PART IV: ORGANIZATIONAL STUDIES OF STRESS

Machine Pacing and Shiftwork: Evidence for Job Stress

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SUMMARY. Machine-paced work and shiftwork are highly prevalent working conditions commonly believed to have adverse individual and organizational consequences. This article examines the empirical evidence for such effects, and acknowledges the conceptual and methodological problems which have clearly plagued pacing and shiftwork researchers. The literature on pacing while suggestive of overall health and performance effects indicates that the magnitude of such effects are in all likelihood situationally and individually determined. Very little is known, however, about such interactions. Similarly, the shiftwork literature is contradictory and inconclusive. Shiftwork appears to affect both the quality and quantity of sleep and to disrupt a wide range of physiological and behavioral circadian rhythms. The long-term consequences of these effects are still not known.

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Almost from inception, machine-paced work and shiftwork have been implicated as risk factors in the development of a variety of psychological and physical disorders. Both figure prominently in current job stress models as potent stressors capable of producing adverse individual and organizational strain consequences. Yet, in spite of these allegations, machine-paced work and shiftwork continue to flourish seemingly as a result of their economic advantages. Indeed, it has been estimated that there are over 50 million people worldwide in machine-paced jobs (Salvendy, 1981) and that over 20 percent of the working population in Europe and North America work some form of shift system (Tasto, Colligan, Skjei & Polly, 1978). This article will examine evidence for both the individual and organizational strain consequences of these highly prevalent working conditions.

MACHINE PACING

The Pacing Concept

The terms pacing, machine-pacing and forced paced work have been commonly used in the literature to refer to activity which requires a worker to perform a response or series of responses at a rate other than that which would be self-selected (Dudley, 1962; Franks, 1974; Murrell, 1963). Attempts to understand the relationship between paced work, health, and performance, however, have been hampered by a general lack of consistency among authors regarding definitions and descriptions of task structures. While several taxonomies have been proposed for the characterization and evaluation of paced work (Dainoff, Hurrell & Happ, 1981; Salvendy, 1981), they have not been widely used.

The extent to which the worker has control over the work process is clearly central to the concept of pacing. In paced work, control is manifested along two orthogonal dimensions: over the initialization of the task and over the duration of the work cycle (Dainoff et al., 1981). The extent to which the worker as opposed to the machine (or external environment) has control over either or both of these functions may be used to classify paced systems (Dainoff et al., 1981). Jobs in which the worker both initiates a task and controls the length of time it takes to complete it are clearly self-paced (sometimes called nonpaced or unpaced). Jobs in which a machine

(or some element of the external environment) both initiates the task and controls its duration are typically referred to as paced or machine-paced. Though little studied, paced jobs also exist in which the worker initiates the task after which the machine (or external environment) controls its duration or the machine initiates the task after which the worker controls its duration.

Temporal parameters are also important in characterizing paced systems. Cycle time is generally defined as the amount of time between beginning work on successive units of work. Service time is the amount of time a worker actually takes when working on a unit and delay or operator waiting time is the difference between operator service time and cycle time. Tolerance time, a machine parameter, is generally defined (cf. Franks, 1974; Sury, 1967) as the amount of time that a unit is available for processing before it is missed. These three parameters—operator service time, delay time (these sum to cycle time) and tolerance time have been used by various researchers to describe the temporal characteristics of pacing.

Adding to the complexity, the nature of the work being paced may vary considerably with respect to both the physical and cognitive effort required to perform it. While most research on pacing has focused on assembly line tasks, the advent of computerized industrial and office systems in recent years has resulted in the creation of a new generation of paced jobs utilizing more of the workers' information processing rather than physical capability. Such jobs are usually short-cycled, repetitive, and involve search and discovery, recognition, decision and action components and unlike assembly line tasks, they often require different responses to each part or element being presented.

Thus, numerous varieties of pacing exist which require vastly different amounts and kinds of cognitive and motor activity from the worker. Unfortunately, as indicated above, studies concerned with the individual and organizational consequences of pacing have often failed to adequately document the control, temporal, and task characteristics of the system being studied. Thus, one often knows little more about the independent variable being considered except that it is something called pacing. The feature or features which produce an effect (e.g., type of control, temporal constraints, cognitive or motor demands, etc.) is (are) difficult to pinpoint. The following review is therefore largely limited to comparing the responses of workers in grossly defined paced systems of work to those of workers having non-paced jobs.

INDIVIDUAL CONSEQUENCES OF PACING

Physiological Effects

Physiological variables have been monitored in both laboratory and field studies to assess the demands of pacing. Cardiovascular parameters have generally received the greatest attention. Studies involving inspection (Koholova & Matoused, 1968), reaction time (Johansson & Lindstrom, 1975), and sorting tasks (Mackay, Cox, Watts, Thirlaway & Lazzerini, 1979) have reported higher mean heart rates (reflecting excess effort) for subjects in paced vs. self-paced conditions. Some evidence exists to suggest that pacing in such tasks may also be associated with elevations in blood pressure (Hokanson, Degood, Forrest & Brittain, 1971). No evidence for either elevated heart rate or blood pressure was found, however, in a study utilizing a paced marking-stapling task (Salvendy & Humphreys, 1979).

Decreases in heart rate variability are thought to reflect increases in mental load. Thus, if pacing places an additional load (above that imposed by self-paced work) on a worker's information processing capacity, it is believed that it should be reflected in decreases in variability. The evidence for such an effect, however, is mixed. While decreases in variability have been found in studies comparing paced vs. self-paced inspection (Coury, 1983; Drury, 1982), paced sorting and loading vs. minding (Mackay et al., 1979) and paced vs. self-paced marking-stapling (Salvendy & Humphreys, 1979), they were not found in a study of paced vs. self-paced light assembly (Manenica, 1977). The reasons for these discrepant findings are not clear.

A number of investigations have examined urinary catecholamine exertion rates (reflecting arousal) of paced and self-paced workers and experimental subjects. In the first of these, Frankenhaeuser and Gardell (1976) compared excretory rates of adrenaline and noradrenaline between fourteen workers engaged in paced jobs and ten workers in maintenance and other comparatively unrestricted work. Noradrenaline excretion was found to be highest among the paced workers while adrenaline excretion was found to

be inversely related to the duration of the work cycle. Similar elevations in noradrenaline were reported by Mackay et al. (1979). Elevations in both adrenaline and noradrenaline for paced compared to self-paced sawmill workers have been reported by Johansson, Aronsson, and Lindstrom (1978). Reports of heightened feelings of arousal (Johansson et al., 1978) and irritation (Frankenhaeuser & Gardell, 1976) among paced workers are clearly consistent with these results.

More frequent health problems among paced workers have also been reported. In a Russian study of women engaged in a variety of paced and self-paced jobs (Samoilova, 1971), paced workers were found to have a higher incidence of cardiovascular disease, peripheral nervous system disorders and gastritis. These findings are consistent with the Frankenhaeuser and Gardells' (1976) results in which paced sawmill workers displayed a higher frequency of psychosomatic, cardiovascular, and nervous disorders than their self-paced controls. Findings of excess asthma and bronchitis among paced telegraphists (Ferguson, 1973) and angina among paced factory workers (Kritsikis, Heinemann & Eitner, 1968) have also been reported. It should also be noted that many paced jobs involve conditions (high demands accompanied by low control) found by Karasek (1981) to be predictive of cardiovascular diseases.

A number of studies (e.g., Luopajarvi, Kuorinka, Virolainen & Holmberg, 1979) have reported excess musculoskeletal complaints among paced workers. These complaints are likely a result of the repetitive movements associated with machine-paced tasks.

Psychological Effects

While it is commonly believed that paced work has adverse psychological consequences, surprisingly few studies have addressed the issue. In a large scale survey of over two thousand male workers in twenty-three occupations, Caplan, Cobb, French, Van Harrison, and Pinneau (1975) found levels of anxiety and depression among paced assemblers to exceed those of other workers engaged in less regimented work. More recently, Broadbent and Gath (1981) conducted an interview study of the mental health effects of pacing in a British auto assembly plant. The study was undertaken because medical records indicated that diagnoses of anxiety were highly prevalent among assembly line workers. The investigation is especially significant because of its attempt to differentiate the effects of pacing from those of repetition. Results of the study indicated that repetition was associated with job dissatisfaction but not increased anxiety. By contrast, pacing was associated with increased anxiety but not job dissatisfaction. Cycle time was also found to have no effect on either satisfaction or anxiety.

A recent study by Hurrell (1985) also found evidence of increased affective disturbances among paced workers. In this study, scores on measures of six mood states from over two thousand male and female operators of paced letter sorting machines were compared to those of male and female postal workers engaged in nonpaced work. No instances were discovered in which either paced males or paced females, failed to report significantly higher scores than their self-paced counterparts.

ORGANIZATIONAL CONSEQUENCES OF PACING

Performance Effects

Unquestionably the greatest amount of research conducted in the area of pacing has been concerned with performance. This research seems to have been given its original impetus by an extensive yet largely descriptive field study conducted by Wyatt and Langdon (1938). This study showed that when machine speeds were progressively changed in paced work, an optimum work rate could be found which differed from worker to worker. In the ensuing years, researchers have attempted to identify factors influencing this optimum work rate.

Conrad (1955, 1960) was the first investigator to systematically consider individual performance in a variety of paced and self-paced tasks. In these studies, it was found that when the tolerance time is relatively long, paced work may yield the same output as unpaced work. But, when the tolerance time is more restricted, there are periods when the subject is unprepared to respond and the unit either waits or is not processed. Periods when subjects were ready too soon were also found.

Expanding upon these studies, Dudley (1962, 1963) examined the distribution of work cycle times of experienced operators in several paced tasks. In general, self-paced workers displayed a positive skewing toward longer cycle times. By contrast, in paced work, there was a strong tendency toward a much more nearly normal

distribution of cycle times. These findings suggest that performance decrements associated with pacing may be a consequence of workers having to accommodate a few longer cycles within tolerance time (Belbin & Stammers, 1972).

Other laboratory and field studies comparing paced and self-paced performance have consistently shown less output and/or more errors in the paced condition. Tasks examined here include: testing electrical parts (Murrell, 1963), conveyor line assembly (e.g., Franks, 1974), card sorting (Salvendy, 1972), stapling-marking (Salvendy & Humphreys, 1979), timber grading (Seppala & Nieminen, 1981) and mail sorting (Bertelson, Boons & Renkin, 1965). Reaction times have also been found to be faster for self-paced subjects (Beck, 1963).

There is some evidence that the effects of pacing on performance may be mediated by individual worker characteristics. Brown (1957), for example, found that the pace set for men in their twenties on a grid matching task could not easily be maintained by men in their forties and fifties. These results are consistent with reports that older workers tend to move away from paced jobs (e.g., Belbin & Stammers, 1972; Chase, 1974). Other studies, however, have found that older workers are more energy efficient under paced conditions and less prone to nontask-related movements (Salvendy, 1972). These discrepancies suggest that the mediating effects of age (and quite likely other individual characteristics) are task dependent.

Personality characteristics also appear to mediate paced performance on certain tasks. Eskew and Riche (1982), for example, found that paced subjects displaying an internal locus of control performed more poorly in an inspection task than those displaying an external locus of control. Individuals who are trusting, introverted, less intelligent, more tense, and possessing a high tolerance for boredom have also been found to be more suited to various kinds of paced work (Salvendy & Humphreys, 1979; Stagner, 1975).

Job Satisfaction

Investigations considering job satisfaction among paced and self-paced workers have yielded mixed findings. While a number of studies have found increased dissatisfaction among paced workers (Caplan et al., 1975; Hurrell, Smith, Burg & Hicks, 1985; Walker & Marriott, 1952), others (Broadbent & Gath, 1981; Kalimo, Leppanen, Verkasalo, Peltomaa & Seppala, 1981; Khaleque, 1979) have found no differences. The reasons for these discrepant results are unclear but may apart from pacing be due to difficulties in controlling differences in the jobs being compared. In the Kalimo et al. (1981) study, for example, the authors could not control for differences in the wages paid to paced and self-paced workers. A prospective study of paced letter sorters (Arndt, Hurrell & Smith, 1981), however, has found progressive decreases in satisfaction following job entry.

Studies of differences in absenteeism and job turnover between paced and self-paced workers have produced more consistent findings. Fried, Weitman and Davis (1972) studied absentee rates in a paper products factory. Pacing, independent of wage, was found to be significantly related to frequency of absence. Likewise, Ferguson (1973) in a study utilizing two-year attendance records from seven hundred paced telegraphists and eight hundred self-paced workers serving as controls, found significantly higher absence among the telegraphists. Similarly, Chase (1974) in a survey of ninety-five large manufacturing companies found the highest turnover rates among paced employees.

Remarkably consistent findings exist concerning potential sources of job dissatisfaction in paced work. Monotony was the most frequently reported complaint among paced workers in studies by Frankenhaeuser and Gardell (1976), Ferguson (1973), and Walker and Marriott (1952). Likewise, Caplan et al. (1975) found that paced assemblers reported greater levels of boredom than the twenty-two other occupations represented in their study. Another consistently reported (Frankenhaeuser & Gardell, 1976; Ferguson, 1973) and objectively verified (Faunce, 1958) complaint among paced workers is the inability to interact with fellow workers. Consistent findings (Caplan et al., 1975; Ferguson, 1973; Hurrell et al., 1985) also exist with respect to paced workers feeling that their skills and abilities are underutilized.

CONCLUSIONS CONCERNING PACING

In addition to the conceptual problems noted earlier many of the studies reviewed here have limitations which further inhibit overall inferences about pacing. The field studies comparing paced and self-paced work are generally retrospective and self-report in nature

and fail to control for a host of potentially confounding variables such as age, pay, shiftwork, length of employment, socioeconomic status and others. The laboratory studies, while giving a somewhat clearer picture of performance consequences, are of short duration and in many ways unrealistic. The extent, magnitude, and long-term health consequences of physiological changes in response to pacing are likewise unclear. Adding to this confusion, some of the effects of pacing appear to be task and individually specific. It seems trite to say that more research is needed but such is clearly the case. Prospective studies controlling for the aforementioned confounding factors are particularly needed. What else can then be said? From the studies reviewed above, it is clear that while the effects of pacing on individuals and organizations are not in all cases negative, they are seldom positive. When a choice is possible, the best choice appears to be self-paced work.

SHIFTWORK

Shiftwork, by requiring that individuals work at times which are contrary to their customary diurnal activity patterns, poses a potential threat to a wide range of physiological, psychological, and behavioral functions. Processes as diverse as respiration and heart rate, blood pressure, urine excretion, cell mitosis, enzyme production, reaction time, vigilance, and memory have been shown to follow a 24-hour (i.e., "circadian") rhythm in relation to the diurnal activity cycle (Luce, 1970). Shiftwork, and particularly night work, imposes on the worker an alteration or inversion of the normal activity cycle by obliging him or her to be alert and active during the night time hours while attempting to rest or sleep during the day. The ease with which an individual can adjust to various shifts is obviously a complicated matter. It can depend not only on the adaptability of the activity cycle to change in accord with the demands of the work schedule, but also on the ability of the numerous circadian processes to maintain their phase relationship with the altered activity cycle and with each other. To get a clearer picture of the issues involved in the adaptation process, it might be helpful to examine the research into the relationship between activity and body temperature.

Body Temperature and Activity

Body temperature evidences a relatively stable and predictable circadian pattern, falling to its ebb or low point at around 4 am during nocturnal sleep, rising rapidly to about 6-8 am when the individual normally awakens. It then gradually increases over the course of the day as the individual becomes more alert and active, reaching its peak at about 6 pm (Aschoff, 1981). The relationship between temperature and activity is more parallel than causal, however, as can be seen when the activity cycle is experimentally altered. Aschoff (1981) has summarized the results of a number of studies in which individuals were either kept active during their normal nocturnal sleep period or kept at bed rest during their normal daytime activity period and body temperature recorded. The effect in both cases was a general flattening of the temperature curve, but for different reasons. For the sleep-deprived individuals, body temperature remained slightly higher than normal throughout the night, whereas for the daytime-rested individuals, body temperature tended to be slightly lower than normal throughout the day. These studies suggest that whereas alterations in the sleep-rest cycle may influence body temperature, they do not produce a homologous phase shift in the temperature cycle. This appears to be the case even after 21 successive days on a night shift (Knauth & Rutenfranz, 1976). The implication, then, is that shiftwork disturbs not only the independent periodicity of the numerous circadian processes, but their interdependent synchrony as well. Given the number of processes involved and the fact that they are likely to be differently affected by a phase shift in the activity cycle, it seems improbable that shiftworkers ever completely adjust to the demands of their work schedule. The implications of this for the individual's health and performance are the topics of the following sections.

Individual Effects of Shiftwork

As one might expect, the most consistent effect of shiftwork on individual adjustment has been an impairment in the quality and quantity of sleep. Thus Tepas, Walsh, and Armstrong (1981) compared the reported sleep of groups of permanent and rotating shiftworkers and found that afternoon shift workers got significantly more sleep (averaging 7-1/2 hours per day) than any other shift while nightworkers got the least (averaging about 6 hours per day). Individuals working a day schedule fell in between, reporting about 7 hours of sleep per night. These findings replicated the results of a national sample of approximately 2000 shiftworkers previously reported by Tasto et al. (1978).

In addition to receiving less sleep than day workers, there is evidence that the quality of sleep of shiftworkers is poorer than that of day workers. As noted by Walsh, Tepas, and Moss (1981) and Weitzman and Kripke (1981), the general picture emerging from the research literature is that daytime sleep, as practiced by someone who must work at night, produces shorter rapid eye movement (REM) latency, fewer absolute minutes of REM sleep, less total sleep time, a greater percentage of slow wave sleep, less absolute stage 1 sleep, greater fragmentation of the sleep stages, and more frequent awakenings toward the end of the sleep cycle. The conclusion is that shiftwork does produce quantitative and qualitative changes in sleeping patterns. This has been related to feelings of fatigue and lethargy similar to that resulting from marginal sleep deprivation (Walsh et al., 1981). Still not understood are the long-range consequences, if any, these altered sleep patterns might have for long-range health and adjustment.

Research into the more general effects of shiftwork on individual physical well-being has produced results which are confusing and inconclusive. In part, this may be attributed to the methodological problems which beset the shiftwork researcher (Colligan, 1980). Field studies have tended to use cross-sectional designs extracting data from existing record sources (e.g., visits to company health clinics, health insurance claims, sickness absence) or self-report surveys to assess worker health. In addition to the deficiencies inherent in these data sources (e.g., reporting biases, validity), most cross-sectional studies suffer from selective attrition, that is, night shift workers who can't adjust to their work schedule may either quit or transfer to a different shift such that the shiftworkers sampled represent only the survivors. Obviously, well-controlled prospective studies are required which would provide a picture of the long-term effects (if any) of shiftwork on specific parameters of worker health.

Recognizing the shortcomings of the available literature, it appears that the most prevalent health consequence of shiftwork involves disorders of digestion and the gastrointestinal tract. This is presumably due to the fact that the diet and eating habits of the shiftworker are made irregular as a result of the work schedule, and that eating times may be out of phase with digestion-related circadian functions. Thus, Thiis-Evensen (1958) reported that 30% of the workers transferring from nondaytime to day schedules complained of gastritis. Digestive disorders were a frequent reason for sickness absence among night workers in a study by Walker and De La Mare (1971), and the results of other investigations (e.g., Thiis-Evensen, 1958, 1969; Wesseldijk, 1961) suggest that the incidence of ulcers may be 2-8 times higher among shiftworkers than among day workers. Still other studies (e.g., Mott, Mann, McLoughlin & Warwick, 1965; Dirken, 1966) have failed to replicate these findings.

The evidence linking shiftwork to other specific illnesses is inconclusive or nonexistent. Rutenfranz et al. (1977) surveyed the literature and concluded that shiftwork has no effects on the incidence of cardiovascular and nervous diseases. Harrington (1978) concluded that there were no dramatic health effects associated with shiftwork following his extensive review of the literature, and Dirken (1966) found that although shiftworkers reported more fatigue and general malaise, there was no clear symptom profile which would distinguish them from day workers.

ORGANIZATIONAL CONSEQUENCES OF SHIFTWORK

Safety and Performance Effects

Much of the research into the effects of shiftwork on safety and productivity suffers from the same methodological limitations cited above. Cross-sectional field comparisons of safety performance or efficiency across shifts are usually contaminated by extraneous differences in the nature and conditions of work being performed. Nevertheless, there is some evidence that industrial accidents tend to occur with greater frequency at certain times of the day, perhaps because worker performance is readily affected by disruption in circadian rhythms (Morgan, Brown & Alluisi, 1974). Although it is difficult to generalize across industries, Menzel (1950) found that most accidents in shift work systems seemed to occur between 10:00 pm and 2:00 am. Studies by Browne (1949) and Bjerner, Holm, and Swensson (1955) of telephone operators and gas meter readers, respectively, demonstrated that there were clear circadian

patterns in the frequency of mistakes, with the greatest number tending to occur during late afternoon and early morning hours. In a more recent study, Colquhoun (1971) experimented with shift worker performance on simple tasks and found that performance was worse on night than on day shifts and that, once the sleep-wake cycle has been disrupted, there was a sharp drop in worker efficiency during the first few days, which tended to level off after about one week. Circadian periodicity in performance efficiency has consistently been demonstrated in the laboratory. Thus, Colquhoun (1976) has demonstrated that efficiency of signal detection, reaction time, and arithmetic calculations vary directly with the body temperature rhythm, peaking at about 4 pm and ebbing at roughly 9 am. Subsequent research (Folkard, Knauth, Monk & Rutenfranz, 1976; Monk & Folkard, 1983) has qualified this finding by suggesting that whereas basic motor responses may be directly related to temperature, cognitive performance such as memory may show an inverse relationship to body temperature. Rutenfranz and Colquhoun (1979) have interpreted this to mean that there may be two types of performance rhythms: one involving immediate information processing operations, which is directly related to body temperature and arousal, and the other involving information storage which may be inversely related to the temperature rhythm. A fruitful area of future research might be to clarify the effects of various work schedules on performance as a function of task demands. The design of optimal work schedules may require tailoring to the specific nature of the work and the characteristics of the workforce. The best approach, therefore, is an empirical one in which both labor and management develop a willingness to implement, and evaluate the efficacy of various schedules in terms of a set of agreed upon criteria.

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