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Biomedical and psychosocial aspects of shift work

A review

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RUTENFRANZ, J., COLQUHOUN, W.P., KNAUTH, P. and GHATA, J.N. Biomedical and psychosocial aspects of shift work: A review. *Scand. j. work environ. & health* 3 (1977) 165—182. A survey of the different types of shift-work systems in use, and the incidence of shift work in different industries and countries, is followed by a discussion of (a) the effects of shift work on health and (b) the physiological problems raised by the phase-shifting of the circadian cycle in night workers. Summaries of the existing knowledge of the effects of shift work on performance efficiency, accidents, and family and social life are then given, and a set of criteria for designing optimal shift systems is proposed. Next, the questions of selection for shift work and the provision of health services for shiftworkers are discussed. Finally, the need for further research on the problems of shift work is explained, and suggestions are offered on the lines such research should follow.

Key words: accidents, attitudes, circadian rhythms, gastrointestinal disease, interpersonal relationships, performance efficiency, personnel selection, psychosocial factors, shift work, sleep.

The literature on shift work is considerable. Most of the available reports concern a particular approach to the problem. However, a more general view is given in some recent publications (22, 52, 68, 73, 90), and several international symposia have been devoted to this subject (e.g., 24, 27, 93, 94). The present paper is a review of the most important and generally accepted facts on shift work and its possible effects on health and related factors.

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DEFINITION AND SHORT REVIEW OF DIFFERENT TYPES OF SHIFT WORK

Over the last 50 years, shift work has increased considerably in many countries. There appear to be three main justifications for this increase: (a) social (provision of "round the clock" services, e.g., medical care, transportation facilities, and security); (b) technological (continuous process operations, e.g., steel production, petrochemical refineries); and (c) economic (optimal use of invested capital, e.g., costly machinery).

It can be argued that shift work introduced for *social* reasons results in an improvement in the quality of life of society as a whole, but it should be pointed out that shift work disturbs the life of the individual workers (and their families) who provide the services. Thus there is a need to create a balance between the needs of

society in general and those of the individual worker in particular.

With the present state of *technology* it must be accepted that in certain industries production can only be carried out in a continuous manner. However, society should not be content with this state of affairs, and technical research should be encouraged which eventually allows production in such industries to be achieved in an alternative way.

In both developed and developing countries *economic* arguments encourage the continuous use of industrial machinery and plants, both because of their high initial cost and their rapid obsolescence due to technological advances and, particularly in developing countries, because of the importance of maximizing plant productivity so that industry can compete effectively in the modern world and therefore continuing employment can be ensured for the working population.

Thus, in any particular situation where the question of shift work arises, it is necessary to weigh the possible health risk to the individual against the requirements or pressures of the state, society, and industry.

Evolution has provided man with a circadian temporal structure that is largely determined by various "synchronizers" which can be social, e.g., the activity patterns of the society in which one lives (5, 46, 90), cognitive, e.g., awareness of clock time (32, 62), or perceptual, e.g., detection of the day/night alternation in the ambient level of light (50). Shift work disturbs this temporal structure and thereby introduces the possibility of a risk to health.

When shift work is discussed, some words have a special meaning. The following definitions are proposed:

Shift: unit of work time (typically 8 h).

Normal day: morning and afternoon work with a lunch break of not more than 2 h.

Rotation period: number of consecutive days on the same shift: (a) short (less than 7 days) and (b) long (7 days or more).

Rotation direction: regular (morning, afternoon, night) or inverse (morning, night, afternoon).

Cycle: time elapsed between identical points in a sequence of rotating shifts.

Split shift: shift with two distinct periods of work separated by an interval of more than 2 h.

Twilight shift: short, evening period of work (typically 1700—2100 or 1800—2200).

A large number of different shift systems exists, but it is possible to categorize the majority of them under one of the following headings:

I. Systems without night work
   Two-team ("double-days")
   a. nonoverlapping (e.g., 0600—1400, 1400—2200)
   b. overlapping (e.g., 0600—1400, 1330—2130)

II. Systems with night work
   Two-team (up to 12-h shifts) ("days and nights")
   Three-team (8-h shifts)
   One-team (night work only) ("permanent night shift"): is often combined with I to provide complete coverage of the 24-h period

III. Systems with night work and including weekend work ("continuous shift work")
   Regular
   a. three-team (12-h shifts)
   b. four-team (8-h shifts)
   Irregular (varying number of teams and cycle lengths)

The complexity of the arrangements is greatest with the systems of type III (continuous shift work). There are many different solutions, some of which have been presented by Graf (42), Knauth (55), Maurice (68), Schunck (92), and Wedderburn (102), as illustrated in tables 1—5.

The current situation regarding the prevalence of shift work in different countries is somewhat confusing since the criteria used for its definition are not always the same. According to Knauth (55) the incidence of shift work was 21.9 % in France in 1974, 20.4 % in the Netherlands in 1969, 18.2 % in the United Kingdom in 1964, and 13.3 % in Japan in 1971.

For certain countries which use constant data collection methods, it is possible to follow the changes in the amount of shift work done over recent years. In most cases there has been an increase. In France

Table 1. An alternating 12-h shift system (4 teams, 4-week cycle) for a 42-h work week (55). [D = day shift (0600—1830), N = night shift (1800—0630), — = rest]

Week	Day						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
1	D	N	—	—	D	N	—
2	—	D	N	—	—	D	N
3	—	—	D	N	—	—	D
4	N	—	—	D	N	—	—

Table 2. A rapidly rotating regular 8-h shift system (4 teams, 4-week cycle) for a 42-h work week (42). (M = morning shift, A = afternoon shift, N = night shift, — = rest)

Week	Day						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
1	N	—	M	A	N	—	—
2	—	M	A	N	—	M	M
3	M	A	N	—	M	A	A
4	A	N	—	M	A	N	N

Table 3. Two rapidly rotating regular 8-h shift systems (102). [M = morning shift (0600—1400), A = afternoon shift (1400—2200), N = night shift (2200—0600), — = rest]

Week	Day						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
2-2-2 shift system [a]							
1	M	M	A	A	N	N	—
2	—	M	M	A	A	N	N
3	—	—	M	M	A	A	N
4	N	—	—	M	M	A	A
5	N	N	—	—	M	M	A
6	A	N	N	—	—	M	M
7	A	A	N	N	—	—	M
8	M	A	A	N	N	—	—
2-2-3 shift system [b]							
1	M	M	A	A	N	N	N
2	—	—	M	M	A	A	A
3	N	N	—	—	M	M	M
4	A	A	N	N	—	—	—

[a] 2-2-2 shift system = "metropolitan rota" (4 teams, 8-week cycle, 42-h week).
[b] 2-2-3 shift system = "continental rota" (4 teams, 4-week cycle, 42-h week).

this increase has been substantial, from 10.3 % in 1957 to 21.9 % in 1974 (69). In other countries its extent may have varied, or may even have shown a tendency towards stabilization. This stabilization may be accompanied by a redistribution of the proportions of workers in different shift systems (table 6).

Table 4. A slowly rotating regular 8-h shift system (4 teams, 4-week cycle) for a 42-h work week (68). (M = morning shift, A = afternoon shift, N = night shift, — = rest)

Week	Day						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
1	M	M	M	M	M	M	M
2	—	—	A	A	A	A	A
3	A	A	—	—	N	N	N
4	N	N	N	N	—	—	—

Table 5. A rapidly rotating irregular shift system (4 teams, 4-week cycle) for a 42-h work week (92). [M = morning shift (0600—1400), A = afternoon shift (1400—2200), $\bar{A}$ = prolonged afternoon shift (1000—2200), N = night shift (2200—0600), $\bar{N}$ = prolonged night shift (2200—1000), — = rest]

Week	Day						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
1	A	—	M	A	N	$\bar{N}$	N
2	—	M	A	N	—	M	—
3	M	A	N	—	M	A	$\bar{A}$
4	N	N	—	N	A	—	—

Table 6. Percentage distribution of shift workers in different shift systems (77).

Year	Shift system			Total
	2 teams	3 teams	4 teams (or more)	
1957	7.7	12.3	2.0	22.0
1960	7.8	12.8	2.4	23.0
1963	7.5	11.1	2.5	21.1
1966	7.1	9.7	3.6	20.4
1969	7.8	8.6	4.0	20.4

Table 7. Proportion of shift workers in different types of industry in France (52).

Type of industry	Proportion %
Metal processing	71.0
Automobile manufacturing	58.3
Textile industry	50.2
Plastics processing	46.6
Chemical industry	34.6
Electrical and electronic manufacturing	21.6
Wood and furniture industry	10.0
House building	1.4

There is a marked variation in the amount of shift work done in different types of industry, ranging, e.g., in France, from 71 % in metal processing to 1.4 % in the building trades (table 7). In general shift work has shown an increase in the majority of industries in all countries. However, there are certain exceptions, which can in some cases be explained by a recession in a particular industry in certain countries, e.g., The Netherlands (mining), the United Kingdom (shipbuilding, for which shift work decreased by 1.3 % per year between 1954 and 1960), Japan (chemical industry, for which the number of shift workers decreased from 36.1 % to 34.2 % of the total labor force between 1958 and 1962).

The size of the plant or organization in question also has a substantial influence on the incidence of shift work. The larger the number of employees, the greater the proportion engaged in shift work (table 8).

Assessments of the general attitude towards shift work have been made by Chazalette (20), Mann (67), Mott et al. (73), Nachreiner and Rutenfranz (76), Wedder-

burn (102, 103), Wyatt and Marriott (109), and others. It has been shown (69) how this attitude varies according to the type of shift system with which the worker is familiar (table 9). It is evident that negative answers to the question posed increase progressively from "permanent shift" to "rotating three-shift" systems. Table 10 shows that where the answer is "Yes, without reservations" attitude is the most strongly affected by feelings about free time. Where the answer is "Yes, with reservations" factors such as age and health are important.

Shift work is traditionally carried out by men. At the international level, night work by women has been governed by the Berne Convention and by ILO (International Labor Organization) conventions number 4 (1919), number 41 (1934), and number 89 (1949). Available information indicates that some countries (e.g., Denmark, Norway and Poland) have adopted a single set of regulations concerning night work which apply equally to men and women. In principle these regulations prohibit night work altogether except in those establishments specified by law. On the other hand, a substantial number of countries have adopted legislation prohibiting night work only in the case of women. This is indicated by the large number of ILO members which had ratified one or the other of the relevant ILO conventions by January 1973 (convention number 4, 57 ratifications; convention number 41, 36 ratifications; and convention number 89, 52 ratifications).

Table 8. Influence of the size of the organization on the proportion of employees engaged in shift work (52).

Number of employees	Percentage of workers in shift work
10—49	5.6
50—199	12.1
200—499	25.1
≥500	43.1

EFFECTS ON HEALTH

The two main sources of health risk commonly identified by physicians in charge of shift workers are *disruption of sleeping patterns* and *variations in eating habits.* Apart from difficulties with sleep, the complaints of the workers themselves center mainly on nervous troubles and disturbances of the alimentary tract. Other factors mentioned are fatigue from traveling between home and work; poor housing conditions (particularly in respect of noise insulation); and the lack of facilities for obtaining a hot meal during night shifts.

Several investigations have been made of the disease patterns associated with shift work. Surveys by Aanonsen (1), Andlauer (4), Thiis-Evensen (95, 96), and Wyatt and Marriott (109) have shown that, whereas gastric and intestinal dysfunctions predominate in shift workers, the incidence of cardiovascular disease and nervous

Table 9. Percentage of answers to the question "Would you like to continue working in shift work in the future?" according to the type of shift system followed at present by the respondent (68).

Shift system followed	Response			No answer
	Yes, without reservations	Yes, with reservations	No	
Permanent shift	68	12	19	1
Rotating two-shift	65	10	17	2
Rotating three-shift (semicontinuous)	33	25	41	1
Rotating three-shift (continuous)	32	35	33	—

Table 10. Factors affecting response to the question "Would you like to continue working in shift work in the future?" (69).[a]

Shift system	Response					
	Yes, without reservations		Yes, with reservations		No	
	Factor	% or no.	Factor	% or no.	Factor	% or no.
Permanent shift	Free time	39 %	Health, family life	18 %	Family life	43 %
	Familiarity with routine	16 %	Age	12 %	Health	17 %
	Family life, transport	12 %				
Rotating two-shift	Free time	44 %	Age	24 %	Family life	26 %
	Transport	15 %	Family life	14 %	Leisure activities, age, more regular life	13 %
	Family life	11 %	Variety	14 %		
Rotating three-shift (semicontinuous)	Free time	28 %	Fatigue caused by night work	28 %	Fatigue caused by night work	27 %
	Familiarity with routine	19 %	Age	18 %	Age, family life	22 %
	Pay	16 %	Health	11 %		
Rotating three-shift (continuous)	Free time	34 %	Age	27 %	More regular life	29 %
	Pay	22 %	Health	18 %	Age	25 %
	Familiarity with routine	16 %	Fatigue caused by night work	14 %	Health	18 %
Number of occasions on which the factors cited were ranked in the top three places over the range of different shift systems.	Free time	4	Age	4	Family life	3
	Familiarity with routine	3	Health	3	Health	3
	Family life	2	Fatique caused by night work	2	Age	3
	Transport	2	Family life	2	More regular life	2
	Pay	2				

[a] The factors shown in this table are those few which were ranked as most important. Where more than one factor was ranked as of equal importance, both have been given.

symptoms does not seem to be higher than in the population at large.

Long-term studies on disease incidence among shift workers are lacking. However, Aanonsen (1) attempted to estimate possible long-term effects by including people who had left shift work in his survey. Table 11 illustrates the results of his well known study. It is evident from the figures given that the group who had left shift work had the highest incidence of disease. In fact about 20 % of shift workers are unable to continue such work (96), and for these people shift work may constitute a health risk (90).

The symptomatology is mainly focused on the gastrointestinal tract, and it is well known that psychosomatic factors are important determinants in this respect. For instance, difficulties are often encountered in the clinical diagnosis of ulcers (43).

Apart from the main diseases and dysfunctions already mentioned, disorders of digestion and sleep are the most common "minor" complaints observed in shift workers.

The frequency of digestive disorders suggests that eating habits may be an important factor. Debry and Bleyer (29) showed that, although shift work does not affect total caloric intake, it alters its distribution over the 24-h period. They pointed out that the social conditions for eating during a work shift are not good and, also, that the disrupted social life of shift workers tends to encourage an increase in the consumption of alcohol. It has been recommended (82) that short

meal breaks should be introduced during the morning and the afternoon, since for social and practical reasons it is often difficult for people to increase the amount of food they eat during the meals before and after their shift. The seriousness of this difficulty may, of course, vary according to local custom in different countries.

It is well known that alcohol, caffeine and tobacco have a pathogenic influence on gastrointestinal dysfunction. It should be noted that night workers tend to increase their intake of caffeine and indulge in heavy tobacco smoking in order to increase their wakefulness during the shift (72).

Sleep is a major concern in the life of shift workers, particularly if they work at night. First, their unusual work hours prevent them from sleeping at the normal time. Second, when they do have an opportunity to sleep, they have to do so in an environment which is geared towards the awakened state. Third, night work and day sleep affect one of the most apparent circadian rhythms (54).

The normal length of sleep, as reported by 18-year-old college students, is shown in table 12. The most common duration of sleep is 7.5—8.5 h for sleep during the normal night hours. This amount is affected by age. It was found (34) that the average number of hours slept by people aged 40—50 was only approximately 6. It has been shown (69) that, whereas 50 % of people with normal day work sleep for 7—8 h, only 40, 35 and 15 % of 3-shift workers in afternoon, morning and night teams, respectively, sleep as long.

Similar results were found by Caillot (19). Foret (36) gives 7.55 h as the mean length of night sleep. In day sleep this time is shortened to 5.56 h, and the lowest figure is found for people going to sleep at the end of the night (5.45 h). It is generally agreed that the duration of day sleep is always less than 7 h (60, 85, 98). Foret (36) summarizes the situation as follows: "One may say that for a morning sleeper the later (in the night) he retires the less he sleeps."

Table 11. Frequency of observed disorders, expressed as the percentage of the number of workers in three categories (1).

Nature of disorder	Category of workers		
	Day (n = 345)	Shift (n = 380)	Day (previous shift workers) (n = 128)
Neuroses and nervous disorders	13.0	10.0	32.5
Ulcus ventriculi S. Duodeni	7.5	6.0	19.0
Peptic symptoms without demonstrable peptic ulcer and other digestive diseases	18.2	20.2	32.5
Angina pectoris and infarctus cordis	2.6	1.1	0.8
"With symptoms"	34.8	34.0	67.0

Table 12. Average length of sleep, expressed as the percentage in different time categories (101).

Sample	Hours of sleep				
	5.5 or less	5.5—6.5	6.5—7.5	7.5—8.5	8.5 or more
2,364 males	1.1	6.1	27.9	48.8	16.0
2,011 females	0.6	9.2	31.1	44.5	14.5

Table 13. Percentage of time spent in different stages of sleep (53, 105).

Author	Stage					
	0 (awake)	I	II	III	IV	REM [a]
Kales et al. (53)	—	4.4	51.2	10.1	11.2	22.9
Williams et al. (105)	1.0	5.4	48.7	7.7	13.2	24.1

[a] REM = rapid eye movement.

A survey of 9,000 shift workers (96) showed that 20 % of them had difficulty adapting to shift work because of lack of sleep. The major complaint about poor sleep is the disturbance caused by noise. It was found (58) that 78.8 % of the people were disturbed in this way when they slept between 0700 and 1900. Children's noise was mentioned in 77.9 % of the complaints, road traffic noise in 63.2 %, telephone ringing in 54.5 % and, among others, aircraft noise in 53.4 %. (The study was conducted in the vicinity of an airport.) By comparison, and for obvious reasons, when sleeping during the night, the same people had almost no complaints about children's noise and telephone ringing, but of those reporting disturbed sleep, road traffic noise was still mentioned in 40.6 % of the cases and aircraft noise in 40.1 %.

The influence of heat on sleep has rarely been taken into account in recent research. All work carried out by man at an effective temperature of more than 30° C appears to reduce the restorative power of subsequent sleep (70). In addition the temperature of the sleeping room will affect sleep (72, 79).

It is not only the length of sleep that is important, but also its "quality." It is normally accepted that the quality of sleep is indicated by its different stages, differentiated in the encephalogram (EEG) by criteria developed by Rechtschaffen and Kales (86). Table 13 shows the percentage of time spent in the different stages of sleep (53, 105). [Note: REM[4] sleep (associated with dreaming) occurs in "bursts," usually separated by intervals of approximately 90 min.]

[4] REM: rapid eye movement.

Several factors may affect the quality of sleep. Although there is no change in REM sleep with age, at least during the active working period of life, the amount of stage IV sleep starts to decline in the midthirties, and this decline is associated with an increase in stage I (34, 101).

Neither presleep conditions (107) nor psychopathological events (48, 110) affect REM sleep. However, environmental heat may produce dissociation between the state of consciousness and neurophysiological alertness, as indicated by the EEG (89).

The sleeping EEG response of individuals to acoustic events varies greatly (31, 47, 64, 66). Awakening occurs at sound levels between 40 dB (A) and 65 dB (A). A field study (100) showed that sleep stages III and IV were reduced by traffic noise. Auditory stimuli presented during stage III or IV produced a shift to stage II in 30 % of the cases (12).

The extent of the effect of noise on shift workers sleeping during the day is largely governed by two factors, i.e., adaptation and motivation. Although much controversy exists concerning the degree to which adaptation can take place (59, 65), it has been shown that with sufficient motivation awakening will only occur in response to those stimuli which the sleeper has previously learned to dicsriminate as being important (104, 106).

There is a relative temporal stability between the different EEG stages that Webb (101) calls "intra-sleep cycling" and Foret (36) refers to as "sleep internal logic." This temporal organization must be acquired by cerebral maturation since it is not seen in the newborn (80).

Foret and Lantin (38), who analyzed the sleep of shift workers, including rail-

road workers (many of whom sleep in noisy stations), bus drivers, and mail carriers, reached the conclusion that the internal logic of sleep was maintained. Variations in the length of sleep were observed, and also an REM deficit, but disruption of the regular cycling of the various sleep stages was never found.

REENTRAINMENT OF PHYSIOLOGICAL FUNCTIONS DURING SHIFT WORK

Perhaps the most important physiological problem regarding shift work, particularly shift work which includes night work, is the problem of the reentrainment of physiological functions after a phase shift of working and sleeping times. The basic facts concerning this problem are well known, having been ascertained from studies with animals (6) and from studies with human subjects under controlled environmental conditions (e.g., in "isolation suites" or caves) where the subject was totally removed from all contact with the outside world (8, 41, 88).

The main fact learned from such studies is that human beings, like animals, have innate circadian rhythms which are entrained by "Zeitgebers" (5) or "synchronizers" (46). The importance of any particular synchronizer may be determined by a series of experiments in which the synchronizer is (a) removed entirely (e.g., by screening the subject from daylight changes), (b) altered in its periodicity (e.g., by changing the length of the "day"), (c) altered in its phase (e.g., by "inverting" the sleep/waking cycle).

It has been shown many times that in animals light is the most important synchronizer. However, in man, the dominant Zeitgebers are the social environment and the awareness of clock time. Light is also a synchronizer in man, but it is a relatively weak one (6).

Shift work produces a situation in which a phase shifting of waking and sleeping times takes place without a corresponding shift in the phasing of the dominant social synchronizers. This is the situation in which the troubles mentioned previously occur. The same troubles occur in the first few days after air travel involving substantial (more than 3 h) time-zone shifts. Thus the results of experiments on transmeridianal flights provide good models for understanding the problems of shift work. Other models leading towards such understanding are provided by the results of animal and insect experiments on longevity as related to phase-shifted light/dark schedules (7). These experiments suggest that different light/dark cycles have different effects on longevity. Although the results of these experiments on lower species cannot be directly related to the problem of shift work, they may act as guidelines for the design of experiments on this topic with human subjects.

The specific problems of the reentrainment of physiological functions caused by shift work have to be studied both in the laboratory and in the field. In both cases the experiments must be specifically designed; post hoc studies are not sufficient. Planned experimental studies of shift work of this kind have been carried out in recent years in several countries (25, 26, 56, 81, 91, 97).

In these experiments different types of shift systems have been examined by measurement of various physiological and psychological functions over periods ranging from one day to several weeks. In the laboratory experiments, an attempt was made to mimic, as far as possible, the real-life situation ("open-door" experiments without social isolation and with real or simulated work). It was observed that in shift systems with single night shifts the circadian rhythm of body temperature was not significantly altered. However, in experiments which involved consecutive night work for periods of one to three weeks, a phase shifting was observed for the temperature minimum; the time of the minimum shifted to a point within the new sleeping period after seven or more days. At present it is not known whether other body functions also reentrain at the same rate as body temperature or whether the phase shifting is delayed, as has been observed in transmeridianal flights (40, 49).

From the medical point of view, the physiological problems of shift work are considered the most important. However, the shift workers themselves have a different attitude. For them the most important problems are psychosocial ones,

such as the extent to which shift work disrupts their family routine or interferes with their social life.

Thus it must be realized that, although it is possible to plan shift systems which minimize physiological problems, these systems may not be acceptable to the worker. On the other hand, experimental studies of shift work can yield guidelines for helping people in industry to construct shift schedules which both take into account basic physiological findings and respect the social needs of the workers.

INTERACTION WITH OTHER FACTORS

Age is an important factor in regard to shift work. Although the total sleep requirement decreases in older people, there is an increased need to sleep in frequent short periods ("naps"). Furthermore, people over 50 years of age are generally less flexible, both physiologically and psychosocially, than younger people. Therefore the ability of older people to adapt to shift work may be reduced (10, 37).

Various other factors may interact with shift work. For example, the effects of a *hot climate* have been observed to differ in night and day shifts (61). *Toxic agents* are another potential factor; as studies in chronopharmacology have shown, the effects of such agents vary considerably at different points in the 24-h cycle (87). A related concern is the *use of drugs* by workers on different shifts. In this regard, and in relation to the concepts of Halberg and Reinberg (45), one must keep in mind the phrase "*tempora minoriae resistentiae.*"

A special problem exists with *immigrant* shift workers, whose sociocultural habits may conflict with those of the community in which they come to live. For example, Moslems, during the annual month-long Ramadan festival, must fast between sunrise and sunset. Therefore those Moslems who are on the night shift tend to take their main meals during their work period, and may, in consequence, suffer from inadequate nutrition (33). In addition immigrant workers often live in overcrowded housing conditions that may aggravate their sleeping problems, particularly during the daytime.

EFFECTS ON PERFORMANCE

"The individual's capacity for doing mental or physical work is not the same throughout the waking period" (54).

Results from earlier studies of performance in relation to time of day are confusing. Wyatt and Langdan (108) attempted to classify changes in observed output rates at different times of the day and by this means construct theoretical performance efficiency curves for different types of work. A similar attempt was made by Freeman and Hovland (39) for various mental test scores. These attempts were somewhat ad hoc and not unduly successful. It was left to Kleitman (54) to advance a coherent theory, which related performance variations to the effect of changes in metabolic rate on the speed of chemical processes in the brain. By careful laboratory experimentation he was able to demonstrate clearly that reaction time is closely related to body temperature (which was taken to be a good index of metabolic rate) as this altered according to its well known 24-h rhythm. Such a relationship was later found to exist in a range of what Hockey and Colquhoun (51) termed "simple information-processing tasks," for which speed of response is the major variable. Thus there appeared to be a "rule" that, whether or not the relationship was actually causal in the way Kleitman (54) had suggested, the rhythms of body temperature and of simple performance exhibited a parallelism over the 24-h period.

One exception to this rule was noted with the "post-lunch dip," a period in which the performance and temperature curves diverge for a time. It was suggested (54) that this dip may reflect the influence of a rhythm with a period of some 80—90 min, i.e., a period of the same order as that of the REM cycle in sleep. This latter question is still under debate, but it seems that, even for simple tasks, one cannot accept the hypothesis that there is a strict association between the curves of performance and temperature (23). Furthermore, in the case of tasks requiring "higher level" or "cognitive" abilities, such as short-term memory (15) or logical reasoning (35), it has now been shown that the rhythms of performance and tempera-

ture can be completely out of phase with each other.

As for actual industrial tasks not involving much cognitive effort, a study of switchboard operators (18) and data from Swedish gasworkers collected over a period of 20 to 30 years (14) showed that the level of performance reaches its lowest point at about 0300; a second "low point" occurs at 1500 (75). Similar conclusions were reached for 3 x 8 shift systems (71, 99), and for 2 x 8 systems (109). As regards night work involving "simple" tasks, Colquhoun (22) concluded from the results of his experimental studies of shift work: (a) that performance during a night shift should be generally worse than during a day shift; (b) that, when the sleep/waking cycle is altered as a result of shift work at night, the temperature rhythm adapts very slowly, and the initial on-shift temperature fall gradually disappears; and (c) that, as a result, efficiency trends during two weeks of consecutive night shifts should be characterized by a change from a pronounced within-shift decrement during the first few days to a relatively constant performance level throughout the shift after about a week.

These findings are all based on average results from groups. But it is clear that considerable individual differences exist. It has been shown (16) that both temperature and (simple) performance curves vary in phase and, in a correlated manner, according to whether the individual is characterized as introverted or extroverted on a personality questionnaire. This conclusion amplifies the original identification of "morning" and "evening" types (54) and may have implications for the selection of workers for different shifts.

SHIFT WORK AND ACCIDENTS

Generally speaking, many factors are involved in accident causation. Some may be specifically related to shift work, but knowledge in this field is conspicuously absent.

Circadian variations in accidents have been investigated by several workers. However, the results are controversial because the times of accident-rate maximums were found to be different in different studies. An exceptionally careful survey was carried out with 11,000 workers in the mining and steel industries (4). Accident rates were compared in comparable populations working different shifts. The rates were found to be higher for the morning and afternoon shifts than for the night shift, but the accidents were more serious in the last case.

Some workers have observed two accident peaks during daytime hours, one at about 1000 and the other at 1600 (13, 61, 74). A survey of 427 daytime accidents showed, on the other hand, that, when these accidents were grouped by 15-min periods, there were three peak times for occurrence, i.e., 0930, 1145 and 1400 (84).

It is difficult to account for these findings. Circadian variation in mental efficiency is unlikely to be the cause since, for industrial tasks, it is known that such efficiency is relatively high between 0900 and 1200 and 1600 and 1800 (14).

When accident rates are analyzed in relation to rest breaks, the results differ for day and night work. Although in day work accidents tend to decrease before the breaks, the effect of the breaks in night work is ambiguous.

Further research is clearly needed on the circadian variation of accidents, since studies of mental efficiency in relation to time of day indicate that at least the potential for accidents in which the human factor is involved (some 80 % of the cases) must vary considerably for different shifts (24). The possible interactive influence of environmental factors, such as heat and cold, and seasonal variations in climate, should also be investigated since such knowledge is also sparse (61). Finally, it should be noted that accidents "off the job" (i.e., in the workers' leisure time) may also be related to the time of the work shift (17).

EFFECTS ON FAMILY LIFE, SOCIAL LIFE AND PROFESSIONAL RELATIONSHIPS

In shift work psychosocial factors are generally involved. These can often be more important than physiological or organizational ones (11). This general assertion may be modified in a situation where shift

work is common for a substantial proportion of the working community or where shift workers have adopted a subculture within a special housing area (103).

People on shift work often perceive their own situation as either peripheral to or quite apart from the general community. Participation in social events is limited, and in some cases shift workers are underrepresented in responsible groups, such as trade unions, professional associations and community councils.

Special difficulties occur in family life. These are related to the size of the family, the personalities of its individual members, the standard of the living accommodations, and financial status. Due to the particular circumstances of shift workers' families, the feeling of being a well-integrated group is often more important to them than to other families (9, 19, 69, 76). On the other hand, only about 20 % of shift workers' wives complain about the changes in the times of meal preparation (9), which time budget studies have revealed (69).

Shift workers complain more frequently about difficulties concerning relationships with friends and about perturbations in sex life than nonshift workers (76, 99). These factors could explain some of the physical and psychosocial disorders which arise from shift work (73), and they may account for the reported marital problems (109).

Nevertheless, it is possible for shift work to have a beneficial influence on family life because of the increased amount of leisure time available during the day. This increase is produced partly by the shift system itself and partly by the reduced amount of sleep taken. Another positive aspect is the possibility of having several consecutive free days at unusual times in the week. These days can be used to pursue special types of hobbies and leisure activities, such as fishing, etc. (2).

The organization of social life is generally synchronized with the work hours of the normal population. Thus it is difficult for shift workers to participate in sociocultural activities such as visits to the theater, watching sports or television, attending educational classes, etc. The generally higher educational standard of present-day workers and the increase in the number of workers from higher socioprofessional levels working shifts aggravates these problems. Probably because of this phenomenon an increasing number of shift workers are demanding that more consideration be given to their abnormal living and working conditions as they relate to community life. They are now asking, for example, for special times for trade union meetings, religious services and TV programs, and they are requesting that changes be made in the opening hours of shops, libraries, etc. (76).

CRITERIA FOR OPTIMAL SHIFT SYSTEMS

It is impossible to construct one single shift schedule which is optimal for all shift workers and for all working and living conditions. But, based on present knowledge, some criteria can be set for schedule construction.

The following statements are based on results obtained from experimental studies of shift work:

1. Single night shifts are better than consecutive night shifts (a) because a single night shift does not significantly disturb circadian rhythms and (b) because more than seven consecutive night shifts are required for reentrainment of the rhythms (25, 26, 56, 81). It could be argued that a sequence of consecutive night shifts longer than seven days would therefore be acceptable. However, for psychosocial reasons most workers need either to change their shift or to have some rest days after no more than one week, so reentrainment is not normally possible in practice.

2. At least 24 h of free time should be allowed after each night shift. Sleep disturbances and reduction of sleeping time are the most common complaints of shift workers, particularly of night workers. The resultant accumulation of sleep deficit over several days may be a risk factor. Thus for preventing the harmful effects of sleep deprivation, a substantial recovery period is necessary after each night shift (42, 58, 59, 90). A similar problem can arise with morning shifts when the starting time is so early that the worker gets an insufficient amount of sleep the night

before; in this case a 24-h break after each such shift should also be allowed. (Alternatively, of course, it may be possible to delay the starting time of the shift by reorganization of the system.)

3. The length of the shift should be related to the type of work, particularly to the energy expenditure required by it. If the work is light the length of the shift may (with caution) be extended to 12 h, but it normally should not exceed 8 h (or even 6 h for certain types of work, e.g., work involving particularly heavy physical energy expenditure or a considerable mental load).

4. The cycle of a shift system should not be too long (4 weeks, for example, is better than 40 weeks). It is also better to have a regular system of rotation than an irregular one. Short cycles and regular systems make it easier for the worker and his family to plan their social life.

5. In the case of continuous shift work it is important to arrange as many free weekends as possible for the worker in order that he can participate at these times in the normal social life of friends who do not do shift work.

Knauth et al. (57) have recently proposed a systematic methodology for evaluating shift systems in relation to these criteria.

SELECTION FOR SHIFT WORK AND PROVISION OF HEALTH SERVICES

Because shift work cannot be sustained by about 20 % of the working population, the appropriate selection of shift workers is important. Unfortunately, it is not possible at present to define positive criteria for selecting such workers, and the criteria thus far developed are mainly negative. In this regard, shift work is contraindicated to a greater or lesser extent for certain categories of people. Industrial medical officers should pay particular attention to the following groups:

1. People under 25 (especially if living alone) and over 50 years of age. Such persons should normally not be selected for shift work, if they are newcomers. However, experienced, well-adapted shift workers can, in most cases, be allowed to remain in shift work beyond the age of 50 (21, 28, 63, 95). The possible difference between chronological and physiological age should be borne in mind.

2. People with a history of digestive tract disorders. Shift work produces special psychophysiological problems and also involves unusual meal times, both of which may affect gastric function (3, 21, 30, 71, 95).

3. Diabetics and thyrotoxicosics. Regular food intake and correct therapeutic timing can be difficult to maintain under shift work conditions (28).

4. Epileptics. Reduction of sleep increases the incidence of fits (28).

5. People living alone. The sleeping time of such people is reduced through having to carry out all the usual domestic tasks by themselves (71).

6. People with sleeping facilities which are inadequately soundproofed. Noise reduces sleeping time (3, 58, 71, 83, 95).

In the future it may be possible to derive positive criteria for selecting shift workers based on the results of special examinations, such as autorhythmometry (44) or psychological tests for appropriate personality characteristics (16, 76, 78).

The medical supervision of shift workers is especially important. Between six months and one year after the initial medical examination, a second examination should be carried out. Subsequent examinations should be made on a regular basis. In general, these should take place at two-year intervals. However, for shift workers over 50 years of age, a shorter interval is recommended (63).

CONCLUSIONS

Further research into the problems of shift work must be oriented towards real-life situations to ensure that the results of any experiments that are carried out are relevant to the needs of the workers.

Special attention must be paid to the long-term effects of shift work on health. There is an urgent need for epidemiologic studies to identify the various possible

harmful effects, particularly in relation to factors such as toxic agents, adverse climatic conditions, age, etc. It is also important that a special study be made of that group of people (comprising approximately 20 % of shift workers) who are unable to continue working on shifts.

More, and reliable, statistics are required on the incidence of accidents, injuries, and "near misses" during different shifts and in different shift systems. Present arrangements for the recording of such occurrences are inadequate, and the development of a uniform data-collection system is urgently needed before appropriate comparisons can be made.

There is a clear need for the development of appropriate models for studying the effects of shift work on the circadian variation of physiological functions. Such models may be formulated from the results of experiments on (a) shift work conducted in the laboratory, (b) shift work conducted in the field, and (c) the effects of repeated phase shifting on insects and animals.

Thus, increased knowledge about the relevance of biomedical and psychosocial factors to shift work is required so that occupational medicine can be properly prepared to deal with the possibly harmful effects of such work.

REFERENCES

1. AANONSEN, A. Medical problems of shift-work. *Ind. med. surg.* 28 (1959) 422—427.
2. AANONSEN, A. *Shiftwork and health.* Universitetsforlaget, Oslo 1964.
3. ANDERSEN, E. J. The main results of the Danish medico-psychosocial investigation of shiftworkers. In: *Proceedings of the XII international congress on occupational health, Helsinki, July 1—6, 1957* (vol. III). Helsinki 1958, pp. 135—136.
4. ANDLAUER, P. and METZ, B. Le travail en équipes alternantes. In: J. SCHERRER (ed.), *Physiologie du travail — Ergonomie,* (tome II). Masson, Paris 1967, pp. 272—281.
5. ASCHOFF, J. Zeitgeber der tierischen Tagesperiodik. *Naturwissenschaften* 41 (1954) 49—56.
6. ASCHOFF, J., HOFFMANN, K., POHL, H. and WEVER, R. Re-entrainment of circadian rhythms after phase-shifts of the Zeitgeber. *Chronobiologia* 2 (1975) 23—78.
7. ASCHOFF, J., SAINT PAUL, U. VON and WEVER, R. Die Lebensdauer von Fliegen unter dem Einfluß von Zeitverschiebungen. *Naturwissenschaften* 58 (1971) 574.
8. ASCHOFF, J. and WEVER, R. Spontanperiodik des Menschen bei Ausschluss aller Zeitgeber. *Naturwissenschaften* 49 (1962) 337—342.
9. BANKS, O. *The attitudes of steelworkers to technical changes.* Liverpool University Press, Liverpool 1960.
10. BANNEL, F. and DERVILLÉE, E. Le travail de nuit aperçus socio-professionnels et médicaux. In: *XVI international congress on occupational health, Sept. 22—27, 1969, Tokyo, Japan.* Tokyo 1971, pp. 107—108.
11. BARHAD, B. and PAFNOTE, M. Contributions à l'étude du travail en équipes alternantes. *Trav. hum.* 33 (1970) 1—19.
12. BERRY, B. and THIESSEN, C. J. *The effect of impulsive noise on sleep* (Publication NRC no. 11597). National Research Council of Canada, 1970.
13. BESSOU, J. and PECHKER, R. Répartition des accidents du travail à l'EDF. *Arch. mal. prof.* 24 (1963) 184—190.
14. BJERNER, B., HOLM, A. and SWENSSON, Å. Diurnal variations in mental performance: A study of three-shift workers. *Br. j. ind. med.* 12 (1955) 103—110.
15. BLAKE, M. J. F. Time of day effects on performance in a range of tasks. *Psychon. sci.* 9 (1967) 349—350.
16. BLAKE, M. J. F. Temperament and time of day. In: W. P. COLQUHOUN (ed.), *Biological rhythms and human performance.* Academic Press, London and New York 1971, pp. 109—148.
17. BRANDT, A. On the influence of various shift systems on the health of the workers. In: *XVI international congress on occupational health, Sept. 22—27, 1969, Tokyo, Japan.* Tokyo 1971, pp. 106—107.
18. BROWNE, R. C. The day and night performance of teleprinter switchboard operators. *Occup. psychol.* 23 (1949) 121—126.
19. CAILLOT, R. Conséquences sociales du travail à feu continu. *Econ. hum.* 122 (1959) 62—72.
20. CHAZALETTE, A. *Une étude sur les conséquences du travail en équipes alternantes et les facteurs explicatifs.* Groupe de sociologie urbaine, Lyon 1973.
21. COLLIER, H. E. *Outlines of industrial medical practice.* Edward Arnold, London 1943.
22. COLQUHOUN, W. P. (ed.). *Biological rhythms and human performance.* Academic Press, London and New York 1971.
23. COLQUHOUN, W. P. (ed.). *Aspects of human efficiency: Diurnal rhythms and loss of sleep.* The English Universities Press, London 1972.
24. COLQUHOUN, W. P. Accidents, injuries and shift work. In: P. G. RENTOS and R. D. SHEPHARD (eds.), *Shift work and health* (Public Health Service HEW

publication no. (NIOSH) 76—203). U.S. Department of Health, Education, and Welfare, Washington, D.C. 1976, pp. 160—175.
25. COLQUHOUN, W. P., BLAKE, M. J. F. and EDWARDS, R. S. Experimental studies of shift-work: II. Stabilized 8-hour shift systems. *Ergonomics* 11 (1968) 527—546.
26. COLQUHOUN, W. P., BLAKE, M. J. F. and EDWARDS, R. S. Experimental studies of shift-work: III. Stabilized 12-hour shift system. *Ergonomics* 12 (1969) 865—882.
27. COLQUHOUN, P., FOLKARD, S., KNAUTH, P. and RUTENFRANTZ, J. *Experimental studies of shiftwork: Proceedings of the 3rd international symposium on night- and shiftwork, Dortmund, October 29—31, 1974.* Westdeutscher Verlag, Opladen 1975.
28. COOK, F. O. *Shiftwork.* Institute of Personnel Management, London 1954.
29. DEBRY, G. and BLEYER, R. Influence du rythme des 3 × 8 sur l'alimentation des travailleurs. In: G. DEBRY and R. BLEYER (eds.), *Alimentation et travail.* Masson, Paris 1972, pp. 153—172.
30. DERVILLÉE, P. and LAZARINI, H. J. A propos du travail en équipe avec changement d'horaires. Incidences familiales et répercussion possible sur la santé des travailleurs. *Arch. mal. prof.* 20 (1959) 306—309.
31. DOBBS, M. E. Behavioural responses to auditory stimulation during sleep. *J. sound vib.* 20 (1972) 467—476.
32. EIFF, A. W. VON, BÖCKH, E. M., GÖPFERT, H., PFLEIDERER, F. and STEFFEN, T. Die Bedeuting des Zeibewußtseins für die 24-Stunden-Rhythmen des erwachsenen Menschen. *Z. gesamte exp. Med.* 120 (1953) 295—307.
33. EL BATAWI, M. A. Food intake and work performance: A study on the effect of fasting on work output in the eastern méditérranéan. In: G. DEBRY and R. BLEYER (eds.), *Alimentation et travail.* Masson, Paris 1972, pp. 261—265.
34. FEINBERG, I. Effects of age on human sleep patterns. In: A. KALES (ed.), *Sleep, physiology and pathology.* Lippincott, Philadelphia, Pa. 1969, pp. 39—52.
35. FOLKARD, S. Diurnal variation in logical reasoning. *Br. j. psychol.* 66 (1975) 1—8.
36. FORET, J. *Sommeil et horaires de travail irréguliers* (Thesis). Lille, France 1973.
37. FORET, J. Horaires de travail et vieillissement. In: A. LAVILLE, C. TEIGER and A. WISNER (eds.), *Age et contraintes de travail.* NEB. Editions scientifique, Jouy-en-Josas (France) 1975, pp. 82—86.
38. FORET, J. and LANTIN, G. The sleep of train drivers: An example of the effects of irregular work schedules on sleep. In: W. P. COLQUHOUN (ed.), *Aspects of human efficiency.* The English Universities Press, London 1972, pp. 273—282.
39. FREEMAN, G. L. and HOVLAND, C. I. Diurnal variations in performance and related physiological processes. *Psychol. bull.* 31 (1939) 777—799.
40. GHATA, J. Effects physiologiques des vols transméridiens. *Arch. mal. prof.* 32 (1971) 385—388.
41. GHATA, J., HALBERG, F., REINBERG, A. and SIFFRE, M. Rythmes circadiens désynchronisés du cycle social (17-hydroxycorticosteroides, température rectale, veille-sommeil) chez deux sujets adultes sains. *Ann. d'endocrinol.* (Paris) 30 (1969) 245—260.
42. GRAF, O. Vorschläge einer Neuregelung. In: E. BLUME, K. DOESE, H. FISCHER, O. GRAF, J. HÖFFNER and H. KRAUT (eds.), *Gutachten über die kontinuierliche Arbeitszeit in SM-Werken der Hüttenwerk Oberhausen AG.* Gutachten im Auftrage des Arbeits- und Sozialministers des Landes Nordrhein-Westfalen 1955 (Unpublished).
43. HADENGUE, A., REYNAUD, J. D. and REINBERG, A. *Les incidences psychophysiologiques et les aspects pathologiques de la répartition des horaires de travail. VII^e Journées Nationales de Médecine du Travail, Septembre 1962.* Masson et Cie, Paris 1963.
44. HALBERG, F., JOHNSON, E. A., NELSON, W., RUNGE, W. and SOTHERN, R. Autorhythmometry-procedures for physiologic self-measurements and their analysis. *Psychol. teach.* 1 (1972) 1—11.
45. HALBERG, F. and REINBERG, A. Rythmes circadiens et rythmes de basses fréquences en physiologie humaine. *J. physiol.* (Paris) 59 (1967) 117—200.
46. HALBERG, F. and VISSCHER, M. B. Some physiologic effects of lighting. In: *Proceedings of the 1st international photobiology congress (4th international light congress),* Amsterdam 1954, pp. 396—398.
47. HARMAN, D. *Effects of trafic noise on sleep.* (Thesis) Portsmouth, United Kingdom 1970.
48. HARTMANN, E. Mania, depression and sleep. In: A. KALES (ed.), *Sleep, physiology and pathology.* Lippincott, Philadelphia, Pa. 1969, pp. 183—191.
49. HAUS, E., HALBERG, F., NELSON, W. and HILLMAN, D. Shifts and drifts in phase of human circadian system following intercontinental flights and in isolation. *Fed. proc.* 27 (1968) 224.
50. HILDEBRANDT, G. and LOWES, E. M. Tagesrhythmische Schwankungen der vegetativen Lichtreaktionen beim Menschen. *J. interdiscip. cycle res.* 3 (1972) 289—301.
51. HOCKEY, G. R. J. and COLQUHOUN, W. P. Diurnal variation in human performance: A review. In: W. P. COLQUHOUN (ed.), *Aspects of human efficiency: Diurnal rhythm and loss of sleep.* The English Universities Press, London 1972, pp. 1—23.
52. INSTITUT NATIONAL DE RECHERCHE ET DE SÉCURITÉ. *Le travail par équipes successives.* (avec collaboration de J. CARPENTIER) (Edition INRS no. 523). Paris 1975.

53. KALES, A., WILSON, T., KALES, J. D., JACOBSON, A., PAULSON, M. J., KOLLAR, E. and WALTER, R. D. Measurements of all-night sleep in normal elderly subjects: Effects of aging. *J am. geriatr. soc.* 15 (1967) 405—414.
54. KLEITMAN, N. *Sleep and wakefulness.* University of Chicago Press, Chicago 1963.
55. KNAUTH, P. *Kriterien für die Beurteilung verschiedener Schichtwechselformen* (Thesis) Darmstadt 1975.
56. KNAUTH, P. and ILMARINEN, J. Continuous measurement of body temperature during a three-week experiment with inverted working and sleeping hours. In: P. COLQUHOUN, S. FOLKARD, P. KNAUTH and J. RUTENFRANZ (eds.), *Experimental studies of shiftwork.* Westdeutscher Verlag, Opladen 1975, pp. 66—73.
57. KNAUTH, P., ROHMERT, W. and RUTENFRANZ, J. Systematic selection of shift plans for continuous production with the aid of work-physiological criteria. In: *Proceedings 6th congress of the international ergonomics association, July, 11—16, 1976, University of Maryland, U. S. A.* pp. 519—525.
58. KNAUTH, P. and RUTENFRANZ, J. Untersuchungen über die Beziehungen zwischen Schichtform und Tagesaufteilung. *Int. Arch. Arbeitsmed.* 30 (1972) 173—191.
59. KNAUTH, P. and RUTENFRANZ, J. The effects of noise on the sleep of night-workers. In: P. COLQUHOUN, S. FOLKARD, P. KNAUTH and J. RUTENFRANZ (eds.), *Experimental studies of shiftwork.* Westdeutscher Verlag, Opladen 1975, pp. 57—65.
60. KRIPKE, D. F., COOK, B. and LEWIS, O. F. Sleep of night workers: EEG recordings. *Psychophysiology* 7 (1970) 377—384.
61. LAMBERT, G. *L'adaptation physiologique et psychologique de l'homme aux conditions de vie désertique.* Hermann, Paris 1968.
62. LEWIS, P. R. and LOBBAN, M. C. Dissociation of diurnal rhythms in human subjects living on abnormal time routines. *Q. j. exp. physiol.* 42 (1957) 371—386.
63. LOSKANT, H. and KNAUTH, P. Kriterien zur Gestaltung der Schichtarbeit. In: W. BRENNER, W. ROHMERT and J. RUTENFRANZ (eds.), *Ergonomische Aspekte der Arbeitsmedizin. Bericht über die 15. Jahrestagung der Deutschen Gesellschaft für Arbeitsmedizin in München vom 24.—26. 4. 1975.* A. W. Gentner Verlag, Stuttgart 1976, pp. 231—240.
64. LUDLOW, J. E. and MORGAN, P. A. Behavioural awakening and subjective reactions to indoor sonic booms. *J. sound vib.* 25 (1972) 479—495.
65. LUKAS, J. S. and DOBBS, M. E. *Effects of aircraft noises on the sleep of women* (NASA report no. CR-2041). 1972.
66. LUKAS, J. S., DOBBS, M. E. and KRYTER, K. D. *Disturbances of human sleep by subsonic jet aircraft noise and simulated sonic booms* (NASA report no. CR-1780). 1971.
67. MANN, F. C. and HOFFMAN, L. R. *Automation and the worker.* Henry Holt, New York, N. Y. 1960.
68. MAURICE, M. *Shift work.* International Labour Office, Geneva 1975.
69. MAURICE, M. and MONTEIL, C. *Vie quotidienne et horaires de travail. Enquête psychophysiologique sur le travail en équipes successives.* Institut des Sciences Sociales du Travail, Centre de Recherches. Université de Paris, Paris 1965.
70. MC FARLAND, R. A. *Human factors in air transportation.* McGraw-Hill, New York, N. Y. 1953.
71. MENZEL, W. *Menschliche Tag-Nacht-Rhythmik und Schichtarbeit.* Benno Schwabe, Basel 1962.
72. METZ, B. Principes physiologiques d'organisation du travail en zone saharienne. In: *Ier congrés de physiologie saharienne. J. Méd. de Dakar, décembre 1960.*
73. MOTT, P. E., MANN, F. C., MC LOUGHLIN, Q. and WARWICK, D. P. *Shiftwork: The social, psychological and physiological consequences.* University of Michigan Press, Ann Arbor, Mich. 1965.
74. MOUTON, A. *Aspects particuliers de l'adaptation du travail à l'homme en milieu saharien* (Thesis). Lille, France 1960.
75. MURRELL, K. F. H. *Ergonomics.* Chapman and Hall, London 1965.
76. NACHREINER, F. and RUTENFRANZ, J. Sozialpsychologische, arbeitspsychologische und arbeitsmedizinische Erhebungen in der Chemischen Industrie. In: F. NACHREINER, R. FRIELINGSDORF, R. ROMAHN, P. KNAUTH, W. KUHLMANN, F. KLIMMER, J. RUTENFRANZ and E. WERNER (eds.), *Schichtarbeit bei kontinuierlicher Produktion* (Forschungsbericht Nr. 141). Bundesanstalt für Arbeitsschutz und Unfallforschung, Dortmund 1975, pp. 83—177.
77. N. N. *Arbeid in Ploegendienst 1969.* Sociale maandstatistiek juni 1972, p. 289.
78. ÖSTBERG, O. and NICHOLL, A. G. The preferred thermal conditions for "morning" and "evening" types of subjects during day and night — Preliminary results. *Build int.* (Eng. ed.) 6 (1973) 147—157.
79. OTTO, E., KRAMER, H. and BRÄUER, D. Einfluss erhöhter Raumlufttemperatur auf Herzschlagfrequenz, Bewegungshäufigkeit, Rectaltemperatur und Elektroencephalogramm schlafender Menschen. *Int. Arch. Arbeitsmed.* 28 (1971) 189—202.
80. PARMELEE, A. H. JR. and STERN, E. Development of states in infants. In: C. D. CLEMENTE, D. P. PURPURA and F. E. MAYER (eds.), *Sleep and the maturing nervous system.* Academic Press, New York, London 1972, pp. 199—218.
81. PATKAI, P., PETTERSSON, K. and ÅKERSTEDT, T. The diurnal pattern of some physiological and psychological functions in permanent night workers and

in men working on a two-shift (day and night) system. In: P. COLQUHOUN, S. FOLKARD, P. KNAUTH and J. RUTENFRANZ (eds.), *Experimental studies in shift work.* Westdeutscher Verlag, Opladen 1975, pp. 131—141.

82. PÉQUIGNOT, G., CLAUDIAN, J. and VINIT, F. Journée continue et alimentation. In: G. DEBRY and R. BLEYER (eds.), *Alimentation et travail.* Masson, Paris 1972, pp. 179—199.
83. PIGORS, P. and PIGORS, F. *Human aspects of multiple shift operations* (series 2, no. 13). Department of Economics and Social Science, Massachusetts Institute of Technology, Cambridge, Mass. 1944.
84. POWELL, P. I., HALE, M., MARTIN, J. and SIMON, M. *2000 accidents: A shopfloor study.* National Institute of Industrial Psychology, London 1971.
85. QUAAS, M. Probleme der Adaptation, Leistungsfähigkeit und Organisation der Schichtarbeit in der DDR. In: Å. SWENSSON (ed.), *On night and shift work. Proceedings of an international symposium on night and shift work, Oslo 1969.* (Studia laboris et salutis, no. 4). Institute of Occupational Health, Stockholm 1969, pp. 112—123.
86. RECHTSCHAFFEN, A. and KALES, A. (eds.). *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects.* (Publication no. 204). National Institute of Health, Public Health Service, U.S. Government Printing Office, Washington, D. C. 1968.
87. REINBERG, A. and HALBERG, F. Circadian chronopharmacology. *Ann. rev. pharmacol.* 11 (1971) 455—492.
88. REINBERG, A., HALBERG, F., GHATA, J. and SIFFRE, M. Spectre thermique d'une femme adulte saine avant, pendant et après son isolement souterrain de trois mois. *C. r. acad. sci.* (Paris) 262 (1966) 782—785.
89. RICHARD, J., FESSARD, J., LAMBERT, G. and BLANC, C. Note préliminaire sur les modifications E. E. G. observées chez des adultes normaux transplantés dans les zones arides. *Rev. neurol.* (Paris) 106 (1962) 134.
90. RUTENFRANZ, J. Probleme der Schichtarbeit. In: R. L. ZIELHUIS and J. HUISDRUKKER (eds.), *Ploegenarbeid.* University of Amsterdam, Amsterdam 1973, pp. 3—25.
91. RUTENFRANZ, J., KLIMMER, F. and KNAUTH, P. Desynchronization of different physiological functions during three weeks of experimental nightshift with limited and unlimited sleep. In: P. COLQUHOUN, S. FOLKARD, P. KNAUTH and J. RUTENFRANZ (eds.), *Experimental studies of shiftwork.* Westdeutscher Verlag, Opladen 1975, pp. 74—77.
92. SCHUNCK, K.-H. Ein neues Schichtsystem in seiner Auswirkung auf den Krankenstand, das Unfallgeschehen und die Freizeitgestaltung. *Dtsch. Gesundheitswes.* 13 (1958) 1092—1095.
93. SWENSSON, Å (ed.). *On night and shift work. Proceedings of an international symposium, Oslo, January 31st — February 1st, 1969* (Studia laboris et salutis, no. 4). National Institute of Occupational Health, Stockholm 1969.
94. SWENSSON, Å (ed.). *Proceedings of the second international symposium on night and shift work, Slanchev Bryag, September 20—24, 1971* (Studia laboris et salutis, no. 11). National Institute of Occupational Health, Stockholm 1972.
95. THIIS-EVENSEN, E. Shift work and health. *Ind. med. surg.* 27 (1958) 493—497.
96. THIIS-EVENSEN, E. Shift work and health. In: Å. SWENSSON (ed.), *On night and shift work. Proceedings of an international symposium, Oslo, January 31st — February 1st, 1969,* (Studia laboris et salutis, no. 4). National Institute of Occupational Health, Stockholm 1969, pp. 81—83.
97. TSANEVA, N. and DALEVA, M. Field study of the diurnal changes of the adrenal system. In: P. COLQUHOUN, S. FOLKARD, P. KNAUTH and J. RUTENFRANZ (eds.), *Experimental studies of shiftwork.* Westdeutscher Verlag, Opladen 1975, pp. 206—212.
98. TUNE, G. S. Sleep and wakefulness in a group of shiftworkers. *Br. j. ind. med.* 26 (1969) 54—58.
99. ULICH, E. *Schicht- und Nachtarbeit im Betrieb.* Westdeutscher Verlag, Köln-Opladen 1964.
100. VALLET, M., BLANCHET, V., BRUYÈRE, J. C. and THALABARD, J. C. *La perturbation du sommeil par le bruit de circulation routière. Etude in situ.* Institut de Recherche des Transports. Centre d'Evaluation et de Recherche des Nuisance, Bron (France) décembre 1975.
101. WEBB, W. B. Sleep behaviour as a biorhythm. In W. P. COLQUHOUN (ed.), *Biological rhythms and human performance.* Academic Press. London and New York 1971, pp. 149—177.
102. WEDDERBURN, A. A. I. Social factors in satisfaction with swiftly rotating shifts. *Occup. psychol.* 41 (1967) 85—107.
103. WEDDERBURN, A. A. I. *Studies on shiftwork in the steel industry.* Herriot-Watt University, Edinburgh 1975.
104. WILLIAMS, H. L. and WILLIAMS, C. L. Nocturnal EEG profiles and performance. *Psychophysiology* 3 (1966) 164—175.
105. WILLIAMS, R. L., AGNEW, H. W. JR. and WEBB, W. B. Sleep patterns in young adults: An EEG study. *Electroenceph. clin. neurophysiol.* 17 (1964) 376—381.
106. WILSON, W. P. and ZUNG, W. W. K. Attention, discrimination and arousal during sleep. *Arch. gen. psychiatry* 15 (1966) 523—528.
107. WITKIN, H. A. and LEWIS, H. B. *Experimental studies in dreaming.* Random House, New York. N. Y. 1967.
108. WYATT, S. and LANGDON, J. N. *Fatigue and boredom in repetitive work* (Medical research council, industrial health

research board, report no. 77). His Majesty's Stationery Office, London 1937.
109. WYATT, S. and MARRIOTT, R. Night work and shift work. *Br. j. ind. med.* 10 (1953) 164—172.
110. ZARCONE, V. and DEMENT, W. Sleep disturbances in schizophrenia. In: A. KALES (ed.), *Sleep physiology and pathology*. Lippincott, Philadelphia, Pa. 1969, pp. 192—199.

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