> whereas reward is more closely associated with self-esteem.<sup>186</sup> In sociological terms, control is associated with power,<sup>101</sup> and reward points to a basic grammar of social exchange, i.e., reciprocity and fairness.<sup>39</sup>

At the conceptual level, the two models differ in several regards: (1) The DCS model has been introduced and measured as a concept that is restricted to the extrinsic or situational aspects of the psychosocial work environment, whereas the ERI model includes both extrinsic and intrinsic components; (2) The DCS model offers a broader approach, as its bidirectional conceptualization includes a stress dimension with relevance to health and a skill dimension with relevance to personal growth and development.<sup>251</sup> In this regard, the ERI model is more narrowly focused on the biopsychosocial determinants of health and well-being; (3) Components of the ERI model (salaries, career opportunities/job security) are linked to more distant macro-economic conditions, while the DCS model's major focus is on workplace characteristics.

### Future Directions

Despite these differences, there is promise in studying the combined effects of the two models in future research.<sup>251</sup> Preliminary evidence comes from currently unpublished findings of a Swedish case-control study and a British prospective study, indicating that combined effects on CV health are considerably stronger compared to the separate effects of each model.<sup>24,192</sup> A second promising future direction of research concerns the study of combined effects of psychosocial work stress and traditional occupational hazards and stressors. For instance, psychosocial work stress as measured by the ERI and DCS models may mediate effects of shiftwork on CV health.<sup>190</sup>

Much remains to be done concerning an adequate conceptualization of the cumulative effects of ERI over time. For instance, elderly workers may be unable to maintain high effort on the job because after many years of exposure their resources are exhausted. If this situation is not reflected in compensatory wage differentials, the stressful effects of imbalance are expected to be much worse than those experienced by younger workers. The dynamic, time-sensitive aspects of the intrinsic part of the model (the coping pattern of overcommitment) has been discussed in more detail elsewhere.<sup>162,228</sup>

Finally, adverse health effects of ERI generated in social roles other than work (e.g., marriage, family, neighborhood, civic life) need to be explored to learn how they compensate or aggravate the afflictions produced by chronically stressful work conditions.

### DEHUMANIZATION VERSUS HUMANIZATION OF WORK: Insights From Cognitive Ergonomics and Brain Research *by Karen Belkić, MD, PhD and Čedo Savić, MD, PhD*

Spectacular advances have been made in our understanding of how the human being—via the central nervous system (CNS)—handles information, transforming it into productive output of various kinds. How can that knowledge be harnessed to inform us in our quest to organize work so that it harmonizes better with human needs and capacities? How is this endeavor relevant to the cardiovascular (CV) system? Mentally stressful work has been associated with a panoply of untoward CV changes, including elevations in blood pressure and rate pressure product, myocardial ischemia, metabolic and coagulation abnormalities, and possibly even cardiac electrical instability (see Chapters 2 and 5). These processes may result in acute cardiac events, which are potentially life-threatening and, at the very least, profoundly debilitating. Thus, it does appear that we can justify our exploration of human cognitive ergonomic process from a clinical–public health perspective.

One particularly salient example concerns the way in which branches of research have developed with respect to heart rate variability (HRV). It was cognitive ergonomists who first described the relation between loss of HRV or respiratory sinus arrhythmia, and mental burden.<sup>25,110,113,149,172</sup> Although there was also some recognition by clinical investigators that diminished HRV was associated with cardiac dysfunction<sup>270</sup> and with sudden arrhythmic cardiac death in infants<sup>92</sup> and in adults,<sup>218,280</sup> nearly two decades elapsed before the clinical importance of HRV became broadly apparent, with the confirmation that HRV is a strong, independent predictor of mortality in post-acute MI patients.<sup>248</sup>

Obviously, there is still a great deal to be elucidated concerning causal webs linking mentally stressful work, the CNS and CV markers such as HRV, and CVD outcomes. It is an intriguing line of inquiry: the more insight we gain into what mental burden actually means, and the better we implement this knowledge to humanize work, the better the CV system might be protected. The emotional dimensions of human labor also need to be interwoven into these considerations. Some principles of cognitive ergonomics and results of advanced neurophysiologic methods allow us to explore these hypotheses, which are broadly coherent with postulations from the Tokyo Declaration:

*The growth of neuroscience and stress science has allowed elucidation of the links between social structures and processes (at work and outside it), the way in which these are perceived and appraised and the resulting interaction between the central nervous system and other organ systems to promote or counteract workers' health, based on a bio-psychosocial ecosystem and its dynamics. These dynamics include organization restructuring, mergers, acquisitions and downsizing, the frantic pace of work and life, the erosion of leisure time and/or the blending of work and home time. Most of these developments are driven by economic and technological changes aiming at short-term productivity and profit gain.<sup>256</sup>*

## A Model of Mental Burden on The Human Operator

### COGNITIVE ERGONOMICS

The domain of cognitive ergonomics encompasses questions about how the human being processes information, makes decisions, and then carries out actions.<sup>238</sup> Examinations of these "levels of information transmission"<sup>269</sup> provides a useful framework both for work simulation studies<sup>148</sup> and on-site, independent-observer job analysis. Work tasks then can be defined in terms of their "mental structure" and, according to "action regulation theory," be viewed within the context of a dynamic interaction between the person and his or her environment vis-à-vis the achievement of defined goals.<sup>62,72,76,261</sup>

Gaillard incorporates the concept of "energy regulation" into cognitive ergonomics.<sup>65</sup> This energy is derived from arousal mechanisms, and when mental processing demands increase, energy resources are mobilized. However, these cognitive energy reserves have their limitations, a fact often ignored, especially in "developments . . . driven by economic and technological changes aiming at short-term productivity and profit gain."<sup>256</sup>

The relative mental burden of a given task can be considered quantitatively: for example, by the number of signals to be processed; the complexity, dynamics, clarity, and congruence of the signals; the nature of the decision<sup>148</sup>; and the type of action taken. The additional burden created by stressors such as time pressure,

adverse physical conditions, and barriers that hinder task performance also can be assessed.<sup>71</sup>

**Quantitization Using the Time Dimension.** Allocation of mental resources is a key concept, for which the time dimension represents one means of measurement. In field studies, Greiner and colleagues demonstrated that each of a number of barriers—such as unruly passengers, obstructions, or vehicular problems—substantially prolonged the average work time of urban transit drivers, and often required intensified concentration and split attention<sup>70,72</sup> (see Chapter 6).

In the laboratory, one way to temporally quantitate the relative burden of various tasks is by examining the reaction time (RT). In the last century it was already known that the mean RT increases curvilinearly with the number of alternatives.<sup>167</sup> Thus, with only one alternative, e.g., a clearly visible red traffic light, the normal simple RT is about 200 milliseconds (ms). It rises to over 300 ms with two equiprobable choices, e.g., a red and a green light, and the target being the latter. With nine alternatives, the RT increases to 600 ms or more.<sup>134</sup> Besides the number of alternatives to be sorted out, many other characteristics of the incoming signal affect RT. If, in a two-choice RT task, the signals are both subtly different shades of green and/or visibility is poor, the signal detection process becomes more difficult, leading to longer RT due to impaired discrimination.<sup>165</sup>

**Overload Versus Underload.** The dynamics of signal flow and the length of the task also affect performance. Overly rapid as well as exceedingly slow rate of incoming signals, especially if of prolonged duration, impair correct and timely action. This finding coincides with the well-known U-shaped curve, showing optimal performance associated with moderate arousal levels, and a performance decrement with heightened catecholamine excretion associated with over- and understimulation.<sup>59,83</sup> Molloy and Parasuraman corroborate this data by demonstrating that accurate and quick detection of a single (i.e., rare) event during a simulated flight paradigm deteriorated over time during highly complex but also during overly simple visual task performance.

Underload or monotony is characteristic of many branches of automatic production as well as long-haul transport operation, in which a high level of vigilance must be maintained to detect infrequently or irregularly occurring signals. The mental burden and safety risks of this type of work, requiring frequent rest breaks and other protective measures, have been underscored.<sup>27,141</sup>

**Controlled Versus Automatic Processing.** On the decision-making level, of critical importance is whether the process is automatic or controlled. *Controlled processing*, which also has been called “knowledge-based,” requires conscious attentional resources and is called into play for decisions involving planning. Human capacity for controlled processing is limited, especially since it is performed in series. Some important examples of knowledge-based decision making include: complex human interactions, use of a new apparatus, emergency operations, apparatus failure, and dealing with irregularities. Kalsbeek has emphasized this distinction in his analysis of air traffic controllers’ (ATC) task load, noting that when new, non-routine decisions are required due to unforeseen events, the ATC must consciously intervene, thereby substantially rearranging the “brain control program.”<sup>111</sup> According to Levi, work requiring continuous, conscious attention should only be performed for very limited periods of time.<sup>141</sup>

In contrast, the human capacity for *automatic processing* (also termed “skill-based”) is much less limited. This type of processing involves rapid, smooth, learned, highly integrated patterns, and can be performed in parallel.<sup>65,175</sup> The ratio

between knowledge-based and skill-based activity is extremely important, with the critical dimension being time. The former is most sensitive to time limitations, whereas a long stretch of solely skill-based processing creates underload. Neerincx and Griffioen formulated this rule of thumb: "The more actions to be executed in a period, the less knowledge-based actions are preferable."<sup>175</sup>

**Conflict-Interference.** "Task load is not a simple summation of the load of the individual processes. Interference between concurrent information processes increases task load."<sup>175</sup> Thus, in contrast to a normal, smooth work routine in which there is reinforcement of the correctness of work decisions and actions, conflict or uncertainty arises when untimely or inaccurate correlations disrupt work and its rhythm. Pavlov termed this the "difficult meeting of excitation and inhibition."<sup>185</sup> Wickens points out that the increase in task load is greatest when the interfering information impinges on the *same* processing dimension, and is much less when different processing dimensions are involved (e.g., spatial and linguistic).<sup>275</sup>

#### COGNITIVE ERGONOMICS AND BRAIN PROCESSES

An almost baffling array of paradigms has been used to model the dynamics of cognitive ergonomics. The actual brain processes occurring in relation to these dynamics can be studied in a number of ways, e.g., power spectrum analysis of the electroencephalogram (EEG), averaged electrocortical event-related potentials, and/or positron emission tomography (PET). The PET scan can reveal the involvement of various neuroanatomic structures and identify which neurochemical pathways are activated.<sup>181</sup> Attenuation or blocking of EEG rhythms within the alpha range, termed "event-related desynchronization," is found to occur with cognitive loading.<sup>194,259</sup> Conversely, occipital beta band activity increases proportionally to mental workload,<sup>128,168</sup> and a frontal midline beta rhythm has been recorded with performance of mental tasks and with learning.<sup>130,173</sup>

**Event-Related Potentials: Latency and Mental Chronometry.** The unique role of event-related potentials (ERP) in reflecting higher nervous system processing required by a given task, as well as the relative objectivity of ERP compared to self-perceptive methods, have been emphasized repeatedly.<sup>35,127,197,282</sup> Besides providing a scalp localization of higher nervous activity, ERP can be a gauge of "mental chronometry."<sup>165</sup> That is, using ERP we can map brain activity *over time* as it processes information, makes decisions, and lays the basis for task execution.<sup>97</sup> Using the concepts from cognitive ergonomics, ERP can help quantitate mental burden using the time dimension.

The following discussion concerns the P300, which is a positively-oriented, averaged electrocortical wave appearing 300–500 ms after stimulus presentation. The P300 is most commonly elicited when the subject's attention is focused on an infrequently-occurring signal, especially if this signal has some motivational or emotional significance. The P300 is produced by task-relevant stimuli that occur relatively unexpectedly, and require either some kind of motor response or cognitive decision.<sup>206</sup> Basic reviews of these processes have appeared elsewhere.<sup>33,35,38</sup>

The latency of the P300 ERP component is related to the time required to evaluate and correctly categorize a signal.<sup>129</sup> When detection is made more difficult, or when contrast is diminished, the latency of the P300 in the visual modality becomes prolonged.<sup>265</sup> The burden of adverse physical or other external conditions on brain chronometry as manifested by ERP component latencies also can be observed. In a simulated aircraft landing paradigm, adding hypoxia and turbulence during task performance was associated with a prolongation of P300 latency.<sup>127</sup> Exposure to noise and to sleep deprivation also increases P300 latency.<sup>73,195</sup>

Subcomponents of the ERP waves can be even more illustrative of how these exacerbating stressors deleteriously affect mental processes. Hohnsbein and colleagues found that when the subject was placed under time pressure to perform two-choice reactions, the choice reaction subcomponent of the P300 shortened, even though the stimulus assessment time remained unchanged.<sup>90</sup> The consequence was a greater number of performance errors. This electrophysiologic data provides insight into the brain mechanisms that may mediate the compromise of safe performance, including the observed increase in accident rate, associated with high levels of time pressure.<sup>67,69,70</sup>

**Allocation of Mental Resources and ERP Amplitude.** The amplitude of ERP components, notably the P300 wave, can reflect allocation of mental resources to a given task.<sup>41</sup> As the complexity of a primary task increases, the amplitude of the P300 as well as some other ERP components is often found to rise.<sup>164,239,258</sup> However, in dual task performance the P300 amplitude to a subsidiary task diminishes as the primary task becomes more difficult. These findings demonstrate the withdrawal of processing resources from a lower priority task as the primary one consumes progressively more of the subject's mental energy.<sup>96,239</sup> Also, as the load upon memory increases, P300 amplitude falls, even with single task performance. This dynamic may similarly reflect competing demands on mental resources; there also may be more uncertainty or equivocation with increasing memory load.<sup>124</sup>

The effect of exacerbating stressors also is observable in the amplitude of the P300. Acute experimental exposures to noise and to sleep deprivation are associated with attenuation of P300 amplitude.<sup>73,195</sup> Among professional drivers, an inverse relation has been reported between number of work hours behind the wheel and the P300 amplitude to a visual, odd-ball, reaction-time task. This finding was considered to be related to fatigue,<sup>16</sup> which is known to attenuate P300 amplitude and prolong its latency.<sup>195</sup>

#### IMPLICATIONS

Approaches to quantizing the mental burden of occupational endeavor using objective means can help circumvent some of the difficulties inherent in self-report methods.<sup>29,70,211,215</sup> Ideally, this information would complement the worker's own perceptions of his or her occupational tasks and in that way help guide participatory intervention strategies. Such an approach is being applied, e.g., among San Francisco transport operators.<sup>70,201,257</sup> Nachreiner describes a "credo," still far from being fully implemented, but which can serve as a goal or guideline: "Applying ergonomics knowledge in the light of practical experience shall provide for optimal working conditions with regard to health and safety and unimpaired performance of the work, and contribute to a more reliable, effective and efficient system performance."<sup>174</sup> This cognitive ergonomic approach was demonstrated by Neerinx and Griffioen to be of greater utility than more traditional noncognitive methods in developing specific recommendations for harmonizing the tasks of railway traffic controllers.<sup>175</sup> The approach provided provisional standards for eliminating the dual risks of momentary overload and underload.

#### MENTAL WORKLOAD VERSUS MENTAL STRAIN: NOT SYNONYMOUS

Mental workload is not synonymous with mental strain. As formulated by Karasek and confirmed by numerous empirical studies, lack of control or decision latitude coupled to high psychological demands is of crucial importance in creating strain conditions and concomitant cardiac risk.<sup>118</sup> High workload alone leads to

According to Rothman and Greenland, it is rare that the effect of exposure to a given factor is completely independent of the effect of exposure to another factor, implying that some kind of interaction is usually taking place.<sup>210</sup> An interaction can be demonstrated insofar as the relative risk of combined exposure to two or more factors is not equal to the sum of the relative risks of each exposure taken separately.<sup>79,210</sup> A greater than additive effect, i.e., synergy, is found when the combined exposure risk exceeds the latter. Various combined exposures to the psychosocial work factors of high psychological demands, low decision latitude, and/or low social support have yielded statistically significant synergistic effects with respect to risk of MI as well as self-reported CVD.<sup>79,99</sup>

More generically, it can be stated that with a synergistic interaction, some cases of disease would occur only if there were combined, and not just singular, exposure to noxious. This principle is illustrated in some (but not all) investigations of psychosocial factors and risk of hypertension, ischemic heart disease (IHD), and progression of carotid atherosclerotic plaque height, in which significant results have been obtained for combined exposure to high psychological demands and low decision latitude<sup>217,254</sup> or to high work demands and low economic rewards.<sup>151</sup> However, there were no significant effects for exposure to each of these stressor dimensions alone.

Rothman and Greenland present some caveats about the practical implementation of analyses for synergy. They note that tests of nonadditivity or statistical interaction of factors "may have limited utility" due to low power for usual sample sizes and low precision of the statistical tests.<sup>210</sup> Dose-response relationships and induction periods further complicate the issue (see Chapter 6). Notwithstanding these difficulties, there is a need for more systematic assessment of synergistic relations between and among cardioxious factors.

### The Total Burden Concept

Hockey elaborates the construct of "resources," or total burden upon the human operator, as an integrative model whose focus is not solely upon performance *per se*, but also encompasses the impact of this burden in relation to fatigue, strain, and health consequences, including those relevant to the cardiovascular system.<sup>89</sup> In this context, some useful inferences can be drawn from laboratory, field, and epidemiologic studies. Cognitive ergonomic and neurophysiologic data demonstrate that there is a limit to the available processing resources, and when the human being is asked to perform multiple tasks, as the primary or prioritized action becomes more difficult, less mental energy is available for subsidiary actions. Exacerbating stressors, of a physical as well as nonphysical nature, further impinge on these processing resources. With multiple exposure to work stressors, attempts to cope may include deliberate mobilization of existing mental resources, e.g., intense concentration, such that concurrent performance proceeds unimpeded. It is known that as demands increase, processing capacity can be augmented up to a certain point. This extra energy is derived from arousal mechanisms.<sup>109</sup> There is residuum, however, which comes after work is over, and can be reflected in difficulty or inability to unwind and/or perform subsequent mental tasks, a decreased likelihood to engage in altruistic behaviors, and delay in return to nonwork baseline of catecholamine levels.<sup>34,54,60,72,98,204</sup>

### DURATION AND TIMING OF EXPOSURE

Perhaps the most important practical implication of the total burden concept is that related to duration and timing of exposure. Previously, we have noted that work



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