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New challenges for the organization of night and shift work

Proceedings of the XIII International Symposium on Night and Shift Work, 23—27 June 1997, Finland

guest editors *Mikko Härmä, Jane Barton, Giovanni Costa, Ken Greenwood, Peter Knauth, Friedhelm Nachreiner, Roger Rosa and Torbjörn Åkerstedt*

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XIV International Symposium on Night and Shift Work: Shift Work in the 21st Century

13–17 September 1999 (Wiesensteig, Germany)

Organizer: Department of Ergonomics, Institute of Industrial Production, University of Karlsruhe, under the auspices of the Scientific Committee on Night and Shiftwork, International Commission on Occupational Health.

Topics: All original material on night and shift work is welcomed. Plenary lectures and poster sessions are planned on the following topics:

Innovative shift schedules (eg, flexible shift systems, part-time)
Alertness, performance, accidents
Shift work in the service sector (eg, hospital, transport, retail business, 24-hour society)
Shift work and health
Interindividual differences (eg, female/male, young/old shift workers)
Biological adjustment (eg, bright light, melatonin)
Computer-aided time scheduling

Who should participate: Researchers and experts on occupational health and safety are encouraged and invited to attend. This interdisciplinary symposium welcomes basic and applied studies related to night and shift work in the medical, biological, behavioral, social and economic sciences.

Dates and venue: 13-17 September 1999 (Monday to Friday) in Haus Lämmerbuckel in Wiesensteig, Germany, a beautiful international training and communication center set in the idyllic landscape of the Swabian mountains.

Organizing Committee: Prof. Dr. Peter Knauth (chair), Dr. Sonia Hornberger, Heidi Dolde (secretary)

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Important deadlines: 31 March 1999 (abstracts), 31 May 1999 (notice of acceptance, instructions for preparing the manuscripts and posters), 30 June 1999 (early registration)

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New work times are here — are we ready?

The rapid changes taking place in current worklife has increased the diversity and amount of irregular workhours. In developed countries like Finland, the current prevalence of worktime models other than regular day work is about 25% (1). At the same time, the average number of weekly workhours and overtime has increased in many sectors. Although night and shift work has been acknowledged as an occupational health and safety problem since the prohibiting of women's night work (contemporary) in many European countries after the International Congress in Bern in 1906, the most recent trends in extended and irregular workhours have given birth to new concerns.

The new concerns are basically due to the extension of operating and service hours leading to more night and shift work. The factors behind the current change in worktimes are related to increased globalization, competition, and fluctuations in demand, all of which force firms to organize workhours more efficiently. The use of new technology and changes in the economy and the labor market have speeded up the process. Workers, on the other hand, give more value to longer vacations nowadays, favoring worktimes which promote the use of leisure time. As a result, the 8-hour workday has almost been relegated to history, together with traditional rigid shift systems. We are facing more complex and diversified worktime models that balance between the needs of the company and the needs of the workers. Whether the change taking place in work organization will result in healthy and safe work schedules should be questioned.

Together with the increase in night and shift work, simultaneous trends towards longer workhours in new expert groups of workers are appearing for public and private organizations. The process is related to the differentiation of the labor market with the formation of such new groups as highly educated experts, consultants, and project leaders — and, on the other hand, a marginalized sector of the population that is partly or permanently unemployed (2). In a recent survey representing evenly the entire working-age population of Finland, 24% of the sample population worked 50 hours a week or more (3). The top was probably achieved in Japan in 1989, when the weekly worktime of 24% of all the workers exceeded 60 hours – without regard for the time needed for the commute to and from work. This was also the time when *karoshi*, sudden cardiovascular death related to extensive overwork, became public knowledge. Current worklife presupposes high commitment, which, together with the increased pace and flow of work, creates pressure for high performance and, as a consequence, longer workhours. The use of portable computers and mobile phones has also given more options for working practically anywhere at any time.

New worktimes are here. But are we ready? How much do we really know about the health and safety effects of shift work and the effects of new worktime models on psychosocial health and well-being? Have society, firms, and employers acknowledged the possible health and safety hazards? Do we have feasible countermeasures to decrease the problems of unsocial and irregular worktimes?

"New Challenges for the Organization of Night and Shift Work" was the theme of the 13th International Symposium on Night and Shift Work, where these and other topical questions were debated. The Symposium was held in Finland in June 1997, and it was organized by the Finnish Institute of Occupational Health, under the auspices of the Scientific Committee on

Night and Shift Work, International Commission on Occupational Health. The present supplement of the *Scandinavian Journal of Work, Environment & Health* is a selection of peer-reviewed original contributions and invited papers presented at the Symposium. Since the scientific questions related to the worktime issues are a fascinating mixture of basic and applied, human and economic sciences, the supplement also follows an interdisciplinary line extending from laboratory studies to epidemiology and from chronobiology to sociology. Only the combination of different disciplines and views renders a comprehensive approach to the complex questions of irregular worktimes possible.

At least the basic mechanism for disturbed sleep and wakefulness during shift work is clear. The rigid endogenous circadian system of the body cannot adjust to the changing rhythm of rotating work. Since the human circadian clock, *suprachiasmatic nuclei*, are regulated by the environmental light-dark cycle, neither is it possible nor comfortable to adjust to permanent night shifts – inside society. Thus 40—50% of night and shift workers continuously complain of insomnia or insufficient sleep (4) and, what is even more important, most shift workers are severely sleepy during night and early morning shifts.

The occurrence of fatigue during night shifts is not surprising, but it is amazing how little attention society, business, and organizations have paid to it. Would we accept a bus or a train driver, or a nuclear power operator, responsible for the life of tens of thousands of people, to work in a drunken state every night? In a paper presented at the Helsinki Symposium, and published later in Nature (5), it was shown that, at the very end of the night shift, sleepiness responds to the effect of moderate alcohol consumption (1.0‰) for psychomotor performance. It should be remembered that this does not concern only a few "exceptional cases"; as a rule, every shift worker gets as sleepy at the end of a night shift if his or her circadian trough (occurring in the early morning hours) and a long time after wake-up (24 hours, as at the end of the first night shift if no naps have been taken before the shift) take place at the same time.

In light of this fact, it is not surprising that there is now much investigative evidence showing that fatigue due to night work increases incidents and accidents in industrial operations and nuclear power plants and that it contributes to virtually all modes of transportation disasters, including rail, marine, aviation, and motor accidents (6). In this issue, Hänecke et al (pages 41—46) analyzed 1.2 million accidents in the German manufacturing industry. An exponentially increasing accident risk was found beyond the 9th hour at work, the effect of which was accentuated in shifts with later starting times. In the United States, the total costs of fatigue-related accidents and loss of performance was estimated to be some 40 billion US dollars (7). In Finland, the total costs of sleep deprivation and sleep disorders to society were estimated to be about 5 billion Finnish marks in 1997 (8).

Irregular workhours may also be related to occupational health hazards other than fatigue and accidents — but the effects on chronic health are less well known. Earlier epidemiologic studies, done 20—50 years ago, linked night and shift work only to gastrointestinal diseases and symptoms. However, the "exposure" — total weekly worktime, shift systems, psychosocial factors — and the understanding of the pathophysiology of gastric disease have changed greatly since then, and whether current worktimes also induce similar risk for gastrointestinal diseases is not known. More epidemiologic research has focused recently on the relationship of shift work to coronary heart disease (CHD), and the best prospective studies indicate that the risk estimate for shift work is about 1.5 when compared with day work. Even if the relative risk is not high, the high prevalence of shift work itself (20% in this calculation) yields a population etiologic fraction of 7% and makes shift work one of the major work environmental factors related to cardiovascular disease (9).

The different mechanisms by which shift work could cause chronic diseases should be clarified. Whether the mechanisms are related to the circadian disturbance of specific gastrointestinal or hormonal functions, sleep deprivation, or some other factors would help to launch new practical research projects and to plan recommendations for optimal shift characteristics. For example, permanent night work seems to induce more sleep deprivation but less circadian disturbance than rapidly rotating shift schedules do. With peptic ulcer, some of the accelerating or effect-modifying factors of night work are related to the marked decrease in gastrointestinal motility and digestive enzyme secretion during the night shift (10). Peptic ulcer may also be aggravated by factors like altered sleep patterns, changes in adrenal secretory patterns, and changes in eating habits. The mechanisms for the increased risk of CHD are still open, but perhaps one of the most promising theories is related to the well-known decrease in fibrinolysis during the early morning hours. Recently, a serum lipid-modulating drug called gemfibrozil, which may also enhance fibrinolysis by the direct diminution of endogenous PAI-1 synthesis, was indirectly shown to decrease the CHD risk of shift workers more than that of day workers, although there were no baseline differences in serum lipids between the groups (11). Another mechanism for the increased risk of CHD in shift work could be related to the observed changes in postprandial glucose and lipid metabolism after a simulated workshift (12).

There is also growing evidence that shift work affects reproductive health, for example, in the form of an increased risk for spontaneous abortion (Nurminen, this issue, pages 26—32). Whether shift work increases breast cancer risk should also be studied. Significant excesses of breast cancer have been shown for at least some shift working populations, for example, nurses and airline cabin attendants (13). It is well known that both bright room light (during night shifts) and bright environmental light (during days) have a major impact on the melatonin secretion of night workers. On the other hand, melatonin has been shown to induce a constant production of prolactin and estrogen, the total lifetime exposure of which (bioavailable estrogens) is related to the risk of breast cancer (13).

There thus seems to be no lack of relevant research issues related to the health and safety aspects of unsocial and irregular worktimes. Since it is clear that we are facing a major occupational health and safety problem, research should also be focused on the possibilities to prevent the observed difficulties. It is well known that many characteristics of shift schedules (like the speed and direction of rotation, the length of shifts, timing of days off) greatly influence the fatigue, performance, and well-being of workers. The significance of these shift system characteristics, the possible existence of other, unknown characteristics, and the interactions of the factors concerning health and safety are still unknown to a great extent.

In Europe, the application of the new *Directive of Working Time* (93/104/EC) has enhanced possibilities for local agreements on worktimes and has thus made the growth of different shift systems possible. The increase of new, occasionally hazardous shift systems creates a need for scientific evaluation and follow-up with respect to the effects on health, safety, performance, well-being and productivity. A major effort is currently being made to study the effects of long workshifts and compressed workhours, as indicated also by six new studies in this issue. Since intervention studies in firms are difficult to conduct, many answers still have to wait. Some other practical questions, like the suggested long-term advantages of 6-hour and part-time systems on the health and work ability of aging workers, are also still waiting for answers.

From the employees' point of view, the advantages of the new worktime models on leisure time and psychosocial factors are often the most important, while the employer is most interested in increasing production by extending operating hours or in adjusting production to fluctuations in demand by adding flexibility to worktime. Since the effect of a new worktime model on psychosocial factors is often critical for the approval of the system, scientific research on the social dimensions of the worktime models is necessary. As reviewed by Nachreiner in this issue (pages 33—40), the existing literature on the individual and social determinants of shiftwork tolerance is still surprisingly inconclusive due to deficiencies in study designs, concepts, the psychomotoric properties of measuring instruments, and even problems with statistical treatment. In that respect, the quality of the scientific literature should be improved by increasing the critical evaluation and review of new studies, their design and methods.

We will never be rid of unsocial and irregular workhours. To improve the situation, new guidelines for the medical surveillance of shift workers have to be developed (Costa, in this issue, pages 151—155), and new information on practical countermeasures for night and shift workers are needed. These countermeasures include factors such as the use of optimal sleeping strategies (Åkerstedt, in this issue, pages 16—25), the use of bright light to synchronize shift workers' circadian rhythms (Foret et al, in this issue, pages 115—120) and napping. The use of short naps during breaks in night shifts seems to decrease fatigue and attention lapses at work, as shown recently for process operators in a paper presented in the Helsinki Symposium (14). In fact, planned napping during work breaks seems to be one of the most promising but also most challenging countermeasures with which to reduce sleepiness on night shifts. There are still many prejudices against "sleeping while at work", but they should be considered in light of the present alternative of workers falling asleep unintentionally, as shown by some on-site studies.

In conclusion, unsocial and irregular workhours seem to be a rapidly growing occupational health and safety risk that is closely bound to employee performance and production, but also to private and public safety. New research on the chronic health effects and their mechanisms, work scheduling questions, and countermeasures to alleviate the observed problems is urgently needed. Combined with the general trends of late leisure-time activities, both at home and outdoors, there are some serious concerns that society as a whole is becoming sleep deprived.

References

1. Kauppinen T, Aaltonen M, Lehtinen S, Lindström K, Näyhä S, et al, editors. Työ ja terveys Suomessa [Work and health in Finland]. Helsinki: Finnish Institute of Occupational Health, 1997. English summary.
2. Johansson AL. Introductory remarks on social responsibility and the future of the labor market. Scand J Work Environ Health 1997;23 suppl 4:7—9.
3. Kalimo R, Toppila S. Työuupumus Suomen työikäisellä väestöllä [Burn-out among the Finnish work-aged population]. Helsinki: Finnish Institute of Occupational Health, 1997.
4. Härmä M, Tenkanen L, Sjöblom T, Alikoski T, Heinsalmi P. Combined effects of shift work and life-style on the prevalence of insomnia, sleep deprivation and daytime sleepiness. Scand J Work Environ Health 1998;24:300—307.
5. Dawson D, Reid K. Fatigue, alcohol and performance impairment. Nature 1997;388:235.
6. Dinges D. An overview of sleepiness and accidents. J Sleep Res 1995;4 suppl:4—14.
7. Leger D. The cost of sleep-related accidents: a report for the National Commission on Sleep Disorders Research. Sleep 1994;17:84—93.
8. Hyyppä M, Kronholm E. Unettomuus ja univaje tulevat kalliiksi [Insomnia and sleep deprivation are expensive]. Sosiaalivakuutus 1997;1:34—7.
9. Åkerstedt T, Knutsson A. Cardiovascular disease and shift work. Scand J Work Environ Health 1997;23:241—2.
10. Vener K, Szabo S, Moore J. The effect of shift work on gastrointestinal (GI) function: a review. Chronobiologia 1989;16:421—39.
11. Tenkanen L, Sjöblom T, Kalimo R, Alikoski T, Härmä M. Shift work, occupation and coronary heart disease over 6 years of follow-up in the Helsinki Heart Study. Scand J Work Environ Health 1997;23:257—65.
12. Hampton S, Morgan L, Lawrence N, Anastasiadou T, Norris F, Deacon S, Ribeiro D, Arendt J. Postprandial hormone and metabolic responses in simulated shift work. J Endocrinol 1996;151(2):259—67.
13. Welp EA, Weiderpass E, Boffetta P, Vainio H, Vasama-Neuvonen K, Petralia S, Partanen TJ. Environmental risk factors of breast cancer. Scand J Environ Health 1998;24(1):3—7.
14. Sallinen M, Härmä M, Åkerstedt T, Rosa R, Lillqvist O. Promoting alertness with a short nap during a night shift. J Sleep Res. In press.

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International regulations on the organization of shift work

by Kazutaka Kogi, Dr Med Sc[1]

Kogi K. International regulations on the organization of shift work. *Scand J Work Environ Health* 1998;24 suppl 3:7—12.

Changes since the early 1990s in international regulations on night and shift work were reviewed, including changes in complex shift systems, greater flexibility, increased female participation in night work and attention to health effects. Recent international regulations have focused on (i) a broadened scope of regulatory measures treating both genders equally, (ii) multifaceted protection, and (iii) consultation weighing many aspects of job design. The application of these international regulations depends on national laws and practice, with possible derogations. It calls for local support measures, including (i) guidelines for enterprise-level consultations on shift schedules, (ii) promotion of health and safety measures, and (iii) participatory strategies for locally adjusted shiftwork arrangements and social support.

Key terms European directives, female night workers, flexibility, international standards, night work, night workers, participation, resting time, safety and health protection, shift schedules.

Changes in international regulations on night and shift work took place in the early 1990s. These changes reflect the renewed interest in shorter workhours and flexible worktime arrangements (1). Most new worktime patterns, deriving from the diverse business demands and worker preferences of today, are associated with changes in approaches to night and shift work (2—4).

Related trends in shift work include (i) increasingly complex shift systems, (ii) greater flexibility in covering extended operating hours, (iii) increased participation of female night workers, and (iv) attention to health effects (4, 5). These trends are more clearly seen in most industrialized countries, but they are more or less common also in many developing countries. It is of particular interest that the trends are based on the changing views of how to regulate night work (1).

To understand this problem, we can look at the following 3 aspects emphasized by recent international regulations on night and shift work: (i) a broadened scope of regulatory measures treating both genders equally, (ii) multifaceted protection, and (iii) consultation weighing many aspects of job design.

Scope of recent international regulations

The international debate leading to new international labor standards (ILO convention no 171 and ILO recommendation no 178) concerning night work has broadened the scope of regulatory measures to apply to both genders and to nearly all occupations (1). This broadened scope has been made necessary, above all, by the increasingly complex forms of shift work patterns that are apparent in all industries and in both industrialized and developing countries.

Complex worktime arrangements derive from both social and economic changes. Greater flexibility in shift work arrangements, increasingly dominant in industrialized countries, relate to diverse business demands resulting from competitive pressures and rapid technological change and workers' preferences about the timing of work (4, 6). The appearance of complex combinations of different categories of worktime arrangements, such as a combination of full-time semi-continuous shifts and part-time weekend shifts, is linked with the decoupling of business hours from individual workhours. Many

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innovative patterns are associated with shorter workhours and diversifying career needs.

Similarly diversifying patterns have come to be seen also in many developing countries. For example, in Thailand, various types of shift systems are found, particularly in manufacturing industries, as shown in table 1 (7). Of the 96 systems adopted by the enterprises surveyed, 10 were continuous systems with varied cycle periods, half of them rotating anti-clockwise. There were 84 systems, or 88%, operating on a semi-continuous or discontinuous basis. Among these semi-continuous or discontinuous systems, 72 had only 1 weekly holiday. Shifts were alternated every week among most of these semi-continuous or discontinuous systems, but there were 9 systems in which the shifts were rotated every 2 weeks. Of about one-third of all the factories having discontinuous systems, half had double day shifts and the other half had day and night shifts separated by an interval of a few hours, which are often filled by overtime work. Various continuous and discontinuous systems are also spreading to the service sector in developing countries.

These trends have resulted in fundamental changes in the concept of night work and that of night workers (1). The changes are apparent in the definitions used in convention no 171 of the International Labour Organisation (ILO). It should be noted that the new definitions were developed through an intense procedure involving governments, employers and workers, and they reflect recent shiftwork research. Thus attention is drawn to the 2 views of night work indicated in table 2. The traditional view defines night work as any work during prescribed hours, thus referring to specific night hours for restriction or compensation purposes. This view, typically represented by the Night Work (Women) Convention (no 89) of 1948, has been seen in many national regulations that prohibit night work for women or young persons. The more recent view on night work focuses on night workers who do night work substantially and therefore need particular protection. The new view is thus linked with the safety and health of night workers and other measures required for improving the quality of their worklife.

The specific measures provided by convention no 171 cover a broad range, as shown in the upper part of table 3. They include health assessment, appropriate medical advice, transfer to day work, maternity protection, compensation in the form of worktime or benefits, appropriate social services, and consultation of concerned workers' representatives. These measures apply to night workers who work at night to a substantial degree. Night is defined as a period of at least 7 consecutive hours, including the interval from 0000 to 0500, to be determined by the competent authority after consultation with the most representative organizations of employers and workers or by collective agreements. This is shorter than the period in earlier standards, such as convention no 89. Night workers are employed persons whose work includes a substantial amount of night work exceeding a specified limit.

Additional measures suggested by recommendation no 178, shown in the lower part of table 3, can be a good basis for designing shift schedules. They include limits on normal workhours, avoidance of overtime and of double shifts, minimum rest periods of at least 11 hours between shifts, breaks, social services, transfer to day work in special situations, training opportunities, early retirement, and others. The limit of 8 hours for normal hours of work in any 24-hour period in which night work is performed does not apply when work includes substantial periods of mere attendance or stand-by, when alternative schedules give workers at least equivalent protection or in cases of exceptional circumstances.

Table 1. Different shift systems adopted in a survey of the manufacturing industries in Thailand.

Shift system	Days off per week			Total
	One	Two	Three	
Fixed system	2	-	-	2
Discontinuous system[a] (2-team, 2-shift)				
Without between-shift interruption	13[a]	1	1	15
With between-shift interruption	15[b]	3	1	19
Semi-continuous system[c]				
2-team, 2-shift	2	-	-	2
3-team, 3-shift	42[d]	4	2	48
Continuous system				
4-team, 3-shift	-	-	-	10

[a] Of the 13 systems for "without between-shift interruption" and 1 day off per week, there was 1 system in which the shifts rotated every 2 weeks.

[b] Of the 15 systems for "with between-shift interruption" and 1 day off per week, there were 4 systems in which the shifts rotated every 2 weeks.

[c] All the discontinuous and semi-continuous systems except those explained had weekly rotation of shifts.

[d] Of the 42 systems for "3-team, 2-shift" and 1 day off per week, there were 4 systems in which the shifts rotated every 2 weeks.

Table 2. Two views of night work in international regulations (taken from reference 1). (ILO=International Labour Organisation)

	Traditional view (ILO convention no 89 and others)	More recent view (ILO convention no 171)
Main purpose	Prohibition of night work for a specific category of workers	Improvement of conditions of work for night workers
Scope	Women and industry	Both men and women and all branches and occupations with a few limited exceptions
Definition of night	Specified period (at least 11 consecutive hours including at least 7 consecutive hours between 2200 and 0700)	Specified period (at least 7 consecutive hours including the interval between 0000 and 0500)
Focus of attention	Any work during the prohibited period	Workers performing a substantial amount of night work

Table 3. Specific core measures required for night workers by the ILO convention concerning night work (no 171) and the recommendation concerning night work (no 178), both published in 1990. (ILO=International Labour Organisation)

Area	Measures to be taken
Convention no 171	
Health assessment or advice	Health assessment and advice on how to reduce or avoid health problems associated with night work (i) before assignment, (ii) at regular intervals, and (iii) when experiencing work-related health problems
Transfer to day work	Transfer to similar job when certified as unfit for night work
Maternity protection	An alternative to night work before and after childbirth for at least 16 weeks and for additional periods necessary during pregnancy, with protection as to no dismissal and income
Compensation	Compensation in the form of worktime, pay or benefits
Social services	Appropriate social services
Consultation	Consultation on the details of schedules, health and social services before work schedules involving the services of night workers
Recommendation no 178	
Hours of work	Normal hours of work not exceeding 8 in any 24-hour periods; avoiding overtime and no overtime in occupations involving special hazards or heavy physical or mental strain; no consecutive full-time shifts; at least 11 hours between shifts
Maternity	Assignment to day work as far as possible at any point during pregnancy
Social services	Services to reduce transport time, improve quality of rest, enable workers to obtain suitable meals and beverages, overcome constraints on family duties or cultural and recreational activities
Training	Benefit from training opportunities, including paid educational leave like other workers
Transfer	Special consideration for transfer to day work for workers with a given number of years of night work
Retirement	Special consideration for voluntary early or phased retirement

These standards were adopted with a clear intention to apply them to both men and women. Together with these standards, ILO adopted the protocol of 1990 to the *Night Work (Women) Convention* (no 89) of 1948, under which national regulations can permit night work by women in industry under defined conditions. Variations can be introduced to the duration of the night period defined by convention no 89, which mentions a period of 11 consecutive hours. Exemptions can also be introduced to the prohibition of night work by women, while the conditions for introducing the variations or exemptions are strictly defined and should include specified protection for female workers during a period before and after childbirth. In this way, the protocol allows some countries to reconcile their desire to protect women with considerations of equality of opportunity and competitiveness.

These new international labor standards express a general consensus that specific, multifaceted measures should be taken for workers performing night work to a substantial degree, irrespective of gender. A related background view relates to the recognition of the need to have greater flexibility in organizing night and shift work (4, 6). The increased emphasis on the safety and health protection of night workers is of special interest, as the consensus is apparently built with the understanding that flexible schedules should not compromise safety and health.

Table 4. Core provisions of European Council directive 93/104/EC.

Area	Measures to be taken
Organization of work	
Daily rest	A minimum daily rest period of 11 consecutive hours per 24-hour period
Breaks	A rest break where the workday is longer than 6 hours
Weekly rest period	A minimum uninterrupted rest period of 35 hours per each 7-day period
Weekly worktime	Maximum workhours of 48 per week
Annual leave	At least 4 weeks of paid annual leave
Night work	
Length of night work	Average 8 hours in any 24-hour period
Health assessment	Free health assessment before assignment and at regular intervals
Transfer to day work	Transfer whenever possible to day work when suffering from health problems recognized as being connected with night work
Other night work matters	Certain guarantees for workers incurring risks to their safety and health linked to night-time work; notification to the competent authorities about regular use of night workers
Night and shift work	
Safety and health	Safety and health protection appropriate to the nature of night work; appropriate protection and prevention services or facilities with regard to the safety and health equivalent to those for others
Pattern of work	Account taken of the general principle of adapting work to workers, with a view, in particular, to alleviating monotonous work and work at a predetermined work rate, and of safety and health requirements, especially regarding breaks during worktime

Review of the European directive

The European directive 93/104/EC also emphasizes the need for multifaceted protection. This emphasis is in accordance with recent national regulations that have been developed in some European countries to consider the need for flexibility and pluriformity (8). The core provisions of the directive are simple and clear, as shown in table 4. As in the case of international labor standards, the directive provides specific measures relating to the scheduling of shifts and resting time, safety and health protection, and related services (8, 9). They include a minimum daily rest period of 11 consecutive hours, one 35-hour period off every 7 days, maximum workhours of 48 per week and 4 weeks of paid annual leave, all of which apply to both day and shift workers. For night workers, the directive provides an average of 8 hours in 24, a maximum of 8 hours in hazardous or physically or mentally straining jobs, health assessment before starting and at regular intervals, transfer when suffering from relevant health problems, appropriate safety and health protection and prevention services, and facilities for safety and health equivalent to other times.

It is noteworthy that the provisions of the European directive are extensively qualified by definitions of reference periods (time periods over which the limits in the directive should be achieved) and derogations. The reference periods are essentially 14 days for the weekly rest period, 4 months for maximum weekly worktime and, for the length of night work, a reference period defined after consultation of the 2 sides of industry or by collective agreements or agreements concluded between the 2 sides of industry at the national or regional level. The derogations, or permissible exceptions, appear to apply to most of the provisions except the health checks and the provision of safety and health facilities. They can be based on a wide variety of grounds related to jobs (eg, security guards), industries (eg, press, radio, television) or circumstances (eg, each time the worker changes shift and cannot take daily or weekly rest periods between the end of 1 shift and the start of the next).

Clearly, the European framework is an important step in setting common minimum standards in the organization of shift systems. In many European countries, the directive is leading to revisions of existing national laws (8). This is important as the new revisions reflect the spreading recognition of the need for protection of shift workers in a multifaceted manner.

Of particular interest is the EC court review of directive 93/104/EC questioned by a member country. The United Kingdom, arguing that the directive is more of a social measure and so should have required unanimous approval, has not accepted it, and it has appealed the case in the European court. This was an important hearing. The EC court, in its judgment on 12 November 1996, confirmed the need for the regulating measures in the EC directive (9). The judgment took into consideration the contribution of these regulatory measures to the improvement of the health and safety protection of night and shift workers (5).

Table 5. Problems and the change process in 26 cases of shift system changes (taken from reference 3).

	Cases (%)
Problems	
Extension of business	73
Flexibility at work	77
Shorter workhours	58
Engagement of part-timers	62
Reorganization of work	88
Change process undertaken	
Group study of problems	88
Data analysis of surveys, etc	54
Planning scheduling options	85
Collective consultation	100
Training about shift work	42
Test periods of new schedules	65

Implications for shiftwork research

An important argument for these regulations is the need for health and safety protection of "night workers" performing a substantial amount of night work. The argument is used for provisions about normal hours of work, rest periods (at least 11 hours between shifts, etc), health services, transfer to day work, maternity protection, social services, and consultations.

The need for international regulations is further justified by the fact that the views of employers and workers are often conflicting about the introduction of night and shift work (4, 6, 10). Trade unions insist that economic reasons alone should not be a sufficient justification for introducing shift work and that shift work could be harmful to the health of workers and disruptive to their family and social life. Employers maintain that, while certain workers may have difficulty, there are no general harmful effects and that night and shift work have positive effects on employment, economic growth and the standard of living. Thus many reports show that, when shift schedules are applied, several options are compared to find a workable pattern. It should also be noted that there are trade-off situations in which workers tend to accept flexible operating hours in return for shorter hours or better services. International regulations cannot guide employers and workers in details of these various options, but nevertheless they can present minimum conditions under which these options should operate.

Reports from different countries show that this change process was more successful when it was provided with concrete support. Such support is useful, particularly when it can provide employers and workers with facts and data about how to select shift schedules, assist in their operation, and help promote participatory development of potential options for informed bargaining. As indicated in table 5, examples of changing shiftwork arrangements reported in an ILO survey (3, 6) show that the main problems dealt with in collective bargaining were common. The 26 cases concerned the introduction of combined systems or the application of flexible hours of work or job-sharing schemes. Combined systems meant a combination of different categories of systems, such as a combination of a full-time shift system and a part-time system. In the majority of these cases, scheduling changes had been proposed as a means of extending business hours and increasing flexibility at work. Part-time schemes or the shortening of workhours were also of concern in the majority of cases. It is interesting that, in most instances, it became necessary to reorganize the work in accordance with the shiftwork changes.

As table 5 shows, the main steps taken in dealing with these problems were also complex. Consultation between management and workers took place in all cases, and a group study of the existing situation was undertaken in 88% of the reported cases. An analysis of data specifically gathered for such group study was done in more than half of the cases. The planning of available options was also a common step. Training sessions for managers and workers were organized in 42%, and 65% had test periods for a new scheme.

The support for this participatory process of changing shift systems will need to be developed. Such support is necessary in both industrialized and developing countries, where the changing process is similarly complex. In the aforementioned survey in Thailand, problems arising from shift work in the 93 enterprises concerned a wide range of managing issues (7). Examples included the sleepiness of workers (mentioned by 38%), machine repair at night (25%), higher absenteeism (24%), nonappearance of workers (21%), lower productivity on unfavored shifts (17%), higher sickness rates among shift workers (15%), and higher accident rates (9%). It is clear that, for improving shiftwork conditions, these enterprises require direct support concerning locally adapted shift system changes and managing measures, and also information on well-informed consensus building in the participatory process.

Furthermore, international regulations are often directly relevant to the management of shift work (11—13). The minimum requirements for shift schedules seem particularly important (1, 14). This is exemplified by frequent resort to double full-time shifts in many countries where these international regulations have yet to be applied. Table 6 gives examples of double and triple shifts worked during a 10-day period in a glass factory. It is striking that such doubling of shifts was worked very frequently, resulting in the obvious overstrain of workers. The need for applying the minimum international standards, as suggested by recommendation no 178 or the European directive, is apparent.

The application of these international regulations depends on national laws and practice, with possible derogations. It calls for research into (i) improved work schedules, including the need to respond to increasing flexibility, (ii) practical measures for multifaceted protection, and (iii) participatory processes of consultation and worker involvement. The future research topics suggested on the basis of these 3 aspects are listed in table 7. In relation to work schedules and flexible patterns of shift work, research is needed to develop scheduling guides, appropriate resting conditions, and work organization. With respect to multifaceted protection, safety and health measures are important topics for research. Among these measures, particular attention is drawn to health assessment and advice about coping measures, work redesign for making night and shift work safer, social support, and maternity protection. In addition, research will be needed to develop direct support for management-worker consultation and for developing an action-oriented participatory strategy that takes into account the relevant aspects of international regulations on shift work.

Table 6. Double shifts during a 10-day period among 3-shift workers in a glass products factory in Thailand, from a case report in 1994. [M = morning shift (0700—1500), A = afternoon shift (1500—2300), N = night shift (2300—0700), H = day off, A+N and M+A = double shifts of 16 hours, M+A+N and N+M+A = triple shifts of 24 hours]

Worker	Shift schedule									
Female, age 24, married	A	N	N	H	H	H	M	M	M	M
Female age 27, married	A	H	A	A	H	H	M	M	M	H
Female, age 28, married	A+N	N	A+N	A	M	M	M+A	A+N	A+N	M
Female, age 32, married	M+A	M+A	M+A	M+A+N	N	N	H	H	M	M
Female, age 35, married	N	N	A	M	M+A	M+A	A	A	M	M
Female, age 20, single	M	M	A	A	N	N	H	H	M+A	M
Female, age 34, single	A	A	N	N	H	H	M	M+A	M+A	M+A
Male, age 20, married	N+M+A	N	H	H	M	M	A	A	N	N
Male, age 25, married	A	A	N	N	H	H	M	M	M	M

Table 7. Future research topics for night and shift work in relation to the development of international regulations.

Area	Development of international regulations	Future research topics
Work schedules and flexibility	Hours of work and overtime Rest periods and breaks Transfer to day work	Scheduling guides Resting conditions Work organization suited to individual career
Multifaceted protection measures	Health services for night workers Safety measures Social services Maternity protection	Health assessment and advice on coping Work redesign Social support Maternity protection
Consultation and worker involvement	Consultation about work schedules Rights of workers	Consultation support Participatory strategy

Concluding remarks

Recent developments confirm the need for upgrading and widely applying international regulations, especially in respect to their contribution to improving the health and safety protection of night and shift workers.

It is important to know the limitations of these international regulations and concentrate on scheduling strategies and health-related measures and on the participation rights of workers. As discussed, the application of these international regulatory measures depends greatly on national laws and collective agreements. It calls for local support measures including (i) guidelines for enterprise-level consultations on shift schedules, (ii) promotion of health and safety measures, and (iii) participatory strategies for locally adjusted shiftwork arrangements and social support. It is vital to promote these support activities on the basis of existing international standards and to develop shift schedule guidelines, health and safety protection services, and, above all, participatory strategies for locally adjusted, well-informed consensus building towards more appropriate arrangements of shift work under different national conditions.

References

1. Kogi K, Thurman JE. Trends in approaches to night and shiftwork and new international standards. Ergonomics 1993;36:3—13.
2. International Labour Office (ILO). Flexibility in working time. Geneva: ILO, 1986. Conditions of work digest, vol 5 no 2.
3. International Labour Office (ILO). The hours we work: new work schedules in policy and practice. Geneva: ILO, 1990. Conditions of work digest, vol 9 no 2.
4. Kogi K. Increasing flexibility in shiftwork arrangements. Work Stress 1995;9:211—8.
5. Kogi K. Job content and working time: the scope for joint change. Ergonomics 1991;34:757—73.
6. Kogi K, Di Martino VG. Trends in the participatory process of changing shiftwork arrangements. Work Stress 1995;9:298—304.
7. Osiri P, Sakai K, Kawakami T, Chaikittiporn C. A survey on shift work systems in Thailand. J Sci Lab 1994;70(3, part II):1—8.
8. Wedderburn A, editor. Statistics and news. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1996. Bulletin of European studies on time, no 9.
9. Spotlight. The working time directive. Ind Rel Law Bull 1996;558:2—10.
10. Bosch G. From 40 to 35 h: reduction and flexibilization of the working week in the Federal Republic of Germany. Int Labour Rev 1990;129:611—27.
11. Folkard S, Monk TH, editors. Hours of work: temporal factors in work-scheduling. Chichester: Wiley, 1985.
12. Corlett EN, Queinnec Y, Paoli P. Adapting shiftwork arrangements. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1988.
13. Wedderburn A. Negotiating shorter working hours in the European Community. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1989. Bulletin of European shiftwork topics, no 1.
14. Thurman JE. Working time. In: Blanpain R, editor. Comparative labour law and industrial relations in industrialized market economies. Deventer: Kluwer, 1990:133—66.

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Innovative worktime arrangements

by Peter Knauth, Dr-Ing[1]

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New worktime models can be introduced from an employer's point of view for many reasons. They can extend operational time for better utilization of expensive equipment, provide customer-oriented service hours, adjust operational time to the varying needs of personnel, adhere to a given operational time despite a reduction in workhours, avoid dismissals, or improve job attractiveness for qualified personnel. On the other hand, there are also many reasons for changing traditional worktime models from an employee's point of view. For example, new models can help fit private needs to occupational demands, change worktime according to life's phases, provide more autonomy for the organization of worktime or the choice of worktime model, and allow for reduced capacity due to illness or age. The paper primarily presents examples of innovative worktime models (eg, annual worktime, time-autonomous group, variable worktime, choice between different worktime models) but also discusses the possible negative effects of new worktime arrangements.

Key terms annual worktime, condensed worktime, flexitime, functional flexitime, optional worktime, part-time, time-autonomous work group, variable worktime.

This paper is not restricted to shift systems. It refers to all kinds of innovative worktime models. A model will be called "innovative", if the following prerequisites are fulfilled: (i) it has noteworthy consequences for the company and the employees and (ii) resistance to change has to be overcome.

We have followed changes in worktime arrangements in many companies in industrial and service sectors. Always, when a new model is discussed that differs substantially from the arrangements in use, fears, doubts, and even resistance are expressed not only by the employees, but also by unions and middle management. If the new model is to be highly accepted, a compromise must be reached that offers improvements for both the company and the employees.

Reasons for introducing new worktime models

There are many reasons for introducing new worktime models both from an employer's and an employee's point of view. First, employers want to adjust operational time to the varying needs of personnel. There is a fluctuating need for personnel if customer demand varies, if absent personnel has to be replaced, or if machinery breaks down. The unpredictable short-term variation of work demands is the most difficult case to cope with. Second, not only in the service sector, but also in industry, service hours have to be adjusted to the needs of internal and external customers. Third, for a better utilization of expensive equipment, operational time has to be extended. Fourth, although weekly workhours have been reduced in the last decade, employers still want to adhere to old operational times. Fifth, for an employer, the change between dismissals and new employment of an essential part of the staff may be very expensive and problematic because of the loss of know how. For example, during a year with reduced customer demand, it may switch from full-time employment to part-time work (eg, the German VW AG switched from 36.0 to 28.8 hours per week for all employees). Sixth, in the future, it will be more difficult to attract, retain, or motivate highly qualified personnel. Therefore the wishes of these employees have to be taken into consideration more than before.

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On the other hand, there are also many reasons from the employee's point of view for introducing new worktime models. For many gainfully employed women, who have to carry the main burden of child care and domestic work, it is very difficult to fit private needs with occupational demands. In Germany the opening hours of most kindergartens and primary schools are restricted to the morning. As the number of gainfully employed women increases, better solutions have to be found. However, also more and more gainfully employed men would like to have more time for their family, hobbies, and education. The wishes of men and women with respect to worktime are not constant over the whole of their worklife, but, instead, depend on life's phases. In the future, there could be more interruptions in worklife due to parental leave, additional training, sabbaticals, and the care of elderly or ill family members. If organizations want to be more flexible in the future and improve the motivation of their employees, they must begin to delegate responsibility to these employees. They also have to grant more autonomy concerning the organization of worktime or the choice of worktime model. Persons with a reduced work ability due to illness or age may prefer a shorter duration of work per day or week. As people are not machines, their performance varies over 24 hours. Morning types have an earlier circadian peak of performance than evening types. Therefore, it would be ideal if employees could adjust their worktime to their circadian type. The goal of the first introduction of flexitime in German industry was to reduce commuting time between home and workplace. Nowadays this goal could even be better achieved by telework.

Classification of worktime models

There are more than 10 000 worktime models in use all over the world. They can be classified roughly according to the following 4 main characteristics: duration,

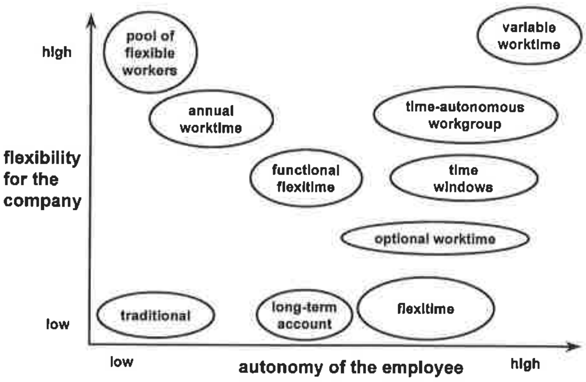

Figure 1. Flexibility for the company and autonomy of the employee with regard to some types of worktime models.

position, distribution, and autonomy. In Germany there has been a considerable reduction in the duration of, for example, weekly worktime in the last decade, down to 35 hours, for instance, in the metal and the printing industries. Parallel to this decrease, in some companies, the regular daily worktime has been increased to 9 hours. Concerning the 2nd characteristic, the position of worktime, an extension of operational times in the evenings, and an extension to Saturdays have also taken place. More and more companies are trying to reduce overtime and flexibly adjust worktimes to the varying needs of personnel. The characteristic "autonomy with regard to worktime" describes the influence of a worker on the duration, position, and distribution of his individual worktime.

Innovative worktime models

In figure 1, the 2 axes represent 2 dimensions of flexibility: flexibility for the company and autonomy for the employee. There are only a few types of worktime models mentioned in this figure. However, in reality the whole area between the y and x axes is covered by existing worktime arrangements.

In most cases, it is very difficult, or even impossible, to achieve high flexibility in a company without some flexibility being granted to the employees at the same time. A "pool of flexible workers" is an exception.

Annual worktime may be useful in coping with predictable seasonal variations. The customers of a company producing agricultural machines do not place many orders in the early months of the year (1). Therefore, the workers only work 7 hours per day, from Monday to Thursday, during the months of February to April. From May to December they work 8 hours each day from Monday to Friday. In a company in the textile industry the demand varies in short intervals. The employer may demand weekly worktime of between 32 and 48 hours at short notice (ie, only 1 week in advance). A producer of windows may even vary the operational time from 44 to 100 hours per week to meet the fluctuating demand (table 1). When this company changes from a 1- to a 2-shift system, temporary helpers are employed. At the beginning of the year a rough plan is made. It is fine-tuned, at the latest, on Wednesday for the next week. In exceptional cases even day-to-day flexibility can be practiced.

The 3 models mentioned are not innovative with regard to the autonomy of workers. To mitigate the problem of short notice, there are several solutions. At the beginning of the year the days off or free weeks can be classified in green, yellow and red. In red weeks a change from a day off to a workday is possible on short notice. In the yellow weeks a longer period of notification is necessary, or an emergency has to be defined. No change from days off is possible in green weeks (2). Another method is the long-term planning of additional shifts on Saturdays. If customer demand is unexpectedly low, these additional shifts can be cancelled. Of course, most of the workers prefer to have an unexpected day off than an unexpected workday. Some companies allow the building up of a time account in particular months of the year and recommend or dictate the reduction of the account in other months.

In an association of drivers the work load is highest in the months of May to August (figure 2). The employer wanted to fix a high weekly worktime during these months and a low one during the remaining months. However, the employees wanted to have more autonomy regarding their worktime. They proposed the model shown in figure 2, which was thereafter introduced. The employees are responsible for the work being done, but they decide themselves how long they work each day. They have the possibility to build up their time account by 40 hours each month from May to August and up to 160 hours per year.

Traditional flexitime is very common in Germany. However, the degree of flexibility for the employee in these arrangements currently fluctuates a great deal. Models differ, for example regarding the extension of the core time or the number of hours that can be transferred to the next month and the next year in the time account. More and more employers are experiencing reduced flexibility for the company, missing customer orientation on the part of the employees, and an inclination of some employees to hoard time even if there is not much work to do. The 2 solutions to this problem are to limit the autonomy of the employees or to delegate responsibility to the employee. Table 2 shows the "traffic light" model of a supplier to the automobile industry. In the food industry another company has introduced a similar model, but the limits are ± 80 and ± 160 hours.

In arrangements with functional flexitime the group of workers guarantees that customers will always find someone to contact or that the necessary service is available. The group decides who is present outside the core time. However everybody has to be at the workplace within the core time.

The highest possible flexibility for a group of workers is obtainable in "time-autonomous work groups". The superior delegates the responsibility for worktime completely to the group and the group guarantees that the work will be done on time. The model of a supplier to the automobile industry has the following characteristics: (i) self-directed teams of 20 to 50 workers, (ii) all workers (even in 2- and 3-shift systems) on variable worktime, (iii) group decision (according to customer demand) about when to work, (iv) financial incentive to the group as a reward for the economical use of worktime, (v) maximum operational time of 142.5 hours per week, and (vi) individual worktime variable between 18 and 48 hours per week. Before the introduction of the model the workers often had to work on Saturdays and got a supplement for the overtime. In the new model, overtime is compensated by days off. Although sales, and consequently production, have increased considerably, work on Saturdays has been reduced by about 50% simply because the groups have learned to use their worktime more economically.

The highest individual autonomy with regard to worktime is obtainable in models with variable worktime (ie, flexitime without any core time). In an informatics department in the chemical industry each employee decides himself when he works between 0600 and 2000 (table 3). However, German law sets a daily limit of 10 hours (only in exceptional cases are regular 12-hour shifts

Table 1. Stepwise increase of reduction in operational time according to varying demand in the course of the year (taken from reference 1).

Model	Operational time (hours/week)	Weekdays	Daily worktime (hours)
Dayshift	44	Monday-Friday	8.8
Dayshift	50	Monday-Friday	8.8
		Saturday	6
Extended dayshift	55	Monday-Friday	9.5
		Saturday	7.5
Extended dayshift	60	Monday-Saturday	10
Two shifts	88	Monday-Friday	8.8
Two shifts	100	Monday-Friday	8.8
		Saturday	6

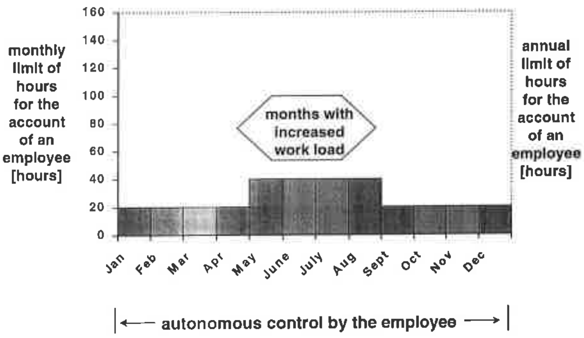

Figure 2. Variable annual worktime in the administration of an association of drivers.

Table 2. Flexitime with the "traffic light" time account of a supplier to the automobile industry (taken from reference 1).

Light	Significance
Green (≤40 hours)	Only the employee is responsible for the management of the time account
Yellow (>40-60 hours)	Employee and superior try to find a way back jointly to the "green light"
Red (>60 hours)	Only the superior decides, when the employee has to work or not to work

allowed). The employee is responsible for the work being done. A similar model has been achieved in the production of weighing machines. The workers decide when they work between 0630 and 1900. They can have ± 72 hours in their time account. The basis for such very flexible models is the culture of trust, which does not exist in many companies.

The last type of model in figure 1 is "optional worktime" which is characterized by the worker having the option to choose his worktime at regular intervals. For instance, in a Swedish company, each year the employees choose between 10 alternatives. They have to indicate which arrangement they like best and which is second best. With the help of an optimizing computer program the company tries to fulfill as many wishes as possible. In other companies the employees choose the amount of worktime (eg, 40%, 65%, 73%, 98% of a full-time worker) and the position of worktime (eg, every 2nd week, 9 months of the year or not during school holidays). The worktime model of a software house has the following options to choose from: (i) option between weekly worktimes (30—40 hours per week, steps: 30 minutes), (ii) option between annual holidays (20—40 days per year, steps: 1 day), and (iii) income increased or reduced in comparison with "normal" worktime (38.5 hours per week, 30 days of holiday per year). As the preferences of employees vary over their lifetime, optional worktimes are a good solution for adjusting worktime to different phases of life. Of course, a balance has to be found between the demands of the company and the wishes of the employees. The examples in table 4 fulfill this prerequisite. Another model of optional worktime has been explained elsewhere (3).

Table 3. Variable worktime in an informatics department in the chemical industry.

Characteristic	Delienation
Earliest start of worktime	0600
Latest end of worktime	2000
Maximum daily worktime	10 hours
Weekly worktime	37.5 hours
Annual worktime	1957.5 hours
Limits of the time account	+75 or –75 hours

Table 4. Examples of optional part-time work in the administration of a producer of biscuits

Work / leisure time	Part-time (%)
One week of work and 1 week off, plus 13 variable workdays per year	55
Three days of work per week and 2 days off	about 60
Two days of work per week fixed, 1 day of work per week flexible and 2 days off	about 60
Three days of work per week fixed, 26 days of work per year variable and rest off	about 70
Thirty weeks of work and 13 weeks off (flexible)	about 75
First quarter of the year 100% work, third quarter 60% work, fourth quarter 40% work and rest off	about 50

Table 5. Potential disadvantages of new worktime arrangements for the employees.

Characteristics of the worktime arrangement	Potential disadvantages
Shift work	Sleep deficits, increased fatigue, disturbances of appetite, gastrointestinal diseases, cardiovascular diseases, reduction of social contacts, disturbances of family life, increase of errors and accidents
No choice between different worktime models	Decreased satisfaction with worktime, no adaptation of worktime to changing preferences and needs in different phases of life or reduced work capacity
No autonomy concerning actual worktime, in particular short-term notice of worktime	Decreased satisfaction with worktime, difficulty to fit in child care and family life, difficulty to plan leisure-time activities, restriction of social contacts
Condensed worktime (per day, week, month)	Loss of sleep and increased fatigue, decrement in job performance, increase in accident risk, increased exposure to toxic substances or physical hazards, long-term health effects

Reservations regarding new worktime models

Although there are many possibilities for innovative worktime models, there are also problems and pitfalls. There are 4 main areas of concern which can occur separately or together, as shown in table 5. Many studies have shown the problems caused by different kinds of shift work [eg, review of Colquhoun et al (4)].

In addition to the problems caused by shift work the fact that one has an option or has no choice between different worktime models may have a strong influence on satisfaction with worktime (3, 5—9). If there is a discrepancy between preference and reality, satisfaction can be low and the feeling of burn-out high (8). The preferences and needs of employees in reference to worktime can vary considerably, depending, for example, on age, gender, personality, hobbies, and phase of life (3, 9—11). If work ability is reduced at the end of worklife or before, the redesigning of jobs, health promotion, training, and, last but not least, the reduction of worktime may help the employee cope with his or her problem (12).

The third area of concern refers to the short-term effects of flexible worktime models. If the autonomy of the employees is very low and if the employer often changes worktime at short notice, there will be negative effects on satisfaction with worktime (13). If the employee has no autonomy, it is very difficult to fit in child care and family life with occupational life. Furthermore, it is impossible to plan leisure-time activities with friends.

Rosa (14) has reviewed studies referring to extended workshifts. Some, but not all, of the studies have shown the negative effects listed in table 5. However, no well-controlled longitudinal studies exist which analyze long-term health effects. Folkard (15) has combined the data of 4 studies to analyze the trend of accidents over the course of a shift. Besides a secondary peak between the 2nd and 4th hour, he found an exponential increase in accidents with extended workshifts.

If a company wants to change worktime arrangements in any way or if a group of workers wants to test a new model, it is very important (i) to try to reach a winning situation on both sides (ie, a compromise which has advantages for both the company and the workers), (ii) to collect information about possible negative and positive effects on the company and the workers in connection with the new model under consideration, and (iii) to measure or determine these effects during a test period.

Concluding remarks

As innovative worktime models offer many opportunities for both employees and employers, all those concerned should have the courage to experiment with new models. However, each new worktime arrangement should be instituted cautiously with the participation of the workers and then evaluated carefully. The conclusion of Rosa (14) concerning extended workshifts is valid for all kinds of new worktime models. He states that "appropriate attention should be given to staffing levels, workload, job rotation, environmental exposures, emergency contingencies, rest breaks, commuting time, and social or domestic responsibilities" [p. 51]. Furthermore, certain minimum limits should be fixed by law to reduce any possible negative effects on employees (15).

References

1. Kutscher J, Weidinger M, Hof A. Flexible Arbeitszeitgestaltung: Praxishandbuch zur Einführung innovativer Arbeitszeitmodelle. Wiesbaden: Gabler, 1996.
2. Bosch G. Jahresarbeitszeiten — Flexibilität auch für Stammbelegschaften. J Sozialforschung 1996;36(1):3—21.
3. Hornberger S, Knauth P. Use of an optional working time model by shiftworkers: an intervention study. Presented at the XIII International Symposium on Night and Shiftwork, 23—27 June 1997.
4. Colquhoun WP, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Frankfurt a.M. (Berlin, Bern): Peter Lang Verlag, 1996.
5. DeHaan EG. Improving shiftwork schedules in a bus company: towards more autonomy. In: Costa G, Cesana G, Kogi K, Wedderburn A, editors. Shiftwork: health, sleep and performance. Frankfurt a.M. (Bern): Peter Lang Verlag, 1990:448—54.
6. Barton J, Smith L, Totterdell E, Spelten E, Folkard S. Does individual choice determine shift systems acceptability? Ergonomics 1993;36(1—3):93—9.
7. Büssing A. Sozialverträglichkeit von Arbeitszeitstrukturen — Untersuchungen eines neuen Konzeptes in der Krankenpflege. WSI Mitt 1993;3:145—63.
8. Baba VV, Jamal M, Fang Y. Discrepancy theory and shift work: a test of unique predictive capacity hypothesis. Presented at the 25th International Congress on Occupational Health, 16 — 20 September 1996.
9. Dirx J. Adaptation to permanent night work: the number of consecutive nights and motivated choice. Ergonomics 1993;36(1—3):29—36.
10. van Limborg C. Compensation for inconvenience: the utility of shift systems. Work Stress 1995;9(2/3):342—50.
11. Hornberger S, Knauth P. Interindividual differences in the subjective valuation of leisure time utility. Ergonomics 1993;36(1—3):255—64.
12. Goedhard WJA. Aging and work 3. In: ICOH Scientific Committee. Aging and work. The Hague: Pamans Offsetdrukkerij bv, 1996.
13. Ottman W, DeVol D, Schwarzenau P, Kylian H, Knauth P, Klimmer F, et al. Überlegungen zu einer ausgleichsorientierten Schichtplangestaltung bei Tätigkeiten mit unregelmäßigem Dienst, I: Vorschläge zur Neugestaltung der Personaldisposition im Außenübertragungsdienst einer Fernsehanstalt. Z Arbeitswiss 1985;39:90—6.
14. Rosa RR. Extended workshifts and excessive fatigue. J Sleep Res 1995;4:51—6.
15. Folkard S. Effects on performance efficiency. In: Colquhoun WP, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Frankfurt a.M. (Berlin, Bern): Peter Lang Verlag, 1996:65—87.

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Is there an optimal sleep-wake pattern in shift work?

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Åkerstedt T. Is there an optimal sleep-wake pattern in shift work?. *Scand J Work Environ Health* 1998;24 suppl 3:18—27.

This paper finds that shift work clearly affects sleep and wakefulness but that there is very little known empirically about optimal sleep-wake patterns — except for the ones commonly used but not evaluated, for example, extension of morning sleep after night work, split sleep (main sleep + nap), nap positioning and duration, delay of main sleep, full commitment to night work (including bright light), phase advance and napping in relation to morning work, and modification of sleep strategies depending on the speed and direction of rotation. Thus computer simulations of the efficacy of alternative strategies must sometimes be used. The paper tries several such approaches and finds some possible ways of optimizing sleep. Still, the need for empirical data is emphasized.

Key terms review, simulation, strategy.

Shift work clearly exerts a negative effect on sleep and wakefulness (1). Since the reason for the problem is the timing of the hours of work and sleep, it would seem possible to establish some sort of "optimum" timing of sleep in order to reduce the negative effects. However, there is very little work available on such optimization, at least in real-life settings. The present paper includes what little solid information there is, but mainly concerns itself with speculation on what approaches might be of interest to gain more information. The term "shift work" is not only used to refer to conventional work in strictly defined "shifts", but also to cover the less rigidly organized "rosters" or "duty schedules" found in transport, nursing, police work, and other areas.

Commonly observed patterns

Before the issue of optimization is addressed, it is necessary to discuss sleep as it is commonly observed in shift work and also how its effects come about. The focus in this section is on traditional forms of shift work with several shifts in a row.

Night work

The night shift characteristically spans the time between 2200 and 0600, although there is considerable variation. The night sleep *before the first night shift* is usually rather long (2— 4), starts rather early, and lasts to around 8 o'clock in the morning or later. It is frequently (30—50% prevalence) associated with napping in the afternoon before the first night shift, especially if the preceding main sleep has been short.

The sleep *after a night shift* is usually initiated 1 hour after the termination of the shift (2, 5—8), with very little variation (30 to 60 minutes standard deviation) between persons. The ensuing sleep is, according to electroencephalographic (EEG) studies, reduced by 2—4 hours (8—12). Most of the loss involves stage 2 and rapid eye movement (REM) sleep, whereas slow wave sleep (SWS) is unaffected. The subjective aspects of sleep seem little affected, apart from premature awakenings and not getting enough sleep (8). Interestingly, about 50% of shift workers experience spontaneous (and effortless) sleep termination (8). Figure 1 illustrates the characteristic pattern of sleep density among a group of shift workers (13).

For about one-third of shift workers, a late afternoon nap is added *between the subsequent night shifts* (2, 4—8). The nap often exceeds 1 hour and the prevalence of napping increases as the length of the prior main sleep decreases. (4, 7).

Night work is also characterized by increased subjective (12, 14—16) and objective sleepiness (12, 16, 17). Several studies indicate that full-blown sleep can occur at work. The effects are particularly severe in the early morning, often involving incidents of involuntary sleep. In addition, during days off, a substantial amount of sleepiness remains.

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Morning work

A morning shift usually spans the time between 0600 and 1400, but, again, variations occur. The sleep pattern appears to be even more rigid in connection with the morning shift than with the night shift. (See figure 1.) As an example, sleep among a group of steel workers (7) with a morning-shift change at 0445 was initiated at 2149 (SD 49), which is almost exactly 70 min earlier than bedtime for days off for the same subjects. In other words, the phase advance of the bedtime was limited (8, 18). The sleep in the example ended at 0349 (SD 50), about 1 hour before the start of the morning shift. Short sleep (6 hours) has also been demonstrated in EEG studies — usually a 2- to 4-hour reduction in sleep length occurs (2, 8, 9, 19). Again, mainly stages 2 and REM are affected.

The main subjective effect is pronounced difficulties awakening, nonspontaneous awakening, and a feeling of not being refreshed by sleep (8). Interestingly, the anticipation of difficulties awakening is associated with reduced SWS (20).

Early times of rising (between 0400 and 0500) are also strongly associated with increased sleepiness during the rest of the day (20—23).

Morning-shift sleep is usually supplemented by an early afternoon nap by about one-third of shift workers (2, 3, 5—8). The nap is taken soon after the worker returns home from the morning shift (7). Again, a short prior sleep seems to be the main precipitating factor for the nap.

Afternoon work

The afternoon shift has been far less investigated than the morning and night shifts. On the whole, one sees a pattern of slightly late bedtimes (2300—0100) with awakenings around 0800 and an absence of napping (2, 5—8). The pattern is less homogeneous, however, than for the other shifts. (See figure 1.) There is more variation in the timing of sleep for the afternoon shift than for the other shifts.

Speed of rotation

Shift schedules frequently differ with respect to the *number of shifts* worked consecutively. While there are no data that indicate that the pattern of attempted sleep would differ depending on such a speed of rotation, there have been discussions on the amount of sleep permitted by certain types of schedules. Thus Foret & Benoit (10) found that neither the total sleep length nor the amount of stages 3 and 4 sleep recovered (changed) significantly across 4 consecutive night shifts (all were strongly reduced in the initial day sleep). Dahlgren (24) found that sleep length was reduced to 4.5 hours (from 6.0 hours) on the first night shift , but it increased again over 6 consecutive night shifts to reach a level of 5.7 hours. The amount of stage 2 sleep and REM also increased as the amount of waking decreased.

Permanent night workers tend to sleep somewhat less than day workers (24—29). For the latter the first day sleep is reduced by 1.1 hours (compared with normal night sleep), and it actually decreases a further 0.8 hours over 6 night shifts. In a review Wilkinson (30) also found that permanent night workers, on the whole, reported longer (6.7 hours) sleep than weekly (6.3 hours) or rapidly rotating (5.8 hours) shift workers. While correct, the results did not consider the effect on the other shifts or days off or free time. Apparently, permanent day workers seem to sleep somewhat less than rotating shift workers when the time is averaged across the entire shift cycle (31, 32).

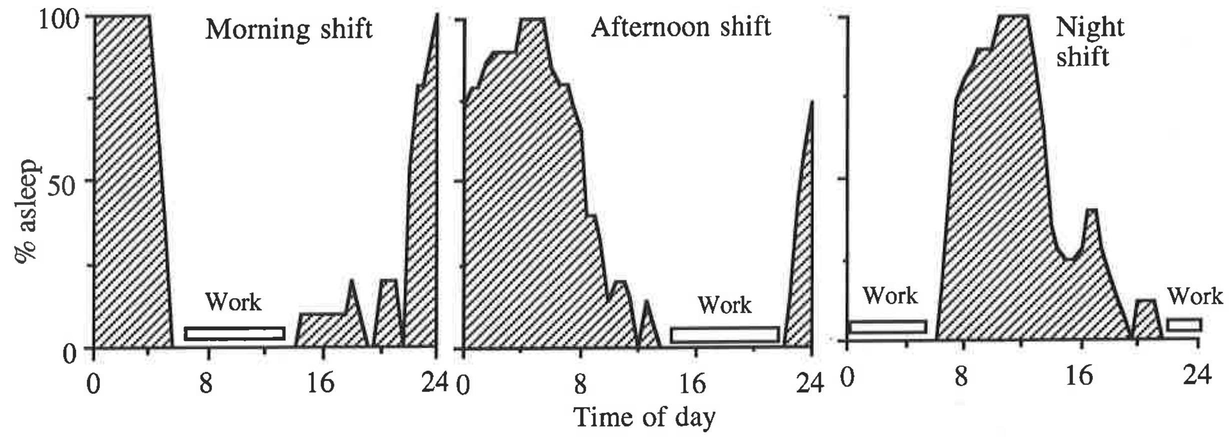

Figure 1. Percentage of 3-shift workers (N=50) asleep at different times of day in connection with the 2nd shift of each type.

Direction of rotation

A third concern is the direction of rotation. It has frequently been claimed that rotation should occur clockwise. While there is some theoretical support for this assumption, there is no solid evidence that sleep should differ depending on the direction of rotation (33), although Barton & Folkard found that a delaying pattern seemed to yield longer sleep (34).

Effects of other aspects of the schedule

Apart from the speed of rotation, one would expect the timing of the shifts to affect sleep. The first concern is the *time of the changeover* between night and morning shifts. Traditionally, this time is around 0600. However, field experiments indicate that sleep before the night shift is sharply curtailed as the phase advance of this time increases, and sleep after the night shift is improved by the same procedure (2, 9). An obvious compromise seems to be to end the shift around 0700 (35).

A second concern is *quick changeovers*, that is, short rest periods (=8 hours) between shifts. The prevalence of this aspect of scheduling is not known, but field work indicates that it is very common because it helps compress the workweek (compared with the conventional 16 hours between shifts) and yields a longer consecutive period of time off from work. This practice invariably curtails sleep (36), and data seem to indicate that the effects start already with 11 hours between shifts (35).

The mechanism

Night shift

One reason for night-shift sleepiness is that the worker is on the job at the nadir (low point) of the well-established circadian pattern, characteristic of most physiological and psychological variables (37—39). Essentially, alertness, performance, and metabolism peak in the late afternoon and reach a nadir in the early morning. The period of maximum alertness also strongly interferes with sleep, whereas the nadir equally strongly promotes sleep (19, 40). Daytime sleep is thus truncated.

The other reason for night-shift sleepiness is that the time awake before a night shift ends is extended to 20—22 hours (since prior sleep termination), in comparison with, for example, the corresponding 9 hours of the day worker. Alertness starts to fall immediately after the termination of sleep and continues for the duration of the time awake (38, 41—43). In addition, reduced prior sleep length increases sleepiness, although alertness seems rather robust against small curtailments of sleep (44—46). Two studies (45—46) show that the effects accumulate over time; a week with 4.5 hours of sleep per day may yield sleepiness close to levels seen in total sleep deprivation.

The homeostatic and circadian systems combine to exert their influence. Thus alertness and performance during sleep deprivation have a circadian pattern superimposed on the gradual fall of alertness and performance (38, 41). Even after several days without sleep one can clearly discern a slight increase in alertness during daytime, even if the mean level is low. The same combination of effects on sleep can be seen. Thus the daytime circadian interference with sleep near the acrophase may be partly counteracted by a high need for sleep (through prior sleep loss), and, of course, a low need may make daytime sleep virtually impossible (19, 47).

On the other hand, one would expect some adjustment of the circadian system across days of night work, which would ameliorate the negative effects of daytime sleep. Under optimal conditions, adjustment to a new circadian phase position occurs at a speed of about 1 hour per day (48, 49), probably through exposure to light at the sensitive portions of the circadian phase (50—52). Exposure before the nadir would lead to a delay and exposure after the nadir to an advance. However, for shift workers, the adjustment is counteracted by a light pattern in opposition to night workhours (53). Thus it appears that only very marginal circadian adjustment occurs in shift workers (54). On the other hand, exposure to artificial light during the hours before the circadian trough may remove most of the sleepiness during night work and improve subsequent sleep (55—58).

Morning shift

Sleep is short before the morning shift mainly because of the need to terminate sleep very early in the morning without being able to advance bedtime to fully compensate. The latter failure may be partly social, but there is also a strong circadian influence on sleep latency. To phase advance bedtime before a morning shift is difficult since it would bring the bedtime close to the circadian acrophase and make sleep difficult to initiate (18, 59, 60). This early evening time of sleep resistance has been called a "forbidden zone" for sleep (61).

The difficult early morning awakening, which seems to be a burden for workers on the morning shift, is also a result of circadian "interference". Thus an early awakening will coincide with the circadian nadir, and this circadian phase seems to be very protective against sleep termination (50) and seems to make forced awakenings very difficult (62). Furthermore the early morning awakening reduces sleep length and thus contributes to morning shift sleepiness. This sleepiness is exacerbated by the fact that the early morning awakening also adds further sleepiness by extending the time spent awake by 2—3 hours. Finally, the difficulties of having to rise at a very difficult time in the early morning seem also to be associated with anticipation stress that suppresses some of the SWS that would normally occur (20).

Optimal sleep-wake patterns

What, then, would constitute an "optimal" sleep-wake pattern? Such an optimal pattern may refer to the ability to sleep as much as possible in relation to a night or morning shift, or it may mean sleep in a way that increases alertness at work as much as possible or sleep in a way that increases alertness during free time as much as possible. The 3 patterns may be in conflict with each other. One also needs to consider the sequential effect of one sleep on the next.

One can conceive of several different ways of trying to achieve optimal sleep: (i) extension of day sleep after night work, (ii) split sleep — main sleep plus a later nap (and the position and duration of the nap), (iii) delayed day bedtime after night work, (iv) phase advance of bedtime before the morning shift.

As indicated, there are too few data available; therefore the discussion will have to focus on potential approaches rather than on established ones. To help the discussion in areas of low data availability, I will also use input from a mathematical model for the regulation of sleep and wakefulness (42, 63—65). The model uses homeostatic and circadian components to predict alertness and sleep length. The former essentially means that alertness starts to fall immediately after rising and starts to rise after sleep onset. The circadian component assumes a maximum value around 1700 and a minimum 12 hours later. The predicted alertness is expressed as the arithmetic sum of the 2 functions . The scale of the model ranges normally from 1 to 16, but in practice "3" corresponds to extreme sleepiness and "14" to high alertness and "7" to a threshold below which EEG/EOG sleep intrusions appear within 5 minutes under conditions of low external stimulation. The latter is also seen as a risk indicator, and time below the threshold constitutes an index of time at risk. Finally, sleep terminates when alertness reaches a predetermined level (14.2), and sleep latency is transformed as an exponential function of alertness.

Extended main sleep

A first and obvious strategy, when faced with several night shifts, is to try to extend the short day sleep after night work. Although this sleep is spontaneously terminated by circadian and homeostatic factors (40, 66), there are probably ways of extending it by improving, insulation from noise and light, and the like. Laboratory studies of shift workers' sleep thus frequently show better sleep than what is expected from reports of home sleep (67). Some of this effect could also be related to lower social pressure to wake up in the laboratory than in the home environment. The needed change in social pressure might, however, be difficult to implement at home.

The effect of extending day sleep at home after a night shift has not been empirically tested in a real-life situation, but several studies of the effects of varying amounts of sleep length in connection with normal night sleep suggest that the alertness-enhancing effects might not be large (44—46), because, normally, the last hours of sleep may not contain large amounts of recuperative value, but the recuperative effect seems to describe a saturating exponential function approaching an asymptote towards the last third of sleep (68). Thus the effect of increased main sleep length is less than what may be obtained later in a nap of the same length. Still, the exponential recovery function also means that the positive effect of an extension will increase in size with decreasing length of the "unextended" sleep. Thus the marginal utility of a 2-hour extension of a 3-hour day sleep will be several times larger than that of a 6-hour day sleep.

Figure 2 shows the simulated effects of a 2-hour extension of a (5.5-hour) day sleep (starting at 0700) on alertness after the first night shift. Alertness is increased, but very little, leaving most of the night trough intact. Still, time in the risk zone (ie, values <7) during an 8-hour night shift starting at 2200 would change from 40% to 23% of the total work shift through the extension.

If instead a 2-hour extension of a 7.5-hour long night sleep (ending at 0730) is considered (one that precedes the first night shift), the time at risk is only reduced to 48%, from 58%, for the 8-hour sleep, mainly because the end of a sleep period contains very little recuperative value. The positive effect is supported by the observation of an increased propensity for afternoon napping among workers with a short prior daytime sleep (7).

It should be emphasized that research on sleep extension among shift workers needs to be experimental. It

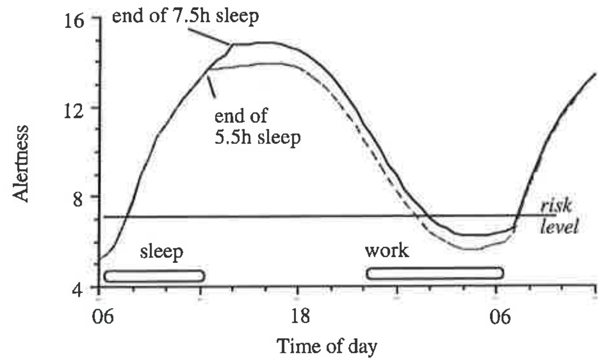

Figure 2. Effect of extension (5.5h to 7.5h) of day sleep between night shifts.

is not sufficient to study alertness in relation to spontaneously occurring differences in sleep length among shift workers. The reason is that strong confounding (sleep loss, caffeine, etc) may cause much of the variation in sleep length. Therefore those who show a long day sleep might have had a large prior sleep debt, while those who show a short day sleep might not have been sleep deprived before. Thus both groups may end up on the same level of postsleep sleepiness instead of showing the expected difference in sleepiness suggested by the length of sleep.

Split sleep — napping

The only shiftwork sleep strategy with any experimental data available is the split-sleep (nap) approach — but most of it still derives from laboratory work, and mainly from naps alone. Essentially, a nap reduces physiological (EEG measures) and subjective sleepiness and also improves performance (69—77). Behavioral measures are frequently the most sensitive ones (75, 78).

Surprisingly, however, there seems to exist no clear results with respect to the importance of the duration of the nap — 20 minutes may be as valuable as 2 hours. In most cases, the alertness-enhancing effects will increase with proximity to the nap (69, 74, 79, 80), up to a point where sleep inertia might interfere (81). The latter may be of importance in occupations which involve on-call work schedules and which require immediate readiness to perform.

Almost no field tests using EEG recordings and performance measures have been carried out. One exception is the National Aeronautics and Space Administration (NASA) study of 30-minute naps of air crew, yielding improved reaction-time performance (82). Many questionnaire studies have compared nappers with non-nappers, but they have yielded inconsistent results — possibly because the nappers are sleep-deprived beforehand — which is why they nap. Therefore causation becomes circular.

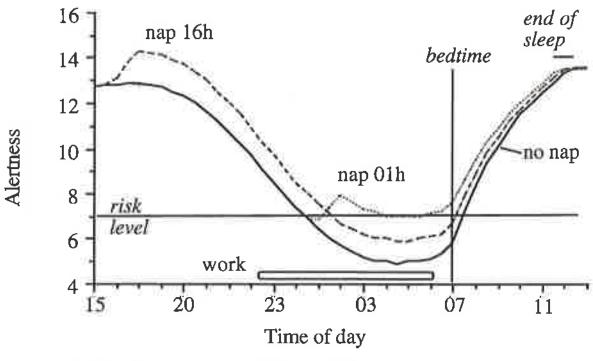

Figure 3. Effect of a nap at 1600 or 0100 on alertness and on subsequent day-sleep length.

Figure 3 illustrates the results of a simulation of a 1-hour nap started at 0100 during a first night shift (prior sleep termination at 0700). Alertness is increased, and the time at risk decreases from 69% to 19%. If the nap instead is taken at 1600, before the first night shift, the time at risk will still be reduced, but only to 54%. The temporal closeness of the nap to the critical work period is obviously of importance (78).

EEG-based field studies are also lacking on how a nightshift nap affects subsequent day sleep or whether a nap after a morning shift will interfere with an early start of the next night sleep and whether that early start implies inferior recuperation and reduced alertness the next day. Again, laboratory studies clearly indicate that the main (night) sleep subsequent to a nap will be reduced with respect to sleep length, SWS, and REM (69, 83—86). Some questionnaire studies seem to support this finding (7, 87).

The simulation in figure 3 also illustrates how the discussed naps reduce sleep length from 5.3 hours for the napless condition to 5.2 hours for the early nap and 4.8 hours for the late night nap. The reason is that, with later napping, recovery starts from a higher alertness level and reaches the sleep termination threshold earlier (64).

One would also need to know whether it would be more advantageous to extend the preceding main (day) sleep period after a night shift, or to reduce it, to make a later nap easier to initiate. One also wonders whether an early night nap would serve as an "anchor", as suggested by Minors et al (88), and thus prevent adjustment to night work. As yet, however, no field studies have been carried out on this topic.

Delays of sleep

Instead of extending day sleep after a night shift, or splitting it, one could try to delay sleep by a few hours, at least if one were willing to commit oneself to a night-oriented life-style. For this purpose bright light during night work, protection against conflicting timing of light, noise reduction, and low room temperature could be used. A laboratory experiment has shown that afternoon sleep is feasible, but it results in a shortening of sleep, as compared with the length of night sleep (89).

Other laboratory studies suggest that the sleep-interfering circadian influence increases with increasing closeness to the circadian acrophase of the rectal temperature rhythm (40, 90, 91), and disturbed afternoon sleep would thus be predicted.

The usefulness of delayed sleep is yet another of the untested sleep-wake tactics, except for 1 study of this type recently carried out on workers on North sea oil rigs. Under conditions of indoor work (no daylight) the workers actually developed a complete reversal of habits. After 2—3 initial days of adjustment a shift that finished at 0700 was followed by sleep delayed to 1030 (92), and the intervening time was used for social activities. Sleep and alertness also reached normal day work levels after this period. The data suggest complete adaptation. However, under these conditions, a return to day work became as difficult as the change to night work.

The simulation shown in figure 4 predicts that moving daytime sleep after a first night shift to bedtime at 1500 (for 5.5 hours of sleep) would reduce the time at risk to 0%, compared with the 58% if the same sleep is taken at 0700, immediately after the end of the night shift. Note that the morning hours before the afternoon sleep would be characterized by severe sleepiness. Probably, however, afternoon sleep would be a difficult strategy to implement for the entrained worker since the circadian rise and social obligations of the evening hours might interfere with sleep.

Delayed sleep would probably also need to include the use of light to phase-delay the circadian system (93), but there have been no real-life tests of this possibility. And, importantly, there has been no evaluation of the long-term effects of frequent phase shifting. Such an evaluation would be important, not only with regard to rotating shift workers, but also with regard to permanent night workers or rotators on very slowly changing shifts. These groups mostly return to day life on their days off, and thus, in effect, behave like rotators. A strategic use of melatonin would also provide a phase shift that may improve night work alertness (94). Practically, however, this approach may not be feasible because of the ethical problems of basing nightwork capacity on the regular use of a hormone.

One delay method that is frequently used by shift workers after the last night shift is to reduce morning sleep and to postpone most of the sleep to the night (2). This has not been subject to polysomnographic field studies, but laboratory experiments suggest that the result is a long and deep sleep (19). Logically, it should be an ideal way of returning to day life after a series of night shifts.

Morning shift — phase advance and napping

Before a morning shift, the shift worker usually tries to phase-advance bedtime. Often this process is difficult, however, since it brings bedtime close to the circadian acrophase and makes sleep difficult to initiate (18, 59, 60). The putative strategy to help shorten sleep latency would be to increase evening sleepiness by curtailing the previous night sleep episode. To the best of my knowledge, such an experiment has not been attempted. However, the simulation in figure 5 suggests that the sleep latency at, for example, 2000 will be 11 minutes for those rising at 0600, rather than the 15 minutes predicted if one were to rise at 0900. Again, this assumption needs empirical verification.

One way of circumventing the difficult phase advance is, again, to use light to phase-advance the circadian system (93), but, again, there has been no real-life test of this possibility. In comparison with light for phase delay on the night shift, the concern for long-term effects is probably less with early morning light, since the phase shift would be limited and within normal ranges of exposure to daylight. Melatonin might provide a similar phase shift (94). Practically, however, administration of a hormone to cope with night work may not be ethically feasible.

Many shift workers use afternoon naps to compensate for the truncated premorning shift sleep (7). However, such sleep makes a subsequent early bedtime difficult. Thus another experiment is needed to decide which strategy would yield the best total sleep and alertness in relation to the morning shift.

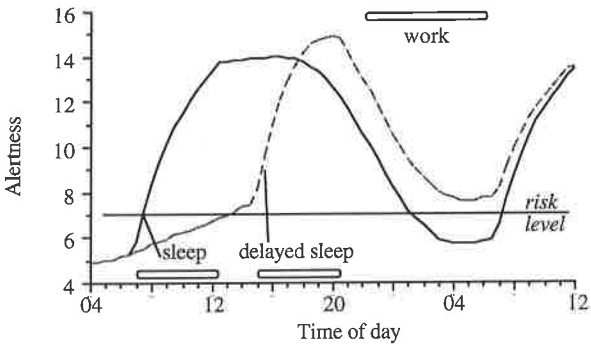

Figure 4. Effect of delaying a 5.5-hour sleep (from bedtime at 0700 to bedtime at 1500) on alertness.

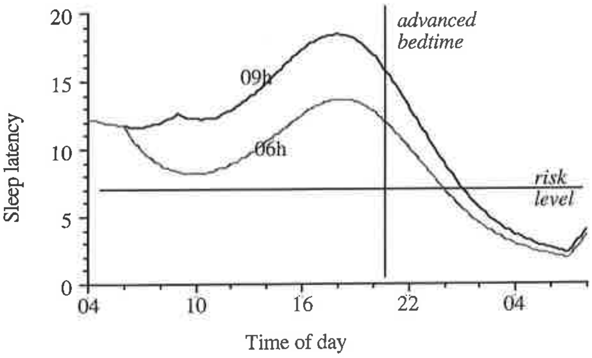

Figure 5. Effect of earlier rising (0600 compared with 0900) on sleep latency.

Modification by the speed of rotation

The preceding discussion was based on a "generic" view of the average type of shift schedule. There are probably calls for modification of one's sleep strategy, however, depending on the pattern of change between shifts, that is, how frequently one switches from one shift to another and in what direction the shift occurs.

Speed of rotation

The speed of rotation of a shift system refers to the number of consecutive shifts of the same type. The number can range from 1 to 10 or even more. Permanent shifts are a special case, but one needs to be aware of the fact that, for example, permanent nights usually mean 4—5 consecutive night shifts, followed by 2—3 days off. The latter are usually day oriented, and, therefore, permanent night work actually involves frequent shifting between night life and day life. As to optimum sleep strategy in relation to the speed of rotation, there is a complete lack of data. However, there is certainly room for speculation based on inference from other types of studies.

First, consider the shift worker who is scheduled to work a *single night shift*, followed by a day-morning shift (24 hours later), that is, a very rapid rotation. Unless there is a strong need for afternoon alertness, it would be possible to postpone sleep after the night shift from conventional bedtime at 0700 to an early night bedtime — around 2100—2300. This postponement would probably be associated with the fastest readjustment back to night work, as already discussed. One would probably recommend "light hygiene" (reduced nighttime light and increased morning light) to prevent a phase delay that might interfere with readjustment to day work. The recommendation would probably be the same even if a day off were interjected before the next workday, although the day off would permit more flexibility in sleep immediately after the night shift. The major research question in relation to sleep strategy on the single night shift would be whether or not to eliminate the day sleep after the shift, or perhaps to find the optimum amount of sleep still permitting proper night sleep later. Incidentally, the single night shift may be rare in traditional shift work, but it is very common in transportation, health care, police work, and the like.

If the schedule requires *2 night shifts in a row*, one would expect conventional post-night-shift sleep behavior with bedtime around 0700 the first day and end-of-night-shift-series behavior after the 2nd night shift, that is, sleep either being postponed entirely to the evening or the morning sleep being sharply truncated.

If there are *many night shifts*, one would be hard pressed not to recommend attempts to adjust through the use of light exposure during night work, avoidance of morning light, and immediate sleep (at 0700) after the end of the night shift (skipped day sleep). Again, end-of-night-work-series behavior would be expected after the last night shift. The effect of the adjustment caused by the sequence of night shifts would, however, require an extra day of recovery before return to day work. The main research question would concern whether full commitment (including treatment with bright light) to night work would, in effect, be preferable to noncommitment. This evaluation would have to include effects on sleep, alertness, and performance during the nightshift sequence, as well as during other shifts and during days off. Alertness during days off may, indeed, be the most important from the point of view of the shift worker.

The *single morning shift* would, as was the case with the single night shift, best be handled by the avoidance of adjustment — most shift workers are diurnal evening types and would probably have difficulties adjusting, and an afternoon nap should be implemented to supplement night sleep. In a slowly rotating shift system (>4 days in a sequence), on the other hand, one would recommend the morning-shift strategy already described. It should probably be supported by light treatment in the morning. Even if the shift workers are evening types, one might still expect some alertness or sleep problems the first days on a subsequent night shift. For extremely slow rotation patterns, light treatment may be a necessity.

Direction of rotation

The direction of rotation may also be of importance. No proper experiments on optimal sleep strategies have been carried out, but one may assume that a clockwise direction of rotation (morning - afternoon - night shift) would yield the standard sleep behavior already discussed. A counter-clockwise rotation (night - afternoon - morning) would probably yield a very late and long lie-in after the last night shift leading to the first afternoon shift. One could also perhaps expect a skipped day sleep, or pronounced difficulties getting to bed in the evening before the first morning shift. One would probably need to use the recommendations of truncating sleep after the last evening shift to increase evening sleep propensity, perhaps in combination with morning bright light. It should be emphasized that the counter-clockwise direction is often rather popular with shift workers since it ends with a morning shift, which starts the time-off period early in the day. It also gives workers a possibility to start their free days without too much readjustment from night work remaining — the readjustment being taken care of on company time, by the last morning shift(s). Counter-clockwise rotation also invites quick changes, that is, only 8 hours between shifts, which is a particular problem for strategic sleeping. The sequence night-afternoon -morning could, thus, become work 2200—0600, 8 hours off, work 1400—2200, 8 hours off, and work

0600—1400 — a very demanding schedule. Another variation may be morning - night - afternoon, that is, work 0600—1400, 8 hours off, work 2200—0600, 8 hours off, and work 1400—2200.

Individual differences

In discussions of optimal sleep strategies, one needs also to consider individual differences. One traditional such factor is morningness-eveningness, as well as "sleep flexibility" (95). There are indications that morning types have more disturbances of daytime sleep (96), which probably necessitates a sleep strategy with more supplementary napping.

However, more important factors may be gender, marriage status, and number of children in the family. Clearly, having small children might prevent sleep, particularly for women (97, 98), and the sleep pattern would have to be adapted to times when the children can be looked after by others. Clearly, being married or cohabiting is of major importance with respect to child care.

Concluding remarks

Shift work clearly affects sleep and wakefulness in a very predictable way and the answer to the question "Is there an optimal sleep-wake pattern in shift work? must be "yes" On the other hand, very little is empirically known about the finer points of shift work, and it can be expected that there is not only one, but numerous optimal sleep strategies, depending on the characteristics of the schedule, and perhaps on the make-up of the person. Obviously, there is a great need for experimentation, and some of the issues to study concern the extension of morning sleep after night work, split sleep (main sleep + a nap), nap positioning and duration, delay of main sleep, full commitment to night work (including treatment with bright light), phase advance and napping in relation to morning work, and modification of sleep strategies depending on the speed and direction of rotation.

References

1. Åkerstedt T, Horne J, editors. Work hours, sleepiness and accidents. J Sleep Res 1995;4 suppl 2:1—83.
2. Knauth P, Rutenfranz J. Duration of sleep related to the type of shift work. In: Reinberg A, Vieux N, Andlauer P, editors. Night and shift work: biological and social aspects. Oxford: Pergamon Press, 1981.
3. Härmä M, Knauth P, Ilmarinen J. Daytime napping and its effects on alertness and short-term memory performance in shiftworkers. Int Arch Occup Environ Health 1989;61:341—5.
4. Rosa R. Napping at home and alertness on the job in rotating shift workers. Sleep 1993;16:727—35.
5. Andersen FE. Three-shift work. Copenhagen: Socialforskningsinstitutet, 1970:
6. Tepas DI. Shiftworker sleep strategies. J Hum Ergol (Tokyo) 1982;11:325—36.
7. Åkerstedt T, Torsvall L. Napping in shift work. Sleep 1985;8:105—9.
8. Åkerstedt T, Kecklund G, Knutsson A. Spectral analysis of sleep electroencephalography in rotating three-shift work. Scand J Work Environ Health 1991;17:330—6.
9. Foret J, Lantin G. The sleep of train drivers: an example of the effects of irregular work schdules on sleep. In: Colquhoun WP, editor. Aspects of human efficiency: diurnal rhythm and loss of sleep. London: The English Universities Press Ltd, 1972:273—81.
10. Foret J, Benoit O. Shiftwork: the level of adjustment to schedule reversal assessed by a sleep study. Waking Sleeping 1978;2:107—12.
11. Tilley AJ, Wilkinson RT, Warren PSG, Watson WB, Drud M. The sleep and performance of shift workers. Hum Factors 1982;24:624—41.
12. Torsvall L, Åkerstedt T, Gillander K, Knutsson A. Sleep on the night shift: 24-hour EEG monitoring of spontaneous sleep/wake behavior. Psychophysiology 1989;26:352—8.
13. Åkerstedt T, Torsvall L, Gillberg M. Napping and shift work. In: Dinges DF, Broughton R, editors. Sleep and alertness: chronobiological, behavioral, and medical aspects of napping. New York (NY): Raven Press, 1989:205—20.
14. Fröberg JE, Karlsson CG, Levi L. Shift work: a study of catecholamine excretion, self-ratings and attitudes. Stud Lab Salutis 1972;11:10—20.
15. Folkard S, Monk TH, Lobban MC. Short and long term adjustment of circadian rhythms in "permanent" night nurses. Ergonomics 1978;21:785—99.
16. Torsvall L, Åkerstedt T. Sleepiness on the job: continuously measured EEG changes in train drivers. Electroencephal Clin Neurophysiol 1987;66:502—11.
17. Kecklund G, Åkerstedt T. Sleepiness in long distance truck driving: an ambulatory EEG study of night driving. Ergonomics 1993;36:1007—17.
18. Folkard S, Barton J. Does the "forbidden zone" for sleep onset influence morning shift sleep duration? Ergonomics 1993;36:85—91.
19. Åkerstedt T, Gillberg M. The circadian variation of experimentally displaced sleep. Sleep 1981;4:159—69.
20. Kecklund G, Åkerstedt T, Lowden A. Morning work: effects of early rising on sleep and alertness. Sleep 1997;20:215—23.
21. Bjerner B, Holm Å, Swensson Å. Natt och skiftarbete [Night and shift work]. Stockholm: Statens Offentliga Utredningar, 1948.
22. Hak A, Kampman R. Working irregular hours: complaints and state of fitness of railway personnel. In: Reinberg A, Vieux N, Andlauer P, editors. Night and shift work: biological and social aspects. Oxford: Pergamon Press, 1981:229—36.
23. Moors SH. Learning from a system of seasonally-determined flexibility: beginning work earlier increases tiredness as much as working longer days. In: Costa G, Cesana G, Kogi K, Wedderburn A, editors. Shiftwork: health, sleep and performance. Frankfurt am Main: Verlag Peter Lang, 1989:310—15.
24. Dahlgren K. Adjustment of circadian rhythms and EEG sleep

functions to day and night sleep among permanent night workers and rotating shift workers. Psychophysiology 1981; 18:381—91.
25. Lille F. Le sommeil de jour d'un groupe de travailleurs de nuit. Trav Hum 1967;30:85—97.
26. Kripke DF, Cook B, Lewis OF. Sleep of night workers: EEG recordings. Psychophysiology 1971;7:377—84.
27. Bryden G, Holdstock TL. Effects of night duty on sleep patterns of nurses. Psychophysiology 1973;10:36—42.
28. Tepas DI, Walsh JK, Armstrong DR. Comprehensive study of the sleep of shift workers. In: Johnson LC, Tepas DI, Colquhoun WP, Colligan MJ, editors. Biological rhythms, sleep and shift work. New York (NY): SP Medical & Scientific Books, 1981:347—56.
29. Tepas DI, Mahan RP. The many meanings of sleep. Work Stress 1989;3:93—102.
30. Wilkinson RT. How fast should the night shift rotate? Ergonomics 1992;35:1425—46.
31. Verhaegen P, Cober R, De Smedt M, Dirkx J, Kerstens J, Ryvers D, et al. The adaptation of night nurses to different work schdules. Ergonomics 1987;30:1301—09.
32. Totterdell P, Folkard S. The effects of changing from a weekly rotating to a rapidly rotating shift schedule. In: Costa G, Cesena G, Kogi K, Wedderburn A, editors. Shiftwork: health, sleep and performance. Frankfurt am Main: Verlag Peter Lang, 1990: 646—50.
33. Knauth P. Speed and direction of shift rotation. J Sleep Res 1995;4 suppl 241—6.
34. Barton J, Folkard S. Advancing versus delaying shift systems. Ergonomics 1993;36:59—64.
35. Kecklund G, Åkerstedt T. Effects of timing of shifts on sleepiness and sleep duration. J Sleep Res 1995;4 suppl 2:47—50.
36. Kurumatani N, Koda S, Nakagiri S, Hisashige A, Sakai K, Saito V, et al. The effects of frequently rotating shiftwork on sleep and the family life of hospital nurses. Ergonomics 1994;37:995—1007.
37. Aschoff J. Circadian rhythms in man. Science 1965;148:1427—32.
38. Fröberg JE, Karlsson CG, Levi L, Lidberg L. Psychological circadian rhythms during a 72-hour vigil. Försvarsmedicin 1975;2:192—201.
39. Folkard S, Monk TH. Circadian performance rhythms. In: Folkard S, Monk TH, editors. Hours of work — temporal factors in work scheduling. New York (NY): John Wiley, 1985:37—52.
40. Czeisler CA, Weitzman ED, Moore-Ede MC, Zimmerman JC, Knauer RS. Human sleep: its duration and organization depend on its circadian phase. Science 1980;210:1264—67.
41. Williams HL, Lubin A, Goodnow JJ. Impaired performance with acute sleep loss. Psychol Mon 1959;73:1—26.
42. Folkard S, Åkerstedt T. A three process model of the regulation of alertness and sleepiness. In: Ogilvie R, Broughton R, editors. Sleep, arousal and performance: problems and promises. Boston (MA): Birkhäuser, 1991:11—26.
43. Dijk DJ, Duffy JF, Czeisler CA. Circadian and sleep-wake dependent aspects of subjective alertness and cognitive performance. J Sleep Res 1992;1:112—7.
44. Wilkinson RT, Edwards RS, Haines E. Performance following a night of reduced sleep. Psychon Sci 1966;5:471—2.
45. Carskadon MA, Dement WC. Cumulative effects of sleep restriction on daytime sleepiness. Psychophysiology 1981;18:107—13.
46. Dinges DF, Pack F, Williams K, Gillen KA, Powell JW, Ott GE, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4—5 hours per night. Sleep 1997;20:267—77.
47. Åkerstedt T, Gillberg M. A dose-response study of sleep loss and spontaneous sleep termination. Psychophysiology 1986;23:293—7.
48. Wever R. Phase shifts of human circadian rhythms due to shifts of artificial Zeitgebers. Chronobiologia 1980;7:303—27.
49. Mills JN. Partial adaptation to simulated time zone shifts. J Physiol 1976;265:23—23.
50. Czeisler CA, Richardson GS, Zimmerman MC, Moore-Ede MC, Weitzman ED. Entrainment of human circadian rhythms by light-dark cycles. Photochem Photobiol 1981;34:239—47.
51. Minors DS, Waterhouse JM, Wirtz-Justice A. A human phase-response curve to light. Neurosci Lett 1991;133:36—40.
52. Czeisler CA, Allan JS, Strogatz SH, Ronda J M, Sanchez R, Rios C D, et al. Bright light resets the human circadian pacemaker independent of the timing of the sleep-wake cycle. Science 1986;233:667—71.
53. Koller M, Kundi M, Stidl H-G, Zidek T, Haider M. Personal light dosimetry in permanent night and day workers. Chronobiology Int 1993;10:143—55.
54. Åkerstedt T. Adjustment of physiological circadian rhythms and the sleep-wake cycle to shift work. In: Monk TH, Folkard S, editors. Hours of work. Chichester: John Wiley, 1985:185—98.
55. Czeisler CA, Johnson MP, Duffy JF, Brown EN, Ronda JM, Kronauer RE. Exposure to bright light and darkness to treat physiologic maladaptation to night work. N Engl J Med 1990;322:1253—9.
56. Eastman CI. High-intensity light for circadian adaptation to a 12-h shift of the sleep schedule. Am J Physiol 1992; 263:R428—36.
57. Czeisler A. Bright light treatment of maladaptation to night shift work. In: Åkerstedt T, Kecklund G, editors. Work hours, sleepiness and accidents. Stockholm: IPM and Karolinska Institute, 1994:75—9.
58. Eastman CI, Stewart KT, Mahoney MP, Liu L, Fogg LF. Shift work: dark goggles and bright light improve circadian rhythm adaption to night-shift work. Sleep 1994;17:535—43.
59. Lavie P, Scherson A. Ultrashort sleep-waking schedule, I: evidence of ultradian rhythmicity in " sleepability". Electroencephal Clin Neurophysiol 1981;52:163—74.
60. Åkerstedt T, Hume KI, Minors DS, Waterhouse JM, Folkard S. Sleep on a shortening day / night schedule. Electroencephal Clinical Neurophysiol 1992;82:102—11.
61. Lavie P. Ultrashort sleep-waking schedule, III: "gates" and "forbidden zones" for sleep. Electroencephal Clin Neurophysiol 1986;63:414—25.
62. Åkerstedt T, Hume K, Minors D, Waterhouse J. Good sleep — its timing and physiological sleep characteristics. J Sleep Res 1997;6:221—9
63. Åkerstedt T, Folkard S. Validation of the S and C components of the three-process model of alertness regulation. Sleep 1995;18:1—6.
64. Åkerstedt T, Folkard S. Predicting duration of sleep from the three-process model of alertness regulation. J Occup Environ Med 1996;53:136—41.
65. Åkerstedt T, Folkard S. Predicting sleep latency from the three-process model of alertness regulation. Psychophysiology 1996;33:385—9.
66. Åkerstedt T, Gillberg M. The circadian pattern of unrestricted sleep and its relation to body temperature, hormones, and

alertness. In: Johnson LC, Tepas DJ, Colquhoun WP, Colligan HJ, editors. Biological rhythms, sleep, and shift work. New York (NY): Spectral Publications, 1981:481—98.
67. Härmä MI, Hakola T, Åkerstedt T, Laitinen JT. Age and adjustment to night work. Occup Environ Med 1994;51:568—73.
68. Borbély AA. A two-process model of sleep regulation. Hum Neurobiol 1982;1:195—204.
69. Bonnet MH. The effect of varying prophylactic naps on performance, alertness and mood throughout a 52-hour continuous operation. Sleep 1991;14:307—15.
70. Bertelson AD. Effects of napping and bedrest on performance and mood [dissertation abstract]. Columbus (OH): Ohio State University, 1980;40, 3358A.
71. Bonnet MH, Arand DL. Consolidated and distributed nap schedules and performance. J Sleep Res 1995;4:71—7.
72. Carskadon MA, Dement WC. Effects of a daytime nap on sleepiness during sleep restriction. Sleep Res 1986;16:69.
73. Dinges DF, Orne EC, Evans FJ, Orne MT. Performance after naps in sleep-conducive and alerting environments. In: Johnson LC, Tepas DI, Colquhoun WP, Colligan MJ, editors. Biological rhythms: sleep and shift work. Lancaster: MTP Press, 1981: 539—52.
74. Dinges DF. Differential effects of prior wakefulness and circadian phase on nap sleep. Electroencephal Clin Neurophysiol 1986;64:224—27.
75. Gillberg M, Kecklund G, Axelsson J, Åkerstedt T. Counteracting sleepiness with a short nap. J Sleep Res 1994;3 suppl 1:90.
76. Horne JA, Reyner LA. Counteracting driver sleepiness: effects of napping, caffeine and placebo. Psychophysiology 1996;33:306—9.
77. Naitoh P, Angus RG. Napping and human functioning during prolonged work. San Diego (CA): Naval Health Research Center, 1987.
78. Dinges DF, Orne MT, Whitehouse WG, Orne EC. Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. Sleep 1987;10:313—29.
79. Gillberg M. The effects of two alternative timings of a one-hour nap on early morning performance. Biol Psychol 1984;19:45—54.
80. Lavie P, Weler B. Timing of naps: effects on post-nap sleepiness levels. Electroencephal Clin Neurophysiol 1989; 72:218—24.
81. Naitoh P, Kelley T, Babkoff H. Sleep inertia: best time not to wake up? Chronobiol Int 1993;10:109—18.
82. Rosekind MR, Smith RM, Miller DL, et al. Alertness management: strategic naps in operational settings. J Sleep Res 1995;4 suppl 2:62—6.
83. Karacan I, Williams RL, Finley WW, Hursch CJ. The effects of naps on nocturnal sleep: influence on the need for stage-1 REM and stage 4 sleep. Biol Psychiatry 1970;2:391—9.
84. Tilley A, Donohoe F, Hensby S. Homeostatic changes in slow wave sleep during recovery sleep following restricted nocturnal sleep and partial slow wave sleep recovery during an afternoon nap. Sleep 1987;10:600—5.
85. Feinberg I, March JD, Floyd TC, Jimison R, Bossom-Demitrack L, Katz PH. Homeostatic changes during post-nap sleep maintain baseline levels of delta EEG. Electroencephal Clin Neurophysiol 1985;61:134—7.
86. Bonnet MH, Arand DL. The use of prophylaptic naps and caffeine to maintain performance during a continuous operation. Ergonomics 1994;37:1009—20.
87. Matsumoto K, Matsui T, Kawamori M, Kogi K. Effects of nighttime naps on sleep patterns of shiftworkers. J Hum Ergol 1982;11:279—89.
88. Minors DS, Waterhouse JM. Anchor sleep as a sychronizer of rhythms on abnormal routines. In: Johnson LC, Tepas DI, Colquhoun WP, Colligan MJ, editors. Advances in sleep research; vol 7 (Biological rhythms, sleep and shift work). New York (NY): Spectrum Publications, 1981:399—414.
89. Kiesswetter E. A polysomnographic study of morning and afternoon sleep quality during simulated night shift work. Ergonomics 1993;36:265—72.
90. Åkerstedt T, Gillberg M. Sleep disturbances and shift work. In: Reinberg A, Vieux N, Andlauer P, editors. Night and shift work: biological and social aspects. Oxford: Pergamon Press, 1981:127—38.
91. Åkerstedt T, Hume K, Minors D, Waterhouse J. The regulation of sleep and naps on an irregular schedule. Sleep 1993;16:736—43.
92. Bjorvatn B, Kecklund G, Åkerstedt T. Rapid adaptation to night work at an oil platform, but slow redaptation following return home. J Occup Environ Med. In press
93. Czeisler CA, Dijk D-J. Use of bright light to treat maladaptation to night shift work and circadian rhythm sleep disorders. J Sleep Res 1995;4 suppl 2:70—3.
94. Arendt J, Deacon S, English J, Hampton S, Morgan L. Melatonin and adjustment to phase shift. J Sleep Res 1995;4 suppl 2:74—9.
95. Folkard S, Monk TH, Lobban MC. Towards a predictive test of adjustment to shift work. Ergonomics 1979;22:79—91.
96. Costa G, Lievore F, Casaletti G, Gaffuri E. Circadian characteristics influencing interindividual differences in tolerance and adjustment to shift work. Ergonomics 1989;32:373—85.
97. Estryn-Behar M, Gadbois C, Vaichere E. Effets du travail de nuit en équipes fixes sur une population féminine: résultats d'une enquete dans le secteur hospitalier. Arch Mal Prof 1978;39:531—5.
98. Anderson RM, Bremer DA. Sleep duration at home and sleepiness on the job in rotating twelve-hour shift workers. Hum Factors 1987;29:477—81.

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Shift work and reproductive health

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Nonstandard workhours may disturb normal body functions, but their relation to reproductive outcome is poorly understood. Two newly published studies suggest an association between rotating shift work and prolonged waiting time to pregnancy. Seven of nine studies on spontaneous abortion suggest that some forms of shift work may be associated with increased risk. Four studies indicate that shift work including night schedules may be related to preterm birth. Moreover, some results have related rotating schedules to intrauterine growth retardation. In the published studies, the type of work schedule examined has varied, and the applied definition of shift work has not necessarily been clear. The main interest areas, however, have been work involving evening and night shifts, rotating or changing schedules, and the irregularity of work patterns. Although the evidence is not ample and remains ambiguous, it is prudent to consider shift work as a potential risk to reproduction.

Key terms birthweight, fecundity, female exposure, menstrual disorders, pregnancy, preterm birth, spontaneous abortion, time to pregnancy.

Nonstandard workhours may disturb normal body functions (1). For example, employees in rotating shift work must adapt each time that their schedule changes, and many physiological functions and systems that are circadian in nature can be disturbed. However, the relation to reproductive outcome is poorly understood. Hormonal disturbances, either as a direct effect of changes in the circadian rhythm or indirectly through psychosocial stress and disturbed sleep, are the factors most often suggested (2). Early fetal loss, preterm birth, and lowered birthweight have received the most attention in connection with shift work (3). Recently, problems with fecundity have increasingly been used as biological indicators of occupational effects on reproduction.

This paper presents a review of the epidemiologic studies on the reproductive hazards of women's shift work. The identification of relevant publications was done stepwise. The references prior to 1989 were collected without literature data bases being consulted (4). In the summer of 1994, MEDLINE, NIOSHTIC, CISDOC, HSELINE, and EMED were searched for articles published since 1989 (3). The key words "shift work" or "work schedule" were combined with the following terms or their synonyms: reproduction, pregnancy, hormonal disturbance, menstruation, fecundity, infertility, abortion, birth defect, birthweight, and gestational age. Complementary searches were performed in late 1995 (for 1994 and 1995) and in late 1996 (for 1995 and 1996). The main results of the identified epidemiologic studies are reviewed. For menstrual disorders, only irregularity of the menstrual cycle has been included (eg, results on dysmenorrhea were excluded). Moreover, individual results on pregnancy complications (eg, vaginal bleeding) and published negative results on selected birth defects (4) have not been reviewed.

Time to pregnancy

According to a Swedish study, midwives doing rotating 2-shift or 3-shift work and those working only nights had reduced fertility as compared with midwives working regularly in the daytime (5). All the women who were born in 1940 or later and who, in 1989, were found in the membership files of the Swedish Midwives' Association comprised the target population of the study. The measure of fertility was the time to pregnancy, that is, the number of menstrual cycles required to become pregnant. A postal questionnaire was sent to all eligible midwives in Sweden for data on their time to pregnancy and their work conditions during the period related to the

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most recent, planned pregnancy that had terminated after 1983. Time to pregnancy provides an estimate of per cycle probability of becoming pregnant, and it was calculated for each work schedule category, and its relation to daytime work was expressed as a fecundability ratio. Each woman was allowed to contribute a maximum of 13 cycles to avoid interference from medical treatment for infertility. The adjusted fecundability ratios for 2-shift, 3-shift, and night work were 0.78 [95% confidence interval (95% CI) 0.65—0.94], 0.77 (95% CI 0.61—0.98), and 0.82 (95% CI 0.65—1.04), respectively.

The data from a European multicenter study were in favor of an association between changing or rotating shift work and prolonged waiting time to pregnancy (6). In the pregnancy-based survey of this European project, the pregnant women encountered during a prenatal visit or women who had given birth at a hospital or a clinic were consecutively enrolled between February 1992 and December 1992. They represented pregnant or delivering women from well-defined geographic areas of Denmark, France, Germany, Italy, and Sweden. The information, collected with self-administered questionnaires or by interviewers, pertained to the current or just-ended pregnancy, including time to pregnancy, occupational and other exposures at the beginning of the waiting time, and help-seeking because of inability to conceive. In the analyses, 9.5 months was used as the cutoff point of the waiting time to identify subfecundity. The adjusted odds ratio of subfecundity was 2.0 (95% CI 1.4—2.8) for changing or rotating shift work as compared with daytime, evening, or night work.

In a recently published study, all women who delivered a live child in the preceding week of the interviews during a period of 2 months in 1993 in 4 hospitals (in Bergamo, Milan, Rome, and Terni) were included (7). In the group of women who had done shift work, the crude percentage of women conceiving after 12 months was 17.9, and in the nonshift group the corresponding percentage was 10.5. However, this difference was markedly reduced when confounding variables were controlled in the analysis. The adjusted conception (fecundability) rate ratio for shift work was 0.9 (95% CI 0.7—1.2).

Shift work was included as a factor of potential interest in an earlier Danish population-based survey that focused on life-style factors and fecundity (8). All pregnant women in 2 cities (Odense and Aalborg) were given a questionnaire in the last trimester of their pregnancy between 1984 and 1987. Subfecundity was defined as a waiting time of 1 year from the cessation of contraception to the achievement of pregnancy. Shift work had no effect on subfecundity; the adjusted odds ratio was 0.9 (95% CI 0.7—1.0) for shift work as compared with no shift work.

In 1981, in Japan, a questionnaire on work conditions and health was distributed to workers belonging to 33 labor unions. The crude rate of pregnancy was lower for the women doing shift work including night work (10.0%) than for the women doing daytime work (18.1%, P<0.01) during the 2 years preceding the study (9). The shift workers were nurses or telephone operators. The reference group of day workers was more heterogeneous, including women with various jobs.

Irregular menstrual cycle

Published study results on irregular menstrual cycles are scant. In a Japanese study on night and shift work (9), the women doing night shifts had a higher crude rate of irregular cycles than did the daytime workers (36% versus 28%, P<0.01). Ten years later, another Japanese study reported similar results concerning night work as compared with daytime work in a population including teachers, office workers, nurses, factory workers, and barmaids (10). In a third study in 1987—1988, a medical examination and questionnaire were administered to workers in 17 poultry slaughterhouses and 6 canning factories in western France (11). Workers with irregularly varying work schedules (varying beginning, ending, or hours per week) not including night shifts had elevated crude rates of irregular menstrual cycles. In the final analysis, the adjusted odds ratio for work with a varying beginning of the workday was 2.0 (95% CI 1.2—3.6) in a comparison with work on a 2-shift schedule changing from the morning to the afternoon shift regularly on a weekly basis.

Spontaneous abortion

Nine studies have been published on shift work and fetal loss (table 1). The most recent is the Swedish study conducted among midwives in which reduced fertility was associated with nonstandard workhours (12). The results indicate that night work and 3-shift schedules may be associated with an increased risk of spontaneous abortion. The odds ratio was 1.63 (95% CI 0.95—2.80) for night work as compared with daytime work, and for 3-shift work the corresponding odds ratio was 1.49 (95% CI 0.86—2.59). The increase in the risk related to night work was found mainly for late spontaneous abortion (table 1).

In addition, 6 of the available 9 studies on nonstandard workhours and fetal loss reported an elevated risk of spontaneous abortion (9, 13—17). Night work seemed to be hazardous in 2 studies (9, 17), but in 2 others (15, 18) no elevated risk was observed when night work was analyzed explicitly. [In reference 15, the adjusted rate ratio for regular night work was 0.9 (95% CI 0.5—1.8).]

Table 1. Studies on shift work during pregnancy and spontaneous abortion. (OR = odds ratio, 95% CI = 95% confidence interval, RR = rate ratio, O/E = ratio of observed to expected)

Location	Exposure	Definition of outcome	Observed effect
Japan (9)	Shift work including night work, according to a retrospective questionnaire administered in 1981	Spontaneous abortion within the past 2 years, reported in the questionnaire	Night work compared with day work associated with higher rate (36% versus 18%, P<0.05)
Sweden (12)	Always night, 2-shift, or 3-shift work as a midwife for more than half of the time during the first trimester of pregnancy between 1980 and 1989, according to a postal questionnaire	Spontaneous abortion reported in the questionnaire if the woman stated that it had been diagnosed by a physician or had been preceded by a positive pregnancy test	Spontaneous abortion after the 12th week of gestation, associated with night work (adjusted OR 3.3, 95% CI 1.1-9.9) in a comparison with day work
Göteborg, Sweden (13)	Shift work during the first trimester of pregnancy in university laboratories from 1968 to 1979, according to a postal questionnaire	Spontaneous abortion, reported in the questionnaire and verified in hospital records	Elevated rate compared with mothers not in shift work (age adjusted RR 3.2, 95% CI 1.4-7.5)
Finland (14)	Work arrangements other than normal daily work in selected departments of general hospitals, according to a postal questionnaire sent to the leading head nurses of the hospitals	Spontaneous abortion between 1973 and 1979, determined from the Finnish Hospital Discharge Register and information on policlinic cases	Elevated OR for rotating 3-shift work compared with day shift or rotating 2-shift work (adjusted OR 1.5, 95% CI 0.9-2.5)
Mölndal, Sweden (15)	Irregular and inconvenient work schedules at a hospital between 1980 and 1984, according to a postal questionnaire	Spontaneous abortion reported in the questionnaire and verified in hospital records	Elevated rates for irregular workhours and rotating 3-shift work compared with work during the day only (adjusted RR 1.4, 95% CI 0.8-2.5, and 1.5, 95% CI 0.6-4.1, respectively)
Montreal, Canada (16)	Employment of ≥30 hours a week doing changing shift work at conception, as reported retrospectively by the mother in an interview	Spontaneous abortion in previous pregnancies of women interviewed after recently completed pregnancies between 1984 and 1985	Elevated O/E (overall O/E 1.3, P<0.01)
Calgary, Canada (27)	Work for pay from 3 months preceding to 4 months after the last menstrual period and shift work schedules based on interview data	Spontaneous abortion, determined by data from 3 hospitals between 1984 and 1985	Effect of shift work nonsignificant in a comparison with nonshift work, when analyzed in several ways
Montreal, Canada (17)	Four types of work schedules, based on interview data	Pregnancy loss (spontaneous abortion or stillbirth), determined by 1 hospital between 1987 and 1989	Elevated OR for fixed evening schedule (adjusted OR 4.2, 95% CI 2.2-7.9) and fixed night schedule (adjusted OR 2.7, 95% CI 0.5-13.4) in a comparison with fixed day schedule
Santa Clara, CA, United States (18)	Evening/night work or variable types of shift schedule, based on interview data	Spontaneous abortion for which a pathology specimen was analyzed between 1986 and 1987 after pregnancies of women residing in Santa Clara	No increased OR values for evening or night work (adjusted OR 0.8, 95% CI 0.5-1.2) or variable shift schedules (adjusted OR 0.6, 95% CI 0.4-1.0) in a comparison with day work

In 3 of the 6 positive studies, spontaneous abortion was related to some form of rotating schedule (14—16).

Preterm birth and birthweight

Preterm birth is a pregnancy complication that has been examined in relation to shift work in 5 studies (table 2). The most recent of these studies was conducted in Canada (19). In it, the increased risk of preterm birth associated with regular evening or night work appeared to be confined to women who had continued working after 23 weeks of pregnancy. The adjusted odds of giving birth before 37 completed weeks of gestation was 2 times higher than for women who did day work only or shift work and who stopped working 3 weeks before the 3rd trimester. The corresponding odds ratio for women who had been exposed to regular evening or night work but had stopped working before 24 weeks of pregnancy was 1.1 (95% CI 0.5—2.8), and, for the group that had done day work only or shift work after 23 weeks of pregnancy, it was also 1.1 (95% CI 0.8—1.6).

Previous published results on preterm birth do not permit an evaluation of the specific effect of regular evening or night work (table 2). The early French study by Mamelle and her colleagues on preterm birth focused on sources of fatigue in the job (20). Shift work was not an element of the composite score of fatigue that correlated with preterm birth in the study data. Instead, a higher crude rate of preterm birth for shift and night work was reported separately (table 2). However, another French study found no association between preterm delivery and night work, at least partly during the first 2 trimesters (21). In a large pregnancy study in Montreal, changing shift work was related to preterm birth, but not consistently (22). A recent Chinese study showed an association between rotating shift work and preterm birth

Table 2. Studies on shift work during pregnancy and preterm birth. (OR = odds ratio, 95% CI = 95% confidence interval, RR = rate ratio, O/E = ratio of observed to expected, NS = not significant)

Location	Exposure	Definition of outcome	Observed effect
Quebec City, Canada (19)	Evening/night only or shift work, according to a telephone interview	Preterm birth in pregnancies that ended in a delivery of a live singleton weighing at least 500 g between January and October 1989, determined from birth certificates and interview data	Increased risk associated with evening or night work among women who had continued working after 23 weeks of pregnancy (adjusted OR 2.0, 95% CI 1.0-3.8)
Lyon, Haguenau, France (20)	Shift and night work, based on a retrospective interview	Preterm birth, determined from data from 2 hospitals between 1977 and 1978	Increased rate in a comparison with all other type of work (RR 1.6, 95% CI 1.0-2.5)
France (21)	Night work at least partly during the first 2 trimesters, according to a retrospective interview	Preterm birth, determined from hospital records of a national sample of births in 1981	Similar rates (3.9% versus 4.8%) in a comparison with employment including no night work
Montreal, Canada (22)	Employment doing changing shift work in similar conditions for ≥30 hours a week from conception until at least the 28th week of gestation, according to a retrospective interview	Preterm birth in pregnancies between 1982 and 1984 determined from medical records, and previous pregnancies, determined mainly from maternal interview data	Elevated O/E in the sales (O/E 1.6, NS) and services (O/E 1.9, P<0.01) sectors
Anhui, China (23)	Employment in 1 of 3 textile mills in 1992 and in rotating shift work, according to a questionnaire administered by trained nurses	Preterm birth in live births, according to the questionnaire	Elevated rate in a comparison with nonrotating day work (adjusted OR 2.0, 95% CI 1.1-3.4)

in a homogeneous sample of never-smoking textile workers (23).

In some of the presented studies on preterm birth, low birthweight (ie, birthweight of <2500 g) was studied as well. Shift work was associated with low birthweight in 2 studies (22, 23), but the results of 1 study did not support this association (21).

To overcome problems due to the large overlap between preterm birth and low birthweight, in some studies on birthweight, gestational age was allowed for when birthweight was analyzed. The later results of the Montreal study by Armstrong et al (24) suggested that changing shift work retarded fetal growth and increased the risk of preterm birth as well. The mean percentage of predicted birthweight for gestational age was 98.2 (95% CI 97.2—99.2). In a Finnish study (4), mothers who had been in different types of shift work throughout most of their pregnancy had a slightly elevated risk of giving birth to babies who were small for their gestational age as compared with mothers in normal day work (adjusted rate ratio 1.4, 95% CI 0.9—2.2). When birthweight was analyzed as a continuous variable and gestational age was allowed for in the Chinese study (23), the estimated adjusted effect of rotating shift work on birthweight was -63 (standard error 42) g. In the most recent published study on shift work and preterm birth (19), night work or shift work was not related to the risk of intrauterine growth retardation. For regular evening or night work the adjusted odds ratio of having an infant that was small for its gestational age was 0.98 (95% CI 0.63—1.53) in a comparison with regular day work; for shift work the corresponding odds ratio was also 0.98 (95% CI 0.75—1.27).

Validity aspects

The accuracy of outcome data is crucial for reliable results, and the best way to avoid misclassifying outcome is to resort to medical records whenever possible. In all of the presented studies, self-reported data on subfecundity and menstrual disorders were acquired retrospectively. The feasibility of studying subfertility using retrospective self-reports has been discussed (25) and retrospective data on time to pregnancy from questionnaires have shown acceptable validity (26). In 3 of the studies on spontaneous abortion, the ascertainment of pregnancy outcome relied on the mother's recall (9, 12, 16), but the other studies used information from medical records (table 1). One of the studies on preterm birth relied only on self-reported data (23). Birthweight was acquired mainly from medical records, except in 1 study (23), but the definition of fetal growth retardation required the length of gestation, which is usually partly based on self-reported information (the first day of the last normal menstrual period).

Moreover, it is important to consider what the exposure being examined is and also what the nonexposure serving as the reference category in the comparison is. In the studies on nonstandard workhours, the type of work schedule examined varied and the applied definition of shift work was not necessarily clear. Thus it is difficult to specify entirely what features of different work schedules were actually studied or what categories of exposure were compared. The main interest areas, however, have been work involving evening and night shifts, rotating or changing schedules, and the irregularity of work patterns.

In the Swedish study on time to pregnancy (5), the data on work schedules was originally categorized as regular daytime, permanent night work, or rotating 2- or 3-shift work. Moreover, in the final analysis the different categories of nonstandard workhours were separately compared with regular daytime work. In the European multicenter study (6), information on worktime schedule was originally categorized as daytime, evening, night, or rotating shifts. In the final analysis, changing or rotating shift work was compared with the pooled category of daytime, evening, or night work. In the 2 other publications on fecundity (7, 8), the exposure was merely defined as shift work, and the comparison was with no shift work. In 2 studies on irregular menstrual cycles (9, 10), shift work including night schedules was of interest, and the comparison was with daytime work. But, in the 3rd study (11), exposure was defined as work with a varying beginning, ending or hours per week, not including night shifts. In this study, the reference category included work on a 2-shift schedule without night shifts. In 5 of the studies on spontaneous abortion (9, 12, 15, 17, 18) (table 1), some form of night work was compared with daytime work. Moreover, in 5 studies (12, 14—17), changing or rotating schedules were examined, and the comparison was mainly with daytime work (12, 14, 15, 17). In the studies on preterm birth (table 2) and fetal growth retardation (4, 19, 23, 24) the examined features of nonstandard workhours and the comparisons made differ. For example, in the recent Chinese study (23), the shift workers rotated on an 8-day week with 2 morning shifts (0600 to 1400), 2 evening shifts (1400 to 2200), 2 night shifts (2200 to 0600), and 2 days of rest. However, some night work was included in all of the schedules.

Shift work can be done in specific work environments, for example, in manufacturing, including other potentially hazardous exposures. Accordingly, in some of the reviewed studies, the study base was restricted by selection criteria already at the design stage (5, 11—15, 23) or further restricted analyses were performed to check the results (4). Moreover, especially in the most recent studies, the analyses were adjusted for other occupational exposures (4, 5, 7, 11, 12, 14, 27, 18, 19, 23). However, without reliable data, it is impossible to control potential confounding at the analysis stage and, as always in nonexperimental studies, the results can be biased by residual confounding or confounding attributable to some unrecognized factors.

The mothers with different work schedules should be comparable, or, otherwise, the results may be confounded by maternal characteristics. The outcome of pregnancy may influence the woman's choice of workhours during her next pregnancy. Therefore, in the Swedish study performed among midwives (5, 12) and in the European multicenter study (6), additional separate analyses were done for the first pregnancies to confirm the results. In addition to the outcome of the mother's previous pregnancies, maternal characteristics that may be relevant to reproductive health include maternal age, maternal habits (such as smoking, coffee drinking, and intake of alcohol), diseases, and intake of drugs during pregnancy. Depending on the study outcome and the extent of data collection, some or many of these variables were adjusted for in the presented studies.

Summary

Most results in connection with women's shift work concern spontaneous abortion. Seven of the 9 published studies suggest that some forms of nonstandard workhours may be associated with an increased risk of spontaneous abortion (table 1). In 4 studies (12, 14—16), the elevated risk was related to rotating schedules. In a Canadian study that demonstrated an association between pregnancy loss (spontaneous abortion or stillbirth) and evening and night work (17), rotating shift work was not associated with this outcome. Of the workers on rotating shifts, 21% worked on a night shift and 49% worked on a schedule of <35 hours a week. In the 2 completely negative studies (27, 18), rotating shifts were included in a broader exposure category and thus were not analyzed explicitly. Night work seemed to be hazardous in 3 studies (9, 12, 17), but in 2 (15, 18) no elevated risk was observed.

Preterm birth has received attention in connection with shift work as well (table 2). Combining the evidence from the studies does not provide a fully straightforward conclusion because the studied features of the nonstandard workhours and the comparisons made differed. Shift and night work (20), rotating or changing schedules (22, 23), and evening or night work (19) were related to preterm birth. However, some night work was included in all of the schedules, and thus 4 studies gave some indication that an elevated risk of preterm birth may be associated with nonstandard workhours including night work. One study found no association between the crude rates of preterm birth among women in night work at least partly during the first 2 trimesters and among women with employment including no night work (21). In 1 study (19), the time of the mother's work cessation modified the effect, and regular evening or night work seemed to be hazardous only if the mother continued working after 23 weeks of pregnancy. In the other studies, gestational age at work cessation was not taken into account explicitly.

Preterm birth is closely related to the baby's birthweight and, consequently, the occurrence of babies small for their gestational age is a more relevant reproductive outcome than low birthweight. Three studies suggest that changing or rotating shift work may retard fetal growth

(4, 23, 24), but in 1 recent study (19) shift work or regular night work were not associated with intrauterine growth retardation.

A recent study suggested that different kinds of nonstandard workhours may be associated with prolonged waiting time to pregnancy (5). The study was performed on an occupationally selected and socially homogeneous population of Swedish midwives. A European multicenter study, however, associated reduced fertility only with changing or rotating shift work (6). The reported results of the European multicenter study indicated that rotating shift work was associated with subfecundity in all the countries involved. In a recently published paper, however, the authors stated that the study used the Italian data of the European multicenter study (7). The observed crude elevated risk of subfecundity was no longer seen when several occupational and maternal potential confounders were adjusted for in the analysis. Also in an earlier Danish study, shift work had no effect on subfecundity (8). It has been suggested that shift work would impair the fecundity of women by reducing sexual activity. However, in the Swedish data on time to pregnancy (5), there were no notable differences in the average frequency of intercourse between women with different work schedules. Similarly, in the European multcenter study (6), shift work did not seem to affect the level of sexual activity.

The researchers of the European multicenter study were surprised that, in their data, shift work did not increase the frequency of irregular menstrual bleedings, which has been hypothesized to be a possible cause of subfecundity. In all, 3 studies have associated some forms of nonstandard workhours with irregular mentsrual cycles (9—11). In the 1992 Japanese study (10), the researchers determined plasma concentrations in subsamples from nurses working at night and nurses resting in their quarters. The findings suggested that night work suppresses the ovarian function by affecting the circadian rhythm of melatonin and prolactin.

In conclusion, the studies published on shift work and reproductive health suggest that some forms of nonstandard workhours may be associated with elevated reproductive risks, and most of the evidence is related to spontaneous abortion, preterm birth, and lowered birthweight. Although the evidence is not ample and remains ambiguous, it is prudent to consider shift work as a potential risk to reproduction.

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References

1. Åkerstedt T. Psychological and psychophysiological effects of shift work. Scand J Work Environ Health 1990;16 suppl 1:67—73.
2. Pastides H. A woman's work [editorial]. Epidemiology 1993;4:1—3.
3. Nurminen T. Female noise exposure, shift work, and reproduction. J Occup Environ Med 1995;37:945—50.
4. Nurminen T. Shift work, fetal development and course of pregnancy. Scand J Work Environ Health 1989;15:395—403.
5. Ahlborg G Jr, Axelsson G, Bodin L. Shift work, nitrous oxide exposure and subfertility among Swedish midwives. Int J Epidemiol 1996;25:783—90.
6. Bisanti L, Olsen J, Basso O, Thonneau P, Karmaus W, the European Study Group on Infertility and Subfecundity. Shift work and subfecundity: a European multicenter study. J Occup Environ Med 1996;38:352—58.
7. Spinelli A, Figa-Talamanga I, Osborn J. Time to pregnancy and occupation in a group of Italian women. Int J Epidemiol 1997;26:601—9.
8. Olsen J. Cigarette smoking, tea and coffee drinking, and subfecundity. Am J Epidemiol 1991;133:734—9.
9. Uehata T, Sasakawa N. The fatigue and maternity disturbances of night workwomen. J Hum Ergol (Tokyo) 1982;11:465—74.
10. Miyauchi F, Nanjo K, Otsuka K. Effects of night shift on plasma concentrations of melatonin, LH, FSH and prolactin, and menstrual irregularity. Jpn J Ind Health 1992;34:545—50.
11. Messing K, Saurel-Cubizolles M-J, Bourgine M, Kaminski M. Menstrual-cycle characteristics and work conditions of workers in poultry slaughterhouses and canneries. Scand J Work Environ Health 1992;18:302—9.
12. Axelsson G, Ahlborg G Jr, Bodin L. Shift work, nitrous oxide exposure, and spontaneous abortion among Swedish midwives. Occup Environ Med 1996;53:374—8.
13. Axelsson G, Lütz C, Rylander R. Exposure to solvents and outcome of pregnancy in university laboratory employees. Br J Ind Med 1984;41:305—12.
14. Hemminki K, Kyyrönen P, Lindbohm M-L. Spontaneous abortions and malformations in the offspring of nurses exposed to anaesthetic gases, cytostatic drugs, and other potential hazards in hospitals, based on registered information of outcome. J Epidemiol Community Health 1985;39:141—7.
15. Axelsson G, Rylander R, Molin I. Outcome of pregnancy in relation to irregular and inconvenient work schedules. Br J Ind Med 1989;46:393—8.
16. McDonald AD, McDonald JC, Armstrong B, Cherry NM, Côté R, Lavoie J, et al. Fetal death and work in pregnancy. Br J Ind Med 1988;45:148—57.
17. Infante-Rivard C, David M, Gauthier R, Rivard G-E. Pregnancy loss and work schedule during pregnancy. Epidemiology 1993;4:73—5.
18. Eskenazi B, Fenster L, Wight S, English P, Windham GW, Swan SH. Physical exertion as a risk factor for spontaneous abortion. Epidemiology 1994;5:6—13.
19. Fortier I, Marcoux S, Brisson J. Maternal work during pregnancy and the risks of delivering a small-for-gestational-age or preterm infant. Scand J Work Environ Health 1995;21:412—8.
20. Mamelle N, Laumon B, Lazar P. Prematurity and occupational activity during pregnancy. Am J Epidemiol 1984;119:309—

22.
21. Saurel-Cubizolles MJ, Kaminski M. Pregnant women's working conditions and their changes during pregnancy: a national study in France. Br J Ind Med 1987;44:236—43.
22. McDonald AD, McDonald JC, Armstrong B, Cherry NM, Nolin AD, Robert D. Prematurity and work in pregnancy. Br J Ind Med 1988;45:56—62.
23. Xu X, Ding M, Li B, Christiani DC. Association of rotating shiftwork with preterm births and low birth weight among never smoking women textile workers in China. Occup Environ Med 1994;51:470—4.
24. Armstrong BG, Nolin AD, McDonald AD. Work in pregnancy and birth weight for gestational age. Br J Ind Med 1989;46:196—9.
25. Joffe M. Feasibility of studying subfertility using retrospective self reports. J Epidemiol Community Health 1989;43:268—74.
26. Joffe M. Time to pregnancy: a measure of reproductive function in either sex. Occup Environ Med 1997;54:289—95.
27. Bryant HE, Love EJ. Effect of employment and its correlates on spontaneous abortion risk. Soc Sci Med 1991;33:795—800.

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Individual and social determinants of shiftwork tolerance

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This paper reviews evidence published on individual and social determinants of shiftwork tolerance since 1993. In agreement with earlier reviews, individual differences show only some low and inconsistent concurrent covariation with shiftwork tolerance, and no predictive power for these measures has been found. It is thus not possible to predict future shiftwork tolerance from individual differences. Social conditions are also related to shiftwork tolerance, although again predictive power has not been demonstrated. An examination of the reasons for this state of the art suggested means of improving the relevance and usability of future research in this area.

Key terms individual differences, research strategies, selection, shift work, social conditions.

Interest in the individual and social determinants of shiftwork tolerance is usually based on 2 approaches to managing shift work. In the 1st approach suitable or shiftwork tolerant people could be selected for shift work — if this were possible — or, on the other hand, potentially unfit or intolerant workers should be prevented from entering shift work. In the other approach, shift workers are counseled on what to do and how to cope effectively with the problems of shift work according to the differences between those who are shiftwork tolerant and those who are not. Whereas selection is a genuine individual differences approach, looking for (relatively) stable personal characteristics that predict future shiftwork tolerance, counseling is much more a form of behavior modification aiming at changing behavior or changing conditions that influence behavior. Both approaches make sense, however, only if there are interindividual differences in shiftwork tolerance, if there is covariation between shiftwork tolerance and individual and social characteristics, if in the case of selection (especially in selecting tolerant shift workers) there are people who can be selected (ie, a greater number of applicants than open positions in shift work) and if the predictors do in fact *predict* and not just *covary* with shiftwork tolerance. Such predictive relationships have not been demonstrated, however. Therefore, Härmä (1), after a thorough review of the available evidence, concluded that "It seems thus unjustified to make any definitive selection of the future 'good' or 'bad' shiftworkers before experience in shiftwork" [p 107]. And, as the present review, roughly 5 years later, shows, nothing has to be added to this statement. The question is "Why is the situation what it is and what should or could be done to improve it?" Some tentative answers are developed in this review after a short presentation of the new evidence on individual and social determinants of shiftwork tolerance.

Some remarks have to be made, however, before the results of this review and the conclusions drawn from it are considered. This is not a comprehensive review in several respects. First, it is based on Härmä's (1); therefore no attempt has been made to review and report the literature presented by him and only the literature published since 1993 is covered, with some few exceptions. Second, no attempt has been made to cover all kinds of (theoretically possible or empirically analyzed) individual or social difference measures. Whether a "comprehensive" review in this respect, irrespective of the space available for publication, would be possible is questionable, since the (theoretically possible) number of individual difference measures is probably limited only by one's imagination. Instead my effort has concentrated on the classical and more-promising newer individual and social difference measures with relevance to predicting shiftwork tolerance. Furthermore, no restrictions on methodological adequacy have been imposed on the reviewed literature, either published in conference proceedings, collections of abstracts for conferences (eg, in the *Shiftwork International Newsletter*), or in reviewed journals. Imposing rigid methodological standards would have reduced the literature to be reviewed dramatically,

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and therefore possible indications of a concurrent or predictive relationship between individual or social difference measures and shiftwork tolerance might have been underestimated, since the literature on individual and social differences and shiftwork tolerance indicates that the better controlled a study is the less support for a truly *predictive* relationship remains. Methodological flaws are widespread and range over the whole research process, from design problems (eg, collecting data for "predictors" time delayed after the dependent variables) and statistically inadequate treatment to the interpretation of predictive relationships from an analysis of statistically significant concurrent covariation (ie, taking the statistical term "coefficient of determination" literally) without due regard to the effect size. It should also be kept in mind that studies published in refereed journals are not methodologically unflawed as well. Therefore, conference abstracts have not been excluded from this review. Where possible, however, preference has been given to published papers.

Another intention of this review, which might well be considered a position paper based on a critical review of the available literature, is to provoke thought for future research in this field.

Individual differences

Gender

In an experimental study (2) no differences in the circadian adaptation process have been observed between men and women, and there are no other data to be reported currently on sex differences. Gender differences will be dealt with under social determinants.

Age

Härmä's (1) findings that shift-related problems tend to increase with increasing age have been supported, for both men and women, for example by Oginska et al (3). These authors also showed, however, that there is a decrease in complaints among women ≥50 years of age. Whether this increase in intolerance with age is associated with (or aggravated or caused by) the general increase in sleeping problems with age and the reported increase in morningness ($r=0.21$) (4) is still open to question, although some results by Brugère et al (5) would seem to indicate an additive effect for shift work and age, at least for sleeping problems, and no interaction. According to these results sleeping problems increase with age for both shift and nonshift workers, shift workers showing more problems in each age group but no higher increase with age than nonshift workers. For emotional reactions no increase with age was found in this study, either for shift or for nonshift workers.

Besides positive covariation, no covariation between age and morningness or health has been reported (6), but sometimes indirect or interactive rather than direct effects have been observed (7). The question thus is whether there are relevant circadian changes with age which would influence shiftwork tolerance (which then should apply to all people and, eg, not only to people without social support). However, as other results (8, 9) show, there is no reduction in circadian rhythmicity with age. Therefore, the question of how age influences shiftwork tolerance and whether the influence holds for all people or only for those with certain additional characteristics, which might then be the real cause of the (in)tolerance, remains open.

Neuroticism and extroversion

Neuroticism and extroversion continue to show their well known (low and inconsistent) correlations with shiftwork tolerance (10—15). Neuroticism tends to be the highest [if not the only significant (15)] predictor in multiple regressions. For example, Iskra-Golec et al (14) reported a correlation of 0.59 between neuroticism and shiftwork tolerance. This value is remarkably high, corresponding to as much as 35% of the variance explained. Usually the correlations are much lower, ranging from 0 to ≈ 0.20 [if the dependent variable is not too similar to neuroticism itself, eg, cognitive anxiety, for which correlations up to 0.57 can be found (15)]. Taking interactions with other variables into account does not seem to improve the proportion of variance explained, at least not substantially (14). In general, the correlations are inconsistent — in magnitude as well as in direction. (See, eg, reference 12.)

Testing the *predictive* power of several individual difference measures in one of the very few controlled longitudinal studies, Kaliterna et al (13) were able to demonstrate that neither neuroticism nor extroversion had any power to *predict* shiftwork intolerance.

In general, neuroticism seems to change or lose its status as a predictor or determinant of shiftwork tolerance and to become a confounding variable, whose effects have to be controlled for in the analysis of shift work and its effects (15), or to become an indicator of shiftwork tolerance, with increasing neuroticism considered as an *effect* of shift work (16, 17).

Morningness, eveningness and circadian type

Again, as with neuroticism, some significant correlations have been reported between morningness, eveningness, or circadian type scores (languidity, flexibility) and shiftwork tolerance (6, 18). One study (12) reports "satisfactory covariation", which, of course, depends on what one is prepared to call satisfactory. As can be seen from an inspection of the results presented by Kaliterna et al (12) and Vidacek et al (10), the correlations are again low and inconsistent. Härmä (1) already reported inconsistencies in the relations of these variables to shiftwork tolerance. In agreement with this pattern of inconsistency, Härmä et al (19) found no relation with attitudes towards shift work. Moog (20) reported better adaptation to shift work by evening types and suggested slowly rotating systems for these people. Brown (21) found some inconsistent covariation between shiftwork tolerance and scores on the Basic Language Morningness Scale. Therefore, again, there seems to be some association between these characteristics and intolerance, but, when tested in a *predictive* context, these characteristics show no validity to *predict* shiftwork tolerance (11, 13).

Circadian variation of body temperature or mood

There seems to be no validity associated with the ability of circadian parameters such as temperature rhythm or circadian variations in mood to predict shiftwork tolerance either. Vidacek et al (10, 11) showed that there is no association and no power for the amplitude, the mesor, or the acrophase of temperature rhythm to *predict* shiftwork tolerance, a finding that has been replicated recently in another longitudinal study — although of rather short duration — by Bohle (22). In fact, the only statistically significant prediction from circadian variables to scores of the General Health Questionnaire in this study (22) was opposed in direction to that hypothesized.

With regard to circadian variations in mood, Prizmic et al (23) found that, although there is some association between mood and circadian variation in mood and shiftwork tolerance in cross-sectional studies (24), *no predictive validity* could be demonstrated.

Newcomers

Hardiness has been introduced as a new personality variable associated with shiftwork tolerance (25), although no causal relationship was suggested. Since the concept is still undergoing development and the available evidence is limited, no conclusions can yet be drawn.

Locus of control, especially *shiftwork locus of control* (ie, the internal versus external attribution of control with regard to managing the problems of shift work) has been introduced as a determinant of shiftwork tolerance (26), again together with some (moderate) concurrent correlations indicating that an external locus of control is associated with more problems. A common feature in the attribution of control is, however, to attribute the causes of failure externally and those for success internally. This characteristic would be consistent with the reported findings, namely, those who report more problems, and thus are regarded as intolerant, would attribute their problems to external conditions while those who report fewer problems would tend to attribute a lack of problems to their own competence in managing with shift work.

Individual differences in strategies to cope with shift work have been analyzed (27) and would, at least theoretically, seem to be a promising candidate for predicting shiftwork tolerance, since coping behavior might directly influence shiftwork tolerance. The reported correlations were moderate again, and other researchers (7) have found only low correlations. But perhaps this result is due to the conceptualization and assessment in that reducing (possibly specific) coping *behavior* to coping *styles* goes again back to some stable personality dispositions, and their well known low and inconsistent correlations with shiftwork tolerance. Since predictive results have not been presented, the question of predictive power is open for speculation. Perhaps a closer view of the individual differences in *actual coping behavior* (instead of coping *styles*) might yield more promising results.

In summary, there is indeed not much new information on individual differences as determinants of shiftwork (in)tolerance, except that the Vidacek group has now shown empirically that *none of the parameters has any predictive value* and this finding has received support elsewhere.

Specific patterns of behavior

The results presented thus far could indicate that it may be more appropriate and efficient to consider specific *patterns of behavior* (eg, effective versus ineffective coping behavior) as determinants of shiftwork tolerance instead of *traits* or personality characteristics. There are a few studies which would seem to support this suggestion.

Physical fitness and *exercising,* which may be considered to be at the crossroads between traits and specific behavior, have again been argued for by Härmä (28, see also reference 1) as determinants of shiftwork tolerance, together with some empirical results supporting the position that physical fitness might work via a sleep connection (induced fatigue) and the timing of activities (zeitgeber) and also via enhanced fitness per se. Again more evidence (especially of a predictive nature) would seem to be required before firm conclusions can be drawn. And as physical fitness and exercising lend themselves to a behavior modification approach, well-controlled intervention studies like those by Härmä would seem appropriate.

Looking directly at a set of specific behavior, Greenwood (29) found remarkable differences in effective versus ineffective coping with shift work, and Härmä et al (19) reported that sleeping longer before the morning shifts, due to an interventive delay in the starting time of the morning shift, resulted in more favorable attitudes, with 65% of the variance explained by this change — a remarkably high proportion in comparison with the variance explained by personality traits.

Finally, Blood et al (30) found that the regularity of social behavior facilitated adaptation to shift work, which might be an indication that the regularity of the *actual behavior* might be more important than the self-assessment of flexibility as a *personality trait.*

Social determinants

Gender

It has been known for a long time that gender has an effect on coping with shift work (31) and that it works mainly via a social rather than a biological pathway. This finding has been supported in the meantime by much evidence. (See, eg, references 3, 32, and 33.) Oginska et al (3) found that women (from an industrial sample) showed more symptoms of intolerance than men — until the age of 50 years. Before 50 years of age symptoms increased with age and women of all age groups showed more symptoms than men, whereas women 50 or more years of age showed a decline in symptoms and no difference in comparison with their male colleagues. One possibility is that the change coincides with children having left the home, and therefore female shift workers experience a significant lessening of their double burden as taking care of dependents is reduced to taking care of the household and the husband. (Another reason for the decline among women after 50 years of age may, of course, be self-selection. Such a possibility would, however, have to rely on the assumption that self-selection works differently for men and women — which again would probably be best explained by differences in their social situations.)

The fact that this socially determined double burden makes the difference has been shown by Beermann (32), who found no differences in the effects of shift work on health between women and men but clear differences in domestic obligations and thus in work load and leisure-time activities. Although no differences in the frequency or severity of health complaints were found between women and men (33), Nachreiner et al (34) reported that women show an earlier development of a shiftwork-specific structure of health complaints than men, probably due to the socially determined role-specific behavior of men and women.

Spouses and partners

Much evidence (32, 33, 35—38) shows that the existence of a partner is a determinant of shiftwork tolerance — either in the form of social support (usually for men) or in the form of someone who has to be taken care of (usually for women). All this evidence tends to support the old saying that shift work is only tolerable with the support of a partner — which is exactly what is missing for women (32, 33).

Children

Children add to domestic obligations and thus to the problems of coping with shift work, especially for women, but also for men (33). The evidence seems to be convincing in this respect (30, 35, 38—40). Grzech-Šukalo & Nachreiner (37) have shown that the statistical relationships among the relevant variables become much more complex with the presence of children in the home (indicating higher complexities in the management of the social situation of the shift worker) and that different characteristics of the shift system become relevant or effective with the presence of children (indicating the importance of *interactions* between individual, social, and work conditions as determinants of shiftwork tolerance).

It becomes clear from the published literature as well that children and spouses are not only determinants of shiftwork tolerance, they also add additional dimensions to it (ie, the relationships with spouses and children, the social interactions with them, and the resulting satisfaction).

Domestic obligations

It has already been argued that domestic obligations play a major role as determinants of shiftwork tolerance, and in fact all the references under the headings of gender, spouses and children could be repeated in this section, since domestic obligations seem to be the mechanism by which these conditions become effective. Support for the validity of this conclusion has been provided by Beermann (32), who analyzed the differential work load and social support of men and women.

Social support

The importance of social support, whether at home from family members or at work from colleagues and superiors, as a determinant of shiftwork tolerance has been shown recently (7, 16, 35, 38, 40, 41), in addition to domestic obligations. This evidence is consistent with the results of (older) sociological studies (42) showing role changes in shiftworker families in which women take over roles (and duties) of a shiftworking spouse in order to support the family and the shift worker in coping with shift work.

Shiftwork tradition and culture

There are some old sayings about the effects of shiftwork tradition within a community. For example, within the old coal and steel communities, where shift work was common (and supported by the surroundings) and not abnormal, shift work was more tolerable than in communities or areas where shift work is definitely "abnormal". However, there seems to be no systematic research into this problem within the last few years. The same is true if one broadens the perspective from the neighborhood, residential area, or community to greater social systems like societies, for example, in the United States with its "rock around the clock" culture, where everything goes all the time, as compared with more time-structured societies like the European countries (eg, Germany, where more flexibility in scheduling workhours is argued for — especially for economic reasons). We simply do not know anything about this phenomenon (ie, whether destroying social rhythms or socially induced time structures for behavior will have any effect on shiftwork tolerance). It would seem important, however, for present and future discussions to have some evidence on the effects of the social system on shiftwork tolerance.

Again, as with individual differences, the question remains of how big the effects of social determinants are on shiftwork tolerance. There is covariation between social conditions and shiftwork tolerance, and there are some estimates about the (relative) strength of the relationships. But again, whether these are predictive is open to question, although, with some variables, an inverse causal relationship seems less probable.

Considering the results on the individual and social determinants of shiftwork tolerance together raises the question of why so little is known about *determinants* of shiftwork tolerance after all these years of intense research and effort. Reviewing the literature leads to the following problems and possible reasons.

Problems in determining determinants of shiftwork tolerance

Concepts and constructs

One of the reasons for the state of the art might be the definition and explication of the concepts involved. What, for example, does shiftwork tolerance mean exactly? According to Härmä (1), who adopted the concept from Reinberg et al (43), it is the absence of complaints with regard to sleep, digestive and nervous disorders, or psychological well-being, usually measured by some questionnaire (eg, the General Health Questionnaire). The question is (i) whether this definition is a good explication (and operationalization) of the concept of shiftwork tolerance and (ii) whether it is comprehensive enough. What about psychosocial problems, problems with spouses, children and friends, or work-nonwork conflicts, changes in personality (eg, towards increased neuroticism or introversion), or changes in the value structure [eg, towards more solitary activities (16, 17)]? And what about negative effects on spouses or children due to ineffective coping with shift work, partially without complaints from shift workers because they might not even note these problems themselves?

Shiftwork tolerance, as the term is used today, is clearly an ill-defined concept that shows a biologically restricted perspective of "tolerance". It obscures relations between the biological and social consequences of shift work — and their possible interactions. This concept should thus be either clearly and adequately defined for future use or abandoned.

What is morningness? Is it the chronometric position of the temperature minimum (under unmasked conditions!) or the length of the circadian period (under free running conditions!) or is it a behavioral concept (eg, the preferred times for certain activities) or is it lack of adaptability to changing time structures? Is it a uni- or a multidimensional physiological or behavioral concept (and it should be remembered that a correlation is not a very convincing argument)? Morningness has been found to be multidimensional (44), yielding 2 to 3 orthogonal factors, which, nevertheless, have been combined into 1 single score. The rationale for such a procedure is difficult to understand, but it can be observed with other instruments as well.

A clear explication and definition of the concept would seem required, since such conceptual weaknesses are clearly not very promising for developing valid measuring instruments.

How stable is morningness over time? If it were to be used to predict (a well-defined) shiftwork tolerance, it should be a relatively stable personality trait, independent of external conditions. Moog (20, 45) has reported satisfactory short-term stability (r=0.84) among students and, as expected, definitely lower long-term stability over 7 years (r=0.46), corresponding to a drop from 65% to 21% in systematic variance, which is clearly not very promising for predictive purposes — especially if one considers that these students probably did not have too many transitions in life circumstances and that correlations indicate only *relative*, not absolute, stability. There have been reports on changes in — or more precisely covariations of — morningness with age (44), although rather low (r=0.20, corresponding to 4% of common variance), and an age-related phase advance of temperature rhythm among older people under normal conditions. The latter was not present, however, under constant routine conditions (9), indicating behavioral dependency. Personal experience would lead one to believe that temporal preferences for certain activities, as asked for in morningness-eveningness questionnaires, change with transitions across life phases — and thus change according to external conditions. It is not clear whether the temperature minimum (under unmasked conditions) changes correspondingly — but behavior does change, as can be easily observed. Why should morningness change with age (if it does)? Could it be due to the effect of a third variable? The answer is not available at the moment. Why does morningness change with the seasons, a definitely external condition, as Pokorski et al (46) showed? The question thus is what morningness really means. Is it a relatively stable personality disposition, dimension, or trait with the possibility to *predict* shiftwork tolerance? — "Probably not" would be the most appropriate conclusion after a critical review of the literature.

Psychometric properties of measuring instruments

Since it is difficult to construct well-designed instruments for badly defined constructs, one would not expect too much with respect of the "determinants" of shiftwork tolerance. In fact, there are remarkable weaknesses in the instruments used. In a factor analysis of the Circadian Type Inventory, Silvério et al (47) found only 23% of the variance explained by the 2 factors, and Smith et al (48) demonstrated that the psychometric properties of the Circadian Type Inventory are definitely not adequate. The problem of combining items belonging to *orthogonal factors* in a single score on a *unidimensional* scale has already been mentioned in the context of morningness-eveningness. If 4 loci of (shiftwork) control can be differentiated, why should they then be combined into a single score — especially if they refer to different areas of impairment and the correlations are higher for the specific scales with their respective area of impairment (26)?

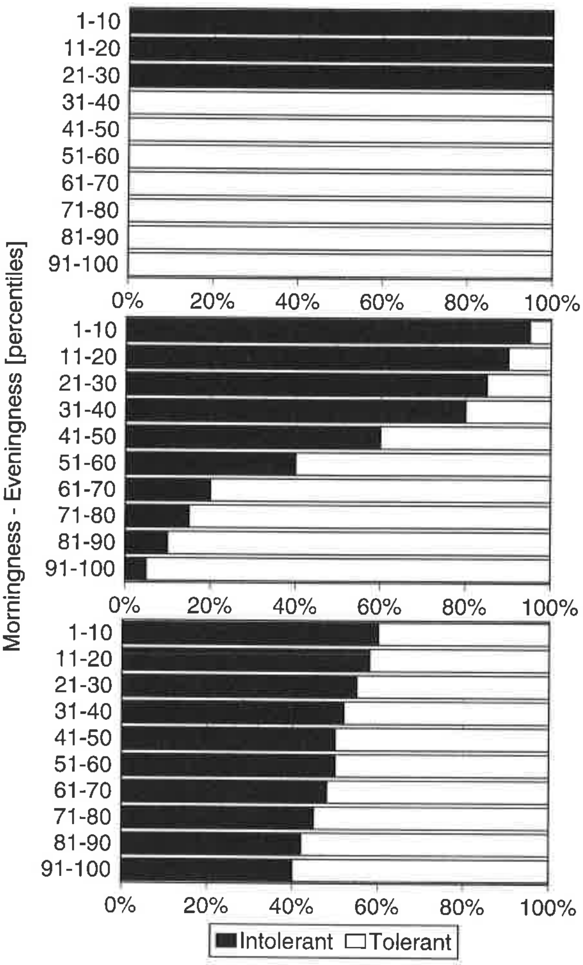

Figure 1. Expectancy charts for different predictor-criterion relationships (theoretical examples).

Statistical treatment

The statistical problems of the measuring instruments lead directly to problems of the statistical treatment of the relations between dependent and independent variables. What one usually finds are multiple dependent (eg, those making up shiftwork tolerance) and multiple independent (eg, neuroticism, morningness, flexibility) variables. However, instead of using adequate statistical methods (eg, canonical correlation) these variables are generally treated by simple bivariate correlational analyses, multiple regressions (or multiple multiple regressions), or (multiple) factor analyses or combinations thereof. The use of these techniques leaves interesting covariation unobserved and leads to repeated tests of the same hypothesis on the same data.

That an adequate statistical treatment offers some interesting insights into the relationships between the variables has been demonstrated earlier (49), where it could be shown that the evaluative component of the attitude towards shift work could be separated from its conative (behavioral) component and that both components are determined by different independent variables, the behavioral component (eg, manifest trials to get out of shift work) being less influenced by personality characteristics (eg, neuroticism) than the evaluative component. The behavioral component on the other hand is much more influenced by motivational and situational variables.

Some improvements, however, have to be noted as well. There is a tendency to use more appropriate and more sophisticated statistics, for example, structural modeling (38, 40, 50), during the last few years.

Design problems

A severe problem is the common cross-sectional design of studies. Longitudinal studies are rare, but offer remarkable insight, as can be seen from the studies of Vidacek et al (11) and Kaliterna et al (13). On the other hand, if longitudinal studies are used, why not repeat the measurement of the predictors as well, not only to estimate their stability but to be able to use cross-lagged analysis techniques to detect complex recursive relations (eg, neuroticism influencing tolerance, which influences neuroticism). Such more-complex approaches, combined with more complex, adequate statistical techniques like structural modeling, may improve the understanding of what really happens in shift work.

Variance explained and linearity of relationships

When one looks at (usually cross-sectional) covariation, another question concerns the amount of variance explained. The amount explained usually varies from very low to low (4 — 10%), 35% being already a rare exception. Considered together with the inconsistencies (in magnitude and direction), the low amount of covariation casts severe doubts on the chances of effective selection.

Usually linear relationships are (tacitly) assumed (eg, as in correlation) without further inspection. Could nonlinearities or stepfunctions be one of the reasons for the low correlations? For circadian type variables, extreme groups are usually compared. But what happens in between? Or do such comparisons imply tacitly favoring a model with a bimodal distribution, quite in contrast to the empirical distributions? If selection is really wanted and if it is to be done in a responsible way, with some estimates of effectiveness, then expectancy charts, giving the odds of correct decisions for different scores on the predictor, may be much more informative than correlation coefficients or extreme group comparisons.

Figure 1 shows 3 theoretical examples of such expectancy charts, all of which would yield a correlation between the predictor and the criterion (partially substantial, eg, 0.80, 0.68 and 0.12 on an individual level and 0.80, 0.97 and 0.99 on the group level from top to bottom). These expectancy charts would show immediately what the chances for an effective selection would be under the particular conditions given. Error-free selection decisions would only be possible with top chart conditions, if the assessment of the predictor were highly reliable, and more than 30% could be rejected from entering shift work. However, such a predictor-criterion relationship has never been observed.

Factors influencing selection efficiency

As figure 1 shows, selection will always yield errors, depending on more variables than merely a substantial predictor-criterion relationship, since there are more factors which influence the efficiency of selection, eg, the base rate (ie, the proportion showing the criterion, eg, shiftwork tolerance, in the unselected population), and the selection rate (ie, the proportion that has to be selected from the population to fill the jobs), which will influence the proportion of false positives, false negatives, true positives, and true negatives with different "costs" associated with each group. But what would be the base rate of shiftwork tolerance (whatever it means) in an unselected population? The fairest answer would seem to be "unknown". And what are realistic selection rates, if there are any at all, in practice?

Concluding remarks

When the facts presented in this review are taken into account, the chances for an effective selection strategy with regard to shiftwork tolerance would appear to be minimal, at least for the time being, and therefore it would not seem to be a professionally serious and responsible activity.

The problem remains, however, with regard to counseling. Intervention studies would appear to be the most helpful in testing hypotheses about determinants of shiftwork tolerance or effective coping with shift work. In this context a concentration on specific patterns of behavior and its hypothesized determinants would seem appropriate and promising.

Nor should oversimplified models for underlying mechanisms or relations be used. If behavior is taken seriously as a function of the person, the environment (including the job and the task), and especially the interaction between the person and the environment, more consideration should be given to a more thorough explanation of the underlying constructs, to more complex, for example, recursive, models of the relationships between them, and to the use of adequate instruments and methodologies to improve the applicability of shiftwork research.

References

1. Härmä M. Individual differences in tolerance to shiftwork: a review. Ergonomics 1993;36(1—3):101—10.
2. Hakola T, Härmä MI, Laitinen JT. Sex and circadian adjustment to night shifts. Shiftwork Int Newsl 1995;12(1):74.
3. Oginska H, Pokorski J, Oginski A. Gender, aging and shiftwork intolerance. Ergonomics 1993;36(1—3):161—8.
4. Brown FM, LaJambe C. Atypical and age-related BALM-scale responses by air-traffic controllers. Shiftwork Int Newsl 1995;12(1):67.
5. Brugère D, Barrit J, Butat C, Cosset M, Volkoff S. Shiftwork, age, and health: an epidemiologic investigation. Int J Occup Environ Health 1997;3 suppl 2:S15—9.
6. Gallwey TJ, McEntee JJ. Effects of individual differences and shift systems on workers' health. Shiftwork Int Newsl 1997;14(1):83.
7. Brady-Elnick A, Labouvie-Vief G. Psychological influences on shiftwork with an aging workforce. Shiftwork Int Newsl 1997;14(1):84.
8. Monk TH, Buysse DJ, Reynolds CF, Kupfer DJ, Houck PR. Age-related shiftwork intolerance: is it mediated by a change in normal temperature rhythm amplitude? Shiftwork Int Newsl 1995;12(1):41.
9. Monk TH, Buysse DJ, Reynolds CF, Kupfer DJ, Houck PR. Circadian temperature rhythms of older people. Exp Gerontol 1995;30:455—74.
10. Vidacek S, Radosevic-Vidacek B, Kaliterna L, Prizmic Z. Individual differences in circadian rhythm parameters and short-term tolerance to shiftwork: a follow-up study. Ergonomics 1993;36(1—3):117—24.
11. Vidacek S, Prizmic Z, Kaliterna L, Radosevic-Vidacek B, Cabrajec-Grbac S, Fornazar-Knezevic B, et al. Shiftwork tolerance and circadian rhythms in oral temperature and heart rate. Work Stress 1995;9(2/3):335—41.

12. Kaliterna L, Vidacek S, Radosevic-Vidacek B, Prizmic Z. The reliability and stability of various individual difference and tolerance to shiftwork measures. Ergonomics 1993;36(1—3):183—90.
13. Kaliterna L, Vidacek S, Prizmic Z, Radosevic-Vidacek B. Is tolerance to shiftwork predictable from individual difference measures? Work Stress 1995;9(2/3):140—7.
14. Iskra-Golec I, Marek T, Noworol C. Interactive effect of individual factors on nurses' health and sleep. Work Stress 1995;9(2/3):256—61.
15. Taylor E, Folkard S, Shapiro D. Shiftwork advantages as predictors of health. Int J Occup Environ Health 1997;3 suppl 2:S20—9.
16. Bohle P, Tilley A. The impact of night work on psychological well-being. Ergonomics 1989;32:1089—99.
17. Nachreiner F. Role perceptions, job satisfaction and attitudes towards shiftwork of workers in different shift systems as related to situational and personal factors. In: Colquhoun P, Folkard S, Knauth P, Rutenfranz J, editors. Experimental studies of shiftwork. Opladen: Westdeutscher Verlag, 1975:232—43.
18. Ognjanova VM, Dalbokova DL, Stanchev V. Stress states, alertness and individual differences under 12-hour shiftwork. Shiftwork Int Newsl 1995;12(1):93.
19. Härmä M, Rosa RR, Pulli K, Mulder M, Näsman O. Individual factors associated with positive attitudes toward later shift start-end times in rotating shift work. Shiftwork Int Newsl 1995;12(1):76.
20. Moog R. Die individuelle circadiane Phasenlage — ein Prädiktor der Nacht- und Schichtarbeitstoleranz [dissertation]. Marburg: Universität Marburg, 1988.
21. Brown FM. Psychometric equivalence of an improved Basic Language Morningness (BALM) Scale using industrial population within comparison. Ergonomics 1993;36(1—3):191—8.
22. Bohle P. Sleep and circadian rhythm characteristics as predictors of adjustment to shiftwork. Int J Occup Environ Health 1997;3 suppl 2:S30—4.
23. Prizmic Z, Vidacek S, Radosevic-Vidacek B, Kaliterna L, Cabrajec-Grbac S, Lalic V, Fornazar-Knezevic B. Shiftwork tolerance and 24-h variations in mood. Work Stress 1995;9(2/3):327—34.
24. Prizmic Z, Kaliterna L. Relationship between positive and negative affect and measures of tolerance to shiftwork. Shiftwork Int Newsl 1995;12(1):96.
25. Wedderburn AAI. Men and women who like continuous shiftwork are more 'hardy': but what does it mean? Work Stress 1995;9(2/3):206—10.
26. Smith L, Spelten E, Norman P. Shiftwork locus of control: scale development. Work Stress 1995;9(2/3):219—26.
27. Spelten E, Smith L, Totterdell P, Barton J, Folkard S, Bohle P. The relationship between coping strategies and GHQ-scores in nurses. Ergonomics 1993;36(1—3):227—32.
28. Härmä M. Ageing, physical fitness and shiftwork tolerance. Appl Ergon 1996;27(1):25—9.
29. Greenwood KM. Strategies used by shiftworkers to improve sleep following the night shift. Shiftwork Int Newsl 1995;12(1):23.
30. Blood ML, Sack RL, Lewy AJ, Monk TH. Regular social rhythms are associated with circadian phase shifts in night workers. Shiftwork Int Newsl 1995;12(1):112.
31. Gadbois C. Women on night shift: interdependence of sleep and off-the-job activities. In: Reinberg A, Vieux N, Andlauer P, editors. Night and shift work: biological and social aspects. Oxford: Pergamon Press, 1981:223—7.
32. Beermann B. Frauen und Männer im Wechselschichtdienst: Belastung, Beanspruchung und Beanspruchungsfolgen bei Nacht- und Schichtarbeit. Frankfurt (aM): Peter Lang, 1993.
33. Beermann B, Nachreiner F. Working shifts — different effects for women and men? Work Stress 1995;9(2/3):289—97.
34. Nachreiner F, Lübeck-Plöger H, Grzech-Šukalo H. Changes in the structure of health complaints as related to shiftwork exposure. Work Stress 1995;9(2/3):227—34.
35. Loudon R, Bohle P. Work/non-work conflict and health in shiftwork: relationships with family status and social support. Int J Occup Environ Health 1997;3 suppl 2:S71—7.
36. Grzech-Šukalo H, Nachreiner F. Structural properties of shift schedules, employment of partners, and their effects on workers' family and leisure activities. Int J Occup Environ Health 1997; 3 suppl 2:S67—70.
37. Grzech-Šukalo H, Nachreiner F. Effects of different structural properties of shift systems on psychosocial impairment — an analysis of direct and indirect effects. Shiftwork Int Newsl 1997;14(1):17.
38. Pisarski A. Work/non-work conflict & shiftworkers health: main and moderating effects of relationship status, support, & coping. Shiftwork Int Newsl 1997;14(1):92.
39. Rotenberg L, Portela LF, Moreno C, Benedito-Silva AA, Menna-Baretto L. Sleep and sleep/fatigue complaints in female nightworkers at an assembly line — differences between those who have and those who do not have young children. Shiftwork Int Newsl 1997;14(1):85.
40. Bohle P. Shiftwork, work/non-work conflict and health in nursing. Shiftwork Int Newsl 1997;14(1):86.
41. Pisarski A, Bohle P. The effects of instrumental and emotional support on work/non-work conflict and health among shiftworkers. Shiftwork Int Newsl 1995;12(1):95.
42. Neuloh O. Sozialisation und Schichtarbeit. Soziale Welt 1964;15(1):50—70.
43. Reinberg A, Vieux N, Andlauer P, Guillet P, Nicolai A. Tolerance of shiftwork, amplitude of circadian rhythms and ageing. In: Reinberg A, Vieux, N, Andlauer P, editors. Night and shiftwork: biological and social aspects. Oxford: Pergamon Press, 1981:341—54.
44. Brown FM. Psychometric equivalence of an improved Basic Language Morningness (BALM) Scale using industrial population within comparison. Ergonomics 1993;36(1—3):191—8.
45. Moog R. Reliability and validity of a morning-eveningness questionnaire. Shiftwork Int Newsl 1997;14(1):88.
46. Pokorski J, Oginska H, Pokorska J. Seasonal variations in chronotype. Shiftwork Int Newsl 1997;14(1):115.
47. Silvério J, Silva C, Azedevo M. Shiftwork, health and individual differences: the Portuguese version of the Circadian Type Inventory (CTI). Shiftwork Int Newsl 1997;14(1):89.
48. Smith PA, Brown DF, Di Milia L, Wragg C. The use of the Circadian Type Inventory as a measure of the circadian constructs of vigour and rigidity. Ergonomics 1993;36(1—3):169—76.
49. Nachreiner F. Über Determinanten der Einstellung zur Schichtarbeit. Z Arbeitswiss 1978;32(1):6—11.
50. Smith C, Robie C, Folkard S, Barton J, MacDonald I, Smith L, et al. Validation of a process model of shiftwork and health. Shiftwork Int Newsl 1997;14(1):129.

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Accident risk as a function of hour at work and time of day as determined from accident data and exposure models for the German working population

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Objectives Recent studies indicate that accident risk may be a function of hour at work and time of day. Further evidence was sought for these assumptions, along with the answer to the question of whether the risk of accident can be conceived as an interaction between hours at work and time of day.

Methods Data on more than 1.2 million accidents for the year 1994 were provided, all listed according to the time of day and hour at work. Since information about how long each day and at what time of day people work is not available in Germany, different exposure models had to be estimated. For estimating the risk of having an accident relative accident risks were calculated from the ratio of accident frequencies to the exposure data.

Results An exponentially increasing accident risk was observed beyond the 9th hour at work. The relative accident risks differed considerably according to the respective exposure model with regard to time of day. A highly significant interaction effect was found for hour at work by time of day, the percentage of accidents at different hours at work varying according to the particular time of day when work is started. For the 3 "traditional" shiftwork starting times, it was shown that, with later starting times, the relative accident risk increased dramatically beyond the 8th hour at work.

Conclusions Since the results clearly indicate that there are time-related effects on occupational accident risk, more detailed analyses are called for. More elaborated exposure models should be used to assess the efficiency of work schedules with extended workhours, especially under shiftwork conditions. The results also indicate the necessity of recording and providing adequate data bases for such analyses.

Key terms extended workhours, safety, shift work, work time.

Recent results in accident research indicate that the risk of accidents at work is a function of hour at work. Folkard (1) and Åkerstedt (2) both reported an exponentially increasing accident risk beyond the 9th hour at work. Åkerstedt (2) used data of the Swedish Occupational Injury Information System as a basis for his report. He found that accident risk is nearly the same for the first 8 to 9 hours at work. Beyond the 9th hour at work, however, the risk increases considerably. Folkard (1) calculated the relative accident risk from 5 published studies and found it to be doubled after the 12th hour and trebled after the 14th hour. He concluded that the safest system would be based on 6- to 9-hour shifts. But he also claimed that these findings have to be supported by further research, especially to identify the underlying causes.

Although, on one hand, an 8-hour workday is legally widely established (eg, in German law on work time), reality is often quite different. Extended work times and overtime are still widespread. On the other hand, in the United States, Australia, and some other countries, there is a marked tendency to expand work time beyond 8 hours. Twelve-hour shifts are increasingly popular for different reasons. Employers appreciate the economic advantages and employees like the long periods of time-off resulting from the longer hours on fewer shifts. Therefore, the development of accident risk over hours at work is an urgent question, and the efficiency of such work schedules needs to be assessed (3).

At the same time it is also likely that the risk of accidents may depend on the time of day. Åkerstedt (2) found

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a clear indication for a nearly doubled accident risk during night hours, and Smith et al (4) found evidence for an increased risk of injuries during the night shift in comparison with morning and afternoon shifts.

Another question which has not yet been addressed thus far is whether there is an interaction between hours at work and time of day with regard to accident risk. It can be hypothesized that working a 12th hour on a job may differ according to the starting time of the shift (eg, when the 12th hour is at 1800 at the end of a day shift or at 0600 at the end of a complete night shift).

In order to shed more light on these problems, a study was conducted to determine whether accident risk can be conceived as a function of hours at work, time of day, or an interaction of the two.

Materials and methods

One of the main problems of answering questions related to associations between hours at work, time of day, and accident risk is the availability of adequate data bases, especially with regard to exposure towards the risk of having an accident. For this reason, accident frequencies must be analyzed together with adequate exposure data on the relevant population.

There have been no difficulties in obtaining data on the frequencies of registered accidents (leading to an absence of >3 days) from the confederation of workers' compensation boards [Hauptverband der Gewerblichen Berufsgenossenschaften (HVBG), public services and agriculture not included] in Germany. More than 1.2 million such accidents were registered for 1994, all listed according to time of day (24 hours) and hour at work (1st to 12th hour, >12th hour).

Unfortunately, information about *how long each day* people work and *at what time of day* they work is not available in Germany because such data are not registered and no complete or workable national statistics have been collected on these work characteristics. Therefore, suitable exposure models, based on the best available evidence, had to be developed for the comparison with accident rates.

For this purpose different exposure models that could be (cross-) checked for consistency were constructed and calculated from the results of 2 independent surveys on problems of workhours in Germany (5, 6).

The first study (5), conducted in 1992, included data from approximately 5000 employed and self-employed respondents from the Federal Republic of Germany (including the former German Democratic Republic). The second study (6), conducted in 1993, was based on data from 2577 respondents from the employed population (aged 18—65 years) from the area comprising the former West Germany, including West Berlin. [A subsequently published survey (7) from 1995, including the former German Democratic Republic showed that there was essentially no difference with regard to the number of overtime hours worked between former West and East Germany; therefore the data can be regarded as representative for the whole of Germany with regard to this point.] The samples of both studies proved to be representative. The calculated exposure models based on the data of these studies, although relying on slightly different samples collected roughly 1 year apart, were in good agreement (and moreover proved to be in good agreement with some later published microcensus results for Germany). Therefore, the exposure models can be assumed to be both representative and valid. A detailed description of the rationale and the calculations performed to arrive at the exposure models are included in an unpublished report by Tiedemann.

For an index for comparing the risk of having an accident according to hour at work and time of day, the relative accident risk was calculated as the ratio of the accident frequencies (from the data of the workers' compensation board) to the calculated exposure data of the German working population by the following formula: relative accident risk = (accidents [in %] x 100) / (working population [in %]), percentages being based on the relevant distribution (ie, hour at work or time of day).

Results

Accident distribution

In figure 1 the distribution of registered accidents provided by the HVBG is shown for 1994. It can be seen that the absolute number of accidents is extremely high for people starting their job at 0600, 0700 or 0800, which is the majority of the work force, including day workers, part-time workers, and shift workers, eg, working 12-hour shifts and starting their work at 0600. There is also another small peak for people starting work at 1400, and another very small peak for people starting their work at 2200 to 2400, probably shift workers starting their afternoon or night shifts.

A decrease in accident frequencies at common times for work breaks can be observed (eg, around 0900 and 1200—1300) in other words after different numbers of hours at work, depending on the starting time (eg, for those starting their work around 0700 during the 2nd or 3rd hour and again during the 5th to the 7th hour at work). The same seems to hold for other starting times (eg, for the 5th hour at work for those starting at 1400).

Hour at work

Figure 2 shows an exposure model of the German working population, accident frequencies, and accident risk

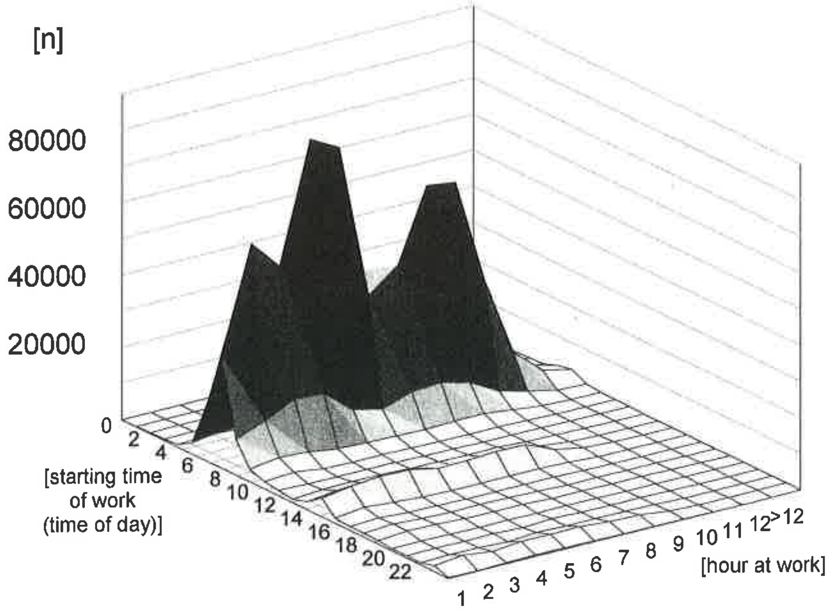

Figure 1. Distribution of registered accidents in 1994 by hour at work and time of day of starting work.

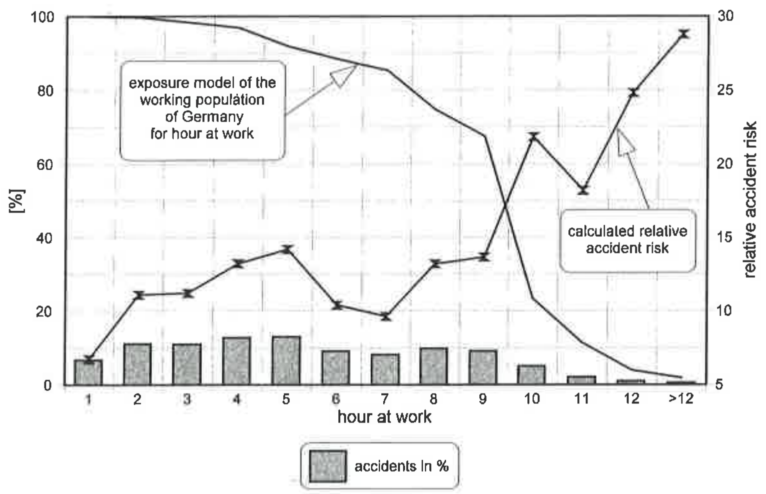

Figure 2. Exposure model of the working population, accident frequencies, and accident risk by hour at work.

by hour at work. According to this model 100% of the employed population works up to 2 hours per day. Thereafter a slight decrease can be seen. Nearly 70% of the population works up to 9 hours per day (including breaks). Beyond the 9th hour the percentage decreases considerably.

The bars at the bottom of figure 2 represent the distribution of accidents from the 1st to the 12th hour at work and for >12 hours at work. The increase in the first 5 hours, a rather even distribution until the 9th hour, and the decrease from the 10th hour are typical for the frequencies of accidents. This distribution has already been reported earlier (8); therefore it can be assumed that the distribution is reliable.

The calculated relative accident risk for hour at work (based on the exposure model and the accident distribution) is also shown in figure 2. It increases exponentially beyond the 9th hour at work.

Time of day

The basis for developing a valid exposure model of the working population over time of day from the available data bases was limited and rather uncertain. A variety of possible exposure models could be constructed. Two were calculated on the basis of the survey data in combination with the distribution of the starting times from the accident data, one as a maximum estimate and the other as a minimum estimate. The effect of a break around noon was taken into account in both models. In figure 3 the 2 different exposure models of the working population and accident frequencies are shown by time of day. It can be seen that, at night and around noon, the 2 graphs are similar. A difference in the estimates can be observed, however, for the hours between 0600 and 1100 and again between 1400 and 1900.

The bars at the bottom of figure 3 represent the distribution of accidents over time of day, according to the

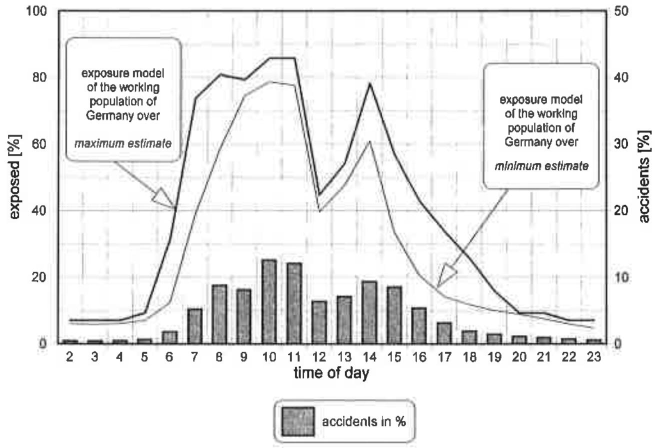

Figure 3. Two exposure models of the working population and accident frequencies by time of day.

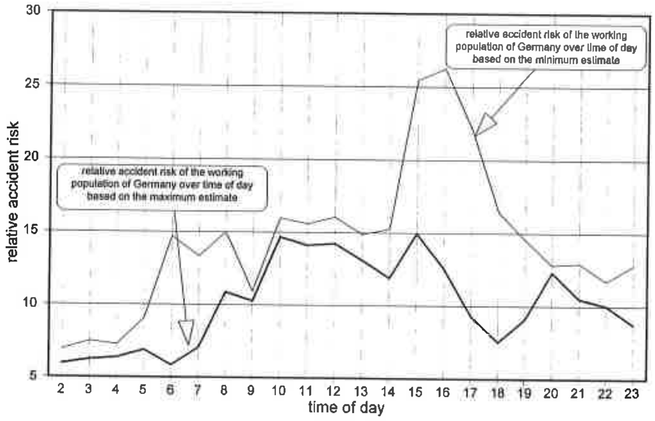

Figure 4. Accident risks for 2 different exposure models by time of day.

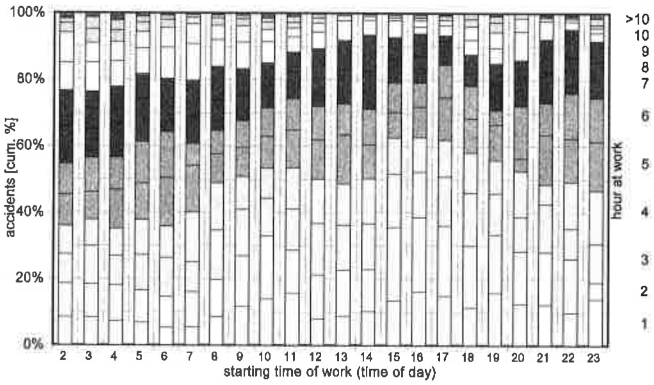

Figure 5. Accident frequencies by hour at work and starting time of work (time of day).

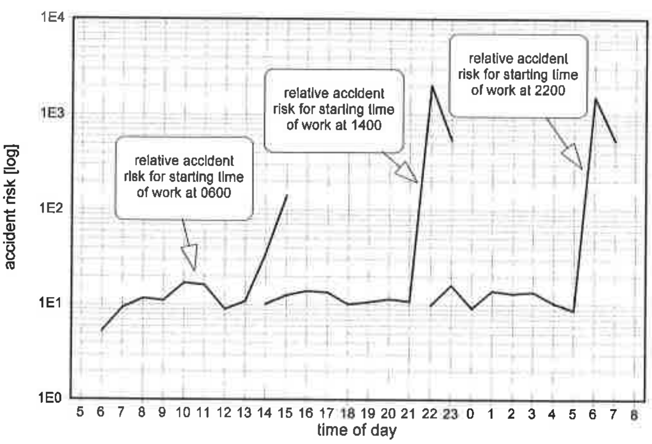

Figure 6. Accident risks on shifts starting at 0600, 1400, and 2200.

data of the workers' compensation board.[3] The data show a peak at 1000 and 1100, a drop between 1200 and 1300, and a second peak at 1400 and 1500.

Figure 4 shows the accident risks for the 2 exposure models by time of day. As shown in this figure, the relative accident risks for both estimates, minimum and maximum, differs considerably in the early morning hours and in the afternoon. It should be emphasized that the relatively small differences in the exposure models yielded relatively big differences in the estimated accident risk.

Time of day by hour at work

An analysis for the effect of time of day by hour at work for the absolute accident frequencies shows a clear and statistically highly significant ($c^2 = 71\,484.9$; df = 264; $P<0.0001$) interaction for hour at work with time of day.

Figure 5 shows the accident frequencies by hour at work and starting time of work (time of day) in cumulative percentages. Each column shows the distribution of accidents across the 1st to the 12th and >12th hour at work for the subsamples of people starting their work at a given time of day (eg, the first column shows the subsample starting work at 0200 and their distribution of accidents for the consecutive hours at work).[4] The darkly shaded parts of the column represent, for example, the relative frequencies of accidents in the 7th and 8th hour at work, which means the time of day between 0800 and 1000 for the first column, where work starts at 0200.

With work starting in the evening (1800 to 2000) or at night or in the early morning (2000 to 0700), the percentage of accidents beyond the 8th hour at work is increased, whereas, for people starting their work in the afternoon, the proportion of accidents beyond the 8th hour is rather small. With work starting at 1400 to 1800, on the other hand, the percentage of accidents in the first 4 hours is increased, whereas the accident rate is relatively low for the first 4 hours when work starts at night and in the early morning (0200 to 0700). These results thus suggest that, in fact, there seems to be a difference in the risk of having an accident at the xth hour at work, depending on the starting time of work. This hypothesis would, however, only be testable with an adequate data base for estimating valid exposure models for every hour of starting time of work, which is not yet available.

Although the available data base used for estimating the exposure models according to the starting time of work was rather vague, different models for the exposure with regard to selected starting times were constructed. As an example, the available data for the 3 "traditional" shiftwork starting times at 0600, 1400, and 2200 were used to calculate exposure models (proportions of people at work). The model (and the accident data) for the starting time 0600 was, of course, confounded by the subsample of people not working shifts (but starting early) or by part-time workers. Therefore, 100% of the working population was not present for the whole 8 hours of the shift. The models for starting times 1400 and 2200 represent, however, 100% of the working population for the first 8 hours, because these starting times are typical for shift workers on 8-hour shifts.

In figure 6 the calculated relative accident risks are shown for shifts starting at 0600, 1400, and 2200, representing the 3 "traditional" shiftwork starting times. Since the risk increases exponentially beyond the 8th hour at work, a logarithmic representation and labeling has been chosen for the y-axis. The results seem to suggest that the exponential increase in the risk of accidents with hour at work is especially distinct with "abnormal" starting times for shifts during the day (eg, those deviating from the "normal" workday).

Figure 6 also shows very clearly another feature of the hypothesized (and for the absolute accident frequencies statistically significant) interaction between hour at work and time of day. There was a marked difference in the risk of having an accident at a certain time of the day, depending on the hour at work (eg, at 1500 when this time was the second hour at work on an afternoon shift, as compared with the 10th hour at work on a morning shift) and the same seems to be true for other combinations of hour at work and time of day as well.

Discussion

The results show that there is clear support for the conclusion already drawn by Folkard (1) and Åkerstedt (2) that accident risk increases exponentially beyond the 8th or 9th hour at work. In addition, this seems to be a rather conservative estimate, as shown by the results of some sensitivity analyses (not presented).

It should also be kept in mind that these results include a wide variety of occupations with different accident risks (eg, from office work to the mining or steel industries). The reported increase in accident risk with

3 Since the data basis for the hours 0000 and 0100 showed inconsistently high values — probably due to the method of assessment — the reliability and validity of these data could not be assumed for these hours. These data were thus excluded from the analyses.

4 The labeling on the y-axis as 1 to 10 and >10 hour at work (while the data are grouped into 1st to 12th and >12th hour at work) has only been chosen for the reason of appropriate and readable labeling, because the proportion of accidents, and thus the size of the segments, was very small beyond the 10th hour at work.

hour at work in this case might thus, as well, be regarded as a conservative estimate from such a different perspective, at least for certain industries. It would therefore seem especially interesting to perform similar analyses for certain professional groups or different branches of industry to obtain differentiated estimates of the time-related risk for different occupational conditions. The accident data would be available for such analyses, but there are no exposure data available nor can they be constructed from available data bases. Therefore, such calculations would be impossible at the moment — at least in Germany.

Another weakness of our approach is that many confounding variables cannot be controlled for in these analyses. This lack of control may obscure some distinct effects that would be revealed if one were able to control for such confounding effects as type and amount of work to be done, and presence of supervisory personnel. Smith et al (4) have raised this issue and shown that there are different risks associated with such factors in conjunction with the effects of worktime. In fact, it could be assumed that one of the reasons why no increased risk could be found for night hours in our analyses was the lack of control for such confounding factors.

On the other hand, the results clearly indicate that, in general, the extension of daily workhours to up to 10 hours (and more under certain conditions, *excluding* breaks), as provided by the directive of the European Union and the German law on workhours, cannot be regarded as not increasing the risk of accidents. In fact the opposite applies, as the available evidence clearly demonstrates.

The effects of time of day on accident risk remain unclear. Our results show no increased risk for night hours, neither with the maximum nor with the minimum exposure model. This may be due to the different conditions of work during the day and the night, an observation that is not uncommon (4, 9), and which may be especially true for this heterogeneous population. Such possibilities can, however, only be hypothesized since reliable data are again missing. Once again, a more-detailed analysis with reliable data for specific subgroups would seem urgently required.

Regarding the interaction of time of day and hour at work, our results suggest that it would be worthwhile to expend more effort on such analyses, trying to develop more adequate exposure models (with possibilities of cross-validation) to arrive at more reliable estimates. But again, more adequate data bases for the exposure, at least for being able to estimate the exposure, would be urgently required. Such a data base could be achieved by registering workhours according to their starting time and duration, and, if such a procedure is too expensive, at least representative samples should be surveyed with questions that deliver the information required from an ergonomic point of view.

To summarize, the results obtained thus far clearly indicate time-related effects on occupational accident risks, which deserve further scientific attention and efforts. However, adequate data bases for estimating the exposure should be provided, even if the results might not be in agreement with the popular requests for more flexibility in the regulation of workhours. From a health and safety perspective, limiting the acceptable amount of hours of work might still make sense, especially for shift workers, as our results indicate. Such a limitation might even be an economically sound approach when the costs of accidents are considered against the benefits of saving personnel or even undermanning, not to mention the question of solving the resulting problems by less efficient (and sometimes even illegal) overtime work.

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References

1. Folkard S. Effects on performance efficiency. In: Colquhoun WP, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Frankfurt aM (Berlin, Bern, New York, Paris, Wien): Peter Lang Verlag, 1996:65—87.
2. Åkerstedt T. Work injuries and time of day — national data. Shiftwork Int Newsl 1995;12(1):2.
3. Duchon JC, Smith TJ. Extended workdays and safety. Int J Ind Ergon 1993;11:37—49.
4. Smith L, Folkard S, Poole CJM. Increased injuries on night shift. Lancet 1994;344:1137—39.
5. Deutsches Institut für Wirtschaftsforschung (DIW). Socioeconomic panel data 1992. Berlin: DIW, 1992.
6. Bauer F, Groß H, Schilling G. Arbeitszeit '93. Düsseldorf: Ministerium für Arbeit, Gesundheit und Soziales des Landes Nordrhein-Westfalen, 1994.
7. Bauer F, Groß H, Schilling G. Arbeitszeit '95. Düsseldorf: Ministerium für Arbeit, Gesundheit und Soziales des Landes Nordrhein-Westfalen, 1996.
8. Hoffmann B, Rostek R. Arbeitszeit und Unfallrisiko. Die Berufsgenossenschaft 1995;10:538—42.
9. Monk TH, Embrey DE. A field study of circadian rhythms in actual and interpolated task performance. In: Reinberg A, Vieux N, Andlauer P, editors. Night and shiftwork: biological and social aspects. Oxford: Pergamon Press, 1981:473—80.

Shift length as a determinant of retrospective on-shift alertness

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Tucker P, Smith L, Macdonald I, Folkard S. Shift length as a determinant of retrospective on-shift alertness. *Scand J Work Environ Health* 1998;24 suppl 3:49—54.

Objectives This study examined the combined effects of shift length (8 versus 12 hours) and night-to-morning-shift changeover time (0600 versus 0700) on retrospective on-shift alertness ratings.

Methods An abridged version of the Standard Shiftwork Index, which included retrospective alertness ratings, was completed by 4 groups of industrial shift workers. Two groups worked 8-hour shift systems and started their morning shifts at either 0600 or 0700; the other 2 groups worked 12-hour systems, starting their day shifts at either 0600 or 0700.

Results The 8-hour workers reported considerably higher levels of alertness in the afternoon, while the 12-hour workers were more alert than the 8-hour workers in the morning and at 2200. Workers who started their shift around 0600 were less alert during the morning than those who started around 0700. The data suggested that the combined effects of working 8-hour shifts and starting the morning shift at around 0600 have particularly deleterious effects upon alertness.

Conclusions Effects on alertness can be explained in terms of differences in elapsed time on duty, sleep duration, sleep disruption, and chronic fatigue. The findings of this study appear to contradict previous research demonstrating that the major deleterious effects of extended shifts and delayed changeovers upon alertness occur at night. However, it is acknowledged that the absence of a difference in alertness at night may have been due to floor effects. Nevertheless, the implications of the alertness ratings for performance and safety, particularly during the afternoon, should not be ignored.

Key terms safety, shift systems, shift timing, 12-hour shifts.

Many serious incidents have been caused or exacerbated by human error at times when sleepiness is high and performance capabilities are depleted. Decreased alertness towards the end of a 12-hour shift can be a major concern, particularly when the job being worked is highly monotonous and sedentary, such as monitoring screens, or requires continuous heavy physical activity. Decrements in performance and alertness have been observed in the last hours of extended work shifts (1). Declines in alertness are the most apparent at night, when lowered circadian arousal adds to fatigue resulting from extended hours of work (2, 3). However, in their comparison of 8- and 12-hour systems, Tucker et al (4) report that the greatest differences in alertness exhibited by workers on the 2 systems occurred in the afternoon, when the 8-hour workers had just begun their afternoon shift and the 12-hour workers were in the second half of their day shift.

Several studies have examined performance on mental or psychomotor tests administered at regular intervals over the duration of 8- and 12-hour shifts. These studies have also tended to report detrimental effects on performance from working extended shifts, especially on night shifts (5, 6). However, a study of computer operators found no apparent costs, in terms of productivity, of a change from 8-hour to 12-hour shifts (7). Even under conditions of high physical work load, a study of mine workers found no differences in levels of fatigue between workers on 8- and 12-hour shifts (8). Another study observed improved performance following the introduction of 12-hour shifts; this was attributed to improved shift hand-overs (ie, when the workers at the end of a shift hand over their duties to their replacements), decreased turnover, and better employee attitudes and communications (9).

Thus, while there is a great deal of interest in the desirability of extended shifts, there is a lack of consensus over their potential detrimental impact. Moreover, there is no published research on how shift length interacts

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with differences in night-to-morning-shift changeover time. The current study examines these 2 aspects of shift-system design in combination.

Subjects and methods

A questionnaire was distributed to volunteers in 17 manufacturing and engineering companies. The sample of respondents comprised 2 groups of workers who started their morning or day shifts at 0600 and worked either 8-hour (N=171) or 12-hour (N=335) shift systems and 2 groups who started at 0700, working either 8-hour (N=89) or 12-hour (N=267) systems. The shift systems examined were all rapidly rotating continuous systems, usually involving 4 teams. Virtually all of the 8-hour systems were advancing or delaying 2—2—3 systems. The 12-hour systems all involved 2 successive day shifts followed by 2 successive nights. For about one-third of the volunteers, the 2 shifts were separated by 2 days of rest. For the remainder, the 1st night shift started 24 hours after the end of the 2nd day shift. Ninety-eight percent of the sample were men, and 89% were married or living with a partner.

The respondents completed a set of retrospective alertness rating scales (10), which were incorporated into a revised version of the Standard Shiftwork Index (SSI) (11) called the Survey of Shiftwork (SOS). The SOS also incorporated items measuring sleep duration and disruption, chronic fatigue (defined as "a general persistent tiredness and lack of energy irrespective of whether an individual has had enough sleep or has been working hard, and which persists even on rest days and holidays"), health and well-being, and biographic information. The results of the analysis of the data relating to health and well-being have been reported elsewhere (12). The retrospective alertness rating scales required the respondents to indicate how alert or sleepy they *normally* felt at 2 hourly intervals before, during, and after each of the shifts on which they normally worked (only on-shift data are reported). All the ratings were made at a single sitting. For night shifts they were asked to make the rating with respect to their second and subsequent successive night shifts rather than their first, so that any potential difference on the first night shift from the typically longer period of prior wakefulness would be avoided. The respondents rated how alert they felt at 2 hourly intervals on a 9- point rating scale, 1 being equal to "very sleepy" (fighting sleep) and 9 being equal to "very alert" [after Akerstedt & Gillberg (13)].

Data relating to on-shift alertness, sleep duration, sleep disruption, and chronic fatigue were subject to both an analysis of variance (ANOVA) and an analysis of covariance (ANCOVA). Potential covariates were identified by comparing the 4 groups of respondents in terms of individual differences and biographic information, as measured by the SOS. Any of the potential covariates could, in theory, impinge on any of the outcome variables, and so a significant main or interaction effect in any of these analyses resulted in the dependent variable in question being used as a covariate in the ANCOVA (table 1). In the analysis of each outcome variable, the results of the relevant ANOVA and ANCOVA were compared, and where a difference between the 2 sets of results was observed, the latter was used. This method optimizes the sensitivity of the analysis while controlling for confounding factors where appropriate (14).

The effects of shift length (8-hour versus 12-hour), time of night-to-morning changeover (0600 versus 0700) and time of day (0000 to 2200) upon on-shift alertness

Table 1. Individual difference and biographic information, as functions of shift changeover time and shift length. (SEM = standard error of the mean)

	Changeover time								Use as a covariate in the analysis of the outcome variable
	Early (morning start 0600)				Late (morning start 0700)				
	8-hour shift		12-hour shift		8-hour shift		12-hour shift		
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
Age (years)	40.32	0.70	41.34	0.53	42.86	0.98	41.19	0.58	Yes
Number of dependents	1.24	0.09	1.43	0.06	1.10	0.12	1.29	0.07	Yes
Shiftwork experience (years)	17.57	0.71	15.03	0.53	18.50	0.98	16.88	0.58	Yes
Work experience (years)	24.22	0.76	24.92	0.57	26.33	1.06	24.70	0.62	Yes
Present rota experience (years)	10.51	0.56	6.46	0.42	13.42	0.77	11.52	0.46	Yes
Actual workhours	45.39	0.53	47.05	0.40	44.49	0.75	45.05	0.44	Yes
Average commuting time (minutes)	19.93	1.12	17.53	0.84	19.42	1.55	19.04	0.92	No
Average perceived work load	3.40	0.05	3.44	0.07	3.25	0.04	3.54	0.04	Yes
Work pace	2.70	0.09	3.08	0.07	2.88	0.13	3.09	0.08	Yes
Flexibility	5.01	0.21	5.09	0.16	4.69	0.30	4.67	0.18	No
Morningness	4.22	0.18	4.66	0.13	4.64	0.24	4.65	0.14	No
Perceived sleep need (hours)	7.50	0.09	7.04	0.06	7.37	0.12	7.31	0.07	Yes

were examined. Where there was an overlap in the data of ratings obtained from workers who were at the end of one shift and those who were at the beginning of the next (ie, at the point of shift changeover), the analysis used only ratings obtained from the latter. A separate analysis examined the effects of shift length and changeover time upon sleep duration, sleep disruption, and chronic fatigue. Post hoc analyses of significant interactions were conducted by way of additional analyses of variance, at each level of the factor under investigation. These analyses incorporated adjustments of the familywise error rate, such that criteria were adjusted for the number of multiple comparisons made within the analysis of a particular interaction (15). All post hoc analyses adopted a significance criterion of $P<0.05$. A large proportion of the data relating to the measure of sleep disruption after the last night was found to be missing, and therefore this item was dropped from the reported analyses.

Results

In the analysis of the alertness data, there was no main effect of either shift length [$F(1, 684) = 0.12$, $P>0.05$] or changeover time [$F(1, 684) = 1.58$, $P>0.05$], but there was a reliable effect of time of day [$F(11, 7524) = 272.63$, $P<0.001$]. There was a reliable interaction between shift length and changeover time [means (and standard errors): 8-hour early changeover = 6.16 (0.10), 8-hour late changeover = 6.49 (0.14), 12-hour early changeover = 6.33 (0.07), 12-hour late changeover = 6.25 (0.08); $F(1, 684) = 3.97$, $P<0.05$], although the effect did not reach significance in the associated analysis of covariance [$F(1, 592) = 2.92$, $P>0.05$]. The interaction between shift length and time of day was highly reliable [$F(11, 7524) = 27.21$, $P<0.001$]. The post hoc analysis of this significant interaction indicated that the 12-hour shift workers were more alert than the 8-hour workers between 0800 and 1200 [$F(1, 687) = 10.64$, $P<0.05$; $F(1, 686) = 18.19$, $P<0.05$; and $F(1, 686) = 13.87$, $P<0.05$, respectively] and also at 2200 [$F(1, 686) = 17.17$, $P<0.05$]. However, superior levels of alertness were reported by the 8-hour workers at 1400 and 1600 [$F(1, 686) = 36.19$, $P<0.05$; and $F(1, 686) = 107.47$, $P<0.05$, respectively]. (See figure 1.)

There was also a highly significant interaction between changeover time and time of day [$F(11, 7524) = 21.67$, $P<0.001$]. The post hoc analysis of this interaction indicated that the early changeover group was more alert at 0600 [$F(1, 686) = 56.69$, $P<0.05$] and at 1800 [$F(1, 686) = 25.69$, $P<0.05$], while the late changeover group was more alert from 0800 to 1200 [$F(1, 686) = 18.69$, $P<0.05$; $F(1, 686) = 21.42$, $P<0.05$; and $F(1, 686) = 16.76$, $P<0.05$, respectively]. (See figure 2.)

Finally, there was a significant 3-way interaction between shift length, shift changeover time, and time of day [$F(11, 7524) = 6.98$, $P>0.001$]. Post hoc analyses indicated that there was a significant effect of shift length at

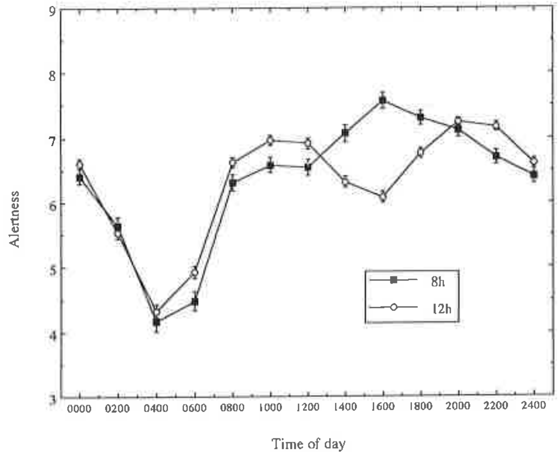

Figure 1. Alertness as a function of time of day — 8-hour versus 12-hour shift systems (means and their standard errors).

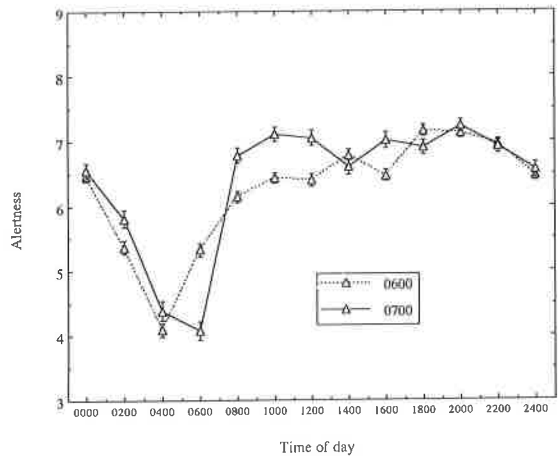

Figure 2. Alertness as a function of time of day — shift systems with early versus late changeovers (means and their standard errors).

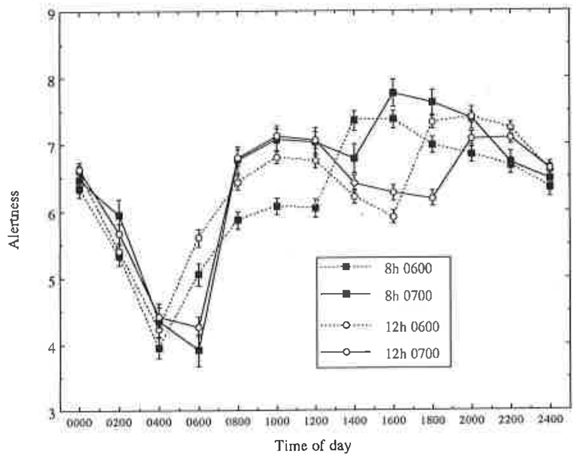

Figure 3. Alertness as a function of time of day — 8-hour versus 12-hour shift systems and early versus late changeovers (adjusted means and their standard errors).

both levels of changeover time. Figure 3 illustrates that, although the previously observed effect of shift length upon alertness in the afternoon held for both changeover times, it was shifted later in the late changeover group. Thus the difference associated with shift length occurred at 1400 [$F(1, 417) = 39.50$, $P<0.05$] and 1600 [$F(1, 417) = 67.67$, $P<0.05$] in the early changeover groups (the dotted lines), but at 1600 [$F(1, 267) = 46.66$, $P<0.05$] and 1800 [$F(1, 267) = 40.34$, $P<0.05$] in the late changeover groups (the solid lines). The post hoc analysis also indicated that there were effects of shift length that were only observed in the early changeover group between 0800 and 1200 [$F(1, 417) = 9.97$, $P<0.05$; $F(1, 417) = 17.17$, $P<0.05$; and $F(1, 417) = 13.20$, $P<0.05$, respectively], at 2000 [$F(1, 417) = 14.50$, $P<0.05$] and at 2200 [$F(1, 417) = 13.91$, $P<0.05$].

Full details of the analyses of the dependent variables relating to sleep and fatigue are given in table 2. Interactions in the analyses of sleep duration suggested that the effect of early starts upon sleep duration before the first night shift was strongest among the 8-hour workers and that, while delaying changeover time has the effect of increasing the sleep duration reported by 12-hour workers on days, it reduces the sleep duration among the 8-hour workers on the afternoon shift.

Discussion

The findings appear to contradict the widely held view that the most deleterious effects of extended shifts upon alertness are observed at night [eg, Rosa (2)], although they are in accordance with our own previous research findings on the effects of shift length (4). It should be noted that these effects were observed despite control for a wide range of variables related to individual differences, biographic details, and job context information. Nevertheless, it is possible that these findings reflect the fact that the current study examined systems which incorporated fewer consecutive shifts in a workweek than is often the case in some other countries. It seems unlikely that the direction of rotation of the 8-hour shifts has any bearing upon the results. The 8-hour sample was

Table 2. Sleep duration, sleep disruption, and chronic fatigue as a function of shift length and shift changeover time. (SEM = Standard error of the mean, df = degrees of freedom)

	Shift length							Changeover time (morning start)							Interaction	
	8-hour		12-hour		df 1	F ratio		Early (0600)		Late (0700)		df 1	F ratio		F ratio	
	Mean	SEM	Mean	SEM		Crude	Covariance	Mean	SEM	Mean	SEM		Crude	Covariance	Crude	Covariance
Sleep duration																
Morning versus day	5.98	0.08	6.30	0.05	759	12.08 ***	12.31 ***	5.80	0.06	6.49	0.07	759	55.19 ***	43.73 ***	2.98	2.24
Afternoon versus day	8.23	0.08	6.30	0.05	767	423.78 ***	353.56 ***	7.46	0.06	7.08	0.07	767	16.13 ***	17.61 ***	93.70 ***	84.95 ***
Afternoon (8-hour system only)										8.53	0.06	7.63	0.13	511	40.68 ***	46.88 ***
Before 1st night	8.80	0.14	9.45	0.08	521	16.04 ***	13.78 ***	9.36	0.09	8.89	0.14	521	8.10 **	10.93 **	8.34 **	4.14 *
Between nights	5.75	0.09	6.17	0.06	753	15.67 ***	19.06 ***	6.11	0.06	5.82	0.08	753	7.36 **	19.11 ***	0.90	0.07
After last night	4.90	0.09	5.02	0.06	753	1.28	3.63	5.29	0.07	4.63	0.09	753	34.52 ***	37.59 ***	6.13 *	3.56
Between rest days	8.89	0.08	8.84	0.05	737	0.35	0.37	8.98	0.06	8.75	0.07	737	6.41 *	7.95 **	3.41	0.38
Sleep disruption																
Morning versus day	3.15	0.05	3.03	0.03	813	3.77	1.50	3.25	0.04	2.94	0.05	813	26.24 ***	22.3 ***	1.33	0.41
Afternoon versus day	2.40	0.05	3.03	0.03	814	120.57 ***	98.8 ***	2.80	0.04	2.64	0.04	814	7.23 **	4.48 *	2.28	2.22
Afternoon (8-hour system only)										2.50	0.03	2.40	0.06	533	2.07	1.36
Between nights	3.25	0.06	3.00	0.04	813	13.46 ***	7.53 **	3.02	0.04	3.23	0.05	813	9.88 **	11.18 **	0.40	0.12
Between rest days	2.25	0.04	2.26	0.03	799	0.08	0.00	2.19	0.03	2.32	0.04	799	7.07 **	8.98 **	0.00	0.03
Chronic fatigue	2.91	0.05	2.71	0.04	812	9.42 **	5.62 *	2.86	0.04	2.75	0.05	812	3.18	3.18	0.97	0.33

* $P<0.05$, ** $P<0.01$, *** $P<0.001$.

split equally in terms of direction of rotation, and our analyses (not reported here) suggest that, while direction of rotation did have a significant effect on overall alertness levels (moderately, but significantly, favoring forward rotation), there was no interaction between direction and time of day. It is possible that the insensitivity of the measures to night-time alertness is due to the retrospective nature of the response, although such an explanation is not supported by previous research (10), which found similar effects in both concurrent and retrospective ratings of alertness.

The levels of alertness were lower among the 12-hour system workers between 1400 and 1800, but higher from 0800 to 1200 and at 2200. The difference in the afternoon coincides with the period at which there is the greatest difference between the 2 sets of workers in terms of elapsed time on the shift. In addition, the effects of differences in elapsed time on shift may have been compounded by the effects of differences in sleep disruption and duration, prior to the shift. Between successive afternoon shifts, markedly longer, less disrupted sleep was reported by the 8-hour workers than by 12-hour workers between successive day shifts. While it is true that there was relatively little difference in alertness levels between the 2 groups at night, despite smaller (but still significant) differences in the reported sleep length and disruption between successive night shifts, the differences in sleep disruption and duration between night shifts were far smaller than those on the day or afternoon shift. Moreover, differences between the 2 groups' alertness levels in the early hours of the morning may have been obscured by floor effects since the lowest overall levels of alertness occurred at this time. Workers may be reluctant to rate their alertness as being any lower than around 4 on the scale since it would constitute an admission of feeling sleepy during workhours. In other words, the range of responses may have been restricted by their proximity to a self-imposed minimum.

The difference in alertness in the afternoon has particularly important implications if an organization changes from using a 3-shift (8-hour) system to a 2-shift (12-hour) rota. Work loads should be distributed to account for critical time periods when fatigue is assumed to be high (2). Afternoons are often some of the busiest times of the day in industrial settings. Workers at the beginning of an 8-hour afternoon shift may be highly alert and fully capable of dealing with high work loads. However, our data suggest that, if a change is made to a 12-hour system, the work load should be redistributed across the day so that workload demands are reduced in the afternoon to compensate for the lower levels of alertness among the workers.

The superior levels of alertness among the 12-hour workers in the morning and at 2200 are consistent with the difference in sleep duration that was reported by the workers on the 2 systems, when working the relevant shifts. Inspection of figure 3 indicates that the difference in alertness levels at these times is largely due to lower levels of alertness among the 8-hour workers on early changeovers, relative to their counterparts on 12-hour systems with early changeovers. The 8-hour workers on late changeovers reported levels of alertness in the morning that were equal to or higher than those reported by the 12-hour workers at that time.

Thus, while some of the largest effects of early shift changeovers were observed in the morning, the effects were greatest among the 8-hour workers at this time.[3] It is suggested that this difference was due to the combined effects of early starts to morning shifts and the deleterious effects of working 8-hour shifts; the 8-hour workers experienced poorer morning shift sleep, as well as higher levels of chronic fatigue, than their 12-hour counterparts. The effects of late changeovers on night shift sleep, together with findings from previous studies (16), might have led us to expect a negative effect of late changeovers on nightshift alertness levels. Once again, the absence of such an effect on the night shift may have been due, in part, to a floor effect.

We must concede that our measures may have been insensitive to differences in alertness at night, effects which may be especially crucial since the effects of disrupted sleep may be compounded by the effects of being required to work through the circadian low point in arousal. Nevertheless, our evidence suggests that a change from 8- to 12-hour shift systems has potentially serious implications for alertness in the afternoon, a period that is traditionally one of the busiest times of day in industrial settings. In addition we have shown that, in terms of alertness, those working 8-hour shift systems are potentially at a disadvantage during the morning, as are workers who start their morning or day shift early (ie, around 0600).

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3 The differences at 0600 and 1800 were artifacts of the design. Six o'clock in the morning corresponds with the time at which the early changeover workers were at the beginning of their day or morning shift and the late changeover group was approaching the end of the night shift; similarly, 1800 corresponds with the changeover from the day shift to the night shift for the 12-hour workers.

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References

1. Rosa R, Bonnet MH. Performance and alertness on 8h and 12h rotating shifts at a natural gas facility. Ergonomics 1993;36(10):1177—93.
2. Rosa R. Extended workshifts and excessive fatigue. J Sleep Res 1995;4(2):51—6.
3. Knauth P, Keller J, Schindele G, Totterdell P. A 14-h night-shift in the control room of a fire brigade. Work Stress 1995;9(2/3):176—86.
4. Tucker P, Barton J, Folkard S. Comparison of eight and 12-hour shifts: impacts on health, well-being and alertness during the shift. Occup Environ Med 1996;53:767—72.
5. Rosa R, Colligan M. Long workdays versus rest days: assessing fatigue and alertness with a portable performance battery. Hum Factors 1988;30(8):305—17.
6. Rosa R, Colligan M, Lewis P. Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on test performance, subjective alertness, sleep patterns and psychosocial variables. Work Stress 1989;3:21—32.
7. Williamson AM, Gower CGI, Clarke BC. Changing the hours of shiftwork: a comparison of 8 and 12-hour shift rosters in a group of computer operators. Ergonomics 1994;37(2):287—98.
8. Duchon J, Keran C. Smith T. Extended workdays in an underground mine: a work performance analysis. Hum Factors 1994;36:258—69.
9. Wilson JT, Rose KM. The twelve hour shift in the petroleum and chemical industries of the United States and Canada: a study of current experience. Philadelphia (PA): Industrial Research Unit, The Wharton School, University of Pennsylvania, 1978. Industrial research reports, no 26.
10. Folkard S, Spelten E, Totterdell P, Barton J, Smith L. The use of survey measures to assess circadian variations in alertness. Sleep 1995;18(5):355—61.
11. Barton J, Costa G, Smith L, Spelten E, Totterdell P, Folkard S. The standard shiftwork index: a battery of questionnaires for assessing shiftwork related problems. Work Stress 1995;9(1):3—30.
12. Tucker P, Smith L, Macdonald I, Folkard S. The impact of early and late shift changeovers upon sleep, health and well-being in 8- and 12-hour shift systems. J Occup Health Psychol 1998;3(3):265—75.
13. Akerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci 1990;52:29—37.
14. Hernberg S. Significance testing of potential confounders and other properties of study groups — misuse of statistics [commentary]. Scand J Work Environ Health 1996;22:315—6.
15. Howell DC. Statistical methods for psychology. 3rd ed. Belmont (CA): Duxbury Press, 1992.
16. Rosa R, Härmä M, Pulli K, Mulder M, Näsman O. Rescheduling a three shift system at a steel rolling mill: effects of a one hour delay of shift starting times on sleep and alertness in younger and older workers. Occup Environ Med 1996;53:677—85.

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Change from slowly rotating 8-hour shifts to rapidly rotating 8-hour and 12-hour shifts using participative shift roster design

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Objectives The study examined the impact of change, from slowly rotating continuous 8-hour shifts to more rapidly rotating continuous 8-hour and 12-hour shifts, on the health and quality of life of shift workers.

Methods Self-report survey data were collected from 72 shift workers at 3 sewage treatment plants before and several months after roster change. After the change 1 plant first worked a rapidly rotating, 8-hour shift roster and then worked a 12-hour shift roster, and the other 2 plants worked continuous 12-hour shift rosters.

Results After the change the shift workers at each plant reported increased satisfaction with roster design, a decrease in physical and psychological circadian malaise associated with shift work, improved day sleep quality, less tiredness, and improvements in the quality of home, social and work life. A between-plant comparison of the rapidly rotating 8-hour and 12-hour shift rosters showed greater improvements had been obtained with the 12-hour shift roster, and no significant differences in tiredness or sleep quality between the redesigned 8- and 12-hour shift rosters. However, a within-plant matched-pairs comparison at the 1st plant of the rapidly rotating 8-hour shift roster and the 12-hour shift roster showed no significant differences.

Conclusions The results show that the prior level of support for change may best explain the impact of roster redesign on individual well-being. They lend further support to shift worker participation in roster design.

Key terms cicadian malaise, health, quality of life, tiredness.

Shiftwork research has, for many years, generally favored continuous three 8-hour shift rosters with faster rather than slower speeds of rotation, on the grounds that faster rotation is somewhat less socially disruptive (1) and results in less cumulative sleep loss and circadian disturbance (2). Continuous 12-hour shift rosters with short spells of day and night shifts fit the criteria for inclusion as rapidly rotating rosters. They have the additional advantage of reducing the number of work shifts and increasing the number of days off, but at the cost that employees must work a longer shift (3) and thus change the pattern of exposure to the occupational stress of shift work. Twelve-hour shifts also typically restrict the opportunity for overtime, and their introduction may therefore both reduce the length of the average workweek and the frequency of double shifts (ie, 16-hour shifts) worked.

The evaluation of shift rosters is usually only possible when there is a change from the existing roster to a "new" roster. Under such conditions the effects of roster difference are influenced by the effects of the change process and the contrast between the "old" and the "new" roster. In many studies of roster redesign the involvement of the shift workers in the design of their "new" roster is unclear, and change to 12-hour shifts also introduces a faster speed of rotation (eg, 4, 5, 6, and 7).

This paper reports the results of a roster change at 3 sewage treatment plants, all with a slowly rotating, continuous, three 8-hour shift roster prior to the change. After the change 2 of the plants moved immediately to continuous 12-hour shift rosters and the 3rd went first to a 6-month trial of a continuous rapidly rotating 8-hour shift roster and then to a trial of a 12-hour shift roster. It was

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therefore possible to compare rapidly rotating 8-hour shifts with 12-hour shifts with both roster conditions operating as "new" shift rosters and to compare the same shift workers on both "new" rosters.

Table 1. Biographical details of the shift workers participating in the roster redesign.

	Mean	Range	%
Age (years)	39.1	20—55	.
Time with corporation (years)	12.2	0.8—34.2	.
Time on "old" roster (years)	5.2	0.3—32.0	.
Years of shiftwork experience	7.8	0.3—32.0	.
Marital status			
Married	.	.	73.3
Separated/divorced/widowed	.	.	10.0
Single			16.7
Partner's employment status			
Waged employment — full-time	.	.	34.5
Waged employment — part-time	.	.	16.1
Not in waged employment			29.3
Families with children at home			
Under 5 years of age	.	.	27.4
6 to 12 years of age	.	.	24.2
13 to 18 years of age	.	.	12.9
No children	.	.	35.5

Table 2. Self-report survey scales.

Questionnaire topic	Number of items	Type of scale	Positive indicator
Attitude towards shift work (13, 14)	1	5-point	Low score
Attitude towards shift roster (15)	1	5-point	Low score
Job satisfaction (15)[a]	5	7-point	High score
Energy and vigor (15)	10	5-point	High score
General Health Questionnaire 12 (16)	12	4-point	Low score
General Health Questonnaire 6[b]	6	4-point	Low score
Digestion (15)	8	4-point	Low score
Cardiovascular symptoms (15)	8	4-point	Low score
Minor complaints (13, 14)	9	4-point	Low score
Circadian malaise (13, 14)	10	4-point	High score
Muscular complaints (13, 14)	4	4-point	Low score
Minor infections (13, 14)	4	4-point	Low score
Dayshift tiredness [b, c]	1	5-point	Low score
Nightshift tiredness [b, c]	1	5-point	Low score
Day-off tiredness [b, c]	1	5-point	Low score
Tiredness (13, 14)	1	3-point	High score
Fatigue (13, 14)	1	3-point	High score
Day sleep quality (13, 14)	14	3-point	Low score
Night sleep quality (13, 14)	14	3-point	Low score
Impact on home life (13, 14)	6	3-point	High score
Impact on social life (13, 14)	7	3-point	High score
Impact on work life (13, 14)	6	3-point	High score
"New" roster improvement[b, c]			
Family life	1	5-point	Low score
Social life	1	5-point	Low score
Mental health	1	5-point	Low score
Work performance	1	5-point	Low score

[a] Not included in the before-change survey.
[b] The first 6 items of the General Health Questionnaire (16).
[c] Single item question designed for this study.

Subjects and methods

Subjects

Twelve shiftwork crews from 3 sewage treatment plants in Sydney, Australia, were studied. Each crew comprised 6 male shift workers. The shift workers' age, time of employment with the corporation, length of service with the "old" roster, total number of years' experience with shift work, marital status, partner's employment status, and percentage with under 18-year-olds living at home at the 1st data collection point are shown in table 1. They were similar for all 3 plants.

Shift rosters

Before the change each plant worked a slowly forward rotating continuous three 8-hour shift roster with 7 consecutive shifts preceding days off. After the change plant 2 and plant 3 worked continuous two 12-hour shift rosters (each following an 8-day cycle with 2 night shifts, 1 or 2 days off, 2 day shifts, and 2 or 3 days off). Plant 1 first tried a forward rotating continuous three 8-hour shift roster with shifts following a 2×2×3 cycle and then introduced 12 hour shifts. The shift change times for the 8-hour shift rosters were 0600, 1400, and 2200, and for the 12-hour shift rosters the shift change occurred at 0700 and 1900. The rosters were as follows (D=day shift, N=night shift, A=afternoon shift, O= off shift):

D D D D D D D O O A A A A A A A O O N N N N N N N O O
(the before-change continuous three 8-hour shift roster)

D D A A N N N O O D D A A A N N O O D D D A A N N O O O
(the after-change 2×2×3 8-hour continuous shift roster used in plant 1)

N N O D D O O O
(the after-change continuous 12-hour shift roster used in plants 1 and 3)

O O D N N O O O O D D N
(the after-change continuous 12-hour shift roster used in plant 2)

Votes for roster trials prior to change

It was agreed that participation in roster design should include a secret ballot at each plant, with a minimum of 65% voting in favor before any change could be introduced (8). In the 1st vote 2 plants voted with a sufficient majority for an immediate trial of 12-hour shifts. At one plant the vote was 75% in favor of a 12-hour shift trial (with no voter indicating that he would not be willing to try a 12-hour shift roster if a 65% majority voted in favor). In the other plant the vote was 100% in favor of the 12-hour shifts. The 3rd plant voted only 53% in favor of 12-hour shifts. This value fell below the agreed

65% majority. At a 2nd vote, for a trial of rapidly rotating 8-hour shifts, 75% voted in favor. Following the 6-month trial of the rapidly rotating 8-hour shift roster another vote was held. On this occasion 67% voted for a trial with 12-hour shifts prior to reaching a final decision about which roster to adopt (8).

Study design, survey scales and other measures

Self-report questionnaire surveys (table 2) were administered to small groups during visits with each crew at work in the 2 months prior to the change from the slowly rotating, 8-hour shift roster. This survey procedure was repeated in the 5th or 6th month after the change and, for the plant which underwent a 2nd change, from the rapid 8-hour shift roster to a 12-hour shift roster, again in the 5th or 6th month of work with the 12-hour shift roster. The surveys of the "old" roster were completed prior to a vote on whether or not to try the "new" rosters. Data collection was undertaken as part of a participative design process which provided an opportunity to collect additional information through individual and group discussion.

The shift workers were also asked to keep sleep diaries in the weeks before roster change and again for some weeks 3 months after the change. Personnel data on overtime hours, near-miss occupational health and safety accident reports, workers' compensation claims, sickness absence, time spent in meetings, and attendance at training claims were also collected. The response rate for returned surveys was 72.2% before the change and 63.8% after the 1st roster change. Before the change 38.5% of the forms had missing data and after the change the corresponding value was 36.0%. The response rate after the 2nd roster change at plant 1 was 66.7%, 18.8% of which was incomplete. Failure to complete a questionnaire resulted from absence from work or being engaged in work which would not allow completion of a survey on the survey day. Individual and group discussion at each plant did not indicate any clear differences between the survey respondents and nonrespondents. Missing data within the returned surveys was primarily a result of there being insufficient time for the workers to check whether all the questions had been answered. Only 3 shift workers refused to complete a survey — all on the grounds that they disliked questionnaires — and only 4 shift workers clearly indicated on their surveys that they refused to answer a particular question or section of the survey. To ensure anonymity, no record of who did or did not complete a survey was kept. However, with the agreement of the shift workers at plant 1, it was possible to match the surveys completed after the change to the rapidly rotating, 8-hour and the 12-hour shift rosters. Less than 25% of shift workers at each plant returned a sleep diary, and few of these diaries included more than 7 days of recording.

Independent sample t-tests were used to compare data collected before and after the 1st roster change and to make between-plant comparisons. Matched pair t-tests were used to compare the "new" 8-hour and 12-hour shifts within plant 1.

Results

Effects of first roster changes

The only significant difference in the attitude towards shift work was with roster satisfaction. After the change there was greater satisfaction with the roster (table 3).

For the 5 health variables included in each testing, only circadian malaise (ie, disturbed appetite and sleep, indigestion, constipation, flatulence, irritability, moodiness, depression, tiredness, and fatigue) showed a significant change. Less malaise was reported after the roster change (table 3).

Day sleep quality was significantly improved after the change. Night sleep quality was not. Self-reported tiredness and fatigue were both lower following the change (table 3).

There was significant improvement in home and social life after the change to the "new" roster (table 3).

Between-plant comparison of rapid 8-hour and 12-hour shifts. Before the roster change a comparison of the 2 plants that moved to 12-hour shifts and the plant that started rapidly rotating 8-hour shifts showed no significant differences in attitudes towards shiftwork, self-report health complaints, day and night sleep quality, and impact of shift work on home, social and work life (table 4). After the roster change there were several significant differences between the plants that moved to either 12-hour shifts or to the rapidly rotating 8-hour shifts.

The only significant difference in attitudes towards shift work and work occurred for roster satisfaction. Those working the 12-hour shifts were more satisfied with their roster than those working the rapid 8-hour shifts (table 5).

For the 8 health variables only the General Health Questionnaire 12 scores differed significantly between the 2 "new" rosters. Those working 12-hour shifts reported fewer psychological health complaints (table 5).

There was no significant difference between those working 12-hour shifts and those working 8-hour shifts on self-reports of tiredness or sleep quality (table 5).

For the 3 life-style impact variables (ie, on home, social, and family life) those working 12-hour shifts reported a less negative impact of shift work on both their home and social lives (table 5).

Those who changed to 12-hour shifts reported greater improvements in their family and social lives and life overall. There was no significant difference in the

Table 3. Effects of roster change. (df = degrees of freedom)

	Before change		After change		Statistical difference		
	Mean	N	Mean	N	t-Value	df	P-value[a]
Attitude towards shift work	2.4	39	2.1	47	1.29	84	0.202
Attitude towards shift roster	2.9	40	1.8	47	3.91	85	0.000
General Health Questionnaire 12	21.8	39	20.7	47	1.55	84	0.125
Minor complaints	30.0	32	31.6	45	-1.94	75	0.056
Circadian malaise	27.3	36	31.8	46	-4.04	80	0.000
Muscular complaints	13.8	37	14.5	46	-2.10	81	0.039
Minor infections	12.9	39	12.9	44	-0.04	81	0.965
Day sleep quality	30.8	52	25.4	30	2.93	80	0.004
Night sleep quality	22.0	52	20.0	30	-1.47	80	0.145
Tiredness	2.2	40	2.8	47	-3.07	85	0.003
Fatigue	2.5	40	3.1	46	-3.06	74.6	0.003
Home life	9.7	38	13.8	44	-6.25	78.1	0.000
Social life	11.1	39	15.8	44	-4.77	81	0.000
Work life	11.0	35	12.3	45	-2.80	7 8	0.007

[a] Bonferroni correction P<0.05 requires a t-score significance of P<0.004.

Table 4. Before-change between-plant comparison of rapid 8-hour shifts and 12-hour shifts. (df=degrees of freedom)

	Before 12-hour shifts		Before rapid 8-hour shifts		Statistical difference		
	Mean	N	Mean	N	t-Value	df	P-value[a]
Attitude towards shift work	2.6	23	2.1	16	1.34	37	0.187
Attitude towards shift roster	3.1	24	2.6	16	1.26	38	0.215
General Health Questionnaire 12	22.5	23	20.8	16	1.92	37	0.062
Minor complaints	30.6	18	29.3	14	-1.07	30	0.294
Circadian malaise	27.5	21	27.1	15	0.22	34	0.824
Muscular complaints	13.7	21	13.8	16	-0.16	35	0.872
Minor infections	11.5	22	11.9	16	-0.64	36	0.528
Day sleep quality	31.5	23	29.5	15	0.62	36	0.540
Night sleep quality	24.2	22	21.1	14	1.35	34	0.185
Tiredness	2.3	24	2.1	16	0.75	38	0.457
Fatigue	2.5	24	2.5	16	-0.13	38	0.900
Home life	9.8	23	9.5	15	0.37	36	0.711
Social life	10.2	23	12.3	16	-1.35	37	0.186
Work life	11.0	20	11.0	15	0.00	33	1.000

[a] Bonferroni correction P<0.05 requires a t-score significance of P<0.004.

reported improvements in physical and mental health or in work performance between the 2 groups (table 5).

Within-plant comparison of rapid 8-hour and 12-hour shifts. The results of the matched pairs t-test comparison are presented in table 6 for the survey data collected in the 5th and 6th months of operation of the 2x2x3 8-hour shift roster and the 12-hour shift roster at plant 1. None of the comparisons showed a significant improvement with 12-hour shifts.

Diary sleep records, overtime work, near-miss occupational health and safety accident reports, and workers' compensation claims. The mean sleep lengths calculated from sleep diaries indicated no major change in the duration of night or day sleep after the roster changes.

Data on the overtime worked at each plant was collected for the 12 weeks prior to the change and for 32 weeks after the change. Before and after the roster change overtime hours were highest at plant 2 and lowest at plant 3. Plant 1 reduced overall overtime by 36% after the rapid 8-hour shifts were introduced; plant 2 reduced overtime by 47% after the introduction of 12-hour shifts, and plant 3 showed a 60% reduction with 12-hour shifts. These reductions were accompanied by less time being spent in training and in meetings between shift crews and with day workers. For the 12-hour shifts the reduction in overtime coupled with less overlapping hours spent at work alongside day-time management and day workers was reported as giving rise to communication difficulties. The shift workers' comments, such as "We seem to be at work much less often with the new roster", need to be

Table 5. After-change between-plant comparison of rapid 8-hour shifts and 12-hour shifts. (df = degrees of freedom)

	12-hour shifts		Rapid 8-hour shifts		Statistical difference		
	N	Mean	N	Mean	t-Value	df	P-value[a]
Attitude towards shift work	32	1.9	15	2.5	-1.93	45	0.060
Attitude towards shift roster	32	1.3	15	2.9	-3.95	16.62	0.001
Job satisfaction	31	21.6	15	21.1	-3.95	16.62	0.001
Energy and vigor	31	38.1	14	36.9	0.93	43	0.358
General Health Questionnaire 12	37	19.3	15	23.5	-4.26	45	0.000
Digestion	32	11.4	14	13.5	-1.91	44	0.063
Cardiovascular symptoms	31	9.3	15	10.7	-1.73	42	0.055
Minor complaints	31	32.6	14	29.6	2.56	43	0.014
Circadian malaise	32	33.0	14	29.2	2.60	44	0.013
Muscular complaints	32	14.9	14	13.7	1.92	16.18	0.073
Minor infections	31	13.0	13	12.6	0.80	42	0.429
Dayshift tiredness	30	2.3	15	2.9	-2.01	43	0.051
Nightshift tiredness	30	3.1	14	3.4	-0.98	42	0.332
Day-off tiredness	30	2.0	15	2.5	-1.98	43	0.055
Day sleep quality	28	25.3	13	28.5	-1.46	39	0.153
Night sleep quality	29	19.9	13	21.8	-1.06	40	0.294
Home life	30	15.4	14	10.4	6.17	42	0.000
Social life	31	17.7	13	11.2	6.64	42	0.000
Work life	31	12.7	14	11.4	1.97	43	0.055
Family life	32	1.5	15	2.9	-3.90	19.34	0.001
Social life	32	1.7	15	3.2	-4.64	45	0.000
Life overall	32	1.7	15	3.1	-3.89	19.05	0.001
Physical health	32	2.2	15	2.8	-2.02	45	0.049
Mental health	32	2.3	15	2.7	-1.62	45	0.112
Work performance	32	2.1	15	2.7	-2.32	45	0.025

[a] Bonferroni correction $P<0.05$ requires a t-score significance of $P<0.002$.

considered against day management comments such as "They don't seem to ever be here with the new roster". The near-miss accident reports and workers' compensation claims were similar prior to and after the roster change. The near-miss occupational health and safety accident reports during the 6 months of "new" roster operation were 1 each for the rapid 8-hour shifts and 12-hour shifts. The 12-hour shift near-miss did not involve a shift worker. Two workers' compensation claims were lodged during the 6 months of "new" roster operation. Both involved claims for long-term hearing loss related to the work environment several years prior to the roster changes. No accidents were recorded in the 6 months preceding or following the change. Sickness absences were similar prior to and after the roster change; however, 2 shift workers went on long-term sick leave after the roster change as a result of nonwork injuries.

Discussion

Reduced disturbance in circadian rhythms and greater social satisfaction resulting from the faster rotation achieved by 12-hour shift rosters may explain the popularity of 12-hour shift rosters. However, a greater contribution to their popularity may be that they provide a

Table 6. Matched-pair comparison of the rapidly rotating 8-hour shifts and the 12-hour shifts. (df = degree of freedom)

	8-hour shifts (2x2x3) (mean)	12-hour shifts (mean)	Statistical difference		
			t-Value	df	P-value[a]
Attitude towards shift roster	2.8	2.5	-0.34	11	0.74
Energy and vigor	32.5	33.1	0.27	10	0.79
General Health Questionnaire 6	11.2	11.6	0.49	11	0.64
Digestion	11.3	15.1	1.30	11	0.22
Cardiovascular symptoms	10.2	11.2	0.74	11	0.48
Dayshift tiredness	2.8	2.9	0.22	11	0.83
Nightsift tiredness	3.4	3.3	-0.19	11	0.85
Day-off tiredness	3.2	2.6	-1.03	10	0.33
Improved family life	2.6	2.3	-0.63	11	0.54
Improved social life	2.9	2.3	-1.70	11	0.26
Improved life overall	2.8	2.3	-0.73	11	0.48
Improved physical health	2.8	2.2	-0.96	11	0.36
Improved mental health	3.1	2.8	-0.56	11	0.59
Improved work performance	3.0	2.8	-0.44	11	0.67
Roster advantages outweigh disadvantages	1.6	1.4	-0.25	11	0.81

[a] Bonferroni correction $P<0.05$ requires a t-score significance of $P<0.003$.

reduction in the number of days involving night work and an increase in the number of days off. Both of these factors may further reduce the stress and social disruption of shift work.

Discussion with the individual shift workers and shift crews involved in these trials of 12-hour shifts indicated that these workers did indeed regard the major advantage of 12-hour shifts to be the reduced number of days spent working shifts and the positive carry-over effects that this had on reducing the impact of shift work on their family and social lives. It also indicated, as earlier research has shown (1), that rapidly rotating continuous 8-hour shifts were more socially acceptable than slowly rotating continuous 8-hour shifts. However, rapid rotation reduced the number of consecutive days off. This was a particular disadvantage for the more frequent 2-day breaks when the 1st day off began at 0600 hours after a spell of night shifts. Because of the need to recover from night work and to make the transition to night sleep, these 2-day breaks were reported as providing only 1 real day off. The results support earlier research which shows that the distribution of time for recovery from night work and for social and family life is an important factor in satisfaction with roster design (9).

Nonetheless, the survey results are contradictory in terms of the support they offer to 12-hour shifts.

The change from "old" to "new" rosters with more rapid rotation through either 8- or 12-hour shifts was supported in advance by 83.3% of the shift workers in the 3 plants. The results showed increased satisfaction with the roster design, a decrease in the physical and psychological circadian malaise associated with shift work, improved day sleep quality, less tiredness, and improvements in the quality of home, social and work life.

The between-plant comparison of the results for the 12-hour shifts and rapidly rotating 8-hour shifts concerned a group voting 87.5% in favor of trying 12-hour shifts and a group voting 75% in favor of trying rapidly rotating 8-hour shifts only after 47% had rejected trying 12-hour shifts. The results showed that satisfaction with roster design, psychological health, and improvement in the quality of home, social and work life were all significantly greater for the 12-hour shifts. Furthermore, there was no significant increase in tiredness or any decrease in sleep quality with the 12-hour shift roster. Nonetheless, earlier research has shown that significantly less sleep may be taken for night shifts following a change from slowly rotating 8-hour shifts to more rapidly rotating 12-hour shifts (7, 6) and that 12-hour shifts have a potential for increased fatigue (10) and increased safety risk (4, 11). Negative effects such as these may be less readily shown by self-report data from shift workers who strongly support roster change.

The within-plant matched-pairs comparison of rapidly rotating 8-hour shifts and 12-hour shifts showed, however, no significant differences between the 2 rosters. It examined the 2 rosters for the group which 1st voted 53% in favor of a 12-hour shift trial, but then, because this was an insufficient majority to proceed with the trial, voted 75% in favor of a trial of rapidly rotating 8-hour shifts as an alternative to the existing slowly rotating 8-hour shift roster; and finally, because of continuing pressure by the majority who had voted for 12-hour shifts, held another vote, which achieved a 67% vote in favor of a 12-hour shift trial prior to a final decision about which roster to adopt.

The voting percentages are reflected in the survey reports of satisfaction with the different rosters. The votes for change showed that the plant which moved 1st to rapidly rotating 8-hour shifts and then to a trial of 12-hour shifts was less clear about the need for roster change and about what change to adopt. These workers were less satisfied with either of the alternative rosters than the workers at the 2 other plants.

The difference between the results obtained with each roster may be associated with the differences in satisfaction expressed by the shift crews at each plant. Furthermore, the overall improvement reported when the rosters were first changed at each plant could be associated with the reduction in overtime which accompanied the change from the original rosters.

These alternative explanations of the results do not deny that, under appropriate work conditions, 12-hour shifts offer real advantages to many shift workers. In particular, for many, they reduce the negative impact of shift work on family and social life by reducing the number of shifts worked. However, there are longer periods of time when 12-hour shift workers are out of direct contact with day working management and employees. This lack of contact was reported as a disadvantage by plant management. Plant managers found that reduced contact with the shift workers exacerbated communication difficulties at work. They also reported that the reduced availability of overtime to provide flexibility in meeting operational demands caused difficulties. In practice greater management discipline was required over the use of overtime, as was greater creativity in tackling the integration of shift crews and day workers.

The trials do, nevertheless, highlight the difficulty that results may be confounded by the prior level of support for existing and new rosters. This prior support may well reflect reasoned individual assessments of the likelihood of a new roster better fitting individual differences in life-style than does the existing roster. The level of prior support is important because the success of a roster in promoting well-being is to a significant extent dependent on the ability of a roster to satisfy the needs of as large a majority of shift workers as possible. It is therefore important to evaluate the results of comparisons between shift rosters, not only in terms of the similarity of shift workers and the work they perform in each roster condition, but also in terms of the advance support each group of shift workers gives to the adoption of a particular roster design.

Finally, the results from these trials provide a further indication that shift workers are able to make a reasonable assessment of the probable impact that a new roster design will have on their individual life-styles. This ability shown by shift workers provides additional support for the importance of shiftworker participation in roster design (12) and for the longitudinal study of the long-term health effects of 12-hour and other shift rosters (2).

References

1. Wedderburn AAI. Social factors in satisfaction with swiftly rotating shifts. Occup Psychol 1967;41:85—107.
2. Colqhoun WP, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Bern (Germany): Peter Lang GmbH, 1996.
3. Wallace M, Greenwood KM. Twelve hour shifts. Work Stress 1995;9(2/3):105—8.
4. Rosa RR, Colligan MJ, Lewis, P. Extended workdays: effects of 8h and 12h rotating shift schedules on performance, subjective alertness, sleep patterns and psychosocial variables. Work Stress 1989;3(1):21—32.
5. Rosa RR, Bonnett, MH. Performance and alertness on 8h and 12h rotating shifts at a natural gas utility. Ergonomics 1993;36(10):1177—93.
6. Williamson AM, Gower CGI, Clarke BC. Changing the hours of shiftwork: a comparison of 8 and 12 hour shift rosters in a group of computer operators. Ergonomics 1994;37(2):287—98.
7. Di Milia L. A longitudinal study of the compressed workweek: comparing sleep on a weekly rotating 8h system to a faster rotating 12h system. Int J Ind Erg 1998;21:199—207.
8. Wright BM, Mackey RW, Milsop HW, Smith PA. Participative shift roster re-design: trials of 8- and 12-hour rapidly rotating continuous shift rosters. International Committee on Occupational Health, XIIIth International Symposium on Night and Shiftwork, Finland, 1997 June 23—27.
9. Knauth P. The design of shift systems. Ergonomics 1993;36(1/3):1311—21.
10. Tepas DI. Flexitime, compressed workweek and other alternative work schedules. In: Folkard S, Monk TH, editors. Hours of work: temporal factors in work scheduling. Chichester: Wiley, 1985;199—210.
11. Kogi K. Job content and working time: the scope for job change. Ergonomics 1991;34(6):757—73.
12. Kogi K, DiMartino VG. Trends in the participatory process of changing shiftwork arrangements. Work Stress 1995;9(2/3):298—304.
13. Smith PA, Bennett S. Report on the joint University of Bradford and Civil Service Union studies of shiftwork. London: Civil Service Union, 1983.
14. Bennett S, Smith PA, Wedderburn AAI. Towards a synthesis of research findings for application with shiftworkers. J Hum Ergol 1982;11:13—9.
15. Barton J, Spelten E, Totterdell P, Smith L, Folkard S, Costa G. The standard shiftwork index: a battery of questionnaires for assessing shiftwork-related problems. Work Stress 1995;9(1):4—30.
16. Goldberg DP. Manual of the general health questionnaire. Windsor: NFER-Nelson, 1972.

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Effects of alternating 8- and 12-hour shifts on sleep, sleepiness, physical effort and performance

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Objectives The aim of the present study was to compare 12-hour shifts during weekends with 8-hour shifts during weekdays with respect to sleep, sleepiness, physical effort, and performance.

Methods Thirty-one subjects at a power plant participated. Sleep, sleepiness, and physical effort were measured with a diary. About half of the subjects carried out a reaction-time test during both 8- and 12-hour morning and night shifts. The remaining subjects carried out a vigilance task.

Results Sleepiness was higher and physical effort lower on the 12-hour night shift than on the 8-hour night shift. However, the subjects who had the same level of physical effort on 8- and 12-hour night shifts did not differ with respect to sleepiness. During the 12-hour morning shift, sleepiness was lower and the sleep length was longer than on the 8-h morning shift. The subjects who had the same amount of sleep for 8- and 12-hour morning shifts showed no difference in sleepiness. Sleep did not differ between 8- and 12-hour night shifts. There was no difference between 8- and 12-hour shifts with respect to performance.

Conclusions It was suggested that the difference in sleepiness between 8- and 12-hour shifts is related to differences in sleep length for the morning shift, and to differences in physical effort for the night shift, rather than to shift duration. Thus the most likely conclusion is that 12-hour shifts do not cause increased sleepiness or impaired performance or disturbed sleep.

Key terms fatigue, reaction time, shift work, subjective ratings, vigilance.

Recently there has been a growing interest in long workhours, and, in particular, 12-hour shifts. One benefit of extended workshifts is that they permit longer and more frequent blocks of free time. On the other hand, there is also a potential risk that extended shifts cause excessive fatigue and sleepiness, which may result in higher risks of accidents and injuries or in a deterioration of health (1, 2). Previous results are inconclusive. For example, Rosa and his co-workers have found increased sleepiness, shorter sleep, and performance decrements after changes to 12-hour shift schedules (3, 4). In contrast, other studies have reported improved sleep, alertness, and well-being as a result of changes to 12-hour shift schedules (5, 6). The reason for the inconsistent results may, at least partly, be methodological. Thus many studies have used a pre- and posttest design, but often without a reference group. Thus it may be that factors other than the change in shift schedule have influenced the results. Another concern is that the evaluation has not extended beyond the initial "Hawthorne" period, when the act of change in itself can be viewed as positive, regardless of content (2).

The aim of the present study was to examine how 12-hour shifts (on weekends), alternating with 8-hour shifts in the same schedule, affect sleep, physical effort, sleepiness, and performance. To our knowledge, this kind of schedule has not been evaluated before. The schedule offers a compromise between the social benefits of having 12-hour shifts on weekends (and not working more than 2 weekends out of 6), but minimizing the risk of accumulating fatigue, since only six 12-hour shifts are worked in a 6-week period. Furthermore, the design also avoids some of the methodological problems of previous studies because the subjects are their own referents, and there is no "Hawthorne effect" since the shift schedule has not changed.

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Subjects and methods

All shift workers (N=76) at a power plant in Stockholm were invited to participate in the study. Twenty-seven abstained or could not participate (changed to day work, changed employment, or pregnancy). Of the remaining 49 subjects another 18 had to be excluded from the analysis because of incomplete data or because of too many deviations from the schedule (changed shifts with colleagues, much overtime, holidays and sick leave). Thus the present study included 31 experienced 3-shift workers, 27 men [mean age 38 (standard error of the mean=SE 2) years] and 4 women [mean age 29 (SE 2) years], who completed a shift cycle. They worked as control room operators, shift engineers, machinists, and shift supervisors.

The shift cycle (comprising 42 days and 6 shift teams) is presented in table 1. The present shift system was introduced more than 1 year before the study.

Eight-hour shifts were worked from Mondays to Thursdays and 12-hour shifts from Fridays to Sundays (the 3rd 12-hour night shift finished at 0700 on Monday morning). The analyses compared the 1st three 8- and 12-hour morning (M) shifts, and, for night (N) shifts, the three 12-hour shifts were compared with the 1st two 8-hour shifts and the 4th 8-hour shift. Since the sleep episode after the last 8- and 12-hour N shifts, respectively, was reduced by about 1.5 hours when compared with the other day sleep episodes, the 4th (and last) 8-hour N shift was considered more appropriate for the present analyses (comparing 8- and 12-hour shifts) than the 3rd shift. Furthermore, there was no significant difference in rated sleepiness [mean KSS between 2400 and 0600; shift 3=5.1 (SE 0.2) versus shift 4=4.9 (SE 0.2), P=0.42)] or physical effort [mean CR-10 between 2400 and 0600; shift 3=1.9 (SE 0.1) versus shift 4=1.8 (SE 0.1), P=0.35] between the 3rd and the 4th 8-hour N shifts. The last days off before the 8- and 12-hour M shifts were also analyzed to investigate the level of recuperation and alertness before the work periods.

The subjects completed the Karolinska Sleep Diary (KSD) (7) and a wake diary across the entire shift cycle. The sleep diary was collected daily after each main sleep period, and it had questions about bed times, wake-up times, napping, and different aspects of sleep quality. A sleep quality index was computed (as a mean across items), containing the items "sleep quality" (phrased "How was your sleep?"), "ease of falling asleep", "calm sleep" and "slept throughout". In previous studies the sleep quality index showed a significant covariation with objective measures of sleep (8). The analysis also included the items "well-rested and refreshing sleep" and "ease of awakening". The response alternatives ranged from 1 ("problems" or "very poor") to 5 ("no problems at all" or "very good").

In the wake diary the subjects were instructed to rate their sleepiness and physical effort every 2nd hour on the Karolinska Sleepiness Scale (KSS) (9) and on the Borg CR-10 scale (10) both during work and free time. The KSS is a 9-point verbally anchored scale that ranges from 1 ("very alert") to 9 ("very sleepy, fighting sleep, an effort to keep awake") . The CR-10 scale ranges from 0 ("none at all") to 10 ("extremely exerted") and has shown a significant covariation with such physiological measures as heart rate and blood lactate (11).

The shift workers were instructed to carry out a performance test at the beginning and end of the M and N shifts (both 8- and 12-hour shifts), respectively. Two tests were used. Half the group did a serial simple reaction-time test and the other half did a vigilance task (VT). The reaction-time test (length=10 minutes) (12) was presented on a handheld computer (Psion Organizer) and was carried out in the normal work environment. Sixteen signals per minute were presented at random intervals (interstimulus interval 2—7 seconds). The present analysis was based on the mean and the 10% longest reaction times across tests. The vigilance task (also 10 minutes) was presented on a computer and was carried out close to the control room. The test was a shorter version of a previously validated 28-minute vigilance task (13).

Table 1. Shift schedule. [A-F=shift teams, D=day shift (0700-1600), A=afternoon shift (1500-2300), M=morning shift (0700-1500), **M**= morning shift (0700-1900), N=night shift (2300-0700), **N**=night shift (1900-0700), blank=day off, bold letters=12-hour shifts, Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fi = Friday, Sa = Saturday, Su = Sunday]

	1							2							3						
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	D	D	D	D	D			A	A	A	A				M	M	M	M	**N**	**N**	**N**
B								D	D	D	D	D			A	A	A	A			
C	N	N	N	N											D	D	D	D	D		
D					**M**	**M**	**M**	N	N	N	N										
E	M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**	N	N	N	N			
F	A	A	A	A				M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**

	4							5							6						
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A					**M**	**M**	**M**	N	N	N	N										
B	M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**	N	N	N	N			
C	A	A	A	A				M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**
D	D	D	D	D	D			A	A	A	A				M	M	M	M	**N**	**N**	**N**
E								D	D	D	D	D			A	A	A	A			
F	N	N	N	N											D	D	D	D	D		

The signal (total=21 signals) that had to be detected was a clockwise rotating dot that jumped a step at random intervals. Some subjects had to be excluded from the analysis, since the tests had interfered too much with their work task. Altogether 13 subjects produced complete data (for at least one 8-hour and one 12-hour N and M shift, respectively) on the reaction-time test, and 15 subjects completed the vigilance task.

The data were analyzed with a repeated-measures analysis of variance (ANOVA) using 2, 3 or 4 within-group factors. The main effects were shift type (N shifts versus M shifts), shift length (8-hour shifts versus 12-hour shifts), shift sequence (1st, 2nd, and 3rd shift in a row) and, when appropriate, time of day. The Huynh-Feldt epsilon correction method was used to correct for sphericity (14). However, for clarity, the unadjusted degrees of freedom are given in the tables. When appropriate (and after a significant main effect), pairwise tests (orthogonal contrasts) were carried out to investigate the simple effects. For the test of relations between variables, correlation coefficients (pooled) were calculated using a least-squares dummy-variable regression model according to the method of pooled time series presented by Totterdell et al (15). The alpha level was set at 0.05.

Results

The means (across shifts) and a summary of the ANOVA procedures are presented for the sleep and wake data in table 2. The time-of-day results for the KSS

Table 2. Means, standard errors (SE), and P-values [3-way analysis of variance (ANOVA) with shift, length and sequence as factors] for ratings of sleep, alertness, and physical exertion on 8- and 12-hour morning and night shifts. [S = shift; L = length; Se = sequence; TST=total sleep time (for the main sleep episode, naps not included); KSS=Karolinska Sleepiness Scale (1 very alert, 9 very sleepy); CR-10=category ratio scale of physical exertion (0=none at all, 10=extremely exerted)]

	Night shifts		Morning shifts		S	L	Se	SxL	SxSe	LxSe	SxLxSe
	Mean	SE	Mean	SE							
TST (h+min)											
8-hour shifts	5:29	12	6:05	8	0.005	0.31	0.06	0.06	0.0002	0.13	0.04
12-hour shifts	5:18	10	6:27	7							
P-value	0.36		0.04								
TST for the last day off (h+min)											
8-hour shifts	8:49	16	7:48	19	0.02	0.37	-	0.16	-	-	-
12-hour shifts	8:42	22	8:26	13							
P-value	0.80		0.04								
Individuals taking naps (%)											
8-hour shifts	48	5	13	4	0.0001	0.04	0.01	0.14	0.002	0.53	0.74
12-hour shifts	46	5	0	0							
P-value	0.66		0.02								
Sleep latency (min)											
8-hour shifts	11.6	2	17.4	2	0.006	0.53	0.23	0.79	0.37	0.39	0.88
12-hour shifts	10.5	1	15.5	2							
P-value	0.64		0.55								
Sleep quality index (1 poor-5 good)											
8-hour shifts	4.1	0.1	3.9	0.1	0.16	0.37	0.40	0.58	0.59	0.08	0.35
12-hour shifts	4.0	0.1	3.9	0.1							
P-value	0.12		0.85								
Well-rested (1 no-5 yes)											
8-hour shifts	3.1	0.1	2.7	0.1	0.38	0.62	0.04	0.07	0.09	0.63	0.18
12-hour shifts	2.9	0.1	3.0	0.1							
P-value	0.35		0.04								
Ease awakening (1 difficult-5 easy)											
8-hour shifts	3.1	0.1	2.6	0.1	0.03	0.04	0.01	0.27	0.64	0.55	0.93
12-hour shifts	3.2	0.1	2.9	0.1							
P-value	0.39		0.03								
KSS (N=2400-0600h, M=0800-1400)											
8-hour shifts	5.1	0.1	4.1	0.1	0.0001	0.19	0.18	0.0002	0.34	0.74	0.17
12-hour shifts	5.7	0.1	3.7	0.1							
P-value	0.001		0.02								
CR-10 (N=2400-0600h, M=0800-1400)											
8-hour shifts	1.8	0.1	2.4	0.1	0.0001	0.001	0.01	0.58	0.60	0.41	0.28
12-hour shifts	1.6	0.1	2.1	0.1							
P-value	0.04		0.03								
Degrees of freedom	1/30		1/30		1/30	1/30	2/60	1/30	2/60	2/60	2/60

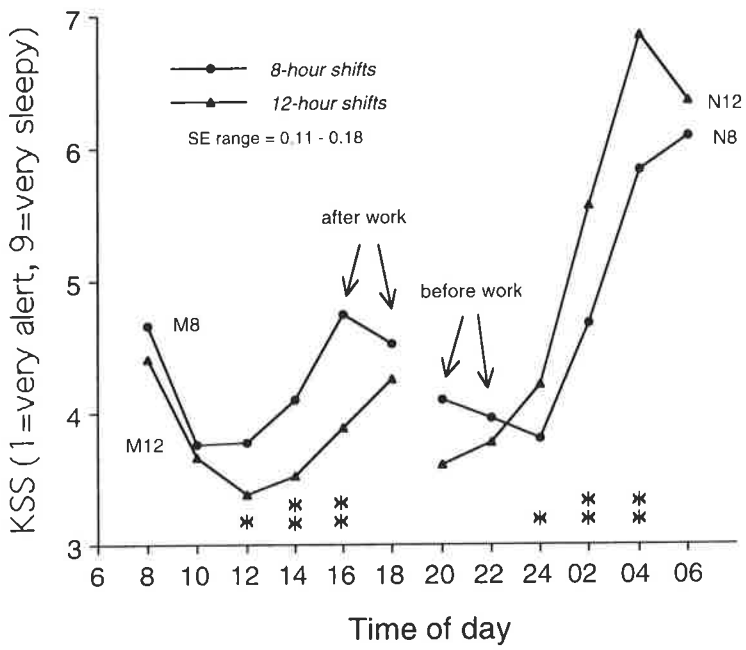

Figure 1. Mean ratings of sleepiness on the Karolinska Sleepiness Scale (KSS) every 2nd hour on 8-hour morning shifts (M8), 12-hour mornings shifts (M12), 8-hour night shifts (N8), and 12-hour night shifts (N12). Two ratings after M8 and before N8 are also plotted. Asterisks indicate significant (*P<0.05, **P<0.01) pairwise differences between 8- and 12-hour shifts.

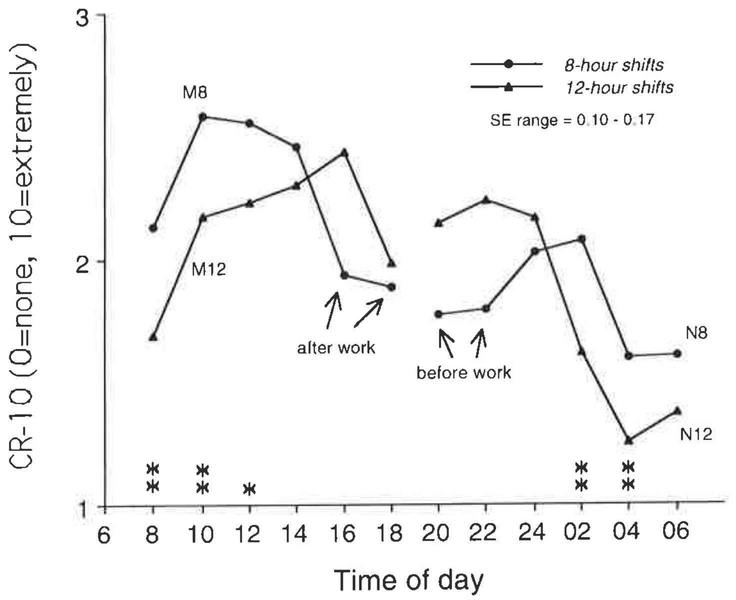

Figure 2. Mean ratings of physical effort on the Borg's category ratio scale (CR-10) every 2nd hour on 8-hour morning shifts (M8), 12-hour mornings shifts (M12), 8-hour night shifts (N8), and 12-hour night shifts (N12). Two ratings after the M8 and before N8 are also plotted. Asterisks indicate significant (*P<0.05, **P<0.01) pairwise differences between 8- and 12-hour shifts.

(sleepiness) and CR-10 (physical effort) are also given in figures 1 and 2. The variables total sleep time, "total sleep time prior to the last day off before shifts" (for the night shifts the last night sleep before the shift sequence was used), sleep latency, ease of awakening, napping (both during free time and on the shift), KSS and CR-10 showed a significant main effect for shift (M versus N shifts). The sleep prior to the last day off before the shift sequence was longer in connection with the N shifts. However, the total sleep time during day sleep (N shifts) was shorter (about 30 minutes) than sleep in connection with the M shifts. The sleep latency was longer in connection with the M shifts. Naps were more frequently taken in connection with N shifts. The rating ease of awakening indicated more difficulties in connection with the M shifts. The M shifts also showed higher alertness and physical effort. Frequency of naps, ease of awakening, and the CR-10 were the only variables that showed a significant difference due to length of shift (8-hour versus 12-hour shifts). It was easier to wake-up in connection with 12-hour shifts than in connection with 8-hour shifts, and more naps were taken in connection with the 8-hour shifts. The physical effort was also lower for the 12-hour shifts. Frequency of naps, well-rested, ease of awakening, and CR-10 also showed significant effects due to sequence (1, 2, and 3 or 4 shifts). The frequency of naps [1 shift (32%) versus 3 or 4 shifts (20%)], as well as the physical effort (about 0.2 scale units), decreased across shifts. The problems with difficulties awakening and unrefreshing sleep accumulated across shifts (decreased by about 0.3 scale units between the first and the last shift). The sleep quality index showed no significant effects at all.

Among the interaction effects, total sleep time and the frequency of naps showed a significant shift-by-sequence effect. The last-day sleep was about 1.5 hours shorter than the other day sleeps, whereas there was no such change for the M shift. The frequency of naps decreased across N shifts (1st 60%, 2nd 48%, 3rd 34%), whereas the occurrence of napping in connection with the M shifts was stable across shifts (~6%). The KSS showed a significant shift-by-length interaction. Thus sleepiness was higher for 12-hour N shifts than for 8-hour N shifts but lower for 12-hour M shifts when compared with 8-hour shifts. The other interactions, except for total sleep time, which showed a significant 3-way interaction, were nonsignificant.

The variables were also subjected to repeated ANOVA procedures for the N and M shifts, separately (2 factors: length of shift and sequence). The P-values for the factor length of shift are listed in table 2 (below the means). For the N shift, significantly higher sleepiness and lower physical effort was found for the 12-hour shift. For the M shifts, significant effects due to length of shift were obtained for the variables total sleep time, total sleep time prior to the last day off, frequency of naps, well-rested, ease of awakening, sleepiness and physical effort. Sleep in connection with the 12-hour shifts was longer and involved no napping; in addition the subjects felt more refreshed and rated the awakening as easier. Furthermore, the sleep prior to the last day off before the 12-hour M shift sequence was about 40 minutes longer. The 12-hour M shift also involved lower ratings of sleepiness and physical effort.

The ANOVA for the KSS and CR-10 ratings also included a 4th factor — time of day. (See figures 1 and 2.) Time of day was significant only for KSS (P=0.0001), and it also showed the expected interaction with shift (P=0.0001). The ratings of sleepiness and physical effort between 2000 and 2200 for the N shifts, and between 1600 and 1800 for the M shifts were also analyzed with respect to length of shift. The mean KSS for the N shifts was 4.0 (SE 0.1) for the 8-hour shifts and 3.7 (SE 0.1) for the 12-hour shifts, and it did not differ between conditions (P=0.13), nor was there a difference in the ratings of CR-10 [8-hour: 1.8 (SE 0.1); 12-hour: 2.2 (SE 0.1), P=0.09] between the N shifts. The CR-10 ratings did not differ for the M shifts [8-hour: 2.0 (SE 0.1); 12-hour: 2.2 (SE 0.1), P=0.26], but the 8-hour M shift was associated with more sleepiness [4.6 (SE 0.1) versus 4.1 (SE 0.1), P=0.005] during the free time between 1600 and 1800.

The KSS and the CR-10 ratings were also subjected to pairwise testing for each time point (figures 1 and 2). Significantly lower sleepiness for the 12-hour shifts was found at 1200, 1400, and 1600, and significantly higher sleepiness was found for the 12-hour shifts at 2400, 0200h and 0400. The analysis for CR-10 showed significantly lower effort for the 12-hour shift at 0800, 1000, 1200, 0200, and 0400.

The difference in physical effort between the 8- and 12-hour N shifts, and in sleep length between the 8- and 12-hour M shifts, may have biased the comparison with respect to sleepiness. In order to control for the bias, some additional analyses were carried out. For the N shift, a subgroup (N=13) was created with subjects with the same level of physical effort (CR-10) during both 8-hour [mean CR-10 1.4 (SE 0.2)] and 12-hour [mean CR-10 1.6 (SE 0.3)] shifts. This subgroup showed no difference in sleepiness between 8- and 12-hour N shifts [KSS: 8-hour

Table 3. Means, standard errors (SE), and P-values (3-way analysis of variance (ANOVA) with shift, length and timing as factors) for performance data [reaction times, degrees of freedom (df)=1/12, and vigilance performance, df=1/14].

	Night shifts				Morning shifts				3-way ANOVA			
	Start		End		Start		End		Shift (S)	Length	Timing (T)	SxT
	Mean	SE	Mean	SE	Mean	SE	Mean	SE				
Reaction times												
Mean (ms)												
8-hour shifts	255	9	284	12	283	11	289	13	0.38	0.83	0.04	0.0002
12-hour shifts	260	9	299	19	280	11	267	11				
10% longest												
8-hour shifts	351	20	411	25	417	32	424	25	0.23	0.38	0.11	0.03
12-hour shifts	368	18	462	52	428	36	402	36				
Vigilance (% misses)												
8-hour shifts	10	2	12	2	6	1	9	2	0.31	0.97	0.85	0.87
12-hour shifts	10	3	8	1	10	2	9	2				

shift=5.2 (SE 0.1), 12-hour shift=5.6 (SE 0.1), P=0.12]. In contrast, the remaining subjects (N=18), who rated their physical effort as lower on the 12-hour N shift, showed significantly higher sleepiness on the extended shift [KSS: 8-hour shift=5.0 (SE 0.1), 12-hour shift=5.8 (SE 0.1), P=0.0001]. A similar analysis was made for the M shift, but the subjects were stratified with respect to prior sleep length. The subgroup (N=14) who obtained the same amount of sleep for both the 8- and 12-hour M shifts [2 subjects actually had slightly less sleep prior to the 12-hour shifts, total sleep time: 8-hour shift=6 hours 40 minutes (SE 14 minutes); 12-hour shift=6 hours 20 minutes (SE 12 minutes)] showed no difference in mean sleepiness [8-hour shift=3.8 (SE 0.1); 12-hour shift=3.6 (SE 0.1), P=0.51]. The group who slept longer in connection with the 12-hour M shift [N=17, 8-hour shift: 5 hours 48 minutes (SE 16 minutes), 12-hour shift=6 hours 34 minutes (SE 14 minutes)], rated lower sleepiness for the 12-hour M shift [8-hour shift=4.3 (SE 0.1); 12-hour shift=3.9 (SE 0.1), P=0.02].

The mean ratings (between 1200 and 2000) of KSS was also computed for the last day off before the first 8-hour and 12-hour M shifts. However, there was no significant difference in sleepiness between the days [8-hour shift: 3.8 (SE 0.1), 12-hour shift: 3.5 (SE 0.1), P=0.27].

The apparent negative covariation between the KSS and CR-10 ratings was tested with a least square dummy variable regression model (all ratings pooled, number of data points=1791), and a correlation coefficient was calculated. A set of n-1 dummy variables represented each participant; the procedure eliminated the difference in level between different subjects. The correlation coefficient for the entire data set was -0.34 [P=0.0001, degrees of freedom (df)=1760, df being calculated as the number of data points minus the number of subjects]. When only N shift data were included, the correlation coefficient became -0.36 (P=0.0001, df=862).

Table 3 shows the results for the performance tests. None of the tests showed any significant main effects for length of shift (8- versus 12-hour shifts) or shift (M versus N). However, the mean reaction time showed a significant main effect for timing (start versus end of shift). The reaction time at the end of the shift was longer than at the start of the shift. Both the mean and the 10% longest reaction times showed a significant interaction between shift and timing. This interaction indicated that the reaction times increased towards the end of the N shift, whereas there was almost no difference between the start and end times for the M shift. No other interactions reached significance. The data were also subjected to a separate comparison between 8- and 12-hour shifts within the M and the N shifts. The analyses did not reveal any significant differences between 8- and 12-hour shifts, although there was a trend towards longer reaction times (10% longest) for the 12-hour N shifts (P=0.08).

Discussion

The comparison between alternating 8- and 12-hour shifts within the same shift system showed higher sleepiness for the extended (12-hour) N shift, but lower sleepiness for the extended M shift. However, there was no difference between 8- and 12-hour shifts with respect to performance on 2 tests (simple reaction time and vigilance) known to be sensitive to variations in sleepiness (16). The 12-hour shifts during the weekend were also, unexpectedly, associated with decreased physical effort; this may indicate a lower physical work load during the extended shifts.

The results partly support the hypothesis that 12-hour workshifts cause more sleepiness. However, it is likely that the shifts during the weekend (and especially during the N shift) involved more passive monitoring of the process than shifts between Monday and Thursday. Thus it may be that a decreased (physical) work load is associated with increased sleepiness during 12-hour N shifts. This suggestion was supported by a subgroup analysis controlling for physical work load, which eliminated the difference in sleepiness. It was also supported by the negative (pooled) correlation found between ratings of sleepiness and physical effort during the night shift. Furthermore, physical work load is also believed to be a strong determinant of sleepiness, although the empirical evidence for this conclusion is rare (17). Clearly, work load requires further investigation in relation to workhours and fatigue.

Among other factors that may explain the difference between 8- and 12-hour shifts during the night, sleep can be ruled out, since no differences were found between conditions for duration of sleep or quality of sleep. However, a possible exception may be the difference in napping behavior between the 8-hour and the 12-hour shifts. The naps did, of course, occur earlier in connection with the 12-hour shift [mean starting (clock)time: 12-hour shift=1454, 8-hour shift=1735, P=0.003], although there was no difference with respect to nap length or frequency. The fact that the naps occurred earlier in connection with the 12-hour shift may imply that their beneficial alertness-enhancing effect had diminished when the critical early morning hours were reached and sleepiness may have increased more during the 2nd half of the 12-hour N shift.

The decreased level of sleepiness during the 12-hour M shift, when compared with the 8-hour M shift, was unexpected. One reason may be that sleep prior to the 12-hour shift was longer and the subjects felt more refreshed and rated the awakening as easier. This possibility was supported by the subgroup analysis controlling for prior sleep length, which eliminated the differences in sleepiness. The duration of sleep and whether sleep is refreshing also seem to be important determinants of (rated) sleepiness in connection with daytime work (18). The reason for better sleep during the weekend is not clear, but commuting time is usually shorter then (the subjects reported a mean commuting time to work of about 40 minutes), permitting a later wake-up time. Another speculation is that sleep was less disturbed by environmental (noise, etc) and psychosocial (stress, mood, etc) factors during the weekend. In addition, the subjects also reported longer sleep in connection with the day off prior to the 12-hour shift sequence. This result suggests that the subjects may have been better prepared and more recuperated before they started the 12-hour shifts. The 12-hour M shifts were also preceded by an additional day off (4 days instead of 3) when compared with the 8-hour shifts.

Among the previous work on extended shifts, the studies by Rosa and his co-workers (3, 4, 19) may be the most relevant to use for comparison because of a similar methodology. Consistent with the present findings, these studies also demonstrated an increase in subjective sleepiness during 12-hour N shifts. In contrast to the present study, they also found performance decrements and disturbed sleep for the 12-hour shifts. In the present study there was only a tendency towards worse performance during the 12-hour N shifts. A possible explanation for these inconsistencies may be related to the differences in schedules. Thus it may be that alternation between 8- and 12-hour shifts, and hence the lower exposure for extended shifts in the present study, did not permit any accumulation of sleepiness and made it easier to tolerate the 12-hour shifts. Another explanation for the difference between the studies may be that, in the Rosa studies, performance was measured more intensively and the measurement included a battery of different tests; in addition it is possible that these factors increased the sensitivity to subtle differences in performance.

In conclusion, the present results showed no indications of 12-hour shifts being worse than 8-hour shifts with respect to sleep, sleepiness, and performance, except for subjective sleepiness during the N shift, which was higher for the extended shift. However, when confounding (lower work load during the extended N shifts) was controlled, the differences in sleepiness between the 8-hour and the 12-hour N shifts became nonsignificant.

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References

1. Knauth P. The design of shift systems. Ergonomics 1993; 36(1—3):15—28.
2. Rosa R. Extended workshifts and excessive fatigue. J Sleep Res 1995;4 suppl 2:51—6.
3. Rosa RR, Colligan MJ. Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables. Work Stress 1989;3:21—32.
4. Rosa RR. Performance, alertness, and sleep after 3.5 years of 12-hour shifts: a follow-up study. Work Stress 1991;5:107—16.
5. Peacock B, Glube R, Miller M, Clune P. Police officers' responses to 8 and 12 hour shift schedules. Ergonomics 1983;25:479—93.
6. Williamson AM, Gower CGI, Clarke BC. Changing the hours of shiftwork: a comparison of 8- and 12-hour shift rosters in a group of computer operators. Ergonomics 1994;37:287—98.
7. Åkerstedt T, Hume K, Minors D, Waterhouse J. The subjective meaning of good sleep — a intraindividual approach using the Karolinska Sleep Diary. Percept Mot Skills 1994;79:287—96.
8. Åkerstedt T, Hume K, Minors D, Waterhouse J. The meaning of good sleep: a longitudinal study of polysomnography and subjective sleep quality. J Sleep Res 1994;3:152—8.
9. Åkerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci 1990;52:29—37.
10. Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. Scand J Work Environ Health 1990;16 suppl 1:55—8.
11. Neely G, Ljunggren G, Sylvén C, Borg G. Comparison between the visual analogue scale (VAS) and the category ratio scale (CR-10) for the evaluation of leg exertion. Int J Sports Med 1992;13:133—6.
12. Gillberg M, Kecklund G, Åkerstedt T. Sleepiness and performance of professional drivers in a truck simulator — comparisons between day and night driving. J Sleep Res 1996;5:12—15.
13. Gillberg M, Kecklund G, Åkerstedt T. Relations between performance and subjective ratings of sleepiness during a night awake. Sleep 1994;17:236—41.
14. Huynh H, Feldt LS. Estimation at the box correction for degrees of freedom for sample data in randomised block and split-plot designs. J Educ Stat 1976;1:69—82.
15. Totterdell P, Reynolds S, Parkinson B, Briner RB. Associations of sleep with everyday mood, minor symptoms and social interaction experience. Sleep 1994;17:466—75.
16. Dinges D, Kribbs NB. Performing while sleepy: effects of experimentally induced sleepiness. In: Monk TH, editor. Sleep, sleepiness and performance. Chichester: John Wiley & Sons Ltd, 1991:97—128.
17. Dinges DF. The nature of sleepiness: causes, contexts, and consequences. In: Stunkard A, Baum A, editors. Perspectives in behavioral medicine: eating, sleeping, and sex. Hillsdale (NJ): Lawrence Erlbaum, 1989:147—79.
18. Kecklund G, Åkerstedt T, Lowden A. Morning work: effects of early rising on sleep and alertness. Sleep 1997;20:215—23.
19. Rosa RR, Bonnet MH. Performance and alertness on 8h and 12h rotating shifts at a natural gas utility. Ergonomics 1993;36:1177—93.

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Change from an 8-hour shift to a 12-hour shift, attitudes, sleep, sleepiness and performance

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Lowden A, Kecklund G, Axelsson J, Åkerstedt T. Change from an 8-hour shift to a 12-hour shift, attitudes, sleep, sleepiness and performance. *Scand J Work Environ Health* 1998;24 suppl 3:69—75.

Objectives The present study sought to evaluate the effect of a change from a rotating 3-shift (8-hour) to a 2-shift shift (12 hour) schedule on sleep, sleepiness, performance, perceived health, and well-being.
Methods Thirty-two shift workers at a chemical plant (control room operators) responded to a questionnaire a few months before a change was made in their shift schedule and 10 months after the change. Fourteen workers also filled out a diary, carried activity loggers, and carried out reaction-time tests (beginning and end of shift). Fourteen day workers served as a reference group for the questionnaires and 9 were intensively studied during a week with workdays and a free weekend.
Results The questionnaire data showed that the shift change increased satisfaction with workhours, sleep, and time for social activities. Health, perceived accident risk, and reaction-time performance were not negatively affected. Alertness improved and subjective recovery time after night work decreased. The quick changes in the 8-hour schedule greatly increased sleep problems and fatigue. Sleepiness integrated across the entire shift cycle showed that the shift workers were less alert than the day workers, across workdays and days off (although alertness increased with the 12-hour shift).
Conclusions The change from 8-hour to 12-hour shifts was positive in most respects, possibly due to the shorter sequences of the workdays, the longer sequences of consecutive days off, the fewer types of shifts (easier planning), and the elimination of quick changes. The results may differ in groups with a higher work load.

Key terms activity logger, health, night work, scheduling, shift duration, shift work.

Shift work, and in particular night work, is associated with reduced alertness and performance, and also with increased accident risk (1). Recently there has been a move from the traditional 8-hour shift to 12-hour shifts, mainly because of the possibility to compress the workweek and thus gain more consecutive days off (2, 3). However, the increased length of the shift may also increase the accident risk (4), and it probably reduces alertness and performance. Scientific data are, as yet, not conclusive on how compressed workweeks and other factors modulate fatigue (5). In a study of police officers (6), no effects on wakefulness could be observed after a change from 8-hour backward rotation (8 days of work in a row) to 12-hour shifts (2 days of work, 1 day of rest). Two other studies, in nursing (7) and industry (8), gave similar results. Another study (9) found that miners did not perform worse on a 12-hour shift than when on an 8-hour shift. On the other hand, several American industries have rejected 12-hour shifts because of the (assumed) accident risk (10), and in Singapore 12-hour shifts have been rejected because of negative health effects (11).

Apparently, it is still unclear whether 12-hour shifts differ from 8-hour shifts with respect to alertness, sleep, and performance. Some of the lack of clarity may be due to the lack of reference groups in many of the studies and to the limited spectrum of variables used. In the present study the purpose was to investigate the effect of change from an 8-hour 3-shift system to a 12-hour system. Sleep diaries, actigraphy, ratings of sleepiness several times per day, reaction-time performance, and subjective estimates of health, attitudes and social functioning were used for this purpose. Apart from the extended

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workday, the new schedule also involved more rapid rotation and more free days in-between shifts. Day workers served as the reference group.

Subjects and methods

The study was carried out at a chemical plant producing industrial cleansing products. The plant was located in a small town, with very short mean commuting times [20 minutes (SD 2)]. The shift workers did light control room work with occasional bouts of more active work. The design involved a questionnaire sent to 40 shift workers and 16 day workers shortly before and 10 months after a change from 8-hour to 12-hour shifts. At the same points in time a subgroup of 14 shift workers and 9 day workers were followed using a sleep diary, 2—4 hourly sleepiness ratings, actigraphy, and reaction-time performance across part of the shift cycle. Four of the respondents to the questionnaire abstained from participation, and 2 dropped out during the course of the study, leaving 34 subjects for the analysis. The mean age was 37 (SD 1.7, range 23—58) years for the shift workers and 41 (SD 3.4, range 23—60) years for the day workers. Altogether 88% of the shift workers and 69% of the day workers were men. Most of the subjects were married or were cohabiting (shift=81%, day=77%).

To aid the selection into subgroups, the subjects were told that the study aimed to include 50% of the workers. In meetings with each shift team, 20 workers and 11 day workers agreed to participate. Only 2 workers were reluctant when asked to participate. Six shift workers and 2 day workers were excluded from the analysis due to technical failures or due to their taking other jobs (no schedule-related reasons were given for the change).

Both shift schedules comprised 35 days, the 8-hour schedule being as follows:

+AMMMM+++NNNNAA+++AAMMM++++NNNNAA+++,

where N = night, A = afternoon, M = morning, D = day, + = free day and the underlined days = intensive measurement period. The AM and NA changes were "quick changes", with only 8 hours of rest in-between. The new 12-hour schedule was as follows:

NN+++++DD++NNN++++DDD++NN+++++DD+++.

The shift change times were 0600—1400—2200 for the 8-hour shift and 0600 and 1800 in the 12-hour shift. The day workers worked Monday through Friday from 0700 to 1600. The reference group was measured during 2 workdays and 2 free days.

The questionnaire (12, 13) covered such topics as background, attitude towards work and workhours, health, sleep-wake problems, life-style (exercise, smoking), and social factors. The second questionnaire also included questions comparing the experience of the 12-hour shift with that of the 8-hour shift. The items were scored from 1 to 5 (except for a few items with 4 alternatives) with verbal anchoring as 1=never, 2=occasionally, 3=sometimes, 4=usually, 5=always. The reference group filled out a similar questionnaire but without the shift-related questions.

Activity was measured on an actigraph, or "activity logger" (Ambulatory Monitoring Inc), which detects acceleration and sums the number of accelerations per minute. Sleep episodes were identified through an automatic sleep scoring program [action 1.24, (14)], yielding data for onset-offset of sleep, sleep length and sleep efficiency. The subjects were instructed to press an event button on the logger when going to bed ("lights out"), when finally awake, and before and after naps.

Subjective sleep quality was reported upon awakening using the Karolinska sleep diary (15). The answers were given on 5-point scales with verbal anchoring, reaching from "very poor" (1) to "very good" (5) or similar adjectives. A sleep quality index was formed using the items: "ease of falling sleep", "sleep quality", "calm sleep" and "slept throughout". The awakening index comprised the 2 items "ease of rising" and "well rested".

Sleepiness ratings were made every 2—4 hours, plus at bedtime and at rising, using the Karolinska sleepiness scale (KSS) (16), which consists of a 9-point scale with verbal anchors as follows: 1=very alert, 3=alert, 5=neither alert nor sleepy, 7=sleepy but no problem staying awake, and 9=very sleepy, fighting sleep, an effort to stay awake.

A simple visual reaction-time test was carried out during the first and last hour of each shift. This test was constructed on the basis of similar tests developed by Lisper & Kjellberg (17) and Wilkinson & Houghton (18). The duration of the test was 10 minutes with 16 signals presented every minute on a PSION handheld computer. The stimulus interval varied between 2.2 and 5 seconds, and the extracted results included the 10-minute median and the mean of the 10% slowest values. If no response was given within 1 second, a new stimulus cycle was initiated, and a value of 1 second was assigned to the nonresponse. Before the experiment all the subjects had practiced the test.

To estimate the effect of the shift change a 2-way analysis of variance (ANOVA) with 1 grouping factor (shift-day workers) and 1 within factor was used where time A=before the shift change and time B=10 months after the change. When several days were compared, the results were corrected for violation of the assumption of equal variances and covariances (19). Post-hoc comparisons were made with the Newman-Keuls t-test.

Table 1. Results of the analysis of variance (ANOVA) for change between times A (before the shift change) and B (10 months after the change). (NS=not significant)

Variable	Shift workers		Day workers		ANOVA		
	A (8-hour shift)	B (12-hour shift)	A	B	Group	Time	Interaction
How satisfied are you with your current workhours? (1-5 very satisfied)	3.53	4.62	4.29	4.50	NS	***	*
Do you experience psychological fatigue at work? (5-1 every day)	3.72	3.91	3.57	3.86	NS	NS	NS
Do your workhours permit enough time for social (family/friends) activities? (1-4 very much)	2.65	3.02	3.25	3.02	NS	NS	*
Has it been easy to fall asleep during the last 6 months? (1-5 always)	3.59	4.12	4.31	4.23	NS	**	*
Have you been rested at awakening during the last 6 months? (1-5 always)	4.06	4.47	4.38	4.23	NS	NS	*
Do you receive sufficient sleep with your workhours? (1-5 yes, definitely enough)	3.84	3.97	3.71	3.86	NS	NS	NS
How has your health generally been in the past year? (1-5 very good)	4.34	4.44	3.86	3.79	NS	NS	NS

* P<0.05, ** P≤0.01, *** P<0.001; Df group = 1/44, GxT =1/44.

Results

Questionnaire

Table 1 summarizes the results for the main topics in the questionnaire. For attitude towards work and workhours, the results showed that the change to the 12-h shift greatly increased the satisfaction with workhours (significant interaction effect). No other significant effects were observed for this topic [for items such as psychological fatigue (in table), job demands, job control, reluctance to go to work, and the security of having a permanent job]. For social factors, the 12-hour shift yielded more time for social (family/friends) activities, but time for other free-time activities such as house work, sports, hobbies, shopping and amusements did not change. With regard to sleep-wake problems, some aspects of sleep improved. Within the health topic, no significant changes were observed for general health (in table) or complaints in respect to other health-related items. No other significant effects were found for the topics listed in table 1. In addition, the subjective recovery time after the period of night work was shorter with the 12-hour schedule, [8-hour shift=1.8 (SE 0.1) days, 12-hour=1.5 (SE 0.1) days, t-test, P<0.05)].

The retrospective evaluation of the change after 10 months showed a significant improvement for several items concerning satisfaction with the schedule, fatigue, time for family, sleep, health, and others (table 2). Altogether 77% considered the 12-hour schedule to be better, and 9% thought it was worse (chi-square, P<0.001). Physical and mental stress did not change significantly, nor did the subjects' perception of perceived accident risk or contacts with supervisors. The only significant negative effects concerned sickness benefits, which were reduced, and less contact between shift teams.

The subjects were also asked to rate the amount of difficulty with sleep and alertness when changing between different shifts (or days off). The change was rated on a 9-point scale where 9=very easy and 1=very difficult. The change from a day off to a day of afternoon work (+A) on the 8-hour schedule was easy and yielded a value of 7.7 (SE 0.4). The other changes were compared with this value using Dunnetts t-test (2-tailed). The only changeover in the 12-hour schedule that deviated significantly was that going from a day off to the first day shift [+D=6.8 (SE 0.3), P<0.05]. For the 8-hour shift, the quick change (only 8 hours of time off) between afternoon (A) and morning (M) shifts deviated strongly and negatively [AM=3.8 (SE 0.2), P<0.001], but also the quick change between the night and afternoon shifts was

Table 2. Change across last 10 months for the shift and day workers (retrospective questions only given in the second questionnaire). (SE=standard error of the mean, NS=not significant)

Variable [a]	Shift		Day		P-value[b]
	Mean	SE	Mean	SE	
Satisfaction with work schedule	4.29	0.19***	3.00	0.00	<0.001
Value of free days	4.29	0.18***	3.00	0.00	<0.001
Contact between shift teams	2.00	0.20***			
Fatigue during free days	3.91	0.14***	2.94	0.11	<0.001
Ability to relax after work	3.78	0.16***	2.94	0.17	<0.01
Possibility to arrange eating breaks	3.74	0.16***	3.12	0.09	<0.05
Health	3.50	0.16**	2.80	0.11	<0.01
Sleep quality	3.61	0.17***	3.07	0.07	<0.05
Sufficient sleep	3.50	0.18**	2.80	0.11	<0.05
Alertness	3.67	0.15***	3.00	0.00	<0.05
Stress at work	3.44	0.14***	2.88	0.18	<0.05
Mental strain	3.14	0.16	2.81	0.14	NS
Physical strain	2.89	0.14	3.06	0.06	NS
Accident risk at work	3.06	0.11	3.12	0.15	NS
Contact with supervisors	2.75	0.16	2.65	0.17	NS
Control over work process	3.47	0.14**	3.33	0.11	NS
Sick leave benefits	2.15	0.15***	3.00	0.00	<0.001

[a] 5 = very positive change, 4 = rather positive change, 3 = no change, 2 = rather negative change, 1 = very negative change.
[b] Differences between shift and day workers, t-test.
*P < 0.05, ** P < 0.01, *** P < 0.001, for t-test against no change (3).

Table 3. Results of the analysis of variance (ANOVA) for actigraphy, ratings, and performance at the end of the night shifts (within frame). (N=night, A=afternoon, +=free day, KSS = Karolinska sleepiness scale, F = F-value, e = epsilon)

	+	N	N	N	A(+)[a]	A(+)[a]	+	F/e	Schedule	Day	Interaction
Bed time (h)[b]											
8-hour	2329	0700	0700	0635	0014	0015	2337	F	0.05	2222***	1.2
12-hour	2325	0712	0648	0651	2409	23.34*	23.33	e		0.43	0.48
Time of rising (h)[b]											
8-hour	07.53	13.32	13.23	11.56	08.56	08.11	08.20	F	0.5	76***	1.2
12-hour	08.14	12.59	13.29	12.42	08.40	06.50*	08.05	e		0.80	0.64
Sleep length (h)[b]											
8-hour	7.07	5.62	5.62	4.72	7.18	6.73	7.63	F	1.9	21***	1.4
12-hour	7.73	5.28	6.30	4.90	7.68	6.27	7.23	e		0.68	0.87
Sleep quality index (1-5 maximum)[b]											
8-hour	4.21	4.07	4.07	3.89	4.39	4.07	4.05	F	9.1**	0.2	1.6
12-hour	4.12	4.32	4.53	4.53	4.46	4.34	4.30	e		0.81	0.85
Awakening index (1-5 maximum/good)[b]											
8-hour	3.61	3.00	2.79	2.32	3.07	2.71	3.00	F	1.6	11***	1.4
12-hour	3.60	2.93	3.29	2.71	3.43	2.96	2.57	e		0.73	0.89
Median reaction time (ms)[c]											
8-hour		241	244	240				F	0.5	0.2	0.4
12-hour		241	236	236				e		0.67	0.70
Mean slow reaction time (ms)[c]											
8-hour		404	392	430				F	0.05	0.02	1.7
12-hour		422	425	390				e		0.64	1.0
Sleepiness start shift (KSS-1-9 very sleepy)[c]											
8-hour		5.3	4.9	4.1				F	9.1**	2.5	3.2
12-hour		3.8*	3.9*	3.9				e		1.0	.73

[a] A=afternoon shift, 8-hour shift; + = free day, 12-hour shift.
[b] DfSchedule=1/13, Day=3/39, SxD=3/39.
[c] DfSchedule=1/13, Day=2/26, SxD=2/26.
* P < 0.05, ** P < 0.01, *** P < 0.001.

Table 4. Results of the analysis of variance (ANOVA) for actigraphy, ratings, and performance at the beginning of the day shifts (within frame). (A=afternoon, D=day shift, +=free day, KSS = Karolinska sleepiness scale, F = F-value, e = epsilon)

	A(+)[a]	A(+)[a]	D	D	D	+	F/e	Schedule	Day	Interaction
Bed time (h)[b]										
8-hour	2352	0052	0002	2235	2247	2232	F	0.1	1.3	5.7**
12-hour	2334	2328	2241*	2300	2323	2308	e		0.61	0.75
Time of rising (h)[b]										
8-hour	0851	0905	0504	0500	0456	0826	F	7.2*	55***	1.6
12-hour	0650*	0757*	0502	0448	0447	0730*	e		0.47	0.38
Sleep length(h)[b]										
8-hour	7.25	7.48	4.23	5.48	5.40	8.43	F	0.0	28***	3.5*
12-hour	6.27	7.23	5.62	5.33	4.83	7.88	e		0.69	0.79
Sleep quality index (1-5maximum)[b]										
8-hour	3.93	3.89	3.57	4.20	4.04	4.34	F	5.3*	3.2*	1.3
12-hour	4.34	4.30	4.33	4.43	4.52	4.46	e		0.73	0.94
Awakening index (1-5maximum/good)[b]										
8-hour	3.25	3.36	1.96	2.21	2.32	3.07	F	2.1	22***	1.8
12-hour	2.96	2.57*	2.43	2.39	2.11	3.46	e		0.82	0.78
Median reaction time (ms)[c]										
8-hour			240	239	240		F	0.7	0.3	0.4
12-hour			230	236	234		e		0.77	0.75
Mean slow reaction time (ms)[c]										
8-hour			402	394	435		F	0.5	0.9	2.0
12-hour			379	413	389		e		0.78	0.95
Sleepiness start shift (KSS-1-9maximum)[c]										
8-hour			5.8	6.0	6.6		F	0.0	4.0*	0.6
12-hour			5.9	6.1	6.5		e		0.95	0.87

[a] A=afternoon shift, 8-hour schedule; + = free day, 12-hour schedule.
[b] DfSchedule=1/13, Day=3/39, SxD=3/39.
[c] DfSchedule=1/13, Day=2/26, SxD=2/26.
* P < 0.05, ** P < 0.01, *** P < 0.001.

significantly more difficult [NA=4.9 (SE 0.3), P<0.05]. The rated fatigue rating showed almost exactly the same results.

Diary, actigraphy and performance

Since there was no straightforward way of comparing the entire 8- and 12-hour shifts on a day-by-day basis, we selected a sequence of comparable days from the 2 schedules — mainly the night and morning-day shifts. These selections were analyzed separately through a 2-factor repeated-measures ANOVA, with subsequent pair-wise tests using the Newman Keuls procedure. Reaction-time performance and sleepiness during work were only analyzed for the days with work. Tables 3 and 4 summarize the results, including the immediately preceding or subsequent days for comparison (not part of the ANOVA, only subjected to a pairwise t-test).

The analysis of the nightshift sequence (including the preceding day off) (table 3) showed that the schedule had a significant effect on the sleep quality index and sleepiness at the start of the shift. No other significant differences between the schedules were obtained. The effect of day was significant for most of the variables.

The analysis of the day shift sequence showed a significant effect for schedule on time of rising and the sleep quality index (table 4), with a later time of rising on the 12-hour shift and better sleep quality on the measured days. Significant interaction effects were found for bed time and sleep length. The effect of day was significant for the time of rising, sleep length, the sleep quality index, the awakening index, and sleepiness (at the start of the shift).

The frequency of napping in connection with night and morning work was considerably reduced on the 12-hour schedule. More than half the subjects took a nap on the old schedule. But after the change only 25% of the subjects took a nap (P<0.05, binomial test).

The median reaction-time performance was reduced from 236 (SE 7) ms to 244 (SE 8) ms (P=0.08) from the start to the end of the 8-hour night shift (averaged across shifts). For the 12-hour night shift the corresponding value was 226 (SE 6) to 238 (SE 7) ms (P<0.05). For the 8-hour morning shift performance improved from 240 (SE 8) to 225 (SE 7) ms (P<0.05) and for the 12-hour morning shift there was no change, 234 (SE 9) to 232 (SE 10) ms (not significant). The median reaction-time performance for the day workers changed from 227 (SE 8) to 223 (SE 6) ms (not significant).

Figure 1 shows the sleepiness pattern (KSS) across selected days of day and night work. All the days displayed showed a highly significant time of day pattern (all with P<0.001, repeated-measures ANOVA with epsilon corrections). When the sequence of the mean KSS levels of the 3 night shifts was analyzed in a 2-factor repeated-measures ANOVA, the effect of the schedule was significant ($F_{1,13}$=7.5, P<0.05), as was the effect of day ($F_{2,26}$=4.8, P<0.05), whereas the interaction was not ($F_{2,26}$=0.2). Thus sleepiness was higher for the 8-hour shift, and there was a reduction in sleepiness across the 3 night shifts. The same type of analysis for the 3 days of day work showed a significant effect for schedule ($F_{1,13}$=7.0, P<0.05), but no significant effect for day ($F_{2,26}$=0.03) or interaction ($F_{2,26}$=1.6). The 12-hour schedule involved less sleepiness. The mean values for the free day in figure 1 did not show any differences between the 8-hour and 12-hour shifts (t-test).

In an attempt to obtain a total measure of (diary-based) sleepiness for the entire shift cycle, the ratings were first averaged across the waking span of each day. The ratings for the unmeasured days were estimated by

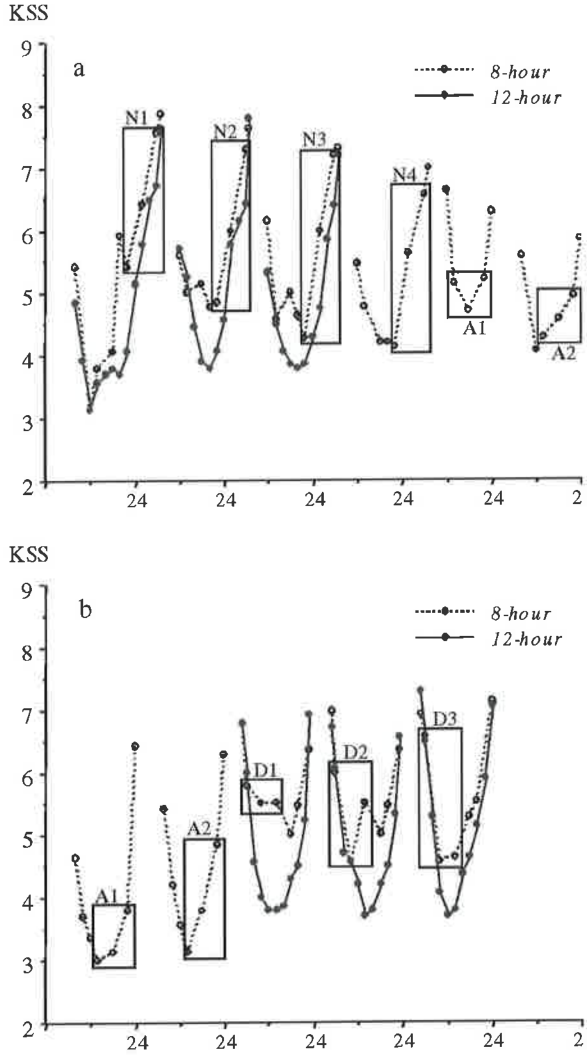

Figure 1. Ratings of sleepiness on the Karolinska sleepiness scale (KSS), in figure a for night (N) shifts and afternoon (A) shifts (8-hour shift=N1-N4+A1-A2; 12-hour shift=N1-N3) and in figure b for afternoon (A) shifts and day (D) shifts (8-h=A1-A2+D1-D3, 12-h=D1-D3), given at the time of rising and every 2—4 hours until bedtime (KSS; 1=very alert, 9=very sleepy, fighting sleep). (Bars = the 8-hour shift-work period)

taking the mean values of corresponding measured days. The 35 days were then averaged across the shift cycle. In addition, averages were computed for workdays and days off. The results showed that the mean sleepiness for the entire shift cycle changed from 5.0 (SE 0.2) to 4.6 (SE 0.2) for the shift workers and from 3.8 (SE 0.2) to 3.2 (SE 0.2) for the day workers. The ANOVA showed a significant effect for group ($F_{1,21}$=15, P<0.001) and time (F_1=11, P<0.01), but no significant interaction ($F_{1,21}$=1.7, not significant). The same analysis for work days yielded 5.4 (SE 0.3) to 5.0 (SE 0.2) for shift workers and 4.1 (SE 0.2) to 3.3 (SE 0.3) for day workers. The ANOVA showed a significant effect for group ($F_{1,21}$=19, P<0.001), and time (F_1=11, P<0.01), but no significant interaction ($F_{1,21}$=2.7). For days off the values were 4.4 (SE 0.2) to 4.4 (SE 0.2) for the shift workers and 3.4 (SE 0.3) to 3.2 (SE 0.2) for the day workers. Again, the ANOVA showed a significant group effect ($F_{1,21}$=15, P<0.001), but no effect for time (F_1=0.2) or interaction ($F_{1,21}$=0.3).

Discussion

The overall impression of the results is that the change to the 12-hour schedule was positive. The strongest effect was seen in the questionnaire data, in which the 12-hour schedule received strong support in the before-after measurements, particularly with respect to attitude towards workhours, increased time for family and friends, and improvement in sleep. Subjective health and mental fatigue were not significantly affected, however.

The retrospective comparison also yielded strong support for the new schedule with strong improvement for social aspects, health and many aspects of sleep, as well as reduced fatigue after work and during days off. In addition, the 12-hour shift did not seem to have caused more physical and mental strain, or an increase in accident risk. An increase in the possibility to organize food intake was also reported; this finding seems to suggest an increase in influence on work organization.

The lack of negative effects on sleep, alertness, and performance is also shown by activity monitoring and diary ratings. If anything, the effects were positive — improved sleep and alertness. Lack of effects also holds for the integration of sleepiness across the entire shift cycle.

Even if the results suggest that the 12-hour shifts were superior, there are alternative interpretations that need to be considered. One may be a concomitant change in worktasks. Such a change can safely be ruled out, however, since the tasks remained the same. In addition, any changes in company atmosphere should have been controlled through the use of the reference group. A more likely confounder may have been an initial negative attitude towards the 8-hour shift. Such negativity may have been operating to some extent, but the before-after design with 10 months of experience with the new schedule should have reduced such effects.

To some extent the effects may have been due to a rather poor 8-hour shift system rather than to a very good 12-hour shift. In particular, the 8-hour shift contained 4 problematic quick changes causing sleep reductions and disturbances. Furthermore, the schedule had a backward rotation with many workdays in a row, including 4 night shifts (NNNNAA). Usually, backwards rotation (20) and slow shift rotation have negative effects on sleep and wakefulness (21). Finally, the number of free days in the 8-hour schedule was fewer, and only 1 of the weekends during the 35-day cycle was completely free. It seems obvious that the more free days inherent in the 12-hour schedule would lead to greater ease of recuperation and more prime weekend time for social activities.

A further confounding factor in the interpretation of the results may have been the selection of the reference group. It had, for obvious reasons, different workhours, but it worked in the same section of the plant as the shift workers. Thus it should suffice as a reference for changes in the social climate of the company. The higher frequency of women (among the day workers) did not seem to be a problem, as the women gave the same ratings as the men on questions of whether or not they had enough time for family and domestic work. Having (paid) extra work (elsewhere) was more common for the shift workers (43% versus 12%), but it was not controlled for in the analysis.

Even if some external influences may have affected the results, the fact remains that the change to the 12-hour shift was very positive (apart from the reduction in sick-leave benefits due to loss because of a longer shift and less contact between shift teams due to the 12-hour shift workers meeting with the same team at all shift changes). The reason can probably be found in the fewer successive shifts worked providing frequent recuperation between shifts. The fewer shifts also meant fewer days disturbed by having to work and fewer days of being exposed to disturbed sleep-wakefulness. It might also be argued that it is probably easier to handle switching between only 2 types of shifts rather than between 3. This possibility needs to be tested empirically however.

Earlier studies of 12-hour schedules have emphasized the particular risk of elevated sleepiness, primarily caused by sleep deficits (11, 21). In the present study strong sleepiness symptoms were rare on the 12-hour shifts, even on the night shifts. As has already been mentioned, 1 reason is probably the decrease in consecutive night shifts and the increase in free time between shifts. The times for change-over between shifts were also well chosen with respect to sleepiness, since the extension of the shifts was added to the start of the shifts (N=1800—2200, D=1400—1800). This was not the case in an earlier study where the authors (22) found negative effects on performance 10 months after the introduction of a 12-hour shift, particularly at night. No such decreases were found in the present study, but both studies show a parallel between performance and circadian variation. Another important difference was that sleep in the study of Rosa & Bonnet (22) was much shorter on some days towards the end of the week and that the work was physically demanding. A 50% increase in work length during the work shift in such a work setting would probably produce negative effects on performance. This question of work load is probably a key to determining the feasibility of implementing 12-hour shifts. Very little empirical data are available, however. Another study of performance in the introduction of a 12-hour schedule for computer operators (23) did not show any deterioration of operator lapses per hour, not even at night.

Finally the attempt to integrate sleepiness across the whole shift cycle indicated that shift workers were sleepier, not only on the average or during workdays, but also during days off. This observation will have to be tested in future studies, but it clearly suggests that shift workers' allotted recovery days may not be sufficient. The suggested technique at integrating "load" across shift cycle may be a tool for estimating the need for improving the shift schedules towards the lighter "load" of day workers.

In summary, it is concluded that the change from 8-hour to 12-hour shifts was positive in most respects, possibly due to the shorter sequences of the workdays, the longer sequences of consecutive days off, the fewer types of shifts (easier planning), and the elimination of quick changes. The results may differ in groups with a higher work load.

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References

1. Åkerstedt T. Work hours, sleepiness and the mechanism. J Sleep Res 1995;4 suppl 2:15—22.
2. Kogi K. Introduction to the problems of shiftwork. In: Folkard S, Monk TH, editors. Hours of work. Chichester: John Wiley & Sons, 1985:165—84.
3. Tepas DI. Flexitime, compressed workweeks and other alternative work schedules. In: Folkard S, Monk TH, editors. Hours of work. Chichester: John Wiley & Sons, 1985:147—64.
4. Folkard S. Effects on performance efficiency. In: Colquhoun P, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Frankfurt am Main (Germany): Peter Lang GmbH, 1996:65—87.
5. Rosa R. Extended workshifts and excessive fatigue. J Sleep Res 1995;4 suppl 2:51—6.
6. Peacock B, Glube R, Miller M, Clune P. Police officers' responses to 8 and 12 hour shift schedules. Ergonomics 1983;325:479—93.
7. Colligan MJ, Tepas D. The stress of hours of work. Am Ind Hyg Assoc J 1986;47:686—95.
8. Mills ME, Arnold B, Mooney Wood, C. Core-12: a controlled study of the impact of 12-hour scheduling. Nurs Res 1983;32:356—61.
9. Duchon JC, Keran CM, Smith T. Extended workdays in an underground mine: a work performance analysis. Hum Factors 1994;36(2):258—68.
10. Wheeler K, Gurman R, Tarnowieski D. The four-day week. New York (NY): American Management Association, 1972:1—41.
11. Kogi K, Ong CN, Cabantog C. Some social aspects of shift work in Asian developing countries. Int J Ind Ergon 1989;4:151—9.
12. Kecklund G, Åkerstedt T. The psychometric properties of the Karolinska Sleep Questionnaire. J Sleep Res 1992;1 suppl 1:113.
13. Lowden A, Åkerstedt T. Jet lag in air crew — a questionnaire study. Stockholm: Section of Stress Research, Karolinska Institute, 1993. Stress research reports, no 237.
14. Cole RJ, Kripke DF, Gruen W, Mullaney DJ, Gillin JC. Automatic sleep/wake identification from wrist activity. Sleep 1992;15(5):461—9.
15. Åkerstedt T, Hume K, Minors D, Waterhouse J. The subjective meaning of good sleep — a intraindividual approach using the Karolinska Sleep Diary. Percept Mot Skills 1994;(79):287—96.
16. Åkerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci 1990;52:29—37.
17. Lisper HO, Kjellberg A. Effects of 24-hour sleep deprivations on rate of decrement in a 10-minute auditory reaction time task. J Exp Psychol 1972;96:287—90.
18. Wilkinson RT, Houghton D. Field test of arousal: a portable reaction timer with data storage. Hum Factors 1982;24(4):487—93.
19. Greenhouse SW, Geisser S. On methods in the analysis of profile data. Psychometrika 1959;24:95—112.
20. Knauth P. Speed and direction of shift rotation. J Sleep Res 1995;4 suppl 2:41—6.
21. Rosa RR, Colligan MJ. Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables. Work Stress 1989;3:21—32.
22. Rosa RR, Bonnet MH. Performance and alertness on 8h and 12h rotating shifts at a natural gas utility. Ergonomics 1993;36(10):1177—93.
23. Williamson AM, Gower CGI, Clarke BC. Changing the hours of shiftwork: a comparison of 8- and 12-hour shift rosters in a group of computer operators. Ergonomics 1994;37(2):287—98.

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Subjective alertness and sleep quality in connection with permanent 12-hour day and night shifts

by Mats Gillberg, PhD[1]

Gillberg M. Subjective alertness and sleep quality in connection with permanent 12-hour day and night shifts. *Scand J Work Environ Health* 1998;24 suppl 3:76—81.

Objectives The aim of this study was to compare permanent 12-hour day and night shifts (shift change over times at 0500 and 1700) in a shift system with 3 work periods followed by 4 free days.

Methods Sleep diaries were collected after main periods of sleep, and sleepiness ratings [Karolinska sleepiness scale (KSS)] were obtained 4 times during the last free day and also during the following 3 workshifts. Eighteen to twenty night workers and 8—10 day workers (depending on the instrument) participated.

Results The day workers were significantly sleepier during their workdays. Times for going to bed and for rising differed between the groups. The amount of sleep per week did not differ between groups, but the pattern across days did in that the day workers had a short sleep (5 hours) before the first day and 6 hours of sleep after the other two. Night workers slept long (9 hours) before the first shift and had 6.5-hour sleep periods after the other shifts. During free time the day workers slept around 9 hours and the night workers around 8 hours. Sleep quality and ease of awakening showed no group differences in overall levels, but the day workers had difficulties awakening before their shifts. The night workers had little variation in sleep quality or difficulties awakening.

Conclusions The suggested explanation for the greater sleepiness and difficulties awakening among the day workers was the early start of the shift and the difficulties the workers had with phase advancing their sleep-wake rhythm.

Key terms shift work, sleepiness, subjective sleep quality, 12-hour shifts.

Compressed workhours based on 12- hour shifts have increased in popularity (1) in recent years. The reasons for this trend may be the associated longer periods of free time and shorter commuting time. For the company, production may become more efficient due to fewer shift changes. It has, however, been shown that long workhours, especially at night, are related to increased sleepiness and degraded performance (2). Rotating 12-hour shift systems have been found to affect alertness negatively (3, 4), but positive effects have been observed as well (5). Permanent 12-hour day and night shifts have also been studied (6, 7), but not with on-shift alertness ratings and sleep diaries. The aim of the present study was to compare the subjective alertness and sleep habits of permanent 12-hour day workers with permanent 12-hour night workers at the same worksite.

Methods

The worksite was fairly small (N≈40) and manufactured electronic components. Approximately 35 workers were invited to participate. The shift system included three 12-hour shifts in a row followed by 4 free days. The permanent day shift started at 0500 and the night shift at 1700. The shift system had been in use for approximately 10 years at the time of the study, and the employees had been active in selecting the system. The worktasks were the same for both shifts. Data were collected during 3 identical measurement periods, 6 months apart. However, due to changes in production, only 5 to 7 subjects (depending on the measurement instrument) participated during all 3 measurement periods. To retain as many subjects as possible in the computations, data from 1 measurement period for each subject (the only period or, for subjects participating more than once, whichever period that came first) were chosen and pooled to form data sets for further analyses. Repeated measures analyses of variance (ANOVA) did not reveal any changes across the measurement periods for the 5 to 7 subjects participating during all 3 periods.

Three types of measurements were obtained from the self-report instruments, which were chosen to assess sleepiness and sleep quality because, apart from practi-

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cal reasons, complaints in connection with different shift systems are based on subjective experience. *Sleep diaries* (the Karolinska Sleep Diary) (8) were filled out daily after each main sleep for 28 days (ie, 4 shift cycles). Bedtimes, times of rising, and sleep duration were obtained from these diaries. In addition, 2 indices were formed using items in the diary. The first index, reflecting ease of awakening, was formed using the items "ease awakening" and "well rested", respectively. The 2nd index was an overall measure of sleep quality containing the items "how was your sleep", "calm sleep", "ease of falling asleep", and "slept throughout", respectively.

Ratings of sleepiness [Karolinska sleepiness scale (KSS) (9); 1= very alert ,9=very sleepy, fighting sleep, an effort to stay awake] were obtained 4 times a day during the last free day and the 3 workshifts of the last shift cycle. The subjects were instructed to rate their sleepiness at the start of the shift, during the 1st and 2nd 30-minute rest periods and at the end of the shift. During their free time, they were to rate their sleepiness upon arising, at lunch time, during the afternoon, and during the early evening. The times for the rating are shown in figure 1. Finally, before the start of each measurement period, the subjects filled out a general work-environment questionnaire (10) containing questions on background variables, satisfaction with work and worktimes, sleep habits, general health, and the like. Questionnaire data were obtained from 20 night workers and 10 day workers. Of these subjects 18 night workers and 8 day workers completed the sleep diaries, and 17 night workers and 9 day workers completed the sleepiness ratings.

The questionnaire was used to obtain background factors and other items describing the 2 study groups (table 1). Age, gender, marital status, and number of children were similar for both groups. The duration of employment was between 5 and 6 years for both groups. The day workers, however, had shorter experience with their shift than the night workers had. Few workers had tried to change their workhours. Satisfaction with work times were on the positive side of the scale for both groups. Even though general satisfaction with the work situation was high for both groups, it was higher for the night workers. Commuting times were short and similar for both groups. The reasons for choosing the current employment and workhours differed between the day and night workers on 2 items. Salary was more important for the night workers, and the day workers could less easily choose which shift they wanted to work.

The data were analyzed using ANOVA. The sleepiness data from the workshifts were analyzed with "type of shift" (day or night work) as a between-group factor and "shift" (3 shifts) and "time of day" (4 times) as within-group factors. For sleepiness during the last free day, the ANOVA used "type of shift" as a between factor and "time of day" as a within factor. The difference in sleepiness between workshifts (collapsed over 3 workdays) and free days were tested in a separate ANOVA for each group, using "type of shift" as a between factor and "workshift-free day" as a within factor. The sleep diary ANOVA had "type of shift" as a between factor

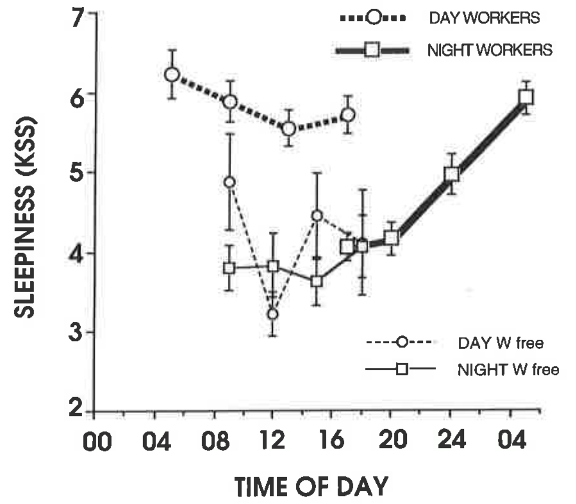

Figure 1. Means of self-rated sleepiness on the Karolinska sleepiness scale (KSS) during workshifts (heavy lines) for the day and night workers. The means were calculated across subjects and across 3 consecutive workdays. Also shown are the mean subjective ratings for both groups during the immediately preceding free day (thin lines). The vertical bars denote standard errors.

Table 1. Means and standard errors (SE) or frequencies of the background variables and of items from the general questionnaire.

	Day workers (N=10)			Night workers (N=20)		
	N	Mean	SE	N	Mean	SE
Age (years)	.	32.9	2.1	.	36.5	1.9
Married (number of subjects)	5	.	.	15	.	.
Gender (number of female/male)	3/9	.	.	7/11	.	.
Having children (number of subjects)	3	.	.	8	.	.
Duration of employment (months)	.	67.6	18.9	.	74.1	9.2
Duration of current worktimes (months)	.	15.2	10.2	.	54.8	8.9
Tried to change shift (number of subjects)	-	.	.	4	.	.
Satisfaction with worktimes (1 very high-5 very low)	.	3.3	0.5	.	4.0	0.3
General satisfaction with work (1 very high-5 very low)	.	3.7	0.3	.	4.4	0.1
Commuting time (minutes)	.	20.4	5.7	.	18.9	2.9
Reason for choosing current employment and worktimes (3 to a high degree, 2 to some degree, 1 not at all)						
Salary	.	1.3	0.2	.	2.1	0.2
Long free periods	.	2.3	0.2	.	2.6	0.1
Could not get another job	.	1.8	0.3	.	1.3	0.2
Could not choose shift	.	1.9	0.3	.	1.2	0.1
Diurnal type (1 evening-4 morning)	.	2.2	0.2	.	1.9	0.1
Sleep need (hours)	.	6.8	0.6	.	6.9	0.4

and "week" (4 weeks) and "day" (7 days) as within factors. When appropriate, Huynh-Feldt epsilon correction was used to adjust the degrees of freedom for the calculations of the P-values. The uncorrected degrees of freedom are, however, given in the text. Unpaired t-tests were used to analyze the differences between the day and night workers for the questionnaire data. The significance level was set at 0.05 in all cases.

Results

A 3-way ANOVA (type of shift × shift × time of day) applied to workshifts only showed that the day workers, on the average, reported significantly greater sleepiness during work than the night workers did [type of shift, degrees of freedom (df)=1, 24, F=12.6, P<0.002]. There were no significant differences between the 3 workshifts (shift, df=2, 48, F=0.16, not significant). Hence the changes in sleepiness across the workshifts are shown in figure 1 as averages of the 3 workshifts. A significant interaction (df=3, 72, F=9.8, P<0.0001) between type of shift and time of day and a significant time of day effect (df=3, 72, F=4.1, P<0.01) supported the impression (figure 1) of a slight decrease in sleepiness for day workers and a steep increase in sleepiness for night workers across the shift. Note that the 1st rating for the day workers was as high as the last rating for the night workers.

A separate ANOVA of sleepiness during free days did not show any significant differences between types of shift (df=1, 24, F=0.7, not significant) or across time of day (df=3, 72, F=1.6, not significant). Both groups were significantly more sleepy during their workshifts than during their free days, as shown by a separate ANOVA for each group (day workers: df=1, 8, F=29.9, P<0.001; night workers: df=1, 16, F=14.5, P<0.002).

The sleep diary data were similar across the 4 weeks. Neither the factor "week" nor the interaction terms containing "week" were significant for any of the 5 variables studied [the F-values for the factor week (df=3, 72) ranging between 0.03 and 1.73, the F-values for the interaction type of shift × week (df=3, 72) ranging between 1.1 and 2.0, and the F values for the interaction week x day (df=18, 450) ranging between 0.8 and 1.6]. The data were therefore averaged to yield means across weeks for each of the 7 days within a shift cycle (table 2). The time patterns for going to bed and getting up differed between the groups for obvious reasons. Note that the day workers went to bed as late as between 2224 and 2320 before workdays. The amount of sleep per week did not differ between the groups, but the pattern across days was clearly different (significant interaction) in that the day workers had a short sleep (around 5 hours) before the 1st day and 6-hour periods of sleep after the other 2 days. The night workers had a long sleep (nearly 10 hours) before the first shift and 6.5-hour periods of sleep after the other shifts. During free days the day workers slept between 9 and 10 hours, that is, approximately 1 hour longer than the night workers. The overall sleep quality and rated ease of awakening showed similar results, namely, no

Table 2 . Means and standard errors (SE) of the sleep diary data and the results of the analysis of variance (ANOVA) of its variables (day workers N=8, night workers N=18). (NS = not significant)

Variable	After 1st workday		After 2nd workday		After 3rd workday		After1st free day		After 2nd free day		After 3rd free day		Before 1st workday		Degrees of freedom, F-values and levels of significance[a]
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Bedtimes (h; decimal times)															
Day workers	22.24	0.21	22.50	0.23	23.77	0.35	24.30	0.33	23.94	0.22	24.58	0.32	23.20	0.26	Group (1, 4)=632.0***
Night workers	05.99	0.09	06.07	0.10	05.85	0.11	23.34	0.56	23.96	0.37	00.16	0.36	00.21	0.30	Day (6, 144)=338.0***
															GrxDay(6,144)=261.0***
Rising time (h; decimal times)															
Day workers	04.16	0.07	04.49	0.33	09.19	0.27	09.23	0.35	08.84	0.29	09.41	0.30	04.38	0.14	Group (1, 24)=93.0***
Night workers	12.61	0.11	12.58	0.15	11.91	0.15	09.06	0.35	08.29	0.16	08.61	0.26	09.72	0.22	Day (6, 144)=28.0***
															GrxDay(6,144)=106.0***
Sleep duration (h; decimal times)															
Day workers	05.98	0.18	06.10	0.26	09.58	0.38	08.84	0.26	08.88	0.25	08.76	0.23	05.11	0.21	Group (1, 24)=0.4 NS
Night workers	6.60	0.10	06.52	0.13	06.06	0.14	08.03	0.21	08.00	0.13	07.86	0.16	09.04	0.26	Day (6, 144)=29.0***
															GrxDay(6,144)=40.0***
Ease of awakening (1=very difficult, 5=very easy)															
Day workers	2.07	0.14	2.09	0.16	3.38	0.12	3.68	0.14	3.86	0.12	3.52	0.17	2.32	0.12	Group (1, 24)=0.8 NS
Night workers	3.23	0.09	3.01	0.10	2.67	0.09	2.96	0.10	3.32	0.10	3.32	0.11	3.59	0.11	Day (6, 144)=15.0***
															GrxDay(6,144)=20.0***
Sleep quality (1=very low 5=very high)															
Day workers	4.21	0.10	4.38	0.11	4.52	0.10	4.63	0.07	4.61	0.06	4.59	0.08	3.87	0.14	Group (1, 24)=0.3 NS
Night workers	4.30	0.08	4.33	0.07	4.34	0.07	4.28	0.08	4.35	0.07	4.23	0.08	4.45	0.07	Day (6, 144)=3.3**
															GrxDay(6,144)=6.5***

[a] Since none of the ANOVA effects for week or for the interaction terms group x week and day x week were significant, these effects were not included in the table.

* P<0.05, ** P<0.01, *** P<0.001. P-values after Huynh-Feldt correction.

group differences in levels, but highly significant interactions (P<0.0001). The significant interactions may be explained by the day workers' slightly lower sleep quality and more difficulties awakening before shifts, and the high quality and few problems awakening during days off when compared with the night workers who had little variation in sleep quality and difficulties awakening across the 7 days. Both groups had high overall sleep quality, however, 4 or higher on a 5-point scale.

Discussion

While the times for going to bed and getting up in connection with work differed between groups for obvious reasons, they were similar during free days. The day workers' pattern of sleep duration across the 7 days was characterized by short periods of sleep before workdays (especially the first) and long sleep after free days. Night workers were characterized by a long sleep before the first shift and 6.5-hour sleeps after the other shifts.

The day workers had short periods of sleep because they did not phase advance their bed times before shifts and their shift started early. Such failures to phase advance bedtimes on morning shifts have been described earlier (11). Night workers might have been favored, however, by the early changeover time, permitting a relatively long sleep before sleep was terminated by the circadian upswing (12). In addition, the early bedtime was close to the presumed circadian alertness trough (13—15) when short sleep latencies could be expected (16).

The day workers seemed to compensate for their short sleep by sleeping longer on days off, whereas night workers slept longer before the first night shift, presumably for "prophylactic" reasons. Overall sleep quality was high for both groups, approximately 4 or higher on the 5-point scale, but the day workers had slightly lower sleep quality before workdays (especially the first). The day workers also experienced more difficulties awakening before shifts (especially the 1st shift), while the night workers had the least problems awakening before their workshifts. The difficulties the day workers had with awakening may have been a consequence of the failure to phase advance bed times and therefore having to rise close to the (presumed) circadian alertness trough. The night workers may have experienced fewer problems since they could sleep until spontaneously awakened.

Our findings on sleep patterns are similar to those observed in connection with morning and night shifts in 3-shift systems (17), and they agree with data from experiments that manipulated the timing of sleep (12). Finally, the sleep diary data showed a stable pattern across the 4 identical cycles of 3 workshifts and 4 free days.

Contrary to expectations, the day workers were sleepier than the night workers on their workshifts. The day workers were as sleepy at the start of their shift as the night workers were at the end of their night shift, and the level of sleepiness remained high for the day workers throughout the day. One probable explanation of the high level of sleepiness among the day workers is the early start of the shift. High levels of sleepiness as a consequence of early rising have been described earlier (18, 19). The subjects were required to rise around 0430, and, since their bedtime was not phase advanced, 1—2 hours of sleep were lost. Several studies have shown negative effects on alertness from such moderate reductions in sleep duration (20, 21). Another contributor to the high levels of sleepiness, especially at the start of the day shift, may have been the closeness to the presumed trough in the circadian rhythm of alertness (13—15). Night workers, on the other hand, were fairly alert at the start of the shift but experienced a steady increase in sleepiness across the shift. Similar results on alertness during night work have been obtained with the same instruments in earlier studies in both field (22) and experimental (23) settings. Both groups reported similar levels of sleepiness during the last of the 4 free days. In both cases sleepiness was clearly lower than during work and therefore indicated that both groups had recovered and maintained day-oriented rhythms during free days.

An additional contributor to the high level of sleepiness among the day workers may have been the short experience with their shift system, which might have made adaptation difficult. Indeed, the lack of phase advance of bedtimes before workdays and the long sleep and late awakening during free days suggest a lack of adaptation. However, since they already had a mean experience of 15 months, it does not seem likely that a further increase of exposure would significantly improve adjustment. Another reason for the day workers' inability to adapt may have been that they had not been able to choose their shift and that they apparently did not have the diurnal type characteristics suited to early morning rising.

The statistical analyses did not reveal any changes in sleepiness across the 3 successive workshifts, neither for the day nor for the night workers. Hence there were no tendencies towards a gradual adaptation to night work among the night workers. However, as several studies have shown, it may take more than 3 night shifts in a row to affect the circadian phase (24—26). Presumably, the 4 free days helped to maintain a day-oriented rhythm. Furthermore, the day workers did not seem to accumulate sleepiness, as might have been expected from experiments on moderate sleep reduction (20, 21). Regarding the latter results, it should, however, be remembered that the number of day workers was relatively small, and therefore statistical power would have been reduced.

A comparison with other studies shows that the workers in my study resembled workers on other work schedules in several important aspects. For instance, satisfaction with the work situation and worktimes was similar to that seen for 3-shift work (27), and the satisfaction of the night workers was close to that of 8-hour day workers (28). Furthermore, sleep quality was high for both and equal to that of 8-hour day workers (27). Sleepiness during the 12-hour night shift resembled that of rotating shift workers on an 8-hour night shift (28). On the whole, then, the present work schedules seemed to be tolerated well.

To summarize, my data indicate that the permanent 12-hour shifts in the type of rota studied were tolerated well. There was, however, an important exception. Day workers experienced unexpectedly high levels of sleepiness during their workdays. In fact, the overall level of sleepiness was higher during the day shift than during the night shift. The likely explanation for this phenomenon is the early start of the shift and the lack of phase advance of bedtime, which, in turn, led to shorter sleep and higher levels of sleepiness. Hence, the timing of especially 12-hour day shifts, may be crucial to sleepiness on the shift, and, depending on the phase relation to the circadian rhythm, relatively small changes in timing may evoke significant increases in sleepiness.

References

1. Tepas DI. Flexitime, compressed workweeks and other alternative work schedules. In: Folkard S, Monk TH, editors. Hours of work. Chichester: John Wiley & Sons, 1985:147—64.
2. Rosa R. Extended workshifts and excessive fatigue. In: Åkerstedt T, Kecklund G, editors. Work hours, sleepiness and accidents. Stockholm: IPM and Karolinska Institute, 1994:64—7. Stress research reports, no 248.
3. Rosa RR, Colligan MJ. Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables. Work Stress 1989;3:21—32.
4. Rosa RR, Bonnet MH. Performance and alertness on 8h and 12h rotating shifts at a natural gas utility. Ergonomics 1993;36(10):1177—93.
5. Williamson AM, Gower CGI, Clarke BC. Changing the hours of shiftwork: a comparison of 8- and 12-hour shift rosters in a group of computer operators. Ergonomics 1994;37(2):287—98.
6. Barton J, Folkard S. The response of day and night nurses to their shift schedules. J Occup Psychol 1991;64:207—18.
7. Chan OY, Gan SL, Yeo MH. Study on the health of female electronics workers on 12 hour shifts. Occup Med 1993;43:143—8.
8. Åkerstedt T, Hume K, Minors D, Waterhouse J. The subjective meaning of good sleep — an intraindividual approach using the Karolinska Sleep Diary. Percept Mot Skills 1994;(79):287—96.
9. Åkerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci 1990;52:29—37.
10. Åkerstedt T, Torsvall L. Experimental changes in shift schedules — their effects on well-being. Ergonomics 1978;21:849—56.
11. Folkard S, Barton J. Does the "forbidden zone" for sleep onset influence morning shift sleep duration? Ergonomics 1993;36(1—3):85—91.
12. Åkerstedt T, Gillberg M. The circadian variation of experimentally displaced sleep. Sleep 1981;4:159—69.
13. Fröberg JE, Karlsson CG, Levi L, Lidberg L. Psychological circadian rhythms during a 72-hour vigil. Försvarsmedicin 1975;II:192—201.
14. Folkard S, Hume KI, Minors DS, Waterhouse JM, Watson FL. Independence of the circadian rhythm in alertness from the sleep/wake cycle. Nature 1985;313:678—9.
15. Dijk DJ, Duffy JF, Czeisler CA. Circadian and sleep-wake dependent aspects of subjective alertness and cognitive performance. J Sleep Res 1992;1:112—7.
16. Åkerstedt T, Folkard S. Predicting sleep latency from the three-process model of alertness regulation. Psychophysiology 1996;33(4):385—9.
17. Åkerstedt T, Kecklund G, Knutsson A. Spectral analysis of sleep electroencephalography in rotating three-shift work. Scand J Work Environ Health 1991;17:330—6.
18. Kecklund G, Åkerstedt T. Effects of timing of shifts on sleepiness and sleep duration. J Sleep Res 1995;4 suppl 2:47—50.
19. Kecklund G, Åkerstedt T, Lowden A. Morning work: effects of early rising on sleep and alertness. Sleep 1997;20(3):215—23.
20. Carskadon MA, Dement WC. Cumulative effects of sleep restriction on daytime sleepiness. Psychophysiology 1981;18:107—13.
21. Dinges DF, Pack F, Williams K, Gillen KA, Powell JW, Ott GO, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4—5 hours per night. Sleep 1997;20(4):267—77.
22. Kecklund G, Åkerstedt T. Sleepiness in long distance truck driving: an ambulatory EEG study of night driving. Ergonomics 1993;36(9):1007—17.
23. Gillberg M, Kecklund G, Åkerstedt T. Relations between performance and subjective ratings of sleepiness during a night awake. Sleep 1994;17(3):236—41.
24. Patkai P, Åkerstedt T, Pettersson K. Field studies of shift work, I: temporal patterns in psychophysical activation in permanent night workers. Ergonomics 1977;20:611—9.
25. Knauth P, Rutenfranz J, Herrmann G, Poppel SJ. Re-entrainment of body temperature in experimental shift work studies. Ergonomics 1978;21:775—83.
26. Roden M, Koller M, Piricc K, Vierhapper H, Waldhauser F. The circadian melatonin and cortisol secretion pattern in permanent night shift workers. Am J Physiol 1993; 265(1pt2):R261—7.
27. Kecklund G, Åkerstedt T, Göranson B, Söderberg K. Omläggning av skiftschema: konsekvenser för välbefinnande, hälsa, sömn/vakenhet och arbetstrivsel: resultatrapport 2: frågeformulär, dagbok och hälsoundersökning [Changing shift schedule: effects on well-being, health, sleep/wake behaviour and work satisfaction: report of results 2: questionnaire, diary data and health examination]. Stockholm: IPM and Karolinska Institute, 1994. Stress research reports, no 242.
28. Lowden A, Kecklund G, Axelsson J, Åkerstedt T. Övergång från 8 till 12 timmars skift [Changing from 8 to 12-hour shift]. Stockholm: IPM and Karolinska Institute, 1996. Stress research reports, no 269.

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Management of health and safety in the organization of worktime at the local level

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Objectives This study examined the consideration of health and safety issues in the local process of organizing worktime within the framework of regulations.

Methods The study encompassed all 7 hospitals in one region of Denmark. Twenty-three semi-structured interviews were carried out with 2 representatives from the different parties involved (management, cooperation committees, health and safety committees from each hospital, and 2 local unions). Furthermore, a questionnaire was sent to all 114 wards with day and night duty. The response rate was 84%. Data were collected on alterations in worktime schedules, responsibilities, reasons for the present design of schedules, and use of inspection reports.

Results The organization of worktime takes place in single wards without external interference and without guidelines other than the minimum standards set in regulations. At the ward level, management and employees were united in a mutual desire for flexibility, despite the fact that regulations were not always followed. No interaction was found in the management of health and safety factors between the parties concerned at different levels.

Conclusions The demands for flexibility in combination with the absence of guidelines and the missing dynamics between the parties involved imply that the handling of health and safety issues in the organization of worktime may be accidental and unsystematic. In order to consider the health and safety of night and shift workers within the framework of regulations, a clarification of responsibilities, operational levels, and cooperation is required between the parties concerned.

Key terms hospitals, participation, prevention, regulations, shift work, work environment.

The organization of worktime is a local process, in which local issues are considered in the light of existing regulations. The variety of different work schedules indicates that the process of designing work schedules has become increasingly complex (1), marked by flexibility (2) and new approaches encompassing employee involvement in the management of health and safety in most industrialized countries.

The demands for more flexibility stem from the growing requirements of companies to work schedules that respond to new concepts of economy and production, technological possibilities, and fluctuations in business activity on one hand (1, 2) and the desire of employees to have their worktime organized according to their personal and social preferences on the other.

Parallel to these demands, health and safety regulatory strategies have changed from detailed technical legislative standards towards regulations offering a framework emphasizing build-up systems, programs, and conditions conducive to health and safety and stipulating the obligations and rights of the involved parties. Attention is also given to the importance of health and safety intervention at the stage of planning and design and also to local activities (3). These framework regulations correspond to the emergence of participatory systems and joint committees as methods of protecting employee rights to interact in company matters concerning such issues as worktime conditions and schedules (4) and health and safety factors (5).

This development is reflected in the European Council directive *Concerning Certain Aspects of the Organization of Working Time* (6). The directive recognizes night work as an occupational risk factor and points out the need for regulations exemplified by certain minimum standards and health programs. At the same time it allows for deviations by means of agreements between the

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2 parties and emphasizes compliance with national labor market traditions and regulations.

Furthermore, the reduction that has occurred in weekly workhours in many countries through the last few decades has caused changes in work schedules, and examples of new systems have been reported (7).

At the local level the organization of worktime often reveals conflicting interests between the parties involved and sometimes among the employees themselves. It has been stressed that at the enterprise level it is necessary to reach compromises that offer advantages to both the employers and the employees in order to obtain practical solutions (1, 8). The way health and safety issues are taken into account within the complexity of different interests, specific local conditions, and traditions is assumed to depend on the implementation of existing regulations and on the functioning of the local parties. The application of participatory principles to the organizational work conditions of companies has been reported earlier with regard to technological change (9) and to health and safety in general (10, 11), but variations in implementation, influence, and foundation have also been accentuated.

In light of the increased complexity and the mutual desire for more flexibility, the purpose of our study was to examine how health and safety issues are taken into consideration in the organization of worktime at the local level within a system of structural regulations and participatory strategies. Special attention was given to clarifying the functions and interactions of the parties involved and the influence of the joint committees.

Material and methods

Material

The study included all 7 somatic hospitals in the region of North Jutland, with a population of around 450 000.

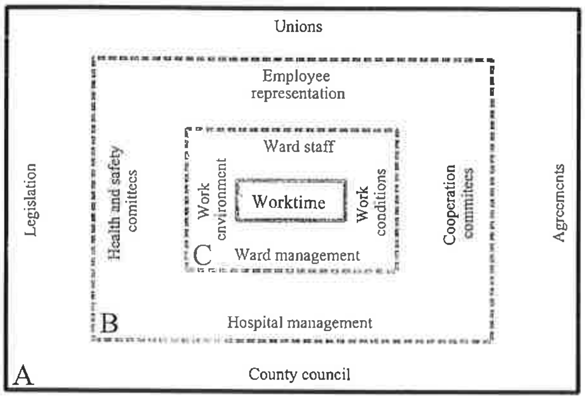

Figure 1. Operational levels of the local participants in the organization of worktime.

The hospitals varied from the regional hospital operating 24-hour services in 53 wards to the smallest hospital with 3 wards. All the hospitals had implemented participatory structures since 1980 according to the regulations of both cooperation committees [the first agreement on cooperation for the public sector was accepted in 1973 (latest, 12)] and the health and safety committees [stipulated in legislation since 1978 (latest, 13)]. The data were collected from October 1994 to February 1995.

Model

In Denmark the regulations concerning the work environment consist of a mixture of collective agreements and a legislative framework for health and safety (14). The parties involved in the agreements manage legal regulations to ensure compliance with the agreements, and, to ensure their implementation and participation, a formal system of joint committees has been introduced both by agreements (cooperation committees) and by legislation (health and safety committees). In this system work conditions, including worktime issues, are negotiated at both the central and the local level. The cooperation committees attend to cooperation and participation concerning the terms for personnel policies and organizational work conditions, including worktime and the daily operation of hospitals (12). According to the legislation the health and safety committees attend to cooperation and employee participation in the same way as the cooperation committees, but they only deal with implementing legislative provisions, monitoring health and safety, and initiating preventive activities (13). The management of a company, or a hospital, is still formally responsible for ensuring that the prescribed tasks of the health and safety committees are carried out. The employee representatives serving on the cooperation committee have to be elected from the shop stewards, who also represent the local unions at the hospital, whereas the health and safety representatives only represent the employees who elect them, and who work in a specific part of the hospital. They need not be unionized and are not considered union representatives.

In Denmark, the county councils determine the economic conditions and the service level of the hospitals in a region, but the management of a single hospital is responsible for the daily function of the hospital, the internal distribution of resources, and the handling of the local collective negotiations on work conditions. The management of a ward is responsible for the daily functioning of that ward. The ward management independently decides the extent of direct participation and involvement in work organization and work conditions in relation to the existing regulations and hospital policies on cooperation and health and safety.

The interaction between the different parties involved in the local process of organizing worktime is illustrated by figure 1. The figure shows the participants and conditions split up into the following three organizational structural levels: (i) the external conditions for single hospitals (A), (ii) the hospital level (B), and (iii) the ward level (C). At each level a dynamic relationship exists that influences the factors and dynamics of the other levels (marked by the dotted lines). This study only examined the 2nd and 3rd levels, as they are the only levels directly involved in the organization of worktime.

Methods

Interview. For all 7 hospitals in the region the participants were the parties involved at the hospital level except for one deviation from the model. As the employee representatives were part of both the cooperation committees and the health and safety committees, they were replaced by the 2 local unions for nurses and nurses aides representing employees involved in the 24-hour service of the wards (membership rate around 90%). Twenty-three interviews were carried out with 2 representatives of each of the parties involved [ie, management, cooperation committee (the chairman was always the top manager of the hospital and the deputy chairman was always an employee representative), health and safety committee (the chairman was always from management and as no deputy chairman exists in the health and safety committees, the employee representative was the employee with the highest seniority) and the employees' 2 local unions (the chairman and another member of the union board)]. The interviews were semistructured and dealt with 3 dimensions of worktime and health and safety: (i) function, responsibility, and authority (as perceived by the party in question) and the dynamics between the involved parties; (ii) the use of an inspection report available for labor inspections, in which deviations from regulations should be reported according to existing legislation; and (iii) the involved parties' conceptions of future regulations.

Each interview was carried out by 2 researchers and it lasted around 1.5 hours. The results were compiled for the 2 participants and sent to each of them for comments and acceptance. The possible corrections were added, and the interview records were returned for final approval.

Questionnaire. Data from a questionnaire to all 114 wards with 24-hour service at the 7 hospitals of the region were used to obtain information from the 3rd level (C) shown in figure 1. The questionnaire was mailed to the ward management and consisted of factual information on experiences with alterations in work schedules, responsibility for the organization of worktime, reasons for the design, changes in the planned schedules, and the use of inspection reports. Proportions were calculated. The response rate was 84%.

Results

Interviews

We analyzed the interviews to identify common features within a group and both common and different features between the groups. Only few divergences were found within the groups. Thus the data are presented for each group as a whole according to their experiences with the main themes.

Hospital management

The representatives of hospital management reported that their function was to wait to act; it was indirect and supervisory in relation to ward management. They did not interfere if there was unity between the employees and management at the ward level. They recognized that they, as management representatives, had certain formal control with respect to the observation of regulations. If employees were satisfied, deviations from the regulations were not recorded. According to hospital management adherence to regulations and the organization of worktime via decentralization belonged to the role of ward management since ward management was close to the staff and must enter into discussions with the staff, including discussions of health and safety. Special preferences concerning, for example, design and consecutive night shifts were determined at the ward level. The representatives of hospital management reported that the cooperation committees were usually informed of any changes in conditions related to worktime, such as new local agreements or the function of wards, whereas the health and safety committees were not involved. It was unanimously stated that the cooperation committees and health and safety committees did not have any authority in these matters. No cooperation between the parties was mentioned. The wards were reported to be the central level of employee involvement. The hospital management had no knowledge of health and safety problems stemming from the organization of worktime. Hospital management did not find any need for inspection reports. There was doubt about whether the reports were used and whether they were available. It was a common wish between ward management and employees not to report deviations in inspection reports. According to hospital management, regulations have to be flexible and should be overseen by the involved groups as much as possible. Agreements were therefore found to be the most appropriate tool, as they more strongly imply the necessity for flexibility and offer better opportunities to comply with employee wishes. Legislation might be necessary to prevent abuse, but legislation also has to be flexible enough to be utilized at individual hospitals.

Cooperation committees

The cooperation committees did not consider the organization and design of work schedules to fall in their sphere of influence. They felt that they may have a function if problems arise, but not until negotiations between the local parties have been tried. They understood that it was their function to wait to act because worktime conditions are determined by collective agreements and the organization of work schedules takes place at the ward level. According to the cooperation committees the organization of worktime and the handling of health and safety have been handed over to ward management. The cooperation committees argued that combining considerations of the treatment of patients and staff could only take place at the ward level. Health and safety issues in the organization of worktime were considered to be subjects for the health and safety committees. The cooperation committees did not report that they had any independent authority over worktime matters. The cooperation committees did not experience any dynamics between the parties. According to the cooperation committees the inspection reports were generally not used because there were no consequences for not filling out the reports. A mutual interest in being able to deviate from regulations was experienced between management and employees. The cooperation committees found that the most appropriate regulations for worktime and health and safety were set by agreement because then possibilities for adhering to the regulations were the greatest and there were better opportunities to take local problems into account. Legislation with minimum standards was considered to be necessary to prevent abuse.

Health and safety committees

The health and safety committees believed their function was to act when matters were raised externally. No such situation had ever arisen for any of the health and safety committees. These committees expressed a greater variation and uncertainty about their function in relation to organizational work conditions in general and worktime in particular than the other committees. The health and safety committees considered ward management to be responsible for and have the authority over worktime arrangements. They believed that ward management was fairly unconstrained in organizing worktime with respect to regulations. With respect to the responsibility and authority for health and safety issues in the organization of worktime, the opinions of the health and safety committees were dominated by uncertainty and variation. Some committees stated that the questions on worktime were subject to rulings by the cooperation committees, while others stated that health and safety matters, as indirect effects, could be subjects for the health and safety committees to consider. The health and safety committees reported no interaction between the parties. Furthermore the health and safety committees experienced ambiguous interfaces with management and the cooperation committees. They found that they had to collaborate with the cooperation committees as regards organizational work conditions. The health and safety committees stated that the inspection reports were not available or not used. They suggested that the reports were not used because of the common preference for flexibility between management and employees. In general the health and safety committees found a need for greater clarification of the regulations. The health and safety committees differed in their emphasis on agreements and legislation, but a common theme was the need for flexibility. A majority believed that agreements would offer the best opportunities for flexibility, while others preferred a frame of legislation complemented by local agreements.

Local unions

Both unions understood their activities to be determined by negotiations between the parties and the activities and preferences of the union members. The utilization of central agreements took place at the local level between shop stewards and hospital management. The role of the local unions was to provide information and supervise the shop stewards, but the unions were not directly involved. According to the unions, shop stewards do not think of health and safety when they enter agreements. The unions also referred to the fact that the health and safety representatives are not representatives of the unions at hospitals and therefore contact and guidance are limited. Sometimes union members presented health and safety problems related to worktime, but they did not want these problems to be brought up formally. It was the impression of the unions that the members tried to solve these problems by moving to another ward or sector. It was suggested that the responsibility for work schedules belonged formally to hospital management but that ward management had a special responsibility via decentralization. The unions considered the cooperation committees and health and safety committees to have the responsibility for linking worktime with health and safety. They also expressed the view that the health and safety representatives regarded worktime to be subject to agreement and managed by shop stewards, who, on the other hand, regarded health and safety issues to be dependent on legislation and therefore managed by health and safety representatives. The unions did not interact at the hospital level. Ward management was considered to be responsible for inspection reports. The unions viewed a broad frame of legislation filled out by local agreements as being the best regulation principle. Furthermore, it was stated that, if legislation was supposed to have some meaning, infringements should lead to consequences.

Questionnaire

The data from the questionnaires were transformed to the same themes used for the interviews, with the exception that both the information and operational role of the persons responding differed. In the description only the main trends are presented.

Wards. Worktime arrangements were discussed and altered frequently in the wards. Eighty percent stated changes during the last 5 years, half of the wards having had 2 changes or more. The causes for the alterations were primarily related to the function of the wards, and they were only linked to health and safety in 6 cases. Reasons for the present design ranged from functional considerations (63%) to patient care (20%), staff (14%), health and safety (1%) and other reasons (2%). In this case, health and safety issues were related to situations beyond the minimum standards in regulations. Responsibility and authority were nearly unanimously accepted by the representatives of ward management as belonging to their sphere. Only 5% mentioned superior management, and 7% expressed the opinion that the responsibility was shared with the staff. At the same time the staff was involved in all changes except 5, either because the employees had proposed the changes or had been consulted. Eighty-eight percent of the representatives of the ward management found that they had possibilities to alter worktime arrangements if they wanted to do so. Initiatives to alter the design of the shift systems had come from other organizational levels only in 4 cases. Representatives of ward management were asked if deviations from regulation standards or infringements were recorded in the inspection reports, and 76% stated that they were not. Future regulations were not a part of the questionnaire.

Discussion

At hospitals no policies or guidelines that go beyond the minimum standards in regulations have been drawn up that consider health and safety issues in the organization of worktime. After the decentralization of hospital structures ward management has had the authority to draw up work schedules and the responsibility to consider health and safety aspects. At the same time the responsibility of ward management embraces the obligation to design work schedules that maintain the function of the ward and consider the preferences of the employees, also under circumstances of altered resources and tasks. The frequent discussions about worktime arrangements and changes in shift schedules illustrate the increasing complexity of factors involved in the local process of organizing worktime and in the changeability of these factors (1). In the absence of a general hospital policy, a system of self-administration has been developed at the ward level in which ward management and the staff are united in a mutual desire for flexibility as the preferred method of organizing worktime. In general, this goal is maintained although it may imply deviations and infringements of regulations, which to a wide extent are not reported, despite legislative requirements for such reports.

The interviews demonstrated that, at the level represented in figure 1 as B, the parties involved display no activities, and thus no interaction takes places at this level concerning the handling of health and safety issues related to worktime. The parties concerned experience their function as an intermediary body waiting to act, and this stance is mutually legitimated by the fact that responsibility has been delegated to the wards and no health and safety problems due to shift work have been raised. The joint committees do not handle the health and safety aspects of worktime. The absence of activity on the part of the health and safety committees is estimated to be linked to the ambiguousness of their function, because worktime is considered to be regulated by negotiations and agreements between the concerned parties. The local unions, on the other hand, are characterized by hesitant attitudes because they believe that they must act in accordance with the prevailing attitudes of their members.

The absence of activity at the hospital level (level B, figure 1) implies that the self-administration of the wards is the dominating regulatory principle in the organization of worktime, whereas legislation as a result of the lack of activity is estimated to have the smallest influence. The existing relationship between influence, regulations, and the involved parties in the design of worktime arrangements is shown in figure 2. The dynamics illustrated in this figure have been found to have different implications for health and safety. Self-administration implies that health and safety issues become

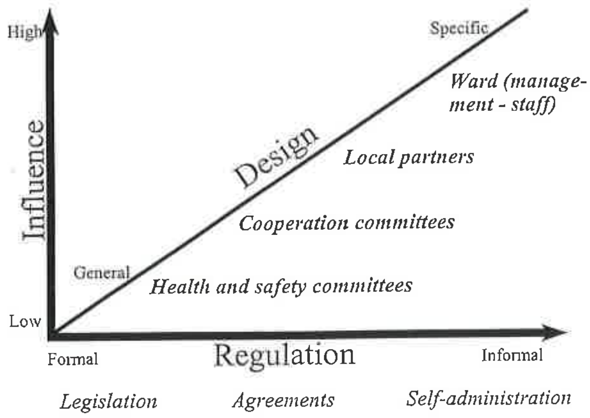

Figure 2. Dynamics between influence, regulations, and the local participants in the organization of worktime arrangements in hospitals within the existing regulatory framework.

ward-specific in terms of how they are managed in combination with other demands on the organization of worktime. Consequently, the management of health and safety has the potential to become unsystematic and sporadic as other issues are dealt with. No steps have been taken to meet the legislative provisions for health and safety or to implement conditions facilitating the function and influence of health and safety committees over worktime. In other words activities like monitoring and prevention, such as designing better shift systems (15), have not been initiated to enhance health and safety beyond minimum standards. The application of legislative framework emphasizing participatory strategies requires increased clarification of the functions of the health and safety committees at the local level to ensure preventive measures against the well-known effects of shift work (16, 17). Greater support from the other parties and their cooperation are necessary as well, especially at a time when the existing worktime systems are under change and new systems are necessary (18). Other approaches, such as further education of health and safety personnel and the development of new operational tools, will also be important when a legislative framework has been introduced.

The parties concerned argue about the lack of health and safety policies on worktime and about the fact that no health and safety problems have been raised, and that they are nonexistent, but, contrary to these arguments, is the fact that unions report on inquiries about worktime and health problems from single members. However, at the same time, their members do not want them to report their cases or raise them as a formal issue, as such a step may be contrary to the preferences of the other employees and management of the ward. Furthermore, there is no tradition for making such reports. This attitude will increase the risk of situations in which the handling of health and safety issues is left to employees themselves.

Employee participation takes place as direct participation at the ward level. It depends on the attitudes of the ward management and not on regulatory standards. The possibilities for representative participatory strategies based on regulations are not being utilized as they should according to their standards with regard to health and safety in the organization of worktime.

A fundamental question for a study of this kind is the extent to which the results can be generalized at both the national and international level. The hospital sector was chosen for study because of its long tradition of 24-hour service and because, as a public sector, it has common features that can be generalized to a national level. Furthermore, hospitals in Denmark are ruled by regional authorities, and the regions have the same hospital structure, consisting of a larger regional hospital and several smaller hospitals. No differences were found between the large and small hospitals. The methods of regulating worktime vary in the European Union according to the priority given to legislation, agreements, or a mixture of both. Thus Denmark has only few standards, and, in accordance with the general requirements for flexibility, it has had a legislative framework for health and safety based on participatory strategies through local action and measures. Therefore, it can be assumed that the results can be generalized to a national level and also to countries with similar regulatory systems for enterprises that have decentralized the authority for designing worktime arrangements at the ward or departmental level. The results cannot be directly generalized to industrial companies, where worktime arrangements are typically set at a central level within the company by agreements between management and shop stewards. On the other hand, the study demonstrates that problems may arise with regard to health and safety issues, even when established participatory strategies exist, if the organization of worktime is traditionally based on agreements and the management of health and safety issues has a legislative framework. Denmark can also be seen as representing the Scandinavian model for health and safety regulation in that it reflects regulations and participatory strategies to which the European directive on worktime also corresponds.

A study that uses interviews as a measure to collect data will always include the risk of interviewer bias. This possibility was taken into account in our study by having 2 researchers carry out the interviews and by compiling the interviews and returning them for acceptance. Another source of bias might have been the fact that representatives of management and the employees were interviewed at the same time, and therefore interpersonal relations might have influenced the outcome. However the interviews of the representatives belonging to the same group tended to be very similar in nature, and thus interpersonal relations probably did not play any important role.

Concluding remarks

A legislative framework for health and safety factors has been introduced to stimulate local cooperation and to ensure that local conditions will not be bypassed in fields with great variation and complexity. Such regulations offer diverse opportunities for organizing worktime, some of which will not necessarily encompass health and safety issues, despite their participatory strategies. In this study the existing legislative framework for handling health and safety issues increased the probability of worktime arrangements being handled through a system of self-administration that subordinates health and safety issues to the demands of flexibility, and health and safety then being treated accidentally and unsystematically.

Furthermore, the risk of the employees themselves having to handle their own health and safety problems increases.

The foregoing statements apply to comprehensive regulation systems, such as that of Denmark, with its well-developed participatory strategies and broad legislative framework that has to be complemented by the involvement of the labor market parties. Managing health and safety within a legislative framework that also allows for flexibility requires new concepts for health and safety policies at the company level. In order to consider the health and safety factors in worktime arrangements, special attention must be given to clarification of the responsibilities, operational levels, and cooperation between the local parties involved, particularly the joint committees.

References

1. International Labour Office (ILO). The hours we work: New work schedules in policy and practice. Geneva: ILO, 1990. Conditions of work digest, vol 9, no 2.
2. Kogi K. Increasing flexibility in shiftwork arrangements. Work Stress 1995;9(2/3):211—8.
3. Rantanen J. Strategies for regulations and services in occupational health and safety. In: Rantanen J, Lehtinen S, Hernberg S, Lindström K, Sorsa M, Starck J, et al, editors. Proceedings of the international symposium from research to prevention; March 1995, Helsinki. Helsinki: Finnish Institute of Occupational Health, 1995:158—66.
4. Kogi K, Thurman JE. Trends in approaches to night and shiftwork and new international standards. Ergonomics 1993;36(1—3):3—13.
5. European Commission. On the introduction of measures to encourage improvements in the safety and health of workers at work: council directive of 12 June 1989. Brussels: European Commission, 1989. 89/391/EEC.
6. European Commission. Concerning certain aspects of the organization of working time: council directive of 23 November 1993. Brussels: European Commission, 1993. 93/104/EC.
7. Wedderburn A, editor. Statistics and news. Loughlinstown House, Shankill, Dublin: European Foundation for the Improvement of Living and Working Conditions, 1996. Bulletin of European studies on time, no 9.
8. Kogi K, Di Martino VG. Trends in the participatory process of changing shiftwork arrangements. Work Stress 1995;9(2/3):298—304.
9. Fröhlich D, Gill C, Krieger H. Roads to participation in the European Community — increasing prospects of employee representatives in technological change. Loughlinstown House, Shankill, Dublin: European Foundation for the Improvement of Living and Working Conditions, 1991.
10. Walters DR, Freeman RJ. Employee representation in health and safety at the workplace. Luxembourg: Commission of the European Communities, Directorate-General Telecommunications, Information Industries and Innovation, 1992.
11. Gill C. Participation in health and safety within the European Community. Loughlinstown House, Shankill, Dublin: European Foundation for the Improvements of Living and Working Conditions, 1993.
12. Associations of County Councils in Denmark and the Organization of Public Workers (KTO). Samarbejdsregler i primærkommuner og amtskommuner [Agreement on cooperation committees in the public sector of 1 April 1995]. Copenhagen: Associations of County Councils in Denmark.
13. Folketinget. Bekendtgørelse om virksomhedernes sikkerheds- og sundhedsarbejde [Provision on Health and Safety Work of the Companies]. Copenhagen: Folketinget, 1992. Provision of the Ministry of Labour no 1181 of 18 December 1992.
14. Folketinget. Lov om arbejdsmiljø [Work environment act]. Copenhagen: Folketinget 1996. Act no 681 23 December 1975 with later changes and amendments as of 1996.
15. Knauth P. Designing better shift systems. Appl Ergon 1996;27(1):39—44.
16. Waterhouse JM, Folkard S, Monors DS. Shiftwork, health and safety: an overview of the scientific literature 1978—1990. London: Her Majesty's Stationary Office, 1993:1—31.
17. Costa G. The impact of shift and night work on health. Appl Ergon 1996;27(1):9—16.
18. Jeppesen HJ, Bøggild H, Larsen K. Regulations as prevention strategies for shiftwork problems. Int J Occup Environ Health 1997;3(3) suppl:82—7.

Scand J Work Environ Health 1998;24 suppl 3:88—95

Knowledge-based support for the participatory design and implementation of shift systems

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Objectives This study developed a knowledge-based software system to support the participatory design and implementation of shift systems as a joint planning process including shift workers, the workers' committee, and management.

Methods The system was developed using a model-based approach. During the 1st phase, group discussions were repeatedly conducted with 2 experts. Thereafter a structure model of the process was generated and subsequently refined by the experts in additional semistructured interviews. Next, a factual knowledge base of 1713 relevant studies was collected on the effects of shift work. Finally, a prototype of the knowledge-based system was tested on 12 case studies.

Results During the first 2 phases of the system, important basic information about the tasks to be carried out is provided for the user. During the 3rd phase this approach uses the problem-solving method of case-based reasoning to determine a shift rota which has already proved successful in other applications. It can then be modified in the 4th phase according to the shift workers' preferences. The last 2 phases support the final testing and evaluation of the system. The application of this system has shown that it is possible to obtain shift rotas suitable to actual problems and representative of good ergonomic solutions.

Conclusions A knowledge-based approach seems to provide valuable support for the complex task of designing and implementing a new shift system. The separation of the task into several phases, the provision of information at all stages, and the integration of all parties concerned seem to be essential factors for the success of the application.

Key terms knowledge-based software system, process model, shift work.

The successful implementation of an effective new shift system is a complex process comprising conflicting interests of the social partners involved (1). To reach a compromise between company goals and the preferences of shift workers, which is very important for the acceptance of a new worktime arrangement, joint planning is recommended (2, 3). Since it has been indicated that a new shift system can be introduced more successfully when operational process support is provided, this support should focus on realistic solutions adapted to local conditions. For this purpose data should be gathered on company operational requirements and the employees' preferences for worktimes, and tools for the participatory development of specific shift systems should be used (4). Training which focuses on the effects of shift work and the development of possible alternative shift systems is also of great importance.

Because of the complexity of arranging shift systems which fulfill constraints on an organizational and ergonomic level, take into account the preferences of workers, and stay within the limits of legal and collective agreements, the use of computer-aided design (CAD) has been proposed for shift schedules (5). Several approaches (6, 7) have successfully demonstrated that computer support can be applied to a variety of tasks within the domain of shiftwork design and implementation. However, problems arise if the whole process has to be covered, as most of the available software tools concentrate on certain subtasks and emphasize the generation of shift rotas.

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On the other hand, numerous concepts aim at supporting the implementation strategy of a new worktime arrangement (8—10). These studies basically cover the complete domain on a descriptive level and are abstract from operability.

To develop a method that both covers the complete process and integrates the expertise of shiftwork research, we carried out a knowledge-based, model-oriented approach that facilitates the required transfer of expert knowledge from research to practical applications (11). The result was a knowledge-based software system that can support available options when a new shift system that has detailed information on the potential advantages and problems of worktime arrangements is introduced.

Methods

As no transferable models have yet been developed that adequately represent the design and implementation of shift systems, we decided to follow a model-oriented approach. The method of model-based and incremental knowledge engineering (12), which subdivides the process of developing knowledge-based systems into knowledge acquisition, design, implementation and evaluation, was used to acquire knowledge, construct a structure model for the domain of shift system design, and realize the first prototype of the system.

The knowledge acquisition was initiated through repeated group discussions with 2 experts, including 1 of the authors, with research experience of 27 and 8 years, respectively, in this field. This discussion resulted in a description of the relevant concepts and subtasks that were integrated into a structured model for the ergonomic design and implementation of shiftwork systems. Subsequently semistructured interviews with one of the experts took place to modify and refine the structured process model.

During the 2nd phase of the knowledge acquisition, an extensive literature search of both printed media and online data bases was carried out. We started with the printed media mentioned by the experts during the interviews and expanded these data by cross-referencing procedures. In addition, the proceedings of former shiftwork symposia were included. Another knowledge source was provided by searching several online data bases for relevant publications. As a prerequisite we constructed a checklist of key words. This checklist was applied to data bases for both books and journals covering the period 1945 through 1996. Altogether 367 relevant studies were identified through the search of printed media and another 1346 publications through an online search, forming a factual knowledge-base of 1713 entities.

In a 3rd step we formalized the structure model and constructed a model of expertise which formed the core of the knowledge-based system. The model of expertise was then tested for performance on 12 case studies which had been collected from both the literature and practical change projects that had been carried out by our institute. As the overall results of the application of the model of expertise have been very positive, we have implemented the prototype of the knowledge-based system on a standard windows platform, attention being paid to conventional user and software interfaces.

Results

The structure model

The structure model provides a semiformal representation of the domain of shift-system design and implementation using different types of modeling primitives. In the structure context, which serves as a view of the data flow of the process, activity nodes containing the description of one step of an expert in his or her problem-solving are given, whereas concept nodes constitute an object which can act as an input to or output from an activity. Inference links are used to connect these 2 types of nodes.

The whole process has been divided into 6 different phases. During the preparation phase the modification of an existing shift system or the implementation of a completely new worktime arrangement is initiated. This step provides information on the aims of the new shift system, the proposed organization of the changeover, and the process support that is available for all parties possibly affected on a company level. In this way communication between the management, the superiors of the departments concerned, the workers' committee, and the shift workers is supported. The central output of this activity is structured information for the system user, and it is also linked to the input of the following orientation phase (figure 1).

In the 2nd phase the most important constraints on the shift system under development are defined. It focuses on determining the workers' preferences concerning worktime and the quantitative description of the company goals. In this context information on the intended operational time and the reasons for the necessary change are acquired. Other important information is provided by the input of the branch of industry that the company belongs to, as it determines the range of legal and union constraints (eg, minimum rest periods between 2 shifts or agreed weekly worktime). In addition, during the orientation phase, decisions on different types of shifts and the planning of the number of crews manning each have to be made. As these decisions may have initial consequences on the possible negative effects of the new shift system from an ergonomic point of view, detailed ergonomic information has to be provided as support. This support comes from the factual knowledge base of 1713 studies in the field of shiftwork research on entities relevant to the characteristics of the shift system under development. Specific features of the new shift system that may induce increased risk for the workers are analyzed. As minor alterations of company goals may have positive effects on the ergonomic quality of shift systems, it is possible to define new projects at this stage. This action corresponds to the creation of a new project file in the software system.

In contrast to other approaches, the set of requirements is not converted to a generating procedure for shift rotas, as it may lead to problems concerning the acceptance of the generated results by the shift workers. During the expert interviews we found that one alternative is to search for a shift system which has already proved to be successful in other companies and which shows a reasonable similarity to the defined requirements, and thus acts as a basis for discussions and improvements. For this basic solution easy adaptation to the new application and consideration of ergonomic recommendations have to be ensured to the greatest possible extent. Therefore a clear area of application is created for the well-known problem-solving method of case-based reasoning. During the following design phase, the negative aspects of the basic solution have to be reduced by incrementally improving the shift system according to the preferences of the workers and ergonomic guidelines. This reduction is achieved through a participative approach supported by adequate software tools for shift system design. As again the decisions taken during this step affect the ergonomic quality of the system, an explanation module is used which is analogous to that of the orientation phase (ie, possible problem areas caused by the features of the system are linked to studies in the field of shiftwork research). In this way constant support is realized concerning a priority list

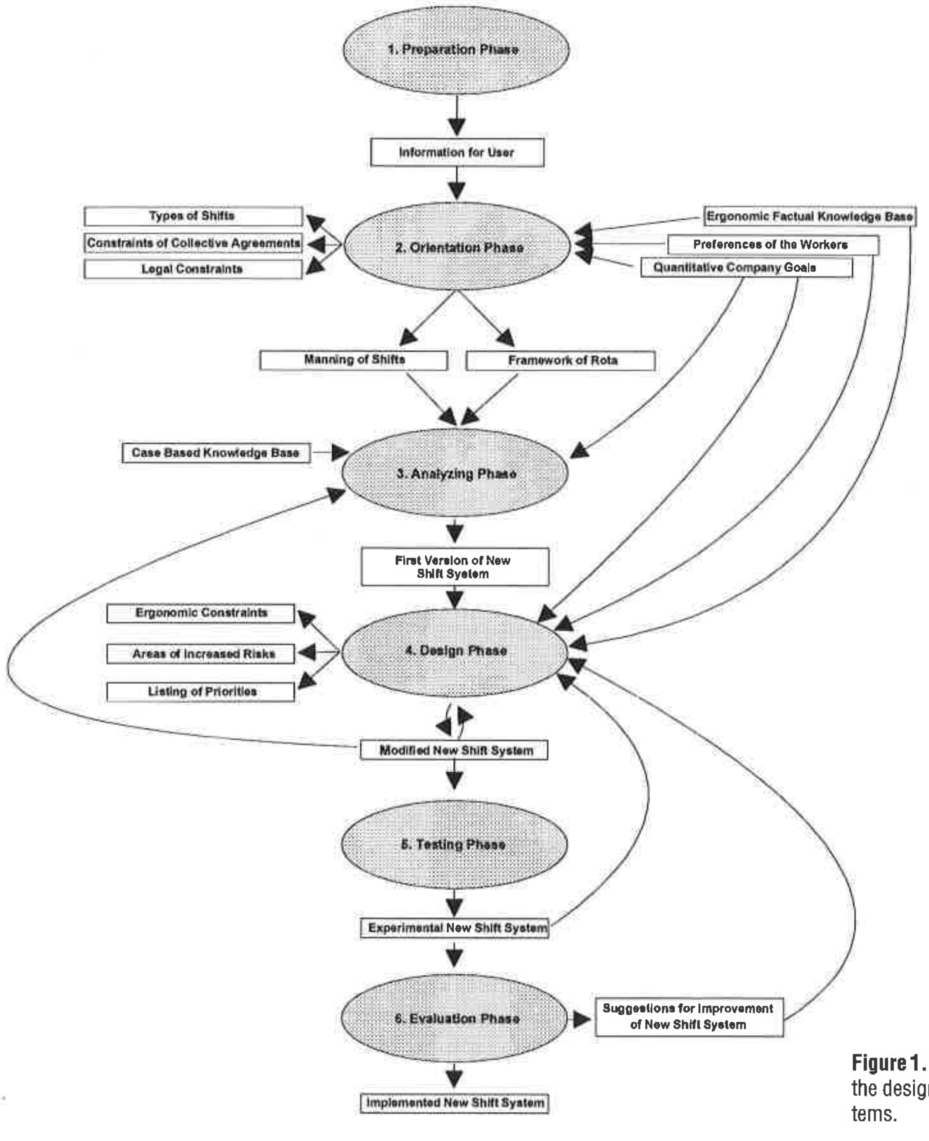

Figure 1. Top layer of the structure model for the design and implementation of shift systems.

of improvements based on the findings of shiftwork research; therefore it is possible to make sound decisions rather than to depend on an automated decision process.

The organizational context of these tasks consists of workshops, which can lead to several alternatives for the new shift system. After being extensively informed, all the workers affected by the new systems are asked to vote on the alternatives. The most favored shift rota is then tested for a predefined period. At the end of the testing phase the employees vote again, and the new system is either implemented with no time limit or the design phase continues with renewed modifications or the tested system is completely canceled. In this case a new design and implementation process can be initiated.

Operationalization and testing of the problem-solving method

During the interviewing phase we discovered that, to avoid the problems inherent in the generation of shift rotas (ie, the possibility of very limited acceptance of the generated results by the shift workers), the 1st version of a new shift system should focus on a search for a worktime model which has already been implemented in other applications and which has been positively evaluated from an ergonomic point of view. The 1st version of the new shift rota can then be modified and adapted to the actual situation, and thus it acts as the basis for a solution.

This is a clear indication for applying the problem-solving method of case-based reasoning, which works as a 3-stage procedure for shift system design and implementation. In the 1st step a preselection has to be made using a data base of existing shift systems to exclude cases irrelevant for the given problem. During the 2nd step the similarity of the shift systems in the data base and the worktime arrangement being designed has to be calculated; the data are then interpreted in the 3rd step. If there is an indication that the data base contains a shift system that is both sufficiently similar and ergonomically well designed, the knowledge-based system suggests this shift rota as a reference case.

The performance of this problem-solving procedure depends to a great extent on the data base from which comparable cases are selected and on the operationalization of the measurement of similarity. In our system the actual case data base contains 409 shifts collected from examples of projects in our institute and information provided by companies and publications. This collection represents a variety of shift systems relevant to practical applications, the focus being on continuous systems. The measurement of similarity is constructed around the 5 dimensions of agreed weekly worktime, operational time, length of the rota, number of crews working on different shifts on each day of the week, and the classification of the shift system (eg, rotating shift systems including night work or permanent morning shift systems). The length of a rota is integrated to identify similar shift systems because it is a characteristic that is important to many shift workers and thus affects the acceptance of a new system. In addition, the personnel required for manning a system may change.

As there is no increase in the required personnel for multiple lengths of shorter rotas, the explanation module indicates to the user that more alternative solutions can be achieved by modifying the requirements of the length of the rota accordingly. To avoid a similarity measure of 0, the default value is set at 1. The checking of the cases in the data base for applicability to a new shift system starts with the calculation of relative differences from the requirements. If predefined tolerances are violated, a shift system is excluded from further checking, which corresponds to the preselection of the problem-solving method (figure 2).

If a shift system successfully passes these criteria, the results for the agreed weekly worktime and operational time are combined and integrated into the calculation of the total difference together with the other 3 dimensions (ie, the length of the rota, the number of crews working different shifts each day of the week, and the classification of the shift system). The decision to suggest a certain shift system as a possible first version for the new system not only depends on similarity, it also considers ergonomic quality. Our approach uses the Besiak procedure (13) to check the compliance of shift systems with ergonomic recommendations on the basis of 14 weighted criteria. The final decision is then based upon the multiplicative combination of the results of the Besiak procedure with the results of the total difference. This procedure takes into consideration the fact that a minor deviation from company goals can be compensated by a better Besiak score, which can be illustrated by the results of case study 8 (table 1).

For this shift system a rota length of 6 weeks, an operational time of 168 hours per week, and an agreed weekly worktime of 40 hours were required. Further requirements comprised 1 night shift crew every day of the workweek, 1 evening shift crew every day except Sunday, 2 crews on morning shifts on Monday, Tuesday, Saturday and Sunday, and 3 crews on morning shifts on Wednesday through Friday. The application of the problem-solving strategy resulted in a shift system which exactly met all dimensions of similarity except for the number of crews working on different shifts on each day of the workweek. The proposed solution had 1 crew on each of the evening and night shifts on every day of the week and 2 crews on the morning shift on all days from Monday to Sunday. Thus a similarity measure of 20.05 resulted. A difference concerning the class of the shift system would have resulted in an increase in this result by a default value of 30 (table 2).

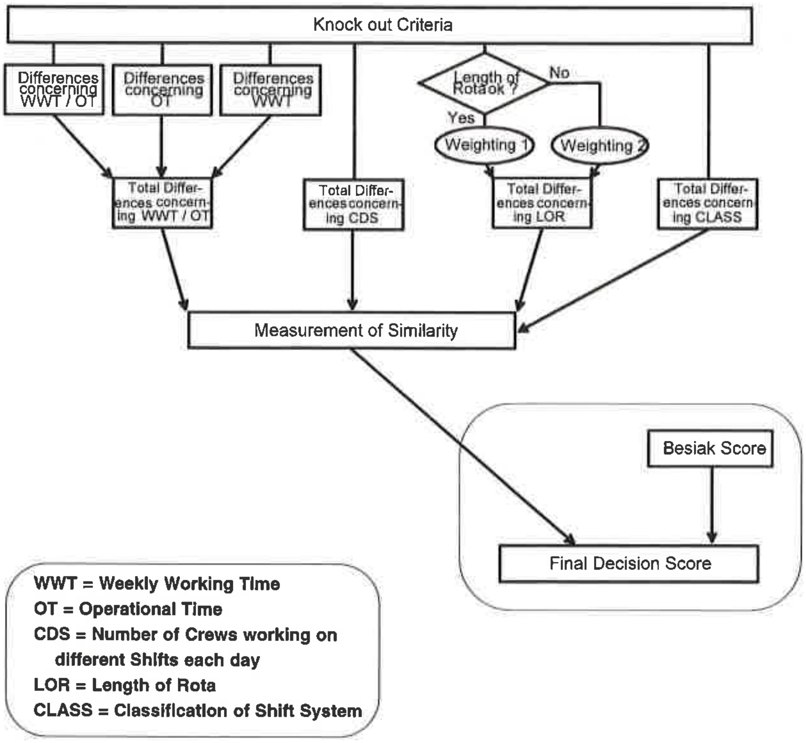

Figure 2. Structure of the problem-solving method of case-based reasoning.

Table 1. Similarity of shift systems obtained by testing case-based reasoning on 12 case studies.

Case	Length of rota (weeks)			Operational time (h/week)			Weekly worktime (h)			Crews on different shifts
	Required	Found	Difference (%)	Required	Found	Difference (%)	Required	Found	Difference (%)	Difference (%)
1	3	3	0	110	108	1.8	36.66	36.00	1.8	4.8
2	4	4	0	168	168	0	38.00	42.00	10.5	0
3	4	4	0	144	144	0	36.00	36.00	0	0
4	4	4	0	144	144	0	36.00	36.00	0	4.8
5	5	5	0	168	168	0	36.50	35.20	3.6	9.5
6	5	5	0	168	168	0	33.60	33.60	0	0
7	6	6	0	168	168	0	38.00	40.00	5.3	19.0
8	6	6	0	168	168	0	40.00	40.00	0	19.0
9	11	10	9.1	168	168	0	38.23	38.40	0.4	19.0
10	10	10	0	168	168	0	33.60	33.60	0	0
11	12	12	0	168	168	0	40.66	37.30	8.2	33.3
12	15	15	0	168	168	0	33.60	33.60	0	0

The Besiak score for this solution was 325.9, and the final decision score was 6534.3. Although the knowledge base detected another possible solution with a better Besiak score of 319.1, this alternative solution was ignored due to its lower similarity of 29.57, which resulted in a final decision score of 9435.79.

For flexibility, both the weightings of the Besiak procedure and those used to determine the results for differences can be modified according to the preferences of the users. The performance of the case-based reasoning module of the knowledge-based system has been tested on 12 case studies as shown in table 1. Nine of these case studies concerned continuous shift systems with an operational time of 168 hours per week, while 3 other studies were in the field of discontinuous shift systems including work at night but excluding work on weekends with an operational time of 110 to 144 hours per week. The required length of the rotas varied between 3 and 15 weeks and the agreed weekly worktime was between 33.6 and 40 hours. The results show that, for the majority of the case studies, the shift systems proposed as a basis for further refinement by the knowledge-based system suited the actual problem well. This was especially the case for the length of the shift rotas, the operational time, and the agreed weekly worktime. The deviation from the requirements for the shift system that was deducted in the knowledge base was 6% or less in at least 8 of the 12 case studies. No deviation at all occurred for the classes of the shift systems, where any differences would have resulted in a fixed increase in the value of the measurement of similarity. Although the comparability concerning the number of crews working on each shift was more restricted, the overall similarity indicated that valuable support is provided. In addition, these basic versions of the new shift systems have already shown to be a good compromise from an ergonomic point of view, even if some improvements could still be implemented during the design phase of the changeover process.

Realization of the prototype

The structure model provides the base for implementing the prototype of the knowledge-based system. Thus the software supports all phases of designing and implementing a new system. With the exception of the 3rd phase of the structure model (eg, the selection of a comparable shift system that can act as a solution for the rota under development) all the steps require extensive user interaction. Therefore the visualization of important data seems to be of great importance. This is especially the case when complicated rotas have to be constructed, which typically include a long shift rota, many different types of shifts, and a complicated structure of the manning of each shift. In this case the system provides an overview concerning the number of crews working on different shifts over a 24 hour period for each day of the week (figure 3).

Support for ergonomic decisions has been realized through the explanation module of the knowledge-based system. By mapping features of the shift system being designed according to the findings of studies in the field of shift work research, possible problems associated with

Table 2. Calculation of the similarity measure for case study 8.[a] (WWT = weekly worktime, OT = operational time, CDS = number of crews working on different shifts each day, LOR = length of rota, CLASS = classification of shift system)

	Crews on morning shift		Crews on evening shift		Crews on night shift	
	Required	Found	Required	Found	Required	Found
Monday	2	2	1	1	1	1
Tuesday	2	2	1	1	1	1
Wednesday	2	3	1	1	1	1
Thursday	2	3	1	1	1	1
Friday	2	3	1	1	1	1
Saturday	2	2	1	1	1	1
Sunday	2	2	0	1	1	1

[a] Similarity = (total differences concerning WWT/OT)
+ (total differences concerning LOR)
+ (total differences concerning CLASS)
+ (total differences concerning CDS)
+ (default value)

$$= (0) + (0) + (0) + \left(\frac{4}{21} \cdot 100\right) + (1)$$

$$= 20.05$$

[shaded box] Difference to company requirements

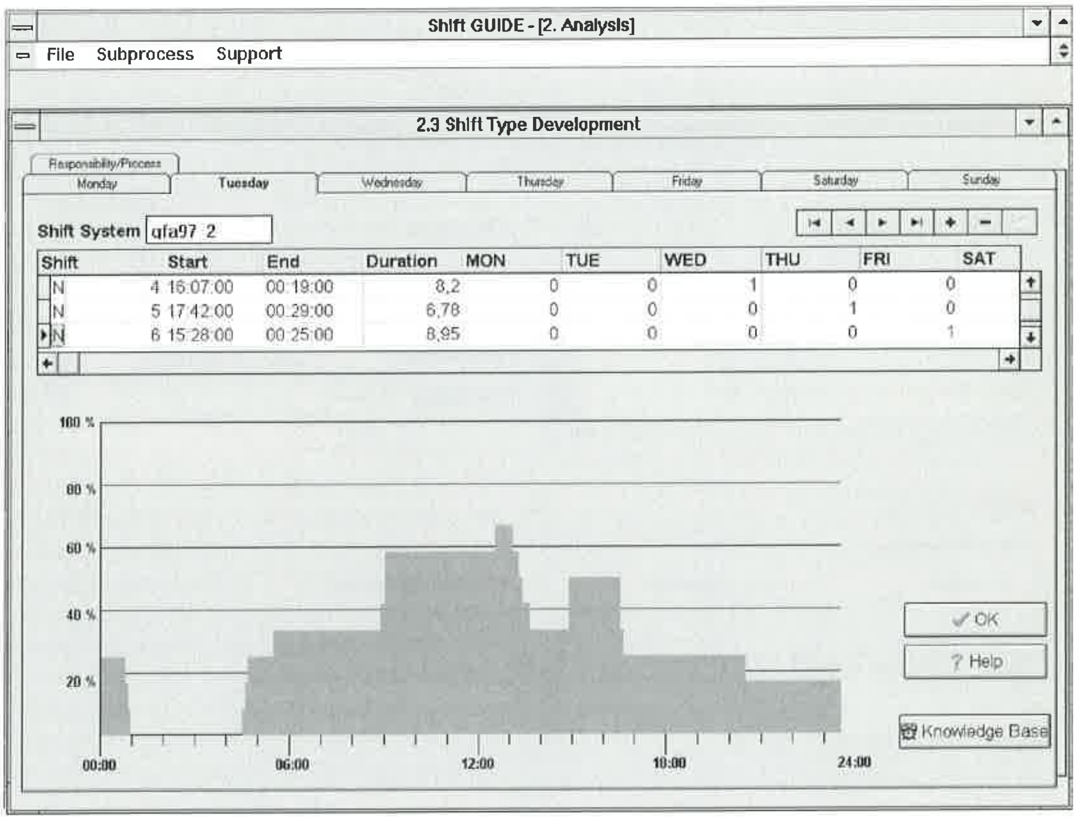

Figure 3. Visualization of different shifts and percentage of work crews present for complex shift systems in the knowledge-based system.

certain features can be detected during the design process. The explanation module shows the features observed in published studies, together with the negative effects on shift workers (figure 4).

This support focuses on covering the definition of different types of shifts during the orientation phase and the final design of the new shift system in the 4th phase. This design step is performed by participative modification of the solution basis acquired by case-based reasoning.

Concluding remarks

The design of shift systems is a complex task that should be carried out as a participatory process involving all parties of a company that might be affected by a change in worktime arrangements. In order to provide support, the use of computer-aided time scheduling is proposed. We used a knowledge-based approach, which subdivides the whole process into 6 phases. Through application of the software tool, the constraints of the new system are defined, a basic version of the new system derived from good examples of shift systems already in use is developed, and the final design is supported.

Our results indicate that, by using case-based reasoning taking into account the main parameters of a shift system (ie, the agreed worktime, operational time, the length of rota, the number of crews working on different shifts on each day of the week and the classification concerning types of shift systems), transferable models can be acquired. The application to 12 case studies showed that, with this procedure, solutions that can act as a basis for further participative discussions and modifications are derived without shift systems being automatically generated. This ability for adjustment can be crucial to the acceptance of a new shift system by the workers.

To facilitate reliable decisions when shift systems are adapted to the preferences of workers (eg, during workshops), an explanation module of the knowledge-based system enables the users to monitor the consequences of the modifications continuously. This explanation module integrates and structures the findings of 1713 studies in the field of shiftwork research and provides information on possible negative effects associated with certain characteristics of a shift system. However, the information contained in the listing of possible negative effects provided by the explanation module might be redundant to a certain degree, especially when specific restrictions are given and all solutions share a high number of problematic features. A possible solution to overcome this problem could be to distinguish between negative effects that can be found in all the solutions and specific negative effects of all the solutions.

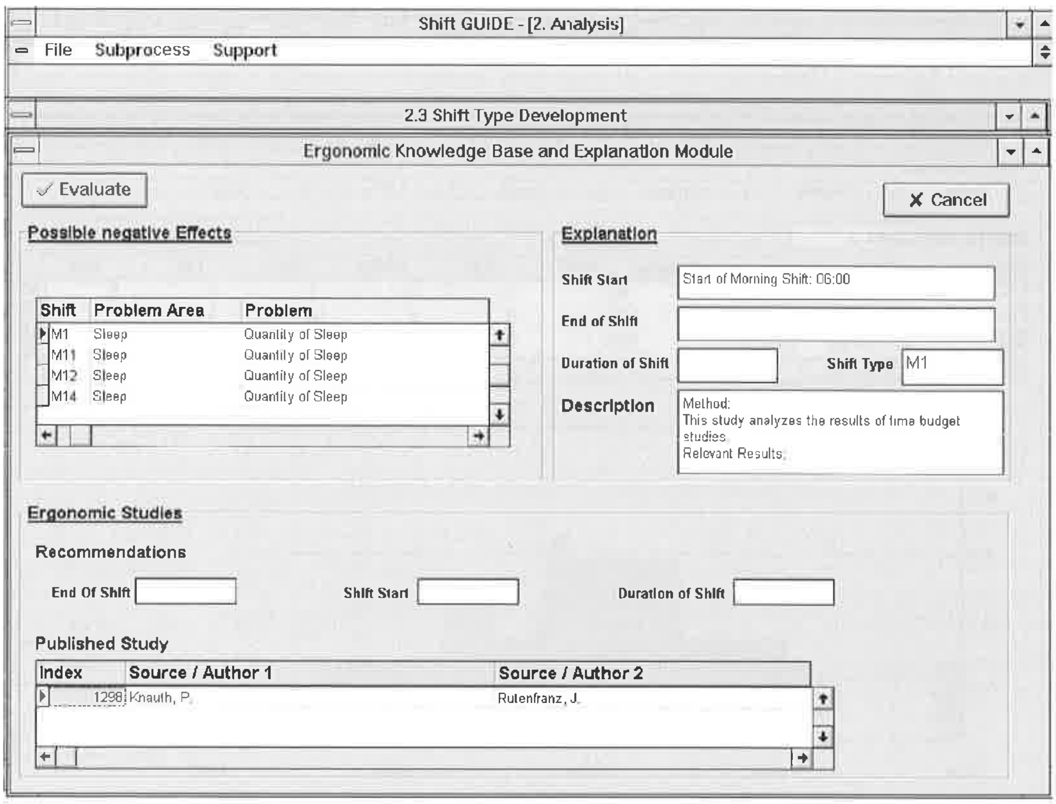

Figure 4. Implementation of the explanation module. [M1=morning shift (start: 0413, end: 1234); M11=morning shift (start: 0459, end 1336); M12=morning shift (start: 0520, end: 1707); M14=morning shift (start 0430, end: 1300]

As so far the testing of the knowledge-based system has focused on rather traditional problems, such as continuous shift systems with a maximum length of rota of 15 weeks, it would be desirable to extend the knowledge base to cover even more complex situations, such as service sector applications or public transport. Moreover, the evaluation of the knowledge-based system should be expanded to cover more discontinuous applications. It is indicated, however, that the limitations of the system are to be expected more because of the structure of the factual knowledge base (ie, a concentration on continuous shift systems), which can act as a possible first version of a new rota, than because of the realized problem-solving method. In addition, further field applications of the system are planned.

References

1. Kogi K, di Martino VG. Trends in the participatory process of changing shiftwork arrangements. Work Stress 1996;9:298—304.
2. Knauth P. Design of shiftwork systems. In: Colquhoun WP, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Frankfurt Main: Peter Lang Verlag, 1996:155—74.
3. Knauth P, Hornberger S. Schichtarbeit und Nachtarbeit. München: Bayerisches Staatsministerium für Arbeit und Sozialordnung, Familie, Frauen und Gesundheit, 1997.
4. Kogi K. Job content and working time: the scope for a joint change. Ergonomics 1991;34:757—73.
5. Nachreiner F, Qin L, Grzech-Sukalo H, Hedden I. Computer aided design of shift schedules. Ergonomics 1993;36:77—83.
6. Knauth P. Computergestützte Gestaltung diskontinuierlicher Schichtpläne nach arbeitswissenschaftlichen Kriterien. Z Arbeitswiss 1987;41:224—6.
7. Gärtner J. CATS — computer aided time scheduling. Wien: TU-Wien, 1992.
8. Ackermann K-F, Hormann M. Systematische Arbeitszeitgestaltung. Köln: Deutscher Instituts Verlag, 1988.
9. Marr R. Die Implementierung eines flexiblen Arbeitszeitsystems als Prozeß organisatorischer Entwicklung. In: Marr R, editor. Arbeitszeitmanagement. Berlin: Erich Schmidt Verlag, 1996:462—76.
10. Hegner F, Bittelmeyer G, van Bruggen W, Heim G, Kramer U. Erfolgsfaktor Zeit. Köln: Arbeitgeberverband Gesamtmetall, 1995.
11. Kogi K. Improving shiftworkers' health and tolerance to shiftwork: recent advances. Appl Ergon 1996;27:5—8.
12. Angele J, Fensel D, Landes D, Neubert S, Studer R. Model based and incremental knowledge engineering. In: Cuena J, editor. Knowledge oriented software design. Amsterdam: North Holland, 1993:139—68.
13. Schönfelder E, Knauth P. A procedure to assess shift systems based on ergonomic criteria. Ergonomics 1993;36:65—76.

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The significance of rota representation in the design of rotas

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Shift scheduling is based on some representation of shift schedules. The number of different representations currently used is high, and one might expect small practical differences between these representations. However, an analysis of several prominent representations revealed strong differences regarding possible outcomes of the scheduling process and the effort needed for their assessment. Limitations of some representations do not only concern specific rota design issues, such as different staffing levels or different workhours, but also rather simple and straightforward rotas. Furthermore, there is no single representation that is strictly and unequivocally better than the others. Most representations simplify the development of some rotas, while they make it very difficult or even impossible to develop others. Therefore, both designers and the computer systems used for design should use and support several representations and therefore allow smooth transitions between them. In addition knowledge about rota construction techniques should be maintained, as it may ease assessment dramatically.

Key terms assessment of shift rotas, complexity analysis, computer-supported shift scheduling, shift scheduling.

The design, evaluation, and implementation of shift rotas are important issues in improving the work conditions of shift workers. Several guidelines exist for the design. (See, for example, reference 1.) In addition, several computer systems aim at easing the design (2—5). This article deals with a fundamental, but seldom discussed, issue of shift rota design, namely, the representation of shift rotas, that is, how they are recorded.

Many representations exist (6, 7). One might expect small differences in their relevance, however. We chose 5 representations that are — in our experience — broadly used for the design of rotas based on a small number of different shifts. In this paper we show that these 5 representations differ substantially in at least 2 dimensions.

First, we analyzed whether each representation is capable of representing all possible rotas. We started from the general definition that rotas are functions that designate duties to employees. We found severe restrictions in prominent representations. These restrictions are often advantageous as they reduce the "search space". However, they may also oppress interesting solutions.

Second, we examined how much effort it takes to assess rotas. The representations differed strongly with respect to specific features of the rotas. Depending on the focus of the design (eg, improving weekends, optimizing rhythms, considering legal constraints) and depending on the rota at hand, the difference is often not gradual but varies by multiples. Considering the time constraints of actual rota development, this type of variation again has practical impact. With suboptimal representations, fewer rotas can be assessed or the assessment is shallower.

Typically, representations are not self-explanatory. They build upon the knowledge of readers to interpret them. Therefore, in the first section, we introduce some important representations and briefly outline their "reading instructions". At least to our knowledge, no well established names are in use for these representations. Therefore, we introduce names for them. A discussion of important theoretical and practical limits of a few prominent and widely used representations follows. In the 3rd section we discuss the effort needed to assess a rota in different representations.

Important representations

The "classical" representation

Prominent representations used by the night- and shift-work community are variants of the one used in the following example, a "traditional schedule" for 120 hours

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a week (8). We call it the "classical" representation (figure 1).

In the example presented in figure 1 there are 3 shifts: M=morning (8 hours, 0600—1400), E=evening (8 hours, 1400—2200), N=night (8 hours, 2200—0600). These kinds of shifts and the symbols "—" or " " for a day off are used throughout this article. The classical representation, as defined here and as typically used in rota design, shows only the 1st week for each group. After 1 week, group A continues with the arrangement shown for group B, then it continues with the arrangement shown for group C, and so forth. Often week numbers instead of group names are listed in the left column, and they represent the week within the shift cycle with the different groups starting their schedule at different weeks within the cycle.

Other representations

In figure 2 we introduce 3 different representations (basic series, extended classical, full-by-groups). The same continuous rota for 4 groups is represented.

Basic series. Basic series build up full rotas by repetition. The cycle length of the whole rota in weeks is typically its length in days (eg, 8 days ⇒ 8 weeks' cycle length). (Exceptions regarding cycle length apply only to basic series whose lengths are multiples of 7 and to some basic series that are concatenations of shorter basic series.) Normally only short basic series are used to avoid rotas that are too long. In the example, the 4 groups start in different positions within the series with 2 days' difference. This system leads to an identical rota with a slightly different group ordering. To get exactly the same rota, the starting order of the groups would be (group A ⇒ M, B ⇒ "—", C ⇒ N, D ⇒ E). Feasible lengths of basic series are multiples of the number of groups (eg, for 4 groups: 4, 8, 12, etc). Basic series cannot be applied if the number of groups is a multiple of 7. A different name for the basic series is "duty cycle" (6).

Extended classical. The extended classical representation shows the first 2 weeks of the example rota for each group. After 2 weeks, group A continues with the rota of group B, then 2 weeks later with the rota of group C, and so forth. The difference from the classical representation is that the extended classical can build upon 2, 3, 4, or more weeks per row.

A similar representation is used in references 8 and 9. In summary, the classical representation could, theoretically, be extended differently. Instead of adding columns, one could add rows (eg, using 8 rows for 4 groups and letting group A start in row 1, group B start in row 3,

	Mo	Tu	We	Th	Fr	Sa	Su
A	M	M	M	M	M		
B	E	E	E	E	E		
C	N	N	N	N	N		

Figure 1. A 120-hour rota in the classical representation. (M = morning, E = evening, N = night)

Representation	Rota:
Basic Series	MMEENN- - with 4 groups, 2 days difference in start

Extended Classical

	1 Mo	1 Tu	1 We	1 Th	1 Fr	1 Sa	1 Su	2 Mo	2 Tu	2 We	2 Th	2 Fr	2 Sa	2 Su
A	M	M	E	E	N	N			M	M	E	E	N	N
B			M	M	E	E	N	N			M	M	E	E
C	N	N			M	M	E	E	N	N			M	M
D	E	E	N	N			M	M	E	E	N	N		

Full-by-groups

	1 Mo	1 Tu	1 We	1 Th	1 Fr	1 Sa	1 Su	2 Mo	2 Tu	2 We	2 Th	2 Fr	2 Sa	2 Su	3 Mo	3 Tu	3 We	3 Th	3 Fr	3 Sa	3 Su	4 Mo	4 Tu	4 We	4 Th	4 Fr	4 Sa	4 Su
A	M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E
B			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M
C	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N		
D	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N

	5 Mo	5 Tu	5 We	5 Th	5 Fr	5 Sa	5 Su	6 Mo	6 Tu	6 We	6 Th	6 Fr	6 Sa	6 Su	7 Mo	7 Tu	7 We	7 Th	7 Fr	7 Sa	7 Su	8 Mo	8 Tu	8 We	8 Th	8 Fr	8 Sa	8 Su
A	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N		
B	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N
C	M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E
D			M	M	E	E	N	N			M	M	E	E	N	N			M	M	E	E	N	N			M	M

Figure 2. Three representations of the same rota for continuous work. (M = morning, E = evening, N = night)

etc). In general the number of weeks could be a multiple or even a divisor of the number of groups. If the starting points of the groups are distributed evenly over the rows, it allows the same rotas to be represented as the extended classical representation. This representation makes it more difficult to assess staffing levels than the extended classical representation does, and we do not know a company where it is used. Therefore it is not discussed hereafter.

Full-by-groups. In the full-by-groups representation the rota for each group is represented in a single row. Therefore the example rota needs columns for 8 weeks. The upper part of figure 2 shows the first 4 weeks; the lower part shows the next 4 weeks. Again, the numbers in the first row denote the week. This is one representation used by Gärtner (5).

Representation by month — hospitals

In this representation, an individual rota is developed for each person. Each rota is written in a single line. The main difference from the full-by-groups representation is that it builds upon months. Typically the rota is developed for each month separately. Amazingly, we found this representation in Austrian, German, American, and Japanese hospitals.

"Blind spots" of the classical representation

Generally speaking, the set of possible rotas can be defined as any time-stamped assignment of employees to duties. Mathematically it has the following function: rota (days, employees) ⇒ duties.

The first analysis investigates whether all rotas can be represented in a specific representation. It leads to the question of whether a representation imposes constraints on some features of a rota. The second analysis is whether the resulting omissions ("blind spots") are practically relevant. In other words, do relevant rotas exist which cannot be covered by the representation?

The classical representation imposes constraints on the rota to be developed. First, the number of groups equals the number of weeks of the cycle length. Second, the rotas of all groups must be equal. The consequences are (i) the cycle length in weeks is equal to the number of groups; (ii) the workhours of all the groups must be equal; (iii) each group has the same number of duties, and the rhythm is identical for all [Therefore, the distribution of days off is identical. In addition the duties to be done on specific weekdays are equal for all (eg, every employee does the same number of night shifts on Sundays). Furthermore, all persons are scheduled to work for the whole cycle length.]; (iv) the staffing level of a shift on a given weekday is constant (eg, on Sunday morning).

These constraints lead to blind spots. Only a subset of the rotas possible can be represented (at least directly). Often schedulers intend the mentioned constraints. Then this representation may spare effort. Still, in some cases, sticking to the classical representation hinders the development of rotas that might be of interest.

Limited options due to the predefined cycle length

Obviously rotas that build upon a monthly basis cannot be represented in the classical representation. This limitation might not be a detriment if designers intend weekly patterns. But there do exist further limitations. The preceding example of the basic series, as well as some other rotas, cannot be represented in the classical representation without extensions. To name a few, the following interesting rotas for 5 groups for continuous work (represented as basic series) are not within the scope of the classical representation:

MMEENN - - - - (length 10 days, cycle length 10 weeks)

MM-EENN - - - (length 10 days, cycle length 10 weeks)

MMM-EEE - - NNN - - - (length 15 days, cycle length 15 weeks)

If we ignore constant shift systems and assume equal staffing levels, then basic series that do not meet the following constraints cannot be represented by the classical representation: (i) the length of the basic series in days must be a factor of the length of the classical representation; (ii) the length of the basic series in days must be a multiple of the number of groups.

Given 4 groups and a continuous rota, only series with 4 or 28 days can be represented in the classical representation. Other series with lengths of 8 days, 12 days, 16 days, and so forth, that might be of interest cannot be represented in the classical representation. An extended classical representation or a full-by-groups representation is needed.

Rotas with different workhours — only partially possible

Reducing workhours is an important approach in improving rotas. General reductions in workhours are not always feasible. Still, it is often profitable for part of the work force to do fewer than standard workhours. For example, older employees may want to reduce their hours or at least their hours in shift work. Overtime or supplements may be paid in the form of reduced workhours instead of cash. Part-timers might be integrated, and persons from other departments might cover parts of a rota.

The classical representation allows the integration of part-timers (i) by building up full groups with, for example, part-timers (10) and (ii) by using separate rotas [eg, the weekend shifts being covered by different groups (8)]. These strategies may be useful. They ease the design process from an ergonomic point of view, since the design of rotas for part-timers and full-timers differs. Still, a high number of potentially relevant rotas that might better exploit the benefits of merging full- and part-timers cannot even be investigated.

Rotas with a different distribution of shifts — not possible

Again, the development of rotas with, for example, differing numbers of night duties, duties on weekends, and the like is not possible directly. This type of system might be of interest in developing rotas for persons with specific requirements, for example, for older persons or for persons with young children. A further important restriction has to be emphasized. It is not possible to represent a rota that exploits variations (eg, a trainee working 3 weeks in the department). If the classical representation is used, several rotas that complement each other have to be developed. Whether a merged rota is better cannot be investigated.

Rotas with different staffing levels — not possible

Different staffing levels can be covered by the classical representation if they differ from day to day (eg, each Friday night only half of the employees being necessary). However, if these variations do not occur on a weekly basis, they cannot be covered directly in the representation. For example, every 3rd week there is an educational course; every 2nd week only half the employees are needed in the night shift due to maintenance; every 4th week there is a change from high load (continuous work) to semi-continuous work; and after 20 weeks of rota A, a change to rota B should be scheduled. Again, a split into several rotas that complement each other is necessary, and it is unclear whether the split leads to better rotas in all cases.

"Blind spots" of other representations

Basic series

Basic series allow more rotas than the classical representation; still they share most of the restrictions described in the last section (rotas with different workhours only partially possible and rotas with a different distribution of shifts and different staffing levels not possible). In addition, not all cycle lengths are allowed. The cycle length in weeks has to be a multiple of the number of groups. Besides, there is an even more important drawback. The typical basic series does not take advantage of weekends very well. In some cases this limitation is not much of a problem (eg, if the length of the series is not close to a multiple of 7 and the number of consecutive days off is high). But in other cases it is. For instance, the example given in figure 2 has only 1 weekend out of 8 completely off.

Extended classical representation

The extended classical representation also shares most of the limitations of the classical representation. The main differences are that it does not predetermine the cycle length very strongly (eg, given 4 groups, cycle lengths' of 8, 12, 16, etc, weeks are feasible). Hence it also allows for staffing levels on a given weekday to vary over weeks (eg, every 2nd week only half the employees are needed in the night shifts because of maintenance).

Full-by-groups

Full-by-groups does not impose restrictions on the design of rotas that build upon weeks. Still, it requires much space. At the same time it allows a combination with a calendar to ease insight into calendar-specific pros and cons.

Representation by month — hospitals

Representation by month imposes no restrictions on design. Therefore it seems to be more adequate for service industries and hospitals, as changing requirements, high fluctuation, short-term assignments, and different weekly workhours are to be considered. The restrictions imposed by the classical representation do not allow such rotas to be developed.

The only relevant technical restriction is short cycle length. Several rotas cannot be used (eg, the example given in the introduction) due to the limitation of a maximum length. Furthermore, it is difficult to maintain a fair balance of strenuous duties between staff members. An advantage of this representation is that it facilitates taking legal and administrative regulations that are based on month into account.

Assessment of rotas

Obviously, the representations differ substantially in their size. However, the effort to assess rotas varies greatly. In the following discussion we have used the rota presented in figure 2 to illustrate the effort necessary to assess 3 representations (basic series, extended classical, full-by-groups).

All the representations discussed share a drawback. As shifts are represented by letters, it is not immediately visible that a night shift impairs the next day. For example, weekends are strongly impaired by night shifts on Fridays. This limitation could only be overcome by a different representation, in which the position of each shift becomes immediately visible, or by the addition of another symbol (eg, "*") to mark such impaired days off.

The basic series allow immediate assessment of most ergonomic criteria (night shifts in a row, duties in a row, number of consecutive days off, rest hours between

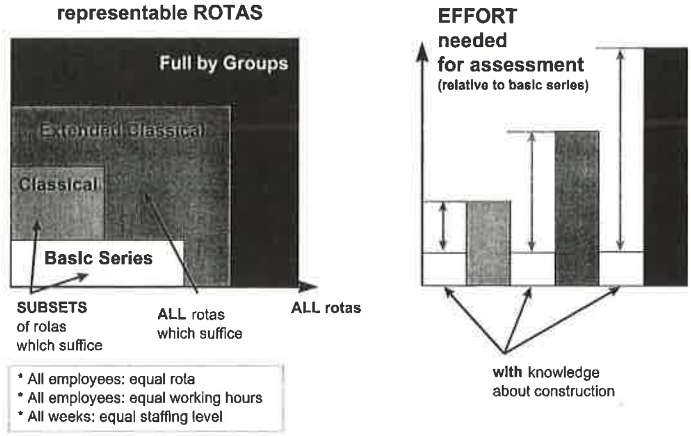

Figure 3. Qualitative description of representable rotas and the effort needed to assess different representations.

duties). Others are easily assessed by simple computations [cycle length, number of days off (number days off = days off in basic series $\cdot$ 7 $\Rightarrow 2 \cdot 7 = 14$), number of blocks of consecutive days off (number blocks off = number blocks off in basic series $\cdot$ 7 $\Rightarrow 1 \cdot 7 = 7$), number of weekends off[2]]. To assess the impairment by night shifts before the days off, the formulas for assessing basic series can be easily adapted. Each length of a block of days off that is preceded by a night shift is reduced by one. (To continue the example: 7 days are really off (in 8 weeks), no weekend is really free). These computations may not be broadly known, but they are quickly learned. Weekly workhours and the distribution of weekends off over the cycle [discrete mathematics: 8 (length of basic series) = 7 (length of week) + 1; therefore, the weekends completely off and partially off are close to each other] can be roughly assessed too.

The assessment of these criteria in the extended classical and in the full-by-groups representations makes substantial counting necessary. If readers know that the rota of each group is the same, the effort for these 2 representations is somehow similar. The representation full-by-groups is longer, but it makes the reading of only one line necessary (with less line breaks). Still, if the reader is not sure about the equality of the rotas for each group, it is necessary to check equality first.

Given that readers are familiar with basic series and their corresponding computations, basic series are superior to the other representations. The effort for assessment differs roughly by a factor of 7 for the example rota. Still, not all rotas can be represented with basic series, and it is difficult to optimize weekends. The computational advantage of the representation in basic series also declines if readers know that the rota represented in the extended classical or full-by-groups representations is built upon a basic series. Then only the basic series and eventual adaptations (eg, weekends) have to be assessed.

Using an exemplary complexity analysis, we can analyze the rest hours between duties, the number of night shifts in a row, and the rest hours after the night shifts. Let us define the corresponding effort to analyze the basic series of figure 2 as a basic assessment unit. The effort in the other representations is then as follows: If readers know that rotas are built upon a basic series, then 1 unit (effort for basic series) is needed. Otherwise, if readers know that the rota is equal for all groups (by using the extended classical representation of equality analysis), then 7 units are needed; otherwise 4 groups $\cdot$ 7 units = 28 units. In this simple example the differences peak at 28 times the effort for a basic series as a maximum. Two issues stand out. First, it is useful to choose the simplest representation capable of covering the design task. (short) basic series are the simplest. Classical and extended classical representations are simpler than a full-by-groups representation. The differences are substantial. Given that the design of rotas in the classical representation is already very complex, a full-by-groups representation is hardly feasible without computer support. Second, knowledge of how the rota was designed may slash the effort to analyze it. In other words, more complex representations can be used if readers know how the rota at hand was developed.

Concluding remarks

The representations discussed in this paper differ strongly in their power to represent all possible rotas. In addition they can differ heavily in the effort needed for the assessment of rotas. This effort again depends on the reader's knowledge of the construction technique applied.

Figure 3 presents different representations and their corresponding representable rotas. On the right side a

2 Weekends off = $\sum_{\text{for each block}_i \text{ of days off in the basic series}} \text{length(block}_i) - 1 \Rightarrow \sum_{\text{one block}} 2 - 1 = 1.$

sketch of the effort for the assessment of typical rotas is given. The effort needed varies with the construction technique applied and with the knowledge of readers about the construction. An exemplary quantitative analysis of the number of rotas representable in each representation is given in the appendix.

Therefore, it is appropriate to use several representations in the design and to change between these representations (eg, basic series for sketches and classical, extended classical, full-by-groups for refinement). Knowledge about the construction of a rota should be maintained. Furthermore, one has to be aware of the limits of each representation to avoid any omission of relevant solutions. Designers of rotas, as well as of computer systems for rota design, should thoroughly consider which representation to choose. They should ideally allow a smooth transition between different representations to grant the exploitation of the benefits of each.

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References

1. Wedderburn A, editor. Guidelines for shiftworkers. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1991. Bulletin of European studies on time, no 3.
2. Schwarzenau P, Knauth P, Kieswetter P, Brockmann W, Rutenfranz J. Algorithmen zur computergesteuerten Schichtplangestaltung nach arbeitswissenschaftlichen Kriterien. Z Arbeitswiss 1984;38/3:151—5.
3. Knauth P. Computergestütze Gestaltung diskontinuierlicher Schichtpläne nach arbeitswissenschaftlichen Kriterien. Z Arbeitswiss 1987;41/4:221—6.
4. Nachreiner F, Qin L, Grzech H, Hedden I. Computer aided design of shift schedules. Ergonomics 1993;36/(1—3):77—83.
5. Gärtner J. Design tools for shift schedules, 1997. Int Ind Ergon. In press.
6. Institute for Public Program Analysis. Work schedule design handbook — methods for assigning employees' work shifts and days off. St Louis (MO): Institute for Public Program Analysis, 1978.
7. Industriegewerkschaft Chemie. Vollkontinuierliche Schichtarbeit und Arbeitszeitverkürzung Eigenverlag: Tagungsbericht; Dec. 1992. Hannover: IG Chemie, 1990.
8. Knauth P. Categories and parameters of shiftwork systems. In: Colquhoun PW, Costa G, Folkard S, Knauth P, editors. Shiftwork — problems and solutions. Frankfurt: Peter Lang — Europäischer Verlag der Wissenschaften, 1996. Arbeitswissenschaft in der betrieblichen Praxis, no 7:17—28.
9. Knauth P. Design of shiftwork systems. In: Colquhoun PW, Costa G, Folkard S, Knauth P, editors. Shiftwork — problems and solutions. Frankfurt: Peter Lang — Europäischer Verlag der Wissenschaften, 1996:155—174. Arbeitswissenschaft in der betrieblichen Praxis, no 7.
10. Knauth P. Innovative Arbeitszeitmodelle für Frauen. Personal 1992;44/12:566—71.

Appendix

Number of rotas that can be represented

Simplifying assumptions

Continuous rota should be used with the cycle length in weeks. Each group must do the same number of duties of each kind of shift. On each day, 1 group is assigned to each shift. No other requirements (eg, rest hours) are considered. Unfortunately, it was not possible to develop a closed formula to compute the size of the solution space so far. Therefore a substantially overestimating upper limit of possible rotas (ro) has been used.

Basic series

Let s be the number of shifts per day. The length of the basic series is a multiple (n) of the number of groups (g). If the basic series is written in n columns with the height g, then each row must meet the staffing level requirement. The number of days off in each column (o) is calculated as $o = g - s$. Rotas that have the same sequence of shifts but start on different days are eliminated by division by the number of groups. Then the upper limit is $ro = (g!/o!)^n \cdot (1/g)$.

Classical representation

The classical representation can be considered as a specific case of the basic series with $n = 7$. Correspondingly: $ro = (g!/o!)^7 \cdot (1/g)$.

Extended classical representation

The extended classical representation can be considered as a specific case of the basic series with $n = 7 \cdot m$, where m is the number of weeks needed for representing the rota. Correspondingly: $ro = (g!/o!)^{7 \cdot m} \cdot (1/g)$.

Classical

cycle length in weeks	l	5	Groups	g	5
possible rotas	ro	6 E+11	Shifts	s	3

Basic Series

number of rows	n	1	2	3	4	5	6	7	8	9	10
cycle length in weeks	l	5	10	15	20	25	30	35	40	45	50
possible rotas	ro	12	720	43200	2592000	2E+08	9E+09	6E+11	3E+13	2E+15	1E+17
representable in Classical		YES	NO	NO	NO	NO	NO	YES	NO	NO	NO

Extended Classical

represented weeks	m	1	2	3	4	5	6	7	8	9	10
number of rows	n	7	14	21	28	35	42	49	56	63	70
cycle length in weeks	l	5	10	15	20	25	30	35	40	45	50
possible rotas	ro	6 E+11	6 E+11	6 E+11	6 E+11	6 E+11	6 E+11	6 E+11	6 E+11	6 E+11	6 E+11

Full by Groups

represented weeks	m	5	10	15	20	25	30	35	40	45	50
number of cells	n	35	70	105	140	175	210	245	280	315	350
cycle length in weeks	l	5	10	15	20	25	30	35	40	45	50
possible rotas	ro	3 E+61	6 E+123	1 E+186	2 E+248	#	#	#	#	#	#

Figure. Rotas representable in each representation for 5 groups and 3 shifts.

Full-by-groups representation

The full-by-groups representation can also be considered as a specific case of the basic series with $n = 7 \cdot g \cdot m$ (ie, a much longer rota). Correspondingly:
$ro = (g!/o!)^{7 \cdot g \cdot m} \cdot (1/g)$.

Comparison

With the use of a maximum cycle of 350 days, the number of rotas shown in the figure above are representable.

Not each rota that is representable in the basic series is also representable in the classical representation. Their number is huge in theory. Practically only short basic series are of relevance. In the case of short basic series their relatively small number makes screening for interesting solutions easier. All basic series can be represented by the extended classical model. All rotas representable by the extended classical model can be represented in the full-by-groups representation. The huge number of possible solutions with the full-by-groups representation makes the need for design strategies obvious.

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A technique to take leave into account in shift-rota design

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Sick leave, vacations, and the like lead to substantial leave factors. Rota design techniques for covering leave are not always feasible. A small company was helped to develop a new rota. The main requirements were an ergonomically better rota, less overtime caused by leave, and a rota that lets employees take their vacation during the summer. The internal evaluation was unanimously positive after 1 year. A prospective leave coverage was used, with different workhours during summer and spring and with a mixture of shift work and flexible day work. Later the rota was further refined, and broader qualifications of the workers made a much simpler rota possible. The experiences of this study indicate that problems with leave can be reduced if expected variations in leave are considered in the rota design by including variations in workhours. A further promising strategy is to mix shift work with other types of work when time is not a critical factor.

Key terms assessment of shift rotas, computer-supported shift scheduling, flexible workhours, leave, shift scheduling.

Sick leave, vacations, and the like lead to substantial leave factors [eg, the Austrian chamber (1) of commerce suggests 15% of total work time as the average]. The amount of leave can vary strongly from company to company, from industry to industry, and from nation to nation. Nevertheless it always has substantial magnitude. In addition to the magnitude of leave, it is only partially known in advance at what times leaves will actually occur.

Companies use the following strategies in dealing with leave:

- In some industries (eg, the automobile industry) the technique of company vacations ("Betriebsurlaub") helps to reduce complications. "Betriebsurlaub" means that the entire work force, or at least the bigger part of it, is on vacation for some weeks. This practice reduces leave during the year and allows time for maintenance work. Still it is only partially feasible (eg, because of the customers' need for continuous supply, technical factors, costs).
- Many tasks can be handled with a work force reduced by leave, if workers can postpone or discard less important tasks or try to compensate by working harder.
- Workers from other departments, temporary workers and the like can help out. Such additional workers then carry the work load on short notice.
- In cases of shift work the size of each shift group is sometimes increased in proportion to the leave factor (reserve). The advantage of this strategy is that it is fairly simple and does not require additional planning. But this strategy has 2 main drawbacks. First, the number of reserve workers remains constant, whereas leave occurs unevenly (especially the demand for vacation). Second, this strategy is very expensive for small groups as it substantially increases the number of workers. Such small groups not only have to be considered in small plants, rotas for small groups also arise if different qualifications are crucial (eg, if electricians and mechanics are needed, and only a few persons have both qualifications).
- For small groups and for peaks of leave that are not covered by augmented groups 2 other strategies are used. The typical strategies we know are overtime for

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the workers at hand and dedicated reserve workers. Both strategies lead to work on short notice and often to poor workhours.

Some of these techniques are fairly simple and do not need much planning ("Betriebsurlaub", augmented groups, delaying or discarding work). But they do not always cover the peaks of leave, especially not for small groups. In such cases long hours and extra duties occur on short notice. Both are problematic in general, especially in shift work (2). A short example would be 3 shifts M... Morning (8 hours, 0600–1400), E... Evening (8 hours, 1400–2200), N... Night (8 hours, 2200–0600) with the symbols " " and "–" used as symbols for days off. These symbols are used throughout this article.

Figure 1 shows a simple rota based on the basic series of MMEENN-- with 4 groups and 2 days' difference at the start. The rota is read from left to right starting with the top row. Given 8-hour shifts, it is based on 42 workhours per week.

If people are on leave in this rota, they have to be substituted by members of other teams. The resulting workhours are extremely poor. Assume that a worker of group C gets sick and has to be substituted by a member of another group. Then a possible reaction would be to adapt the rota as shown in figure 2.

A worker of group D is called in, on short notice, and does 2 extra evening shifts (EE). Rest hours are shortened to 8 hours from N to EE and from EE to M. Furthermore, this worker has 14 days in a row of mixed shifts. These are extremely poor workhours. In addition, a worker of group B does 2 morning shifts (EM) on short notice. Given this rota, other solutions are hardly better.

The example highlights the most important problems of this kind of leave management: (i) work on short notice, (ii) long periods of work, (iii) extremely short periods of rest, (iv) overtime, and (v) high costs (overtime payment).

	1 Mo	1 Tu	1 We	1 Th	1 Fr	1 Sa	1 Su	2 Mo	2 Tu	2 We	2 Th	2 Fr	2 Sa	2 Su
A	M	M	E	E	N	N			M	M	E	E	N	N
B			M	M	E	E	N	N			M	M	E	E
C	N	N			M	M	E	E	N	N			M	M
D	E	E	N	N			M	M	E	E	N	N		

Figure 1. A simple rota for continuous work. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night)

	1 Mo	1 Tu	1 We	1 Th	1 Fr	1 Sa	1 Su	2 Mo	2 Tu	2 We	2 Th	2 Fr	2 Sa	2 Su
A	M	M	E	E	N	N			M	M	E	E	N	N
B			M	M	**EM**	**EM**	N	N			M	M	E	E
C	N	N		**Sick**	**Sick**	**Sick**	E	E	N	N			M	M
D	E	E	N	N	**EE**	**EE**	M	M	E	E	N	N		

Figure 2. A simple rota for continuous work with assignments to cover leave. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night)

Such problems even accumulate during summertime when most people take their vacations. Sometimes managers may even drop the rota altogether.

In this article we describe a different technique, one developed in a small company. From the beginning we took leave into account in the rota design, using both different workhours and different rotas for spring and summer. The rotas developed were used for a year, internally evaluated, and then refined in the 2nd year. Our experiences indicate that these techniques actually allow substantial improvements in workhours.

Case

First year

A shop steward of a small plant with continuous work asked us to support the company in developing a new rota. The existing rota for spring and summer was built on the series (MMEENN--). Several years ago, they had a slow forward rotating rota. They preferred the quick forward rotation. The average number of workhours was supposed to be 38.0. Four workers were needed from Monday to Sunday, 24 hours a day. In addition, 1 person from Monday to Friday did repairs for 8 hours. Another person was assigned to do extra shifts to cover planned and unexpected leave. People should have extra days off to stay within the number of workhours agreed upon. Overall 18 persons were employed. A "Betriebsurlaub" of the plant in summer would have been the easiest way to facilitate vacations and reduce variations in leave, but it was not feasible due to the technical difficulties of stopping the facility and due also to reasons of capacity.

The main requirements for the new rota were (i) an ergonomically better rota, (ii) less overtime caused by leave, (iii) a rota which lets the employees take their vacations in summertime. The main focus with respect to ergonomics was on reducing differences between the agreed rota and the actual workhours. Sick leave caused a high number of short-term changes (eg, extra duties, switches to other shift groups) with very poor workhours (eg, poor shift changeovers, high number of duties in a row). At the same time, the advantages of the old rota MMEENN-- (eg, quick forward rotation) should also be included in the new rota. Weekends should be improved if feasible. Regarding vacations, people complained that they could not go on vacation. Generally they still had their entire vacation left over from the previous year (5 to 6 weeks).

The task was to design a rota for 32 weeks in the spring and summer. In the autumn again a rota with MMEENN-- was used, but this time on the basis of a 42-hour week and with more work force. In the autumn no vacations were allowed. In addition there was no reserve for sick leave as the 18 employees and some others were assigned to work only on that facility. If someone got sick, fewer people worked in the plant. This rota should not be changed because it was effective and employees did not want to lose the high salaries they earned for 42 hours per week.

In 3 workshops we developed a new rota using computer support (3). The analysis of leaves showed that 20 workers instead of 18 were needed to take leave fully into account. This change should have substantially reduced the overtime indirectly caused by leaves. The reduction should have led to decreased costs (overtime supplements being 50% to 100% depending on the day of the week). The management agreed to employ these 2 additional workers and also prepared their qualification.

The problem of leave was the most dominant. We therefore analyzed leave data from the previous year. The idea of 2 different rotas emerged in order to prepare for different leaves in the spring and summertime. The hours of leave of the previous year (weeks 6 to 37) and the amount of reserve to be scheduled is illustrated in the figure 3. The hours shown represent the total hours of leave of the whole work force (eg, 280 hours ≈7 persons on leave). Before the necessary level of reserve was calculated, the decision was made that more maintenance shifts per week should be scheduled and, in exchange, be used both for the nontime-critical repair work and reserve shifts. To establish the level of reserve needed, the average hours of leave were calculated as 166.31 hours per week during springtime and 261.20 hours per week during summer. At least 5 maintenance shifts per week (5 shifts × 8 hours = 40 hours) were necessary. Only full-time employees with 38 hours per week should be employed.

The first rotas developed had a higher number of workhours in summer (42 hours) and reduced workhours in the spring (about 35.6 hours). Higher workhours in summer led to more duties per employee and hence to higher reserves. The reserve was very high to allow more vacations than had been taken the year before. The length of these 2 periods (spring = 20 weeks, summer = 12 weeks) reflected early decisions on the basic series of the rota chosen and the aim to meet the number of workhours agreed upon for the full period. Thus the level of reserve (= the number of workhours in maintenance shifts) was set at 208 extra workhours per week during springtime and 336 extra workhours per week during summer. In autumn and in winter no reserve was to be scheduled. Therefore, no leave data for these periods were analyzed.

The working group decided that each worker should do reserve shifts [a concept similar to the flexible shifts discussed earlier by Knauth (4)]. Repairs were not time critical. We therefore exploited maintenance work as a reserve buffer. If workers were not needed to cover leave, they were assigned to do repairs. The name of the maintenance shift was Ma. During the spring 3–4 persons per day did reserve duties (= maintenance duties); during the summer there were 6 persons for this purpose.

The design of the rota varied around 2 basic series and additional parts for the maintenance work: MMEENN---- for spring (a 10-week rota) and MMEENN-- for summer (an 8-week rota).

Theses series were sometimes replaced by blocks of 3–6 maintenance shifts in a row followed by 2–4 days off. During the summer period the maintenance blocks were inserted in quicker succession. In addition 2 qualification teams, A (12 persons) and B (8 persons), had to be considered, the result being that B had more maintenance shifts than A. Two short parts of the rota for the first weeks of the spring and the summer rota are shown in figures 4 and 5, respectively. Please note that each group's rota is written on a single line.

A lack of appropriately qualified workers also made the design difficult. We had to ensure that sufficient persons of qualification B were scheduled for each day.

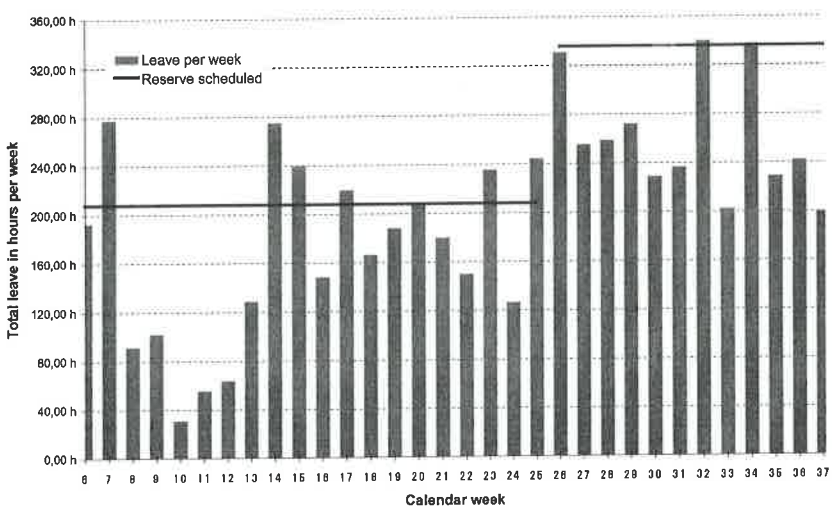

Figure 3. Total hours of leave among the work force in the spring and summer of the previous year and the reserve scheduled (weeks 6 to 37).

	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A.1	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma			M	M	E	E	N	N					M	M	E	E	N	N
A.2	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma			M	M	E	E	N	N					M	M	E	E	N	N
A.3	M	M	E	E	N	N					M	M	E	E	N	N					M	M	E	E	N	N		
A.4	M	M	E	E	N	N					M	M	E	E	N	N					M	M	E	E	N	N		
A.5	E	E	N	N					M	M	E	E	N	N					M	M	E	E	N	N				
A.6	E	E	N	N					M	M	E	E	N	N					M	M	E	E	N	N				
A.7	N	N					M	M	E	E	N	N					M	M	E	E	N	N			M	M	E	E
A.8	N	N					M	M	E	E	N	N					M	M	E	E	N	N			M	M	E	E
A.9					M	M	E	E	N	N					M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma
A.10					M	M	E	E	N	N					M	M	E	E	N	N			Ma	Ma	Ma	Ma		
A.11			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma	Ma				M	M
A.12			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma	Ma					M	M
B.1	M	M	E	E	N	N					Ma	Ma	Ma	Ma			M	M	E	E	N	N					Ma	Ma
B.2	E	E	N	N					Ma	Ma	Ma	Ma			M	M	E	E	N	N					Ma	Ma	Ma	Ma
B.3	N	N			Ma	Ma	Ma	Ma	Ma				M	M	E	E	N	N					Ma	Ma	Ma	Ma		
B.4					Ma	Ma	Ma	Ma			M	M	E	E	N	N					Ma	Ma	Ma	Ma			M	M
B.5			Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E
B.6	Ma	Ma	Ma	Ma			M	M	E	E	N	N				Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N
B.7	Ma	Ma			M	M	E	E	N	N					Ma	Ma	Ma	Ma			M	M	E	E	N	N		
B.8			M	M	E	E	N	N					Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma

Figure 4. First 4 weeks of the spring rota (rota for each group in a separate row) showing longer periods of days off and maintenance shifts. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

	21	21	21	21	21	21	21	22	22	22	22	22	22	22	23	23	23	23	23	23	23	24	24	24	24	24	24	24
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A.1			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma
A.2			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M
A.3			M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M
A.4	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma		
A.5	Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma
A.6	M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E
A.7	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma
A.8	M	M	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E
A.9	E	E	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N
A.10	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N
A.11	N	N			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N		
A.12	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			M	M	E	E	N	N		
B.1	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N
B.2			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M
B.3	Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E
B.4	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma
B.5	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma		
B.6					M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N		
B.7	M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma	Ma	Ma
B.8			M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M	M	E	E	N	N			Ma	Ma

Figure 5. First 4 weeks of the summer rota (rota for each group in a separate row) showing shorter periods of days off and maintenance shifts. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance))

	20	20	20	20	20	20	20	21	21	21	21	21	21	21
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A.1		M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma
A.2		M	M	E	E	N	N	Ma	Ma	Ma	Ma	Ma	Ma	
A.3	Ma			Ma	Ma	Ma	Ma	Ma	Ma	Ma	Ma			M
A.4	Ma	Ma			Ma	Ma	Ma	Ma	Ma			M	M	E
A.5	M	E	E	N	N					M	M	E	E	N
A.6	M	E	E	N	N					M	M	E	E	N
A.7	E	N	N					M	M	E	E	N	N	
A.8	E	N	N					M	M	E	E	N	N	
A.9	N					M	M	E	E	N	N			M
A.10	N					M	M	E	E	N	N			Ma
A.11				M	M	E	E	N	N			M	M	E
A.12				M	M	E	E	N	N			Ma	Ma	Ma
B.1	N											M	M	E
B.2			Ma	Ma	Ma	Ma	Ma			M	M	E	E	N
B.3	Ma	Ma	Ma	Ma				M	M	E	E	N	N	
B.4	Ma	Ma	Ma			M	M	E	E	N	N			Ma
B.5				M	M	E	E	N	N			Ma	Ma	Ma
B.6		M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma
B.7	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma	
B.8	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma			M

Figure 6. Transition between spring and summer rota without adjustments leading to prohibited and unfavorable changeovers. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

Only 8 persons had qualification B. In every shift at least 1 person with B qualifications was needed. The problems of qualification resulted in several refinements of the rota. Otherwise the design of the rota for each period was not difficult.

Much care had to be taken to plan the transition between these periods to meet the demands for the individual worktime agreed upon and to avoid prohibited or unfavorable shift changeovers. The main technique was to develop the plans separately and then look for ways to assign the rotas to persons that met the requirements as close as possible. Consider the rota at the transition between the 20th and the 21st week. If the rota were to be continued as shown in figure 6, person A.2 would have a prohibited changeover, person A.4 would have 8 duties in a row, and person B.1 would not only have a considerable advantage over all the other workers in team B (10 days off) but would also build up a big difference between the individual worktime agreed upon and the actual workhours.

To reach a more equal distribution of shifts and ensure that each person met the individual worktime agreed upon, rota assignments for weeks 21–32 were changed according to figure 7.

By these adjustments the number of shifts can be distributed more evenly. As the overall rota may look confusing, individual and reordered schedules were compiled.

As rotas were similar in their basic rhythms in the spring, summer, and autumn (all based on MMEENN and some days off), there was finally no changeover with less than 2 days off and no period of work with more than 6 duties. The worktimes agreed upon were met rather closely (overall differences in weeks 1–32 slightly more than 1 duty at most). The differences in worktime were to be balanced by future switches between rotas.

The rota started at the end of January 1996, after extensive discussion between the shop stewards and all the employees. The discussions took a great deal of time, but the prospect of real opportunities for taking vacations was the basis of acceptance for the new rota. The rota was used until autumn. The internal evaluation by both the management and the shop stewards (made in a 1-day workshop in autumn) was unanimously positive. Overtime and extra duties were close to zero. Short-term changes were close to zero. Only in an ill-scheduled week with a lot of further education were some extra shifts needed. People could take their vacation. Sick leave dropped from 7% to 3.31%, people were on vacation for an average of 268 hours.

Second year

The management and shop stewards wanted further improvements, since the workhours and the reserve were considered too high in summertime with respect to the reduced amount of sick leave. The workers did not like to work an average 42 hours and took vacation whenever they could, especially to avoid single maintenance shifts (ie, when the maintenance block was partially used for leave and partially used for maintenance).

We developed a new rota in a 1-day workshop, again using the maintenance shifts as a buffer. The differences in workhours between the summer and spring were reduced. Repair work was grouped more strongly, and broader qualifications made a much simpler rota possible since there were now 10 persons with qualification B instead of 8. It was no longer necessary to build a rota for 2 different groups. Only 1 group (C) with 20 persons (C1, C2, C3, ...) was used. The basic series (both 20 days) for the summer and spring became MMMEEE--NNN---MaMaMaMa-- (39.2 h) and MMMEEE--NNN---MaMaMa--- (36.4 h), respectively.

The group members with the critical qualification were assigned to C1, C3, C5, and so forth. By construction we thereby made sure that, on each day, each shift had at least 1 person with qualification B. The design of the rota was extremely simple. In addition the transition between spring and summer did not impose any problems.

The rota for the autumn was not changed. Transition to the rota for autumn was not difficult since there was a reordering of groups such that they phased into the new rhythm without problematic changeovers.

This time the discussion was easier for the shop stewards. The rota was immediately accepted by the employees. The management also liked the much simpler structure.

	20	20	20	20	20	20	20	21	21	21	21	21	21	21
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A.1		M	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma
A.2		M	M	E	E	N	N			M	M	E	E	N
A.3	Ma			Ma	Ma	Ma	Ma			M	M	E	E	N
A.4	Ma	Ma			Ma	Ma	Ma	Ma	Ma			M	M	E
A.5	M	E	E	N	N			Ma	Ma	Ma	Ma	Ma	Ma	
A.6	M	E	E	N	N			M	M	E	E	N	N	
A.7	E	N	N					Ma	Ma	Ma	Ma			M
A.8	E	N	N					M	M	E	E	N	N	
A.9	N					M	M	E	E	N	N			M
A.10	N					M	M	E	E	N	N			Ma
A.11				M	M	E	E	N	N			M	M	E
A.12				M	M	E	E	N	N			Ma	Ma	Ma
B.1	N							Ma	Ma	Ma	Ma			M
B.2			Ma	Ma	Ma	Ma	Ma			Ma	Ma	Ma	Ma	Ma
B.3	Ma	Ma	Ma	Ma				Ma	Ma	Ma	Ma	Ma	Ma	
B.4	Ma	Ma	Ma			M	M	E	E	N	N			Ma
B.5				M	M	E	E	N	N			Ma	Ma	Ma
B.6		M	M	E	E	N	N					M	M	E
B.7	M	E	E	N	N			M	M	E	E	N	N	
B.8	E	N	N			Ma	Ma			M	M	E	E	N

Figure 7. Transition between spring and summer rota with adjustments leading to legally and ergonomically acceptable changeovers. (Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fr = Friday, Sa = Saturday, Su = Sunday, M = morning, E = evening, N = night, Ma = maintenance)

Concluding remarks

Two issues stand out given our experiences thus far. First, in both design projects, we worked with a prospective leave coverage, with different workhours in summer and spring as well as with a mixture of shift work and flexible day work. These techniques allowed substantial improvements in the actual workhours since we were able to use known differences between the leave caused by demand for vacations in the spring and summer. Still, the difference between the workhours in summer and spring should not vary too strongly. In addition a certain degree of regularity and forseeability of the vacations was necessary for applying these planning techniques. However, in our experience, typical patterns of leave caused by vacations can be identified in most companies with slight regional, social demographic, and sectoral differences.

Second, qualifications may be crucial in allowing for simpler rota design and a merging of tasks. Not only were plant workers able to do maintenance, which was the basis of the actual design, but also the broader qualification in the 2nd year made it possible to abolish any internal differentiation within the rota. Therefore, a rather simple basic series could be applied. It was enough to distribute the specific qualification evenly.

More generally, the following 4 promising strategies for taking leave into account were devised:

1. Expected leave variations can be considered in the rota design by defining periods of different workhours.

2. Merging shift work with other work regimes may reduce work load and, given that this additional field of work is less time critical, allow a build up of reserve buffers. Qualification, however, is a critical issue in this respect.

3. If leave cannot be covered by other means, rotas can be built upon flexible reserve shifts. Such rotas should work with reduced workhours that take these extra shifts into account on short notice. In such a shift system, these extra shifts are not overtime; instead they are part of the regular workhours. The ergonomic quality of such a rota should be higher, as overall workhours are lower and time-off is increased as overtime is decreased. Still, a bargaining solution might be appropriate to soften the corresponding reduction in income.

4. The times within the rota in which employees can expect to have flexible duties to cover leave should be discussed in advance. This discussion reduces the insecurity the employees feel about their freetime. In addition possible conflicts with ergonomic requirements (eg, rest hours) can be checked in advance.

References

1. Kreiser H. Der Preis einer Arbeitsstunde. Wien: Wirtschaftskammer, 1996. Schriftenreihe des Wirtschaftsförderungsinstituts 282.
2. Wedderburn A, editor. Guidelines for shiftworkers. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1991. Bulletin of European studies on time, no 3.
3. Gärtner J. Design tools for shift schedules, 1997. Int J Ind Ergonomics. In press.
4. Knauth P. Design of shiftwork systems. In: Colquhoun PW, Costa G, Folkard S, Knauth P, editors. Shiftwork — problems and solutions. Frankfurt: Peter Lang — Europäischer Verlag der Wissenschaften, 1996. Arbeitswissenschaft in der betrieblichen Praxis, no 7.

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Diurnal trends in mood and performance do not all parallel alertness

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Owens DS, Macdonald I, Tucker P, Sytnik N, Minors D, Waterhouse J, Totterdell P, Folkard S. Diurnal trends in mood and performance do not all parallel alertness. *Scand J Work Environ Health* 1998;24 suppl 3:109—114.

Objectives This study examined the hypothesis that alertness can be used to predict time-of-day effects on performance.

Methods For 6 or 7 days the volunteers (24, highly preacticed young women) were required to retire to bed at 0000 and were awakened at 0800. A battery of mood and performance tests was completed every 2 hours while the women were awake; the result was 9 equally spaced measures per day. Measures of mood, serial reaction time, and memory scanning were recorded. Rectal temperature was recorded continuously.

Results After omitting the data from the first day to avoid any carry-over from the "first-night" effect on sleep, average time-of-day functions were calculated for each subject, for each variable, and were then z-transformed. Cross-correlations between the pooled time-of-day trends indicated that, while alertness was a reasonably good "predictor" of the simple perceptual-motor speed measures, it fared less well for some of the other measures. Two-way analyses of variance indicated that the time-of-day trend for all measures differed from that for alertness, although the magnitude of this difference varied substantially and, for some measures, was very largely due to the last reading of the day (0000).

Conclusion It is clear from these results that, while alertness may successfully "predict" variations in some measures of performance capability, and especially those of simple perceptual motor speed, care should be exercised in extrapolating to other performance measures.

Key terms circadian, memory, psychological functioning, reaction time.

Although similarities in mood and performance rhythms have been reported by some authors (1,2), others have concluded that rhythms in performance are not simply the direct result of circadian variations in mood (3). Nevertheless, over the past 10 years the 3-process model of alertness has been developed, validated, and used to predict diurnal variations in alertness (4—9), sleep latency (4,10), duration (4,11), and hits on a 30-minute vigilance task (6). More recently it has been suggested that alertness can be used to predict psychological performance (4). This suggestion implies that all performance measures show a similar time-of-day trend towards alertness, a prediction that the current paper aims to examine.

Measures of subjective alertness are quicker and easier to obtain and less disruptive to a normal schedule than the assessment of performance; thus predicting performance from alertness is an attractive idea that could prove to be extremely valuable in an applied setting. An alertness nomogram (4) has been developed to predict low levels of alertness among shift workers dependent upon the time of day and length of time since their last sleep. A similar nomogram predicting performance could be invaluable for determining the safety implications of various types of work and could potentially be used in the development of safer shift systems.

The tasks employed in the present study ranged from relatively simple measures, such as response speed on a serial reaction-time task, to more demanding tasks calling for considerable working memory involvement. Thus we were able to examine the relationship between

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alertness and a wide range of other psychological functions that placed varying demands upon the highly practiced volunteers.

Subjects and methods

Subjects

Twenty-four female undergraduates aged 18—30 (mean 19.98) years participated in a series of experiments. All of them gave their informed consent and were pronounced medically fit by a medically qualified doctor.

Procedure

The volunteers attended a training session with the experimenters 2 weeks prior to the start of the study. At this session the use of hand-held computers (PSION organisers, see reference 12) to be used to collect the data was explained to them and the importance of familiarizing themselves with the tests prior to the start of the study was emphasized. The volunteers were asked to practice performing the battery of tasks at 2 hourly intervals while awake for 8—10 days during the fortnight preceding the start of the study. An average of 64.5 (SD 8.32) practice trials was completed. After the practice days the volunteers entered the experimental facility to which they were confined for a total of 23 or 31 days. Normal time cues were present throughout, including clocks and watches and access to television and radio programs. Ten volunteers were exposed to the natural light-dark cycle through windows. On the afternoon that they first entered the facility, the volunteers were familiarized with the procedures involved in the study, including the continuous recording of rectal temperature. On the subsequent 6 or 7 days they were required to retire to bed at 0000 at night and were awakened by an alarm at 0800 the following morning [mean sleep time 7.03 h (SD 12.09 min)]. It is the data from this period of 24-hour days that is reported.

Tests of mood and cognition were completed at 2 hourly intervals while the volunteers were awake throughout the duration of each study. Meals were consumed at specific times by 16 of the volunteers after awakening each day: breakfast at 0900, lunch at 1300, dinner at 1900, and a bedtime drink 30 minutes before retiring. The remaining 8 volunteers were free to eat whatever and whenever they chose, but were required to keep the timing of meals consistent across the days.

Temperature

Rectal temperature was recorded every 6 minutes using Squirrel Data Loggers (Eltek, Cambridge, England). The mean rectal temperature was calculated using readings taken during the 30 minutes prior to and the 30 minutes following each hour of the day. The means corresponding to the times that the performance tests were completed were analyzed further. Temperature data were not available for 1 volunteer due to technical failure.

Mood scales

Visual analogue (20-point) scales (12) were employed to assess mood both before and after 2 cognitive tests. Three bipolar scales (- to +) were used to measure alertness, calmness and cheerfulness for 8 volunteers in the first experiment. The remaining 16 volunteers completed 9 monopolar scales (0 to +), which were used to compute the 3 bipolar dimensions of alertness [alert+energetic +(20-sluggish)/3], calmness [calm+relaxed+ (20-tense)/ 3] and cheerfulness [cheerful+happy+(20-sad)/3].

Serial reaction time

A 400-trial, serial, 4-choice reaction-time task (12) was completed. An asterisk symbol appeared in 1 of the 4 positions on the handheld computer (PSION) display, each position corresponding to that of 1 of 4 response keys on the keyboard. The volunteer was required to rest the first and second fingers of each hand over the appropriate, spatially compatible response keys and to press the key corresponding to the position of the asterisk as quickly as possible, after which the next stimulus was presented immediately. Three derived measures are reported, namely, mean correct reaction time, accuracy, (ie, the percentage of correct responses), and "gaps" (ie, the percentage of responses above 1 second).

Memory-search task

The memory-search task was based on Sternberg's (13) paradigm. The subject had to remember a set of letters and then indicate whether they were present or not in a series of 40 probes presented one at a time in the middle of the display by pressing the T (true) or F (false) key (12). Four memory sets were presented (1, 5, 3, and 7 letters), each followed by 40 probes.

The number of correct responses (accuracy) was recorded for each memory set. Reaction times to true positive and true negative probes were used to compute the mean correct reaction time. Only the accuracy and correct reaction time data from the low (1 item) and high (7 items) load memory sets were analyzed further. However, to represent the speed (and accuracy) of processing across the different levels of memory load, a regression line was fitted to the mean correct reaction times for each of the memory sets at each time-of-day, and the slope and intercept were calculated. Before a regression line was fitted, a minimum of 80% accuracy had to be achieved on at least 3 of the 4 memory sets at each of the test sessions.

Statistical methods

The data from the first day were omitted to avoid any carry-over from a "first-night" effect on sleep, familiarization with the laboratory, and the like. The response-time measures, including the intercept values for the memory-search task, were then inverted (1/CRT) to normalize their distributions, while the "gaps" were transformed using the formula $\sqrt{(X)} + \sqrt{(X+1)}$ to stabilize variance and reduce the skewness associated with near 0 values. The mean time-of-day function for each measure for each subject was then calculated and subjected to a z-transformation. This procedure equated the means and standard deviations across both subjects and measures, and therefore greatly facilitated the comparison of the different measures by putting them all on an identical scale.

One-way repeated analyses of variance (ANOVA) were employed to look for significant time-of-day effects in each of the variables. Correlations were then performed between the 216 (24 subjects x 9 times of day) alertness z values and those for each of the other measures to assess the extent of their covariation. A 2-way ANOVA (with the Greenhouse-Geisser correction for sphericity applied) was used to compare the time-of-day effect for each variable with that of alertness.

Results

The initial, 1-way repeated ANOVA confirmed that there were significant time-of-day effects for each of the variables except calmness, the slope of the regression line fitted to the memory search results and accuracy on the 1-target memory search task. Pooled correlations (table 1) indicated that variations in alertness accounted for much of the variance in the measures of simple, perceptual-motor speed (correct reaction time, $r^2 = 0.381$; 1-target reaction time on the memory search test, $r^2 = 0.279$; and the intercept value, $r^2 = 0.287$) as illustrated in figure 1, which shows the average time-of day trends for these measures. It is clear that, with the possible exception of the 0000 reading, these measures paralleled variations in alertness over the day very closely. In contrast, accuracy on the 1- and 7-target versions of the memory search task showed virtually no relationship to alertness (1-target, $r^2 = 0.004$; 7-target, $r^2 = 0.003$), while that for gaps showed only a very modest, but nevertheless statistically reliable relation ($r^2 = 0.046$). This finding is illustrated in figure 2, which shows the average time-of-day trends for these measures.

The failure of some measures to show a relationship to alertness need not necessarily have reflected the sort

Table 1. Mean time-of-day values for each variable and the results from the comparison of the time-of-day trends in mood and performance with that of alertness. (CRT = correct reaction time, Acc = accuracy, RT = reaction time, Temp = temperature, df = degrees of freedom)

Variable	Mean values at each time of day (standardized)[a]									Pooled correlation	ANOVA	
	0800	1000	1200	1400	1600	1800	2000	2200	0000	r^2 (df=214)	Main effect F (8, 184)	Interaction F (8, 184)
Alert	**-1.574**	**-0.032**	**0.690**	**0.525**	**0.461**	**0.550**	**0.391**	**-0.109**	**-0.903**	N/A	N/A	N/A
	0.134	*0.109*	*0.087*	*0.117*	*0.105*	*0.077*	*0.076*	*0.100*	*0.113*			
Calm	**-0.370**	**-0.070**	**0.134**	**0.082**	**0.067**	**-0.129**	**0.127**	**0.090**	**0.071**	0.015	19.26***	11.79***
	0.257	*0.140*	*0.122*	*0.136*	*0.142*	*0.177*	*0.109*	*0.137*	*0.136*			
Cheerful	**-1.410**	**-0.247**	**0.325**	**0.368**	**0.199**	**0.174**	**0.266**	**0.320**	**0.004**	0.324***	36.16***	7.66***
	0.141	*0.156*	*0.146*	*0.124*	*0.120*	*0.188*	*0.118*	*0.122*	*0.141*			
CRT	**-1.986**	**0.215**	**0.492**	**0.394**	**0.414**	**0.613**	**0.181**	**0.013**	**-0.336**	0.381***	83.78***	3.05**
	0.116	*0.142*	*0.131*	*0.086*	*0.116*	*0.118*	*0.089*	*0.116*	*0.142*			
Gaps	**-0.596**	**0.307**	**0.499**	**0.473**	**-0.111**	**0.388**	**-0.279**	**-0.262**	**-0.418**	0.046**	28.84***	5.21***
	0.205	*0.156*	*0.184*	*0.178*	*0.133*	*0.179*	*0.178*	*0.215*	*0.166*			
Errors	**-0.775**	**-0.114**	**0.115**	**0.021**	**0.080**	**0.457**	**0.377**	**0.045**	**-0.204**	0.083***	22.95***	4.98***
	0.215	*0.244*	*0.164*	*0.167*	*0.206*	*0.121*	*0.185*	*0.173*	*0.145*			
Acc1	**-0.115**	**0.064**	**-0.464**	**0.050**	**0.083**	**0.481**	**-0.078**	**0.118**	**-0.138**	0.004	16.09***	9.69***
	0.217	*0.230*	*0.213*	*0.173*	*0.178*	*0.158*	*0.140*	*0.195*	*0.191*			
Acc7	**0.388**	**0.430**	**0.284**	**0.241**	**-0.171**	**0.050**	**-0.346**	**-0.427**	**-0.449**	0.003	12.94***	15.99***
	0.205	*0.177*	*0.183*	*0.159*	*0.201*	*0.164*	*0.176*	*0.198*	*0.185*			
RT1	**-1.876**	**0.082**	**0.488**	**0.362**	**0.212**	**0.260**	**0.449**	**0.046**	**-0.023**	0.279***	63.53***	4.33***
	0.157	*0.148*	*0.124*	*0.077*	*0.178*	*0.124*	*0.113*	*0.146*	*0.126*			
RT7	**-1.216**	**0.246**	**0.252**	**0.240**	**0.504**	**0.313**	**-0.054**	**-0.088**	**-0.196**	0.122***	36.30***	3.34**
	0.236	*0.111*	*0.171*	*0.153*	*0.190*	*0.162*	*0.154*	*0.154*	*0.167*			
Intercept	**-1.817**	**0.036**	**0.514**	**0.434**	**0.106**	**0.289**	**0.399**	**0.074**	**-0.035**	0.287***	57.73***	4.25**
	0.146	*0.167*	*0.120*	*0.086*	*0.173*	*0.112*	*0.114*	*0.153*	*0.153*			
Slope	**0.265**	**0.217**	**-0.089**	**-0.040**	**0.254**	**0.068**	**-0.473**	**-0.032**	**-0.170**	0.008	11.02***	13.21***
	0.195	*0.194*	*0.218*	*0.151*	*0.231*	*0.155*	*0.149*	*0.213*	*0.193*			
Temp	**-1.960**	**-0.230**	**0.062**	**0.192**	**0.225**	**0.721**	**0.813**	**0.538**	**-0.361**	0.431***	74.02***	9.37***
	0.067	*0.124*	*0.155*	*0.097*	*0.088*	*0.101*	*0.074*	*0.088*	*0.159*			

[a] The mean values are in boldface with the standard error of the mean in italics.
** P<0.01, *** P<0.001.

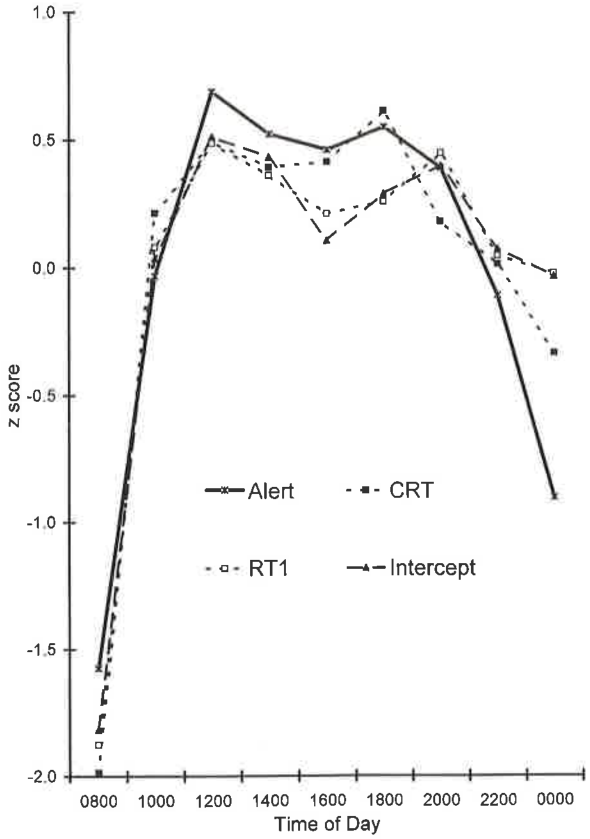

Figure 1. Time-of-day profiles of alertness and speed of simple perceptual performance. All the values were z-transformed, for each subject, prior to the plotting of the mean values for each time of day. In all cases the higher the score the better the performance. See the legend of table 1 for an explanation of the terms.

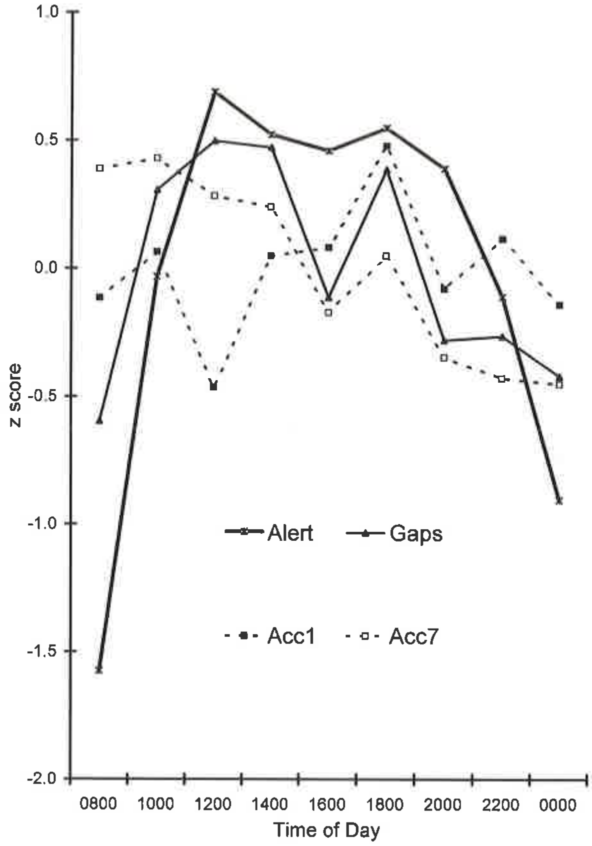

Figure 2. Time-of-day profiles of alertness and more complex performance measures. All the values were z-transformed, for each subject, prior to the plotting of the mean values for each time of day. In all cases the higher the score the better the performance. See the legend of table 1 for an explanation of the terms.

of systematic differences that might be expected if there had been a genuine difference in the timing or nature of the underlying control processes of alertness and other variables. However, comparisons of the time of day effect for each variable with that of alertness indicated that there was a reliable interaction between time of day and measure (ie, alertness versus variable under consideration) for all the variables and therefore suggested that the time-of-day effect for each of the considered variables differed systematically from that of alertness (table 1).

In the case of the 3 measures of simple, perceptual motor speed (correct reaction time, 1-target reaction time on the memory-search test, and the intercept value) (figure 1), the interaction term, although statistically reliable, accounted for very little of the explained variance (3—6%) and was no longer reliable when the 0000 readings were omitted and the analyses repeated. Thus for these measures the interaction appeared to simply reflect the fact that at the end of the day alertness decreased to a greater extent than response speed. However, for other measures, such as accuracy on the 1- and 7-target memory and search tasks, and gaps on the serial-choice task (figure 2), the interaction was both highly significant and accounted for a more substantial percentage of the explained variance (17—50%). Furthermore, these interactions remained significant when the first (0800) or last (0000) readings of the day were omitted from consideration. Thus the time-of-day trends for these measures appeared to differ reliably and systematically from that of alertness.

For completeness, table 1 also shows the main effect of time of day from these analyses. While it is clear that these main effects were all reliable, they should be interpreted with extreme caution since they may simply reflect the massively reliable time-of-day effect of alertness rather than any similarity between alertness and the measure under consideration. Thus, for example, there were reliable main effects of time of day in the analyses comparing alertness and accuracy on the 1- and 7-target versions of the memory-search task. This result occurred despite the fact that accuracy on the 1-target version did not show a significant time of day effect when analyzed by itself and the fact that there was a total lack of any evidence for a relationship between these 2 accuracy measures and alertness from the pooled correlations.

Discussion

We assessed a range of performance and mood variables for highly practiced subjects, and, although some showed a very similar time-of-day trend to that shown by alertness, they all differed reliably from it. For the 3 measures of simple perceptual motor speed that were obtained, this difference was largely confined to the last reading of the day (0000) when alertness had decreased to a greater extent than response speed. It is noteworthy in this context that, like response speed, the 3-process model of alertness also frequently underestimates the fall in subjectively rated alertness at the end of a period of wakefulness. Thus the subjects' knowledge of clock time and of how long they had been awake may have resulted in their overestimating the extent of their fatigue when they made subjective ratings at the end of their waking day.

However, for other measures, the time-of-day trends differed rather more substantially from that of alertness, and this finding is particularly important given the recent suggestion that the 3-process model of alertness may be generalized to predict measures of performance (4). While it is certainly the case that the time-of-day trends for some measures of performance parallel that of alertness, a finding noted by others following visual inspection of their data (1), it is equally true that other performance measures show no such parallelism. Our results suggest that the 3-process model of alertness may predict simple perceptual motor speed with considerable accuracy, especially if modified to take account of the "end-of-day" effect. However, they also suggest that minor modifications to the "wake-up" and "end-of-day" effects would prove insufficient to enable accurate prediction to be derived for other measures of mood and performance and, in particular, the performance of tasks requiring more complex cognitive functioning.

It is, of course, the case that the measures obtained by us were limited to the normal waking day. It is possible that, if readings had been obtained during the nighttime hours, when the subjects would normally have been asleep, a rather different pattern of results might have emerged. Thus, for example, if all measures showed similar low values in the early hours of the morning to those typically obtained for alertness, their relationship to alertness would be increased. In contrast, if the rather different trend found over the day for accuracy on the 7-target version of the memory-search task reflected the nighttime peak in performance previously reported for high-memory-load tasks (14), then this ability of alertness to predict variations in this measure would be reduced even further.

To summarize, the present study collected mood and performance data at regular intervals throughout the normal waking day from 24 highly practiced volunteers living in a controlled environment. Under such conditions reliable time-of-day trends were found for most of the variables, and, while some such trends paralleled that of alertness fairly closely, in all cases they differed reliably from it. It is concluded that the 3-process model of alertness cannot be generalized to predict successfully all measures of mood and performance.

Acknowledgments

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References

1. Dijk DJ, Duffy JF, Czeisler CA. Circadian and sleep/wake dependent aspects of subjective alertness and cognitive performance. J Sleep Res 1992;1:112—7.
2. Johnson MP, Duffy JF, Dijk DJ, Ronda JM, Dyal CM, Czeisler CA. Short-term memory, alertness and performance: a reappraisal of their relationship to body temperature. J Sleep Res 1992;1:24—9.
3. Monk TM, Buysse DJ, Reynolds III CF, Berga SL, Jarrett DB, Begley AE, et al. Circadian rhythms in human performance and mood under constant conditions. J Sleep Res 1997;6:9—18.
4. Åkerstedt T, Folkard S. The three-process model of alertness and its extension to performance, sleep latency, and sleep length. Chronobiol Int 1997;14:115—23.
5. Folkard S, Åkerstedt T. Towards a model for the prediction of alertness and/or fatigue on different sleep/wake schedules. In: Oginski A, Pokorski J, Rutenfranz J, editors. Contemporary advances in shiftwork research: theoretical and practical aspects in the late eighties. Krakow: Medical Academy, 1987:231—40.
6. Folkard S, Åkerstedt T. Towards a prediction of alertness on abnormal sleep/wake schedules. In: Coblentz A, editor. Vigilance and performance in automatized systems. Dordrecht: Kluwer Academic Publishers, 1989:287—96.
7. Folkard S, Åkerstedt T. A three-process model of the regulation of alertness-sleepiness. In: Broughton RJ, Ogilvie BD, editors. Sleep, arousal and performance. Boston (MA); Birkhauser, 1992:11—26.
8. Åkerstedt T, Folkard S. A model of human sleepiness. In: Horne J, editor. Sleep '90; Bochum: Pontenagel Press, 1990:310—4.
9. Åkerstedt T, Folkard S. Validation of the S and C components of the three-process model of alertness regulation. Sleep 1995;18:1—6.
10. Åkerstedt T, Folkard S. Predicting sleep latency from the three-process model of alertness regulation. Psychophysiology 1996;33:385—9.
11. Åkerstedt T, Folkard S. Predicting duration of sleep from the

three-process model of regulation of alertness. Occup Environ Med 1996;53:136—41.

12. Totterdell P, Folkard S. In situ repeated measures of affect and cognitive performance facilitated by use of a hand-held computer. Behav Res Methods Instrum Comput 1992; 24:545—53.
13. Sternberg S. Memory-scanning: mental processes revealed by reaction-time experiments. Am Scientist, 1969;57:421—57.
14. Folkard S, Knauth P, Monk TH, Rutenfranz J. The effect of memory load on the circadian variation in performance efficiency under a rapidly rotating shift system. Ergonomics 1976;19:479—88.

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Effect of bright light at night on core temperature, subjective alertness and performance as a function of exposure time

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Foret J, Daurat A, Tirilly G. Effect of bright light at night on core temperature, subjective alertness and performance as a function of exposure time. *Scand J Work Environ Health* 1998;24 suppl 3:115—120.

Objectives This simulated night shift study measured the effects of moderate bright light (a 4-hour pulse starting at 2000 or 0400) during the exposure night and subsequent night (dim light).

Methods Eight young males remained confined with little physical activity to a laboratory in groups of 4. After a night of reference, they were active for 24 hours; then after a morning recovery sleep, they were active again for 16 hours.

Results Continuously measured rectal temperature proved to be immediately sensitive to 4 hours of bright light, particularly when given at the end of the night. Self-assessed alertness and also performance on a task with a high requirement for short-term memory were improved by the exposure to bright light. During the subsequent night the subjects were exposed only to dim light. Core temperature, subjective alertness and performance continued to show a time course depending on the preceding bright light exposure.

Conclusions Probably because evening exposure to bright light and morning sleep both had a phase-delaying effect, the effects on the circadian pacemaker were more pronounced. Thus, for practical applications in long night shifts, bright light can be considered to improve mood and alertness immediately but the possibility of modifying the circadian "clock" during subsequent nights should be taken into consideration, in particular after exposure to bright light in the evening.

Key terms circadian phase shift, circadian rhythms, laboratory study, pilot study.

Many studies with different approaches have been devoted to the effects of rotating shift work on circadian rhythm and performance. The extent of disruption due to shift systems has not always been assessed in the same way. For instance, in terms of sleep length, morning shifts resulting in very early rising times were found to be the most detrimental, but, when the efficiency of operators and incident risk were assessed, night periods were the worst (1, 2). Although it has been hypothesized that some serious accidents or catastrophes are related to night hours, the available literature does not report any evidence of decreasing efficiency in modern industrial processes as a function of time of day, contrary to what had been concluded by Folkard & Monk (3) on the basis of earlier field results. The explanation is that processes and work organizations have been especially designed to be insensitive to the circadian decline of individual performance. In contrast, generally speaking, shift workers rate the night shift as the worst when well-being, subjective fatigue, and social life are taken into consideration.

Thus many workers have agreed to trade longer shifts for fewer workdays and particularly fewer work nights. With a workweek of around 35 hours, such a shift often comprises only 3 days or nights. However, as Smith et al (4) put it aptly, are 12-h shifts a solution despite a generally positive response to the introduction of a 3- to 4-day 12-hour rotating shift schedule (4—7)? In addition, although they recognized the rapid spread of the 12-hour shift in the petroleum and chemical industries as early as around 1970, Northrup et al (8) expressed some doubt concerning its generalization because of its negative effects on some older workers and also because of the negative effects in industries in which work is more

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arduous. In fact a 10-hour nightshift system implemented in a French car assembly plant had to be discontinued in spite of productivity increases because of the growing opposition of the workers (9).

Attempts have been made to improve the efficiency and well-being of workers during long night shifts by treating them with bright light. It is well known that circadian regulation, particularly the phase position of most physiological functions, can be modified by bright light, provided it is applied at appropriate times of the night. Several laboratory studies (10—13) and a few studies involving actual shiftwork (14, 15) have shown that appropriately timed bright-light exposure is a promising means of countering the negative effects of night activity. However, several important points still need to be better defined, among them: (i) the best timing of bright light exposure to produce an adequate response to the demands of the night shift, (ii) the extent to which the effects of bright light on temperature are correlated with the effects on alertness and performance, and (iii) the extent to which bright light produces a significant effect during the subsequent night even if there is no bright light exposure (ie, to what extent has the circadian oscillator been phase shifted).

These 3 issues have been investigated in the present study. The subjects were confined in a sleep laboratory and kept awake for 2 nights. During the 1st night, they were exposed to a 4-hour pulse of bright light starting at either 2000 or 0400. During the 2nd night, they received only normal artificial light (≤100 lux at eye level).

Subjects and methods

Eight paid male volunteers aged 19—23 years were studied. They had normal sleeping times and were free of medication and drugs. They did not smoke and had normal psychological profiles, in particular in terms of anxiety (Minnesota Multiphasic Personality Inventory, Cattell Questionnaire, Eysenck Personality Inventory).

In groups of 4, they were confined to a room where they remained seated except for going to the bathroom. Apart from test sessions, electroencephalographic recordings, and blood sampling, they read, played cards and studied. They were prevented from dozing off by the investigator. The 60-hour protocol was performed twice, at 2-week intervals (figure 1), with 2 different light treatments. One group (4 subjects) was studied in March and the other in September to obtain approximately the same photoperiod (0800—1800). The order in which they experienced the 2 conditions was counterbalanced. During the day (0800—2000)), the subjects received natural light through the window. From 2000 to 0800 (1st night called N1), they received either dim light using conventional bulbs (about 50 lux) or a 4-hour pulse of bright light supplied by a ceiling fixture. The bright-light intensity measured at eye level varied between 700 and 1000 lux according to the angle of gaze. With the exception of the light level, environmental conditions were kept as constant as possible: ambient temperature (≅24° C), humidity, noise and contacts with the experimenters. Naps, cigarettes, alcohol, and coffee were not allowed during the entire experiment. During the 2nd night (N2) of both conditions, the measurements were made in identical conditions but with constant dim light.

Rectal temperature was monitored continuously by a portable recorder (MiniMitter with Yellow Springs disposable probes) and recorded every 5 minutes.

Self-rated alertness was assessed using a French shortened version of the Activation/Deactivation Adjective Checklist (16). The ratio of GA (general activation) to DS (deactivation sleepiness) was used as an indication of the alertness level (11). Performance tests were "Search and Memory Tests" (SAM tests) derived from

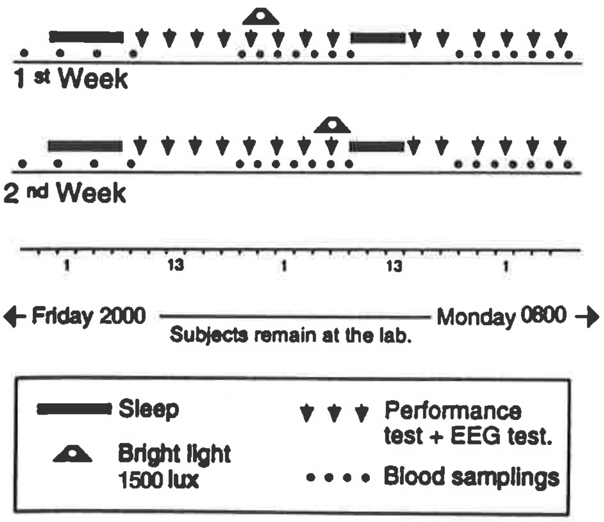

Figure 1. Study protocol — the subjects remained in the laboratory for 60 hours from Friday 2000 to Monday 0800. After 1 sleep night, they were kept awake but sedentary for 24 hours, had a morning recovery sleep, and then a 2nd sleepless night (about 18 hours awake). During the wake time they had performance tests, electroencephalographic tests, meals every 3 hours and, at night, blood sampling every 2nd hour. (BL= bright light)

the Memory and Search Task (MAST) (17) with different memory demands. The subject's task was to memorize 1, 3 or 5 letters, search through a line of 20 letters and indicate the first occurrence of 1 of the targets.

Time courses of the variables were compared using a repeated-measures analysis of variance (ANOVA). The comparisons between light conditions at given times were made by a paired t-test.

Results

The temporal changes in the variables are presented as a function of the bright-light exposure (2000—2400 versus 0400—0800). The results from the 1st night (N1) indicate immediate effects of bright light, or those occurring a few hours after the exposure between 2000 and 2400. Any long-lasting effect of the bright light was estimated from the results of the 2nd night (N2).

Rectal temperature

There was no difference for the mean levels during the first night, but the interaction between the time and the bright light condition was highly significant (df=142, F=1.7, P<0.0001). The 2000—2400 exposure did not result in any clear-cut increase in comparison with the dim light condition, instead there was a prolonged plateau followed by a steep decline after 0100. In the 2nd half of the night, the 0400—0800 bright-light condition corresponded to a higher temperature (slightly significant difference at 0538, df=6, t=2.51 P<0.07) (figure 2).

On the whole the time course of the 2nd night showed the same pattern as during the preceding light-exposure night. There was no difference in the mean level and a strong interaction between time and the bright-light condition (df=142, F= 1.6 P<0.0001). During the 1st half of the night, the temperature was higher between 2000 and 2400 during the bright-light condition (significant at 2230, df=6, P<0.05); during the 2nd half, it was higher during the 0400—0800 bright-light condition (significant at 0540, df=6,t=2.64, P<0.04). Figure 3 suggests a phase delay with the 2000—2400 bright-light and an advance with the 0400—0800 bright light condition. In fact, the mean of the actual individual minimum times was respectively 0516 and 0424 (no significant difference)

Performances

In an attempt to diminish the intersubject variability, performances were presented as the percentage of an individual's mean measured over the whole period. All of the performance variables were analyzed with a repeated measures ANOVA (time × light condition). Neither an effect of time nor a difference between the light condition was found, probably because of the low memory load and thus the facility of the task in the SAM test for 1 letter.

The subject's performance showed a significant time-of-day effect [F(7,98)= 5,17, P<0.001] for the SAM test with 3 letters during the 1st night of the experiment. It was best in the evening (2030) and declined throughout the night (ie, time needed increased). The last test was an exception probably due to the "end-of-the-session" effect. In the 4 night tests (from 2330 to 0730) the interaction between time and the bright-light condition was marginally significant [F(3,42) = 2.2, P<0.1]. Figure 4 shows that performance was improved at 2330 by the

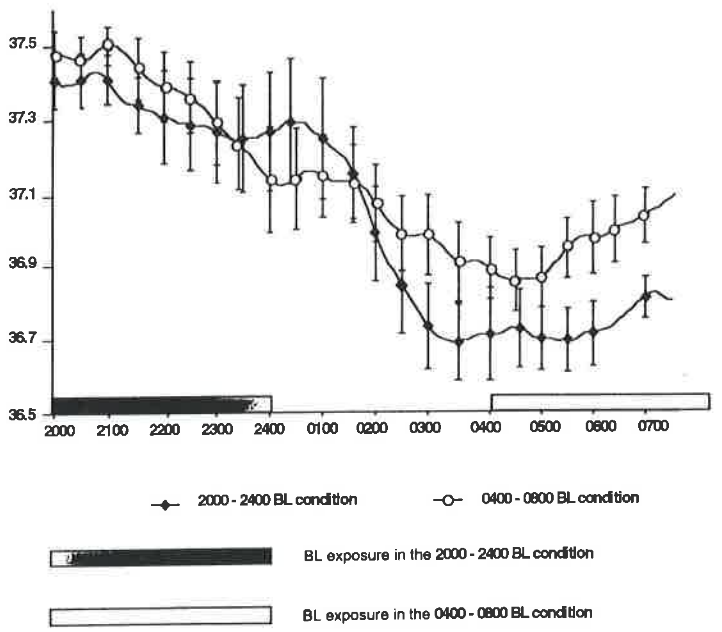

Figure 2. Means and standard errors of the means of the rectal temperature waveforms between 2000 and 0800 during the 1st exposure night in the 2 bright light conditions, one with 2000—2400 exposure and the other with 0400—0800 exposure (BL= bright light).

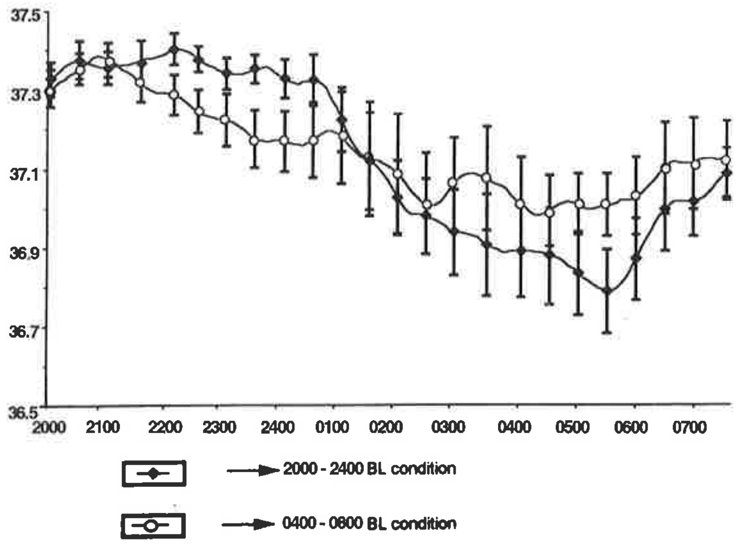

Figure 3. Means and standard errors of the means of the rectal temperature waveforms between 2000 and 0800 during the 2nd night in dim light in the 2 bright light conditions, 1 after 2000—2400 exposure and the other after 0400—0800 exposure.

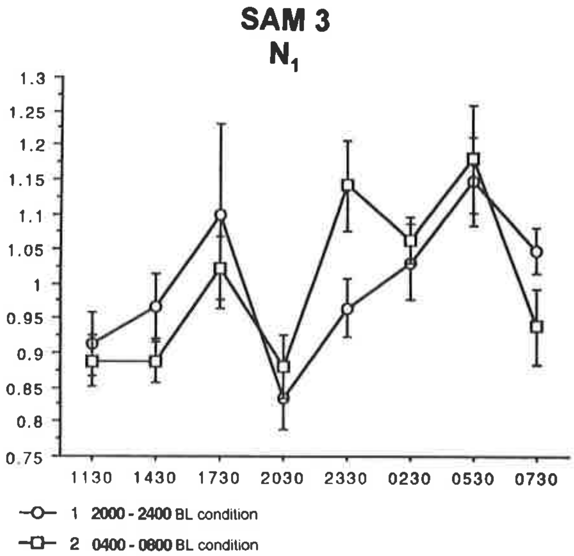

Figure 4. Mean time needed to find 1 memorized letter during the night of bright-light exposure (N1), the higher the value, the worse the performance. The task consisted of memorizing letters (SAM 3 = 3 letters) and finding the 1st occurrence of 1 of them in a row of letters. The values are the means of the percentage of the subjects' mean values measured across the whole experiment.

2000—2400 bright-light condition (t=2.91, P<0.05) and at 0730 by the 0400—0800 bright-light condition (t=2.65, P<0.05)

No significant difference between the bright-light conditions was found for the SAM test performance with 3 letters on the 2nd night.

A decrease in performance was observed throughout the experiment [F(7,98)= 3.4, P<0.003] with the SAM test involving 5 letters on the 1st night. On the 4 night tests between 2330 and 0730, the interaction between time and the bright-light condition showed only a trend [F(3,42)= 2.3, P<0.09] reflecting a better performance on the 0230 test in

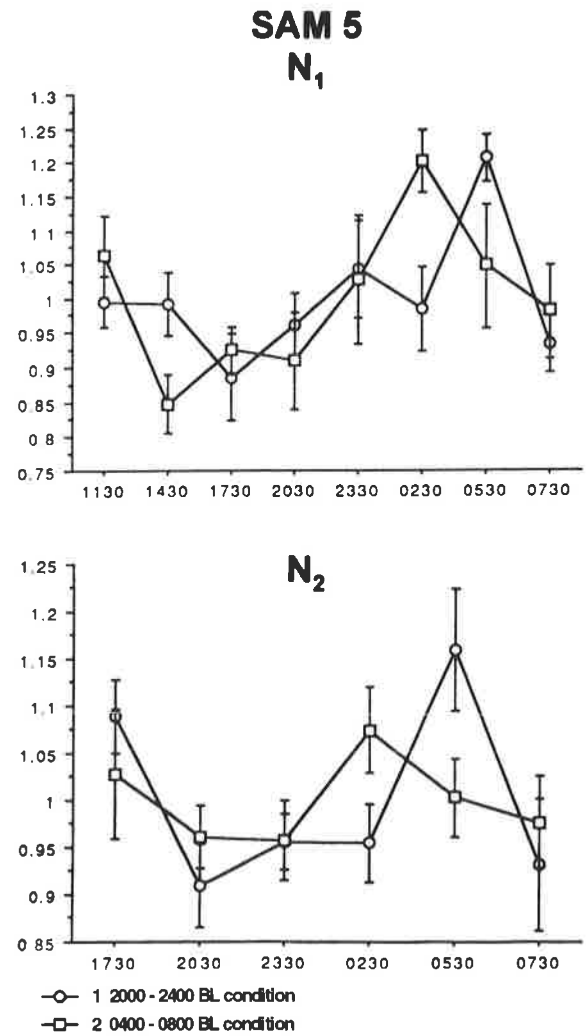

Figure 5. Mean time needed to find 1 memorized letter among 5 letters (SAM 5 = 5 letters) during the night of bright-light (BL) exposure (N1) and the subsequent night (N2).

2000—2400 bright-light exposure (t=3.24, P<0.05) and on the 0530 test after the 0400—0800 bright light exposure (trend with t=1.7, P<0.13) (figure 5).

On the 2nd night the time curve of the performance displayed a remarkably similar pattern for both bright-light conditions when compared with the results of the 1st night, though with a somewhat less pronounced time-of-day effect [F(5,70)= 2.6, P<0.05]. The interaction between time and the bright-light condition for the 4 night tests was marginal [f(3,42)= 2.3, P<0.1]. Differences were observed at 0230 (t= 1.94, trend at P<0.09) and at 0530 (t=2.49, P<0.05) (figure 5).

During both the 1st and the 2nd nights, a steep deterioration in performance was noted on the 0530 test after the end of the 2000—2400 bright-light exposure.

Subjective alertness

The GA/DS for both bright-light conditions continuously decreased throughout the night [time-of-day effect F (8,112)= 21.23, P<0.0001]. There was a tendency for the 0400—0800 bright-light condition to result in a better alertness when assessed from 2130 to 0800 [F(4,56)= 2.3, P<0.07) because during the light exposure alertness was significantly improved at 0630 (t=2.45, P<0.05) and at 0800 (t=3.93, P<0.01) when compared with the results of the 2000—2400 bright-light exposure. In contrast the 2000—2400 bright-light exposure did not produce the same immediate effect (figure 6).

As on the 1st night, the GA/DS determined on the 2nd night for both bright-light conditions declined throughout the afternoon and night (time-of-day effect F(5,70)=10.81 P<0.001), but it was higher for the 2000—2400 bright-light condition [F(1,70)= 2.2, P<0.15 computed across all the tests of the 2nd night] with the most significant difference at 24.30 (t=2.74, P<0.05).

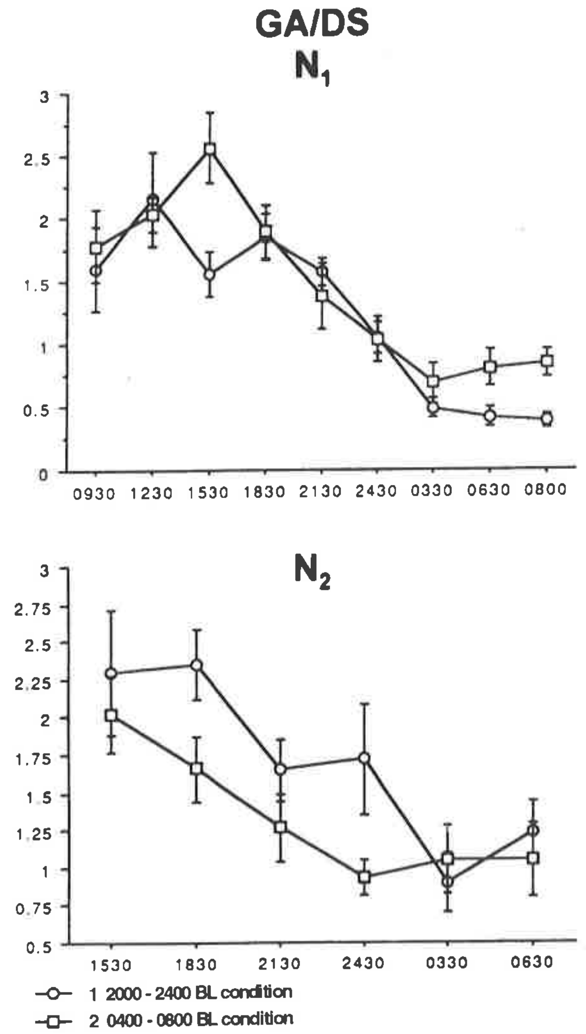

Figure 6. Subjective index of alertness [GA (general activation)/ DS (deactivation sleepiness)] during the night of exposure (N1) and the subsequent night (N2).(BL = bright light).

Discussion

The immediate effect of the 2000—2400 bright-light exposure resulted in an improvement in performance (3-letter SAM at 2330 and 5-letter SAM at 0230) only. No effect was noted on temperature and subjective alertness. The 0400—0800 exposure had a clearer impact since, when compared with the 2000—2400 condition, temperature, subjective alertness, the 3-letter SAM and the 5-letter SAM performance were all better. This finding agrees well with, for instance, the results of Wright et al (18). In addition our results were obtained even though the light intensity was less than the intensities used in some earlier studies on actual shift workers (14, 15). Therefore, subjective alertness appeared to be linked with temperature, but performance at night exhibits a more complex relationship with temperature.

The main result of our study was the fact that there was a large differential effect of the 2 bright-light conditions on temperature, performance, and alertness during the following night, even though the light condition (<100 lux) was the same. The time course of temperature tended to be flatter after the 0400—0800 bright-light exposure than after the 2000—2400 exposure. This effect did not reflect the immediate positive effect obtained in the last hours of the 1st night (better alertness and better performance). During the night following the 2000—2400 bright-light exposure, temperature amplitude was increased and the minimum tended to be delayed. The hypothesis of a phase delay of the circadian oscillator is plausible in that the bright light between 2000 and 2400 before the temperature trough, the delayed sleep onset, and the delayed beginning of the dark period all facilitated phase delay. In contrast a delayed sleep or dark period and a period of bright light between 0400 and 0800 (ie, favoring phase advance) were in conflict. This finding may explain the very limited phase effect during the following night. This result is in good agreement with the results of Mitchell et al (19) and confirms the conclusions of Foret et al (20) that evening exposure is recommended if a circadian phase delay is needed.

In summary, our study demonstrated that a moderately intense and moderately long nocturnal light exposure is sufficient to produce (i) an immediate effect on the well-being of night workers, particularly when given at the end of the night, and (ii) marked physiological and psychological effects on the circadian system during the subsequent night, particularly if the light exposure occurs at the beginning of the preceding night. The results of this preliminary study with a limited number of subjects (N=8) should be confirmed by measurements made on a larger population.

Acknowledgments

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References

1. Monk TH, Folkard S. Shiftwork and performance. In: Folkard S, Monk TH, editors. Hours of work. Chichester: John Wiley and Sons, 1985:239.
2. Folkard S. Circadian performance rhythms: some practical and theoretical implications. Philos Trans R Soc Lond [Biol] 1990;B327:543—53.
3. Folkard S, Monk TH. Shiftwork and performance. Hum Factors 1979;21:483—92.
4. Smith L, McDonald I, Hammond M, Folkard S. 12-h shifts are popular but are they a solution? Shiftwork Int Newslet 1995;12:100.
5. Rosa RR, Colligan MJ, Lewis P. Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns and psychosocial variables. Work Stress 1989;3:21—32.
6. Williamson AM, Gower CGI, Clarke BC. Changing the hours of shiftwork: a comparison of 8- and 12-hour shift roster in a group of computer operators. Ergonomics 1994;37:287—98.
7. Rosa RR. Performance, alertness and sleep after 3,5 years of 12h shifts: a follow-up study. Work Stress 1991;5:107—16.
8. Northrup H, Wilson JT, Ros KM. The twelve-hour shift in the petroleum and chemical industries. Ind Lab Relat Rev 1979;32:312—26.
9. Chanut JC. Quatre jours de travail, trois jours de repos: un bilan de l'expérience des 4 × 10 à Peugeot Poissy. Liaisons Soc 1992;66. Cited in Problèmes Economiques 1992;2270: 25—27.
10. Dawson D, Campbell SS. Timed exposure to bright light improves sleep and alertness during simulated night shifts. Sleep 1991;14:511—6.
11. Daurat A, Aguirre A, Foret J, Gonnet P, Keromes A, Benoit O. Bright light affects alertness and performance rhythms during a 24-h constant routine. Physiol Behav 1993;53:929—36.
12. Thessing VC, Anch AM, Muelbach MJ, Schweitzer PK, Walsh JK. Two- and 4-hour bright light exposures differentially effect sleepiness and performance the subsequent night. Sleep 1994;17:140—5.
13. Dawson D, Encel N, Lushington K. Improving adaptation to simulated night shift: timed exposure to bright light versus daytime melatonin administration. Sleep 1995;18:11—21.
14. Stewart KT, Hayes BC, Eastman CI. Light treatment for NASA shiftworkers. Chronobiol Int 1995;12:141—51.
15. Samel A, Gander P. Bright light as a chronobiological countermeasure for shiftwork in space. Acta Astronaut 1995; 36:8—12.
16. Thayer RE. Activation/deactivation adjective checklist: current overview and structural analysis. Psychol Rep 1986;58:607—14.
17. Folkard S, Knauth P, Monk TH, Rutenfranz J. The effect of memory load on the circadian variation in performance efficiency under a rapidly rotating shift system. Ergonomics 1976;19:479—88.
18. Wright KP, Badia P, Myers BL, Plenzler SC. Combination of bright light and caffeine as a countermeasure for impaired alertness and performance during extended sleep deprivation. J Sleep Res 1997;6:26—35.
19. Mitchell P, Hoese EK, Liu L, Fogg LF, Eastman CI. Conflicting bright light exposure during night shifts impedes circadian adaptation. J Biol Rhythms 1997;12:5—15.
20. Foret J, Daurat A, Touitou Y, Aguirre A, Benoit O. The effect on body temperature and melatonin of a 39-h constant routine with two different light levels at nighttime. Chronobiol Int 1996;13:35—45.

Scand J Work Environ Health 1998;24 suppl 3:121—127

Three-process model of supervisory activity over 24 hours

by Valérie Andorre-Gruet, PhD,[1] Yvon Queinnec, PhD,[1] Didier Concordet, PhD[2]

Andorre-Gruet V, Queinnec Y, Concordet D. Three-process model of supervisory activity over 24 hours. *Scand J Work Environ Health* 1998;24 suppl 3:121—127.

Objectives This study used endogenous and exogenous factors to develop a model for sampling supervisory activity that implied consulting numerous data on computer systems. .

Methods The study was carried out in an automated workshop of a chemical plant. Five crews worked on a 3×8 hour shift system, with changes at 0400, 1200 and 2000. Each team included 2 experienced controllers who supervised the process from computer systems in a control room. Starting and ending duty at the same time as the operators, the researchers used real time to code of all the screen pages selected on the computers by 8 controllers (from 4 teams) over 18 shifts.

Results The time-of-day fluctuations of the call frequency confirmed the existence of endogenous factors (biological rhythms or fatigue), but they cannot explain all the variations observed. The modeling of the data yielded the following 3 explanatory factors: (i) the cognitive demands of the tasks, as an external factor, mainly concern the impact of shift changeover characterized by a strong peak of information gathering at the beginning of the shift, even at 0400; (ii) the shift duration appears as a "fatigue" factor and reflects a rapid reduction of information gathering over the shift; (iii) circadian rhythms are characterized by a minimum of activity at night and a maximum in the afternoon.

Conclusion In other similar work situations, in addition to an essential work analysis, our model could help the design of shift duration or schedules for shift changeover.

Key terms complex system, control room, information gathering, shiftwork arrangements, supervision modeling.

Working in dynamic complex systems such as refineries and chemical and nuclear plants requires operators to cope with 2 types of work constraints, namely working on a rotating schedule (generally on 3×8 hour or 2×12 hour shift systems) and performing a supervisory activity with high mental demands.

The rotating shift systems involve working and reasoning during day and night shifts. But many studies have shown that circadian rhythms influence the operators' performance (1, 2). The differences appear in cognitive tasks such as visual research, memorization, logical reasoning and information processing (3, 4). Investigations in actual work situations (particularly in automated complex processes) offer similar results. During regular operation (without incident), the controllers do not operate and supervise a complex system in the same way at different times of the day (5). The variations appear in the frequency and the type of information gathering in a control room (6). Clearly, these variations may have serious consequences for the safe running of complex systems. For example, in nuclear plants, the number of human errors increases over the night shift, but also at the beginning and the end of the morning and afternoon shifts (7).

The cognitive demands of tasks have increased through the evolution of new supervisory computer systems (greater complexity and size of installations) that have modified the presentation of information. Therefore, due to the partition of information, a controller needs to consult several screen pages to check the proper operation of the process. This selective information gathering (the operator cannot see all the information he needs at any one time) will depend on the operator's mental image of the function of the system (8). The operator will generally form this image at the start of the shift by

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memorizing previous process data. In this way, the incoming operator can check what happened in the workshop during his absence. During the remainder of the shift, he or she briefly samples information to update his or her image of the process (9, 10). This sampling activity is essential for the supervision of a complex system which consists of the prevention of and recovery from malfunction. In both cases, the mental image enables the past and present states of the system to be identified and the future status of the system to be predicted in order to guide action (11, 12, 13).

To study the effects of the workhours and the cognitive demands of the tasks involved in the operation of supervisory computer systems, we have applied available models (2, 14, 15, 16, 17) that emphasize the masking effect of external factors on circadian rhythms. With this approach we have attempted to develop a model of process operating behavior; the model takes cognitive demands, type of shift, and time into shift into consideration.

Subjects and methods

The study was carried out in an automated workshop of a chemical plant. The continuous process produced ammonia from natural gas. Five teams of 8 male operators worked in shifts to supervise the operation of the process on a rotating schedule (2 mornings, 2 afternoons, 2 nights and then 4 rest days) with shift changes at 0400, 1200 and 2000. Each team was supervised by a foreman. It included 2 controllers who supervised the system from the computerized control room, while 4 patrollers and 1 assistant shift foreman worked outside in the plant itself. The 2 controllers shared the process supervision. Each of them was officially responsible for only some parts of the system. This work distribution did not differ during or between the shifts.

The control room was equipped with 5 computer consoles displaying data on about 2400 parameters over 600 screen pages. Each screen page displayed a specific identification code comprising 1 letter and 3 digits at the top left.

We investigated the supervisory activity of 8 controllers between 35 and 50 years of age. Each of them had long experience with shift work (more than 10 years) and also with the job (5 years to more than 10 years). After 1 month of familiarization, they were observed during their regular work without any monetary incentive to participate.

Data were collected through observation and scoring (in real time) of all the screen pages selected by the controllers. This recording required 2 researchers to control fluctuations in vigilance and to allow for successive breaks. They stood behind the computer screens in order to be able to see and take notes on each display. Later, the recordings of both researchers were compared and then transcribed to computer files. The scorers started and ended their duty period at the same time as the operators did. In this research, we did not study the whole shift changeover; instead we focused on the work period after the departure of the outgoing operators. Therefore, the observations only concerned the incoming controllers' activity.

Data were collected over 18 shifts, equally divided between the 3 shift periods (6 morning, 6 afternoon and 6 night shifts) to analyze the effect of workhours. From these data, we studied the frequency of consultation, the type of information displayed, and the consultation sequences over the different shifts (18). In this report, we have taken only the mean number of screen pages accessed per hour into account. A repeated-measures analysis of variance using Greenhouse-Geisser correction was performed. Then we developed the model of sampling activity applying a nonlinear regression with Systat software (19).

As performance and behavior could vary according to the state of the process, particularly if there was an emergency, we only analyzed the controllers' activity during normal operation of the plant (excluding also maintenance periods). Under these conditions, the controllers' task generally did not differ between the shifts.

We also controlled a few additional factors. The number of operators behind the monitors was recorded, bearing in mind that the display access was essentially reserved for the 2 controllers. Therefore each of them always used 2 computers, and the fifth remained available for the other members of the team. No significant effect was found for the number of operators working at the monitors.

During the study, the controllers could choose the time and duration of their "informal" rest period. We recorded this information, but there was no time effect of the rest period on the activity because there was neither regularity in their occurrence (the operator could leave the control room either at the beginning, the middle or the end of the shift) nor in their duration.

Results

Description of sampling activity over 24 hours

We initially verified the distribution of the hourly rate of screen pages (black curves) selected over the 3 shifts (figure 1). Each shift was divided into eight 1-hour blocks from the beginning to the end of the shift. It can be seen from figure 1 that there was a considerable variation in the rate of consultation on the screen pages within a shift [$F(7,77) = 11.82$, $P<0.001$; after the Greenhouse-Geisser

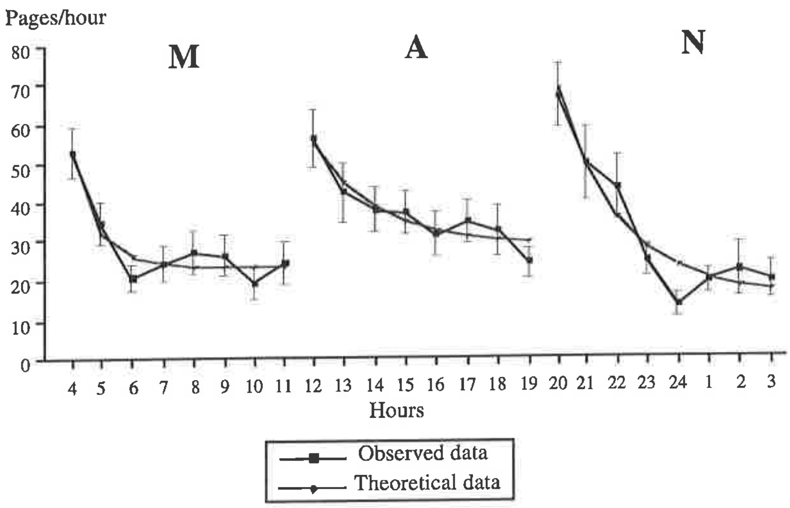

Figure 1. Mean hourly frequency of pages (observed data in black line) displayed during the shifts and the standard error of the mean. (M=morning, A=afternoon, N=night)

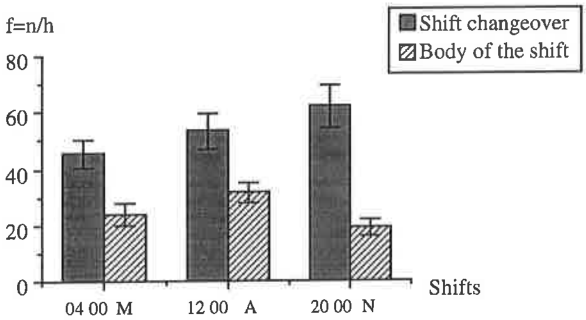

Figure 2. Mean hourly rate of consultation of screen pages (f) during shift changeover and during the body of the shift (normal supervision) (ie, last 5 hours of shift) and the standard error of the mean. (M=morning, A=afternoon, N=night)

correction], characterized by a consultation peak at the beginning of the shifts, followed by a decrease. But, due to the importance of shift changeover, there was no significant effect of type of shift [$F(2,22) = 2.68$, $P > 0.09$]. Nevertheless, this evolution into the shift depended on the type of shift. In other words, there was an interaction between the shifts and the duration of work [$F(14,154) = 1.99$, $P < 0.02$].

Let us consider the 2 results. First, during each shift, the operators' activity was characterized by a high frequency of consultation at the beginning of each shift (0400, 1200 or 2000) during almost the first 2 hours of work. During the remainder of the shift, the rate of consultation decreased and led to a basic level of supervision.

We estimated the asymptotic level of the curve to determine when this basic rate was reached. It appeared when the frequency of consultation remained stable around a mean value. We called this work phase "the body of the shift", where the controller really supervised the process. Confirming previous data of controllers' activity, the latter was found to depend on the time of day, the maximum occurring in the afternoon (an average of 30 screen pages selected per hour) and the minimum at night (18 screen pages per hour). It was reached more or less quickly depending on the shift: within 90 minutes in the afternoon, after 120 minutes in the morning, and after about 3 hours at night.

Therefore the controllers' activity varied within a shift and consisted of 2 main stages (figure 2), namely, the shift changeover and the supervision period (basic level of supervisory activity).

The mean frequencies at the start of the shift differed significantly from those later in the body of the shift. The controllers' activity was 2 or 3 times higher during the shift changeover [$F(1,11) = 32.1$, $P<0.001$] than during the supervision period, but the difference between the 3 shift changeovers was not significant [$F(2,22) = 2.41$, $P>0.1$]. On the other hand, an analysis solely based on the body of the work (the last 5 hours of supervision) revealed a significant variation between the 3 shifts [$F(2,22) = 4.15$, $P<0.03$]. These hourly differences were confirmed by the significant interaction between the shifts and the 2 stages (beginning and body of the shift) [$F(2,22) = 6.78$, $P<0.01$]. This time-of-day effect can be more clearly distinguished in figure 3.

As does figure 1, figure 3 represents the hourly call frequency over 2x24 hours. When we joined the equivalent points of the curve, a "circadian-like" component appeared. For example, with the 1st hour of work, the 2nd hour of work, and the 6th hour of work.

Three-process model of the supervisory activity

For each shift, we developed a model of the supervisory activity (figure 4), as based on the hourly frequency of consultation over 24 hours (figure 1). First, the data were carefully described to eliminate noise and enable the appropriate framework to be drawn so that a mechanistic interpretation of the process would be possible.

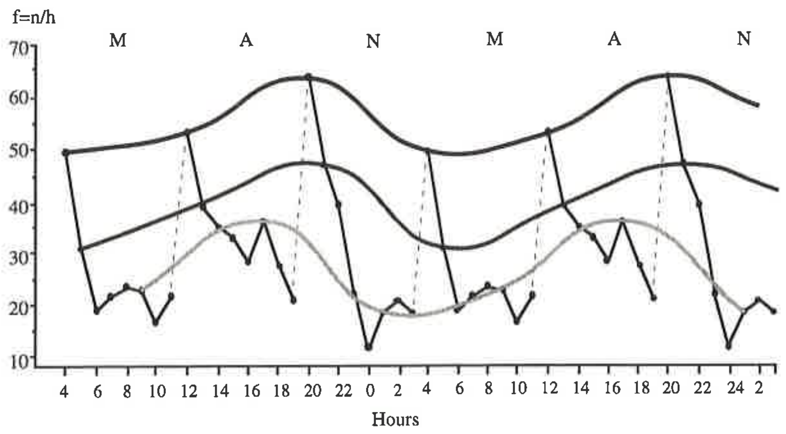

Figure 3. Mean hourly frequency of consultation over 2×24 hours and a representation of the circadian component (in grey curves). (M=morning, A=afternoon, N=night)

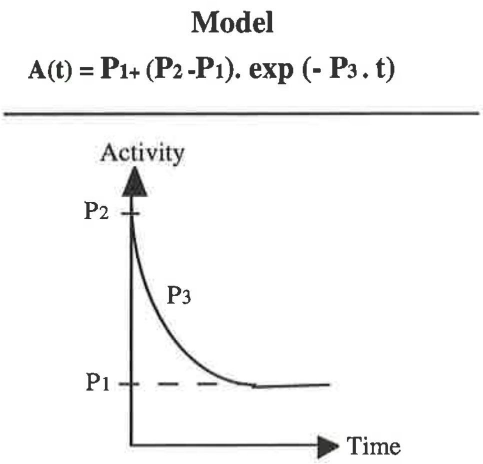

Figure 4. Three-process model of information gathering. [A(t)=activity(t), P_1=basic level, P_2=maximum, P_3=decreasing factor, t=time]

Table 1. Estimated values of the different components of supervisory activity according to the model. (M=morning, A=afternoon, N=night).

Description	Parameters	Shifts		
		M	A	N
Basic level	P1	23.204	28.335	14.293
Maximum of consultation	P2	52.943	54.577	68.265
Decreasing factor	P3	1.239	0.476	0.464

The first descriptive step led us to build a model with the following 3 components: (i) a basic level reached asymptotically (P1), (ii) a maximum activity at the beginning of the shift (P2), and (iii) a decreasing factor (P3).

To model the decrease of activity, we tried a first-order decreasing factor. As the fit was good (grey curves in figure 1), according to the principle of parsimony, we did not try to fit a second-order decreasing rate. By a first-order decreasing factor, we refer to the instantaneous decrease of activity being proportional to the instantaneous activity, the coefficient of proportionality being P3. Thus we assumed that A(t) denotes the activity at time t, Δt represents the change in time, and $A(t+\Delta t)$ is the activity at time $t+\Delta t$. Then a first-order decreasing rate was defined by $(A(t+\Delta t)-A(t))/\Delta t=-P3\, A(t)$.

After algebric manipulation, we obtained the model represented in figure 4.

It is clear that the created model cannot fit the data exactly; therefore the model which had to be used had to have another term (denoted εt), which measured the differences between the data and the model presented previously. Thus the following statistical model was arrived at: $A(t) = P1 + (P2 - P1)\exp(-P3 \cdot t) + \varepsilon t$.

Applying nonlinear regression (19) to the empirical data, we obtained the parameters shown in table 1.

The variations in the information gathering over the 3 shifts were correctly explained by the model (observed and theoretical data in figure 1). The goodness of fit was assessed by the calculation of R^2 (90.9%, 89.3% and 92.1% for the morning, the afternoon and the night shifts, respectively).

Discussion

Three interactive factors of supervisory activity

Presumably, the beginning of the morning shift (0400) is characterized by a low level of vigilance and a short previous sleep (20). Therefore, the existence of a relatively low peak of consultation and a large decreasing factor (P3=1,23) revealed a major effort to update the operators' mental image. As assessed by the operators, early morning hours quickly result in weak vigilance and low fatigue level. Thus they try to verify the state of the process more rapidly, when compared with the other 2 shift changeovers. In the afternoon, a high and increasing level of vigilance favors the persistence of a high level of activity over the shift (weak slope of the curve).

Finally, at night, the highest level of consultation peak occurs (68 pages per hour) due to a maximum of vigilance at the end of the afternoon (at 2000). It then decreases to a minimum of 14 pages per hour, a value coinciding with the decrease in alertness in the middle of the night.

The results show that the supervisory activity found in the present study depends on 3 main factors (figure 5). First, there is a workhour effect (or time-of-day effect, represented by the letter "C"), which leads to variations as predicted by chronobiological models. It is represented by a sinusoid with the lowest level in the middle of the night, an increase in the morning until a maximum in the evening. But, as already discussed, the data do not permit a firm conclusion about circadian effects. The second factor is a shift duration ("D"), which induces "fatigue", followed by a decrease in sampling activity (oblique lines in figure 5). No ratings of fatigue were really reported, but interviews with the operators and the record of postural, motoral, and verbal activities (21) suggested this effect. Moreover, from previous studies carried out in the same work situation and with the same operators, various measures (urinary cortisol) confirmed classical and well-established results concerning circadian variations (22). The third factor was task demands ("P"), particularly during the shift changeover. These demands are represented by a peak of consultations as compared with the basic level (horizontal line).

The interaction between the 3 factors (represented by C×D×P) leads to the 3 different evolutions, depending on the shift, observed in the supervisory activity (lower part of figure 5). According to our data, these evolutions are represented by 3 different curves.

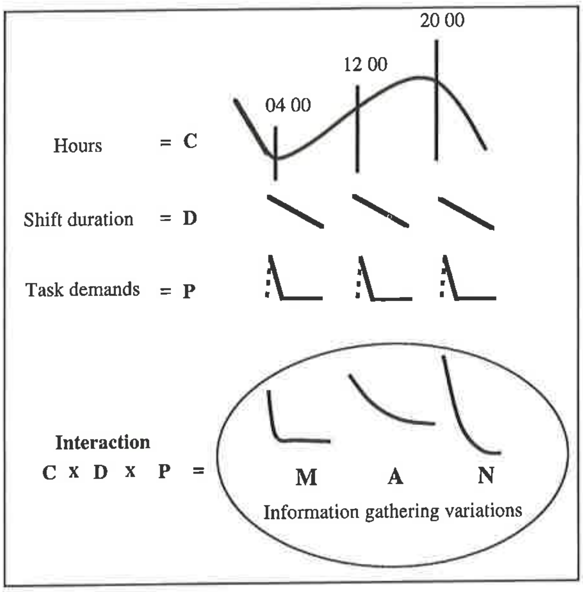

Figure 5. Three factors determining supervisory activity and information-gathering variations resulting from interaction of the factors according to the shift. (M=morning, A=afternoon, N=night)

Towards applications of the model

The classical sinusoidal model found in chronobiology cannot explain all the variations in observed operators' activity, such as a strong peak of consultation at 0400. The supervisory activity involves an interaction between the effect of biological rhythmicities and other external and internal factors. The cognitive demands of the task, which mainly concern the differences between the 2 work stages, and particularly their impact at the time of shift changeover, can mask, in part, the effect of circadian rhythms.

Our model was developed for a particular work situation and during regular operation. Thus generalization must take into account these conditions. Even if it concerns specific work situations (automated process control), we can however emphasize that, in any other situation, the impact of some task demands can modulate the time-of-day effect (14, 15). Whatever the process state (regular or not), the operators have to start their duty and update their mental image of the system at the start of the shift. Thus, even if an incident occurs, the shift changeover effect always appears more or less strongly. During a specific shift, an incident emergency will certainly influence the supervisory behavior at that moment (increase in the number of screen pages selected), but this kind of situation is punctual and independent of the time of day and does not disturb the model generalization over several days. On the average, the model predicts general and predominating behavior. Nevertheless, one may assume that the speed of the decreasing rate depends on the work load. This assumption needs, of course, further empirical validation. Nevertheless, some results presented recently showed a comparable evolution of activity over a 12-hour shift, in a power station (23).

If the model describes supervisory activity correctly, it may also lead to predictive hypotheses. Thus some applications of the model in the determination of work schedules could be inferred, in addition to an essential analysis of actual work activity to define job constraints.

For example, a computerized simulation based on the model could help the design of the best-shift duration. In a work situation, if the decreasing factor (P3) appears to be very high, it could be concluded that a short time is necessary to update the mental image or that the work constraints cause severe fatigue. Then it would be desirable to implement short shifts. On the other hand, a lower decreasing factor could reflect a long time to update the image or a lower level of fatigue induced by the work constraints. In this case a 12-hour shift would be acceptable. Furthermore, if the updating period is costly for the operator (that is, if he has to make a major effort to consult and memorize a large quantity of information at the beginning of the shift), it would be better to reduce the number of shift changeovers during the circadian cycle and thus profit by the updating for a longer time.

For work content and the consultation peak (P2), we could examine the schedule from a shift changeover point of view. As cognitive demands are always present at the beginning of the shift (the operators must update their mental image of the process whatever the shift), we can assume that these demands require effort that varies according to the time of day. In this case, the circadian constraints are important. We have noticed that the consultation peak is higher at 2000, when the level of vigilance is highest, than at 0400, when it is lowest. This finding suggests that 0400 is a bad hour for shift changeover and may lead to an unreliable mental image.

Another implication of the analysis is the importance of a staggered shift changeover. Our results showed a strong consultation peak during the 1st hour of work. If the entire team starts the shift at the same hour (as in the situation studied), all the operators have to update their image of the system at the same time, and none of them are totally operational during the 1st hour of work. The shift changeover is therefore a critical period for security. On the other hand, if the operators do not start their shift at the same time (some of them could successively arrive in the workshop every 30 minutes), there will be at least 1 operator who is operational. Moreover, much more information would be checked during 2 hours, and the probability of detecting a problem would increase. The shift changeover is then less critical.

From these 3 examples, we emphasize the necessity to supplement our model by analyzing actual work activity. The combination of these 2 methods could help to determine work schedules according to work load and reliability.

Conclusions

Supervisory activity varies according to the shift, and it results from the interaction between the effects of work hours, duration of shift, and cognitive demands of the tasks. This interaction is represented by a high level of mobilization during the shift changeover, followed by a progressive decrease to reach a basic rate of consultation. This latter corresponds to the supervision period. From an applied point of view, such a model would be helpful when shift duration and the time and duration of shift changeovers are being planned.

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References

1. Folkard S. Shiftwork and performance. In: Johnson LC, Tepas DI, Colquhoun WP, Colligan MJ, editors. Biological rhythms, sleep and shiftwork. Jamaica, New-York: MTP Press, 1981:283—306.
2. Folkard S, Monk TH. Shiftwork and performance. Hum Factors 1979;21:483—92.
3. Monk TH. Shiftworker performance. In: Scott AJ, editor. Occupational medicine. Philadelphia (PA): Hanley & Belfus, 1990:183—98. State of the art review, vol 5, no 2.
4. Maury P, Quéinnec Y. Effects of 24-hours day on depth of processing in recall memory. Br J Psychol 1992;83:249—60.
5. de Terssac G, Quéinnec Y, Thon P. Horaires de travail et organisation de l'activité de surveillance. Trav Hum 1983;46(1):65—79.
6. Quéinnec Y, De Terssac G, Dorel M. Temporal organization of activities in process control. In: Weddeburn A, Smith P, editors. Psychological approaches to night and shiftwork. Edinburgh: Heriot-Watt University, 1984:201—7.
7. Dorel M. Human failure in the control of nuclear power stations: temporal logic of occurrence and alterning work times. In: Stanton N, editor. Human actors in nuclear safety. London: Taylor & Francis Publishers, 1996:217—50.
8. Hoc JM. Strategies in controlling a continuous process with long response latencies: needs for computer support for diagnosis. Int J Man-Mach Stud 1989;30:47—67.
9. Iosif GH, Ene P. On operators' mental proceedings used in diagnosis. Rev Roum Sci Soc 1978;22(2):173—83.
10. Bainbridge LA. The process controller. In: Singleton WT, editor. The study of real skills, vol 1: The analysis of practical skills. St Leonardgate: MTP, 1987:236—63.
11. Samurçay R, Hoc JM. Causal versus topographical support for diagnosis in a dynamic situation. Trav Hum 1996,59(1):45—68.
12. Rouse WB, Morris NM. On looking into the black box: prospects and limits in the search of mental models. Psychol Bull 1986;100:349—63.
13. Hanish KA, Kramer AF, Hulin CL. Cognitive representations, control and understanding of complex systems: a field study focusing on components of users' mental models and expert/novice differences. Ergonomics 1991;34(8):1129—45.
14. Gadbois C, Quéinnec Y. Travail de nuit, rythmes circadiens et régulation des activités. Trav Hum 1984;47(3):195—226.
15. De Vries-Griever AHG, Meijman ThF. The impact of abnormal hours of work on various modes of information processing: a process model on human costs of performance. Ergonomics 1987;30:1287—300.
16. Folkard S. Some practical problems of shiftworking: effects on performance efficiency. In: Colquhoun WP, Costa G, Folkard S, Knauth P, editors. Shiftwork: problems and solutions. Berlin: Peter Land, 1996:65—87.
17. Folkard S, Akerstedt T. Towards a model for the prediction of alertness and/or fatigue on different sleep/wake schedules. In: Oginski A, Pokorski J, Rutenfranz J, editors. Contemporary advances in shiftwork research. Krakow: Medical academy, 1987:231—40.
18. Andorre-Gruet V. Approche chronopsychologique de la prise de poste et de la surveillance d'un processus dynamique continu [doctorat d'ergonomie]. Toulouse: Université Toulouse 2, 1997.
19. Systat Inc. Systat V. 5. Evanston (IL): Systat Inc, 1992.
20. Knauth P, Rutenfranz J. Duration of sleep related to the type of shift work. In: Reinberg A, Vieux N, Andlaeur P, editors. Night and shiftwork, biological and social aspects. Oxford:

Pergamon Press, 1981:161—8. Advances in the biosciences, vol 30.
21. Fezzani K, Maury P, Quéinnec Y. Impact of computerization of a continuous-process control room on the activity of operators: behavioral approach. In: Quéinnec Y, Daniellou F, editors. Designing for everyone. London: Taylor and Francis, 1991;1:810—2.
22. Quéinnec Y, Dorel M, De Terssac G, Thon P. Travail posté et régulations comportementales inter et intra-individuelles. Toulouse: DGRST, 1982:45p. Report no 79.7.1107.
23. Smith L, Gardner P. Temporal patterning of activity in control rooms. Shiftwork Int Newsl, 1997;14(1):45.

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Shift work and sick leave

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Objective Shift workers working nights are known to have higher morbidity from certain illnesses than day workers. This study examined episodes of certified sick leaves of day workers and shift workers in a large industrial plant to examine whether slowly rotating shift work leads to increased risk of sick leave.

Methods In a case-base design more than 11 000 episodes of sick leave, lasting more than 3 days, were obtained from the sick-leave files of a chemical plant in Norway. The diagnoses were grouped into 5 categories according to information on their work schedules. The workers included in the study were divided into 3 groups. They worked slowly rotating 3 shifts, 2 shifts without night work, and daytime schedules.

Results For all the diagnoses the shift workers and day workers were evenly distributed among the cases and the referents, the odds ratios ranging from 0.8 to 1.2. The risk of sick leave did not change with the number of years in shift work. There was a higher risk of sick leave with musculoskeletal diagnoses among the 2-shift workers.

Conclusions In this study shift workers did not have a higher risk of sick leave for diseases that, in previous studies, have been shown to be related to shift and night work. Although bias may be present in the study, the results are in line with those of previous studies, and they suggest that even certified sick leaves are not a valid proxy for morbidity.

Key terms cardiovascular disease, case-referent study, gastrointestinal disease, morbidity, night work.

Shift workers working nights are known to have a higher morbidity than day workers, although the difference in risk has been debated for some time. Higher risks have been found for gastrointestinal diseases, heart diseases, and minor mental illnesses (1—8). A few studies have focused on musculoskeletal diseases among shift workers. One study found a higher incidence of musculoskeletal diseases for this group (9), while another did not (10), even though the shift workers had more complaints of muscular pain. One study investigated a possible relationship between night work and cancer (11), which could theoretically be explained by the influence of night work on the production of the pineal hormone melatonin, followed by a possible weakening of the immune system (12). The evidence suggests a relationship between shift work and the development of specific diseases that might lead to sick leave documented by sick leave certificates.

Differences in absence from work and certified sick leave between day and shift workers have been explored in several studies with varying results. In general no differences in sick-related absenteeism between permanent shift workers and day workers have been found (9, 10, 13—15), although ex-shift workers are reported to have higher absence rates. Some studies have found differences between shift and day workers for certain shift work systems, but others have not (16—18). One explanation may be the differences in the type of data used.

In our study we used the physician-diagnosed sick leave episodes of more than 3500 persons over a period of 11 years, including all episodes of sick leave lasting more than 3 days, in order to clarify whether (i) a slowly rotating shift system leads to increased risk for sick leave for diagnoses known to be related to shift work, (ii) there is a difference in the length of sick leave between shift workers and day workers, (iii) shift workers have a higher

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risk of further sick leaves than day workers, and (iv) sick leave caused by musculoskeletal diseases is more frequent for shift workers than for day workers.

The study focused on whether the excess morbidity risk for specific diseases found in previous studies can be also seen in certified sick leaves of shift workers within the same diagnostic groups. In this manner, the study would be able to contribute to a further understanding of the importance of sick leave data in the consideration of disease risk related to shift work.

Methods

Thiis-Evensen studied the morbidity among day and shift workers in a Norwegian industrial plant (19, 20). He did not find any differences in mortality or morbidity except for former shift workers who had been transferred to day work for medical reasons. Our study was done at the same industrial plant, Norsk Hydro, Porsgrunn, located in the southern part of Norway. The main products of this chemical plant are fertilizers, magnesium, and polyvinyl chloride, and there are about 3500 employees in the plant today, including about 1200 3-shift workers. The plant has practiced different shiftwork systems over the years, but for the last 3 decades slowly rotating systems have been used.

According to Norwegian legislation, workers must obtain a sick-leave certificate from a physician after 3 calendar days of absence from work. Through 1979—1989 the Department of Occupational Health at the plant obtained information from the National Insurance Fund authorities about the causes of sick leaves lasting for more than 3 days and documented by a physician's diagnosis for all the workers in the plant. In 1990 the transfer of such information was stopped for legal reasons. This information was computerized in the Department of Occupational Health, and the physician' diagnoses were translated to WONCA-codes (World Organization of National Colleges, Academics and Academic Association of General Practitioners) , according to the International Classification of Health Problems in Primary Care (ICHPPC), developed in 1977 (21). This work was done by the same person during the whole period. In the plant's administrative computer system, the date of starting work at the plant, the dates of starting and ending work in different departments, department codes, and worktime systems have been registered since the mid-1970s, and data from about 1950 have been computerized later.

Our study base was defined as all employees in the parts of the plant where shift work was done in 1979—1989. Daywork and shiftwork schedules co-existed in all these areas. Persons who worked in sections of the plant without shiftwork systems were excluded.

Because information about earlier engagements in the plant was only complete for workers still working in the plant in the mid-1970s, when the administrative computer system was introduced, it was not possible to follow a cohort before this time, and the study was therefore designed as a case-base study in order to obtain potential long exposures.

In the computer-system of the Department of Occupational Health all sick-leave episodes in the period were identified and transferred to an independent data base with information on personal identification number, date of sick leave, length of absence, diagnosis, and the WONCA code of the diagnosis. From the administrative system 2 referents were chosen for each case. The randomization of these referents was achieved by choosing the 2 persons with the birth dates closest to the cases, independent of whether or not they had had a sick leave in the same period (22).

Some episodes of sick leave lasting less than 3 days were coded with diagnoses, but since the diagnoses were only complete for sick leaves of more than 3 days, all certified sickness absence for less than 3 days was excluded from the study.

For each sickness episode information on year of birth, gender and work commencement date was added from the administrative system. Finally, from the administrative system, information was added about all work in different sections of the plant with the starting and stopping dates, department code, and work system. For the cases this information was given from the date of starting work until the date of sickness episode, and for the referents there was information from the date of starting work until the date of the sickness episode of the paired case. Therefore the information on worktime, for both the cases and the referents, consisted of the worktime system at the time of the relevant episode of sickness and information on the worktime system from the start of work in the plant until the sickness episode.

For several periods of work there was no information about the work system at the time of the sickness absence (or the case person's absence). These episodes (N=862) have been excluded from the study. Furthermore, 13 080 (14.7%) posts were not coded with information on worktime arrangements. These episodes occurred especially before 1970 and were included with missing values. The final data base was thereafter anonymized by eliminating the personal identification numbers.

With the use of the information on birth date and the date of sickness absence, the age at the time of the sickness absence was calculated, and the period of work was calculated as the difference between the date of starting work in the plant and the date of the sickness absence.

The WONCA diagnoses were aggregated into 5 groups for neoplasms, minor mental illnesses, gastrointestinal diseases, coronary heart diseases, and musculoskeletal diseases. The first incidence of a diagnosis with a WONCA code within each of these groups was registered as the first sick leave, and information on later episodes within the same group (even if there were different diagnoses) were aggregated.

The computer system registered 14 different work systems. According to experience within the plant, they were aggregated into the following 3 main types of systems: day work, 2-shift work (day and afternoon), and 3-shift work (primary slowly rotating, including day, afternoon and night work, 7 days a week). With the use of this aggregation the number of years of work within each group was calculated until the time of the sick leave. Ex-shift workers were defined as persons who were day workers at the time of the sickness absence, but who earlier in their work career at the plant had been registered as 3-shift workers (without regard for the duration of the work system).

The construction of the data bases was done in Paradox for Windows 1.0, and the analyses were carried out by and written out from SPSS for Windows 6.03. The material was compared using a nonparametric analysis (chi-square and Mann-Whitney U-test). As the comparison was done for pooled referents, age, period of engagement, and gender were entered together with work history into a logistic regression model in a forward stepwise selection for each diagnostic group.

Table 1. Median and interquartile range (IQR) of the age and worktime of the cases (N=3580) (first-time sick leave) and referents (N=7582), as well as the proportion of men.

	Age (years)		Length of work in the company		Male gender (%)
	Median	IQR	Median	IQR	
Cases	39.0	29.0	11.9	19.9	91.8
Referents	38.0	29.0	12.0	20.0	91.5
P-value	0.65	0.07	0.65		

Table 2. Distribution of first-time sick leave, grouped according to the WONCA diagnoses. (WONCA = World Organization of National Colleges, Academics and Academic Association of General Practitioners)

Diagnosis group[a]	N	%
Minor mental illnesses (W3000-W3009)	116	3.2
Gastrointestinal diseases(W0080-W0090, W5300- W5360, W5640, W7841,W7855)	142	4.0
Coronary heart disease (W3900-W4290)	103	2.9
Musculoskeletal disease (W7170-W7380)	667	18.6
Neoplasms (W1510-W2390)	36	1.0
Other diagnoses (Other W diagnoses and all Y diagnoses)	2 517	70.3
All the diseases combined	3 581	100

[a] The codes of the WONCA classification are given in parentheses.

Table 3. First-time sick leave for the 5 defined diagnosed groups distributed according to work system. Chi-square: 0.03

Work system	Cases (N)	Referents (N)
Day work	649	1325
Two-shift work	64	80
Three-shift work	334	639
Ex-shift work	17	29
Total	1064	2073

Results

A total of 11 657 sick leaves was found for 3581 persons for the entire period. In addition 25 597 episodes were chosen for the referents randomly by the computer. There were no differences in age, number of years at work, or gender between the shift workers with sickness absences and the referents (table 1).

The first-time sickness absences and the grouped WONCA codes for the 5 defined groups of diseases are shown in table 2.

The distribution of the case persons and the referents according to the worktime systems at the time of the sick leave is shown in table 3. There was an excess of 2-shift workers among the case persons, when they were compared with the referents, and a smaller excess of 3-shift workers. Two-shift workers had greater odds of being cases than the day workers, the crude odds ratio being 1.63 [95% confidence interval (95% CI) 1.16—2.30]. The 3-shift workers (OR 1.07, 95% CI 0.91—1.26) and ex-shift workers (OR 1.20, 95% CI 0.65—2.19) also had higher odds ratios, but the difference did not reach statistical significance.

Table 4 presents the odds ratios of the 3-shift workers and the ex-shift workers, in comparison with the day workers. No elevated risks were seen for any of the diseases. As 3-shift workers were in general both younger with a shorter duration of employment, it was decided to regard age and employment length as potential confounder variables and to control for these factors in a logistic regression model. The interaction between age and employment length was tested, but it did not alter the odds ratios, and it was excluded from the models. The adjusted odds ratios are presented for the 3-shift workers. The odds ratio did not differ to any degree, meaning that age, employment length, and gender did not confound the results.

The 2-shift workers had an elevated risk of musculoskeletal disease (crude OR 1.91, 95% CI 1.25—2.90). The odds ratio for the remaining disease groups was 1.69 (95% CI 0.50—5.74) for minor mental diseases, 1.30

(95% CI 0.45—3.78) for gastrointestinal diseases, 1.16 (95% CI 0.43—3.78) for coronary heart diseases, and 0.45 (95% CI 0.05—4.25) for neoplasms.

The odds ratios for different lengths of employment in 3-shift work are shown in table 5. With shift work for less than 1 year as reference, the odds ratios did not differ in any of the groups. This finding suggests that the risk of sick leave did not increase with length of shift work.

The total number of sick leaves in the 10-year period within the same diagnostic group did not differ between the 3-shift workers and day workers. The length of first sick leave was also the same for all the diagnostic groups, except that shift workers with musculoskeletal diseases had a statistically significant longer first sick leave (median 12 days compared with 10 days for the day workers).

Table 4. Odds ratios (OR) and 95% confidence intervals (95% CI) for first-time sick leave for the current 3-shift workers and former 3-shift (ex-shift) workers in relation to day work.

Disease group	N	Crude OR[a]	95% CI for crude OR	Adjusted OR[a]	95% CI for adjusted OR[a]
Minor mental illnesses					
Day workers (referents)	203	1	.	1	.
Current 3-shift workers	118	1.04	0.64—1.68	1.04	0.64—1.70
Former 3-shift workers	12	1.01	0.30—3.49	.	.
Gastrointestinal diseases					
Day workers (referents)	275	1	.	1	.
Current 3-shift workers	123	1.01	0.65—1.59	1.02	0.64—1.63
Former 3-shift workers	4	0.65	0.07-6.36	.	.
Coronary heart diseases					
Day workers (referents)	200	1	.	1	.
Current 3-shift workers	86	0.74	0.643—1.29	0.75	0.42—1.31
Former 3-shift workers	3	.	.	.	.
Musculoskeletal Illnesses					
Day workers (referents)	1.226	1	.	1	.
Current 3-shift workers	615	1.16	0.95—1.43	1.14	0.92—1.40
Former 3-shift workers	12	1.01	0.30—3.49	.	.
Neoplams					
Day workers (referents)	70	1	.	1	.
Current 3-shift workers	31	0.74	0.29—1.84	0.75	0.29—1.94
Former 3-shift workers	12	1.01	.	.	.

[a] Adjusted for age, seniority, and gender in a logistic regression model.

Discussion

Three-shift workers do not appear to have an excess risk of sick leave, as there were no differences in the odds ratios between the day and shift workers with respect to sick-leaves for specific diagnostic groups combined or for any single diagnostic groups. This finding might be surprising, as the diagnoses selected for grouping were those associated with shift work (ie, minor mental illnesses, gastrointestinal diseases, and coronary heart diseases). The 2-shift workers had a significant excess of sick leaves from diagnoses in the musculoskeletal group. However, the 2-shift workers in this plant mainly had heavy manual work in packaging departments and also in the handling of ship cargo, and these results can, thereby, probably not be related to the worktime system.

Several studies have been published on the sickness absence of shift workers, but few have been published during the last few years. Some concluded that day workers had a higher rate of sickness absence (14, 19, 20), others came to the opposite conclusion (9, 23), and some found no difference (10, 24). The variations may be have been caused by, for example, national and cultural differences, methodological and design variations, including or not including ex-shift workers in the day work force, the quality of the sickness reports and personnel records (25), and the like.

Angersbach et al (9) found, for instance, no differences in sick-related absenteeism between permanent shift workers and day workers, but sickness absence was twice as high among ex-shift workers. Likewise, Koller (10) found no differences between day and shift workers in the average number of days of absence due to sickness, but she found a difference for former shift workers and also an increase in the number of days of sick leave with increasing exposure to shift work. In our study, the group of ex-shift workers, although this group was surprisingly small, did not differ from the other shift workers. We were not able to distinguish between those who left shift work for medical reasons and those who left for other reasons, and the data may also have been biased by the fact that former shift workers who eventually transferred to day

Table 5. Odds ratios (OR) and 95% confidence intervals (95% CI) for the 5 diagnostic groups for current shift workers according to years in shift work.

Length of shift work	Minor mental illnesses		Gastrointestinal illnesses		Coronary heart diseases		Musculoskeletal illnesses		Neoplasms	
	OR	95% CI	OR	95% CI	OR	95%CI	OR	95% CI	OR	95% CI
0-1 years (reference group)	1	.	1	.	1	.	1	.	1	.
1-5 years	0.82	0.40—1.69	1.24	0.55—2.82	5.02	0.63—40.27	0.79	0.54—1.14	1.08	0.09—12.52
6-10 years	1.18	0.50—2.84	0.76	0.32—1.74	1.22	0.44—3.33	1.13	0.79—1.62	1.90	0.37—9.80
≥11 years	0.94	0.49—1.81	1.24	0.68—2.27	1.25	0.67—2.32	0.88	0.68—1.15	1.26	0.43—3.68

work or to other departments of the plant than those integrated in the study were not included. There were no differences in the duration of sick leave between the groups.

This study used incidence sampling of all first-time sick leaves in a 10-year period, thereby minimizing selection bias. There may have been differences in sick leave by work pattern, but, for all the years studied, the national insurance or the employer paid full wages for absence days for both shift and day workers. In other words, economic incentives between the groups were not important.

Information on diagnosis came from different physicians, and 1 source of information bias could have been the their interpretation of the patients' symptoms. Such differences could have influenced the quality of the diagnosis. If information on the work pattern influenced the diagnosis (a shift worker being more likely to be diagnosed as having a disease common among shift workers), the risk estimates would have tended to be higher. Diagnoses were interpreted and translated into WONCA codes by the Department of Occupational Health, but the same person did this job and was blind to the work pattern of the sick. Using a broadly defined diagnostic grouping might further have diluted an information bias due to diagnoses, but it could also have led to nondifferential misclassification.

Information on the work pattern was found in administrative files and was independent of sick leave. The files were, however, incomplete and could theoretically have led to differential misclassification if certain work schedules had been more likely to be missed.

As a consequence of Thiis-Evensen's research (19, 20), there had been a preemployment screening of shift workers until the early 1970s, which had excluded workers with gastrointestinal problems or sleep disorders. There is no information available on how many workers were excluded through the screening. Workers with coronary heart diseases and muscular complaints were not excluded, and, if preemployment classification led to the observed effect, lower risk estimates would have been evident only for gastrointestinal diseases and minor mental illnesses, which was not the case. The effect of this possibility leads, in addition, to the general healthy worker effect, which is known to result in self-selection among shift workers.

The data offered no possibilities of controlling for selection bias with respect to preemployment screening or changing to departments inside the company with no shift work or to day work outside the company.

Differences in other work factors might have confounded the work schedules. The shift workers were all operators of factories that had been automated for decades. The day workers comprised a large group of maintenance personnel, but also office workers and management were included so that the organizational work conditions may have been different. The chemical and physical exposure to gases, dust, and noise was the same for all the groups of the day and shift workers, except for some white-collar workers. The 2-shift workers had handled ship cargo and packaging. Besides being engaged mainly in manual labor, these workers may have had other self-selecting mechanisms, and different reasons for quiting shift work than the 3-shift workers did.

As in several other reports, we cannot account for differences between shift and day workers that may have confounded the study, for example, eating habits, organizational and social relations, and smoking habits (17, 26).

The higher morbidity for shift workers documented in several studies (1), such as differences in sick leave between the day and shift workers, was not found in this study. An interesting topic for this discussion is, however, the meaning of absence or sickness absence, and the coherence between sick leave and morbidity. Taylor et al (15) stated that sickness absence is not synonymous with morbidity; instead it can be looked upon as a way of withdrawal from work. Several factors may explain the possible differences in sickness absence behavior between co-workers and between shift and day workers. Taylor (13) described shift workers who had a higher involvement and higher job satisfaction than day workers, and concluded that these factors may influence shift workers' experience of work stress and their threshold for sickness absence, or that they may simply represent differences in other organizational work conditions. Fisher (17) referred to a range of different connections found in studies of sick leave among shift workers, and this range represents the variations of factors that influence absence and sick leave. It has also been stressed that shift workers' concept of symptoms may differ from the day workers' because shiftwork problems are looked upon as natural a priori conditions linked to shift work, and they do not qualify as reasons for sick leave (27). Furthermore, there may be intergroup relations among shift workers, such as work group coherence and loyalty, which differ from that of day workers and which may affect sickness absence behavior.

As in most studies of sick leave among shift workers, this study showed that the incidence of sick leave is not higher among shift workers than among day workers. The results must be seen in relation to the conclusions of earlier studies, and they point towards the fact that the level of sick leave among employees cannot be related to morbidity (10, 14, 18), and that the coherence between shift work and sick leave is still unclear. We do not question the fact that shift work is a risk factor for disease (28). It would be important to verify the assumptions that shift work implies work culture and attitudes which differ from those of day work and that these factors are expressed in sickness-absence behavior.

Knowledge about this subject would increase our understanding of the dynamics of shift work in relation to health and later risk of morbidity. Currently sickness absence should not be used as a proxy for morbidity among shift workers.

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References

1. Waterhouse JM, Folkard S, Minors DS. Shiftwork, health and safety: an overview of the scientific literature 1978—1990. London: Her Majesty's Stationery Office, 1993:1—31.
2. Scott A, Ladou J. Shiftwork: effects on sleep and health with recommendation for medical surveillance and screening. In: Scott AJ, editor. Shiftwork. Philadelphia (PA): Hanley & Belfus Inc, 1990:273—99. Occupational Medicine State of the Art Reviews, no 5.
3. Moore-Ede M, Richardson G. Medical implications of shift work. Ann Rev Med 1985;36:607—17.
4. Jeppesen H. Skiftarbeide — et kendt og fortrængt problem [Shift work: a well known and forgotten problem]. København: Specialarbeiderforbundet i Danmark, 1990:1—101.
5. Akerstedt T, Knutsson A. Shiftwork. In: Occupational health, recognizing and preventing work-related disease. Boston (MA): Little, Brown & Co, 1994:407—17.
6. Tüchsen F, Jeppesen H, Bach E. Employment status, non-daytime work and gastric ulcer in men. Int J Epidemiol 1994;23:365—70.
7. Kristensen T. Cardiovascular diseases and the work environment: a critical review of the epidemiologic literature on nonchemical factors. Scand J Work Environ Health 1989;15:165—79.
8. Knutsson A. Shift Work and coronary heart disease. Scand J Soc Med 1989;44 suppl:1—36.
9. Angersbach D, Knauth P, Loskant H, Karvonen MJ, Undeutsch K, Rutenfranz J. A retrospective cohort study comparing complaints and diseases in day and shift workers. Int Arch Occup Environ Health 1980;45:127—40.
10. Koller M. Health risks related to shift work. Int Arch Occup Environ Health 1983;53:59—75.
11. Taylor P, Pocock S. Mortality of shift and day workers 1956—68. Br J Ind Med 1972;29:201—7.
12. Tamarkin L, Almeida OF, Danforth DN Jr. Melatonin and malignant disease. Ciba Found Symp 1985;117:284—99.
13. Taylor P. Shift and day work, a comparison of sickness absence, lateness, and other absence behavior at an oil refinery from 1962 to 1965. Br J Ind Med 1967;24:93—102.
14. Pocock SJ, Sergean R, Taylor P. Absence of continuous three-shift workers. Occup Psychol 1972;46:7—13.
15. Taylor PJ, Pocock SJ, Sergean R. Absenteeism of shift and day workers. Br J Ind Med 1972;29:208—13.
16. Smith MJ, Colligan MJ, Tasto DL. Health and Safety consequences of shift work in the food processing industry. Ergonomics 1982;2:133—44.
17. Fisher FM. Retrospective study regarding absenteeism among shiftworkers. Int Arch Occup Environ Health 1986;58:301—20.
18. Costa G, Lievore F, Micciolo R. Morbidity and absenteeism of railway shiftworkers. In: Oginsky A, Pokorski J, Rutenfranz J, editors. Contemporary advances in shiftwork research. Krakow: Medical Academy, 1987:297—304.
19. Thiis-Evensen E. Skiftarbeid og helse — II [shift work and health]. Porsgrunn (Norway): Norsk Hydro, 1956:pp 1—67. In Norwegian.
20. Thiis-Evensen E. Shift work and health. Ind Med Surg 1958;27:493—7.
21. University of Trondheim. International classification of health problems in primary care. Norwegian Edition. Trondheim (Norway): University of Trondheim, 1977.
22. Rothman K. Modern epidemiology. Boston (MA): Little, Brown & Co, 1986.
23. Lai CS. Sickness absence in a Singapore refinery 1981—92. Ann Acad Med Singapore 1994;5:660—4.
24. Fujita T. A retrospective cohort study on long-term health effects of shiftwork [abstract]. Nippon Koshu Eisei Zasshi 1993;40:273—83.
25. Colligan MJ, Smith MJ, Hurrell JJ, Tasto DL. Shiftwork: a record study approach. Behav Res Methods Instrum 1979;11(1):5—8.
26. Walker J, de la Mare G. Absence from work in relation to length and distribution of shift hours. Br J Ind Med 1971;28:36—44.
27. Agervold M. Shiftwork — a critical review. Scand Psychol 1967;17:181—8.
28. Costa C. The impact of shift and night work on health. Appl Ergon 1996;27:9—16.

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Combined effects of shift systems and work requirements on customs officers

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Prunier-Poulmaire S, Gadbois C, Volkoff S. Combined effects of shift systems and work requirements on customs officers. *Scand J Work Environ Health* 1998;24 suppl 3:134—140.

Objectives The aim of this study was to examine the combined impact of different shift schedules and job demands on the physical health of customs officers.
Methods The following schedules were used: 4×6 hours, 3×8 hours, 2×12 hours, and day work. Data were collected via a questionnaire specially designed for the evaluation of specific job demands on the basis of ergonomic analyses in 10 units. A correspondence analysis led to the identification of 3 variables representing different categories of work-related constraints, namely, physically demanding job, boring, monotonous job, and conflicting relations with travelers. These variables were included in a series of logistic regression analyses on the health aspects of the customs officers.
Results The analyses highlighted the dominating effect of the 3×8 hour and 4×6 hour schedules on the occurrence of health problems but also showed strong effects for confrontation with travelers. The conflictual relations with travelers had the largest and most marked influence, it played a role in the area of sleep and cardiovascular and digestive problems. All of the 3 central job demands had an effect on sleep.
Conclusions The results point to a need for a multifaceted approach to research and intervention regarding the difficulties encountered by shift workers, from both the occupational medicine and the work design point of view. This conclusion seems particularly relevant for several professional sectors in which workers are confronted with both shift work and customer-focused jobs (police, prison guards, nurses, and the like).

Key terms 2×12 hours, 4×6 hours, customer-focused job, health, job demands.

Today, it is recognized that the negative effects of shift work are not merely the result of biological and social desynchronization, but may also stem from other adverse conditions linked to the work performed. This idea, expressed 20 years ago (1) and further developed since then (2—5), has not yet been fully integrated into the theoretical models presented in the shiftwork literature (6). It has only been explored in a limited manner by a relatively small number of laboratory and field studies. The long-term combined effects of shift schedules and job demands on health have been documented by only a few studies (7—9). Thus it seemed necessary to analyze further data gathered within the framework of a survey of customs officers who carry out somewhat similar jobs in different locations and on different schedules. The results and implications of other aspects of this research have been presented in earlier papers (10, 11).

Subjects and methods

Subjects

At the joint request of the French customs service and the unions, a survey was carried out in order to evaluate the repercussions of job demands and shift systems on the health, family life, and social life of customs officers. The customs service carries out the task of permanent surveillance of the borders and runs numerous controls within France. Forty-four national units representative of the diversity of shift systems, job demands, and local conditions were covered. The shift systems practiced by these units varied in function according to the geographic location of the unit and the nature of the job performed. The shift schedules primarily differed around 2 parameters, namely, the daily duration of work (6, 8, 9 or 12 hours) and the shift cycle. From these, a

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subsample of 4 groups was selected for the purpose of this study (6 hours, 8 hours, 12 hours, and day work) giving a total of 302 participants.

Shift schedules

4×6-hour shift. The 1st schedule is based on 4 shifts of 6 hours each, morning (0700—1300), afternoon (1300—1900), evening (1900—0100) and night (0100—0700). Shift rotation is rapid, with a highly irregular cycle characterized by the need to schedule 6.5 shifts to accomplish the weekly work. This necessity results in an obligation to work at least 6 days out of 7 and to accumulate periodically 2 shifts on the same day (usually 0700—1300 and 1900—0100). Seven of the units studied used this work schedule and were included in the analyses. In these units, of the 94 employees who participated in the survey, 42% were 40 or more years of age.

3×8-hour shift. Two units used a 3-shift schedule with each shift of roughly equal duration, namely, morning (0500 or 0600—1300), afternoon (1300—2000 or 2100), night (2100—0500). These units generally operated at fixed border crossings and performed their work inside specialized check-points protected from the elements. Shift rotation was rapid, and the schedule was highly variable. Then work sequences ranged from 2 to 5 days. Of the 53 employees who participated in the survey, 39% were 40 or more years of age.

2×12-hour shift. A schedule of two 12-hour shifts (day shift 0700—1900, night shift 1900—0700) was carried out by 5 units of customs service employees who worked at the Paris airport authority. The employees work 1 night shift for every 2 day shifts in a fast rotation system. A theoretical sequence of day-day-night was followed with some variation, depending on the requirements of the unit and the employees' wishes. Of the 115 employees who participated in the survey, 28% were 40 or more years of age.

Day work. Among the customs surveillance units, only the airborne divisions work exclusively daytime hours due to the nature of their work (identification and monitoring of suspicious vessels and pleasure boats). Two such units were surveyed: one organized exclusively on the basis of day work (0800 to 1200—1400 to 1700), and the other combining long days (0700—1900) with short days (0700—1200 or 1300—1900). Of the 40 employees who participated in the survey, 66%were 40 or more years of age.

Procedure

Data collection

The data collection contained 2 steps (figure 1). The first, carried out among 10 units, consisted of an ergonomic analysis (by observation and interviews) of the unfolding of the work activities, and it was intended to provide the elements necessary for the construction of a support questionnaire for the 2nd step of the study. This questionnaire was constructed in such a way as to be balanced with regard to the diversity of shift systems and work conditions. It contained 223 items selected on the basis of the presurvey and related shiftwork literature.

The following 8 areas were covered: personal data, housing and commuting conditions, family situation, shift schedules (structures and practice, attitude towards), work history (how long on shift work, geographic moves), job demands, health and sleep, and leisure-time activities.

The items used for health were taken from existing health measures (12). They mainly covered gastrointestinal and cardiovascular complaints (11 items), medication (10 items), and questions about health behavior (eating habits, caffeine consumption, smoking) and sleep difficulties (3 items).

Work conditions were evaluated by a series of 39 questions covering the following different factors inventoried during the course of the initial step (ergonomic analysis of work): (i) physical and postural demands of the job; (ii) environmental factors (temperature, luminosity, etc) and their possible effects on physical painfulness of the job; (iii) psychological demands for attention

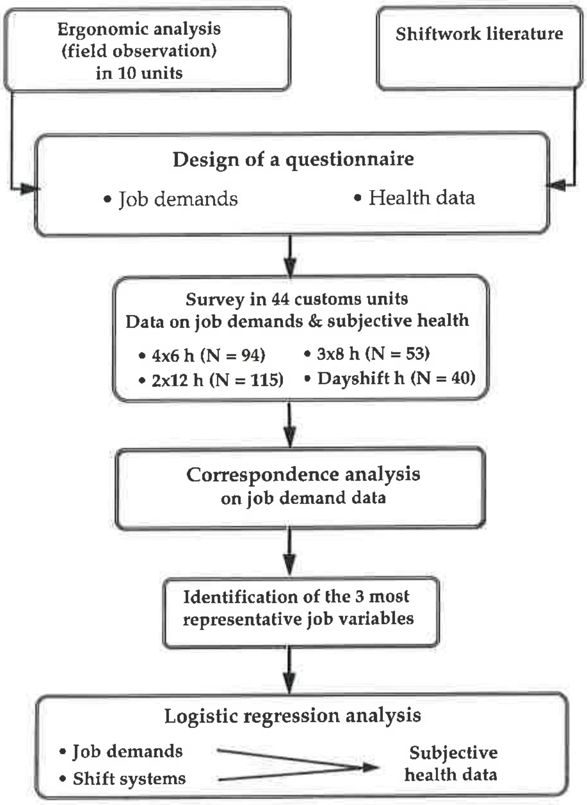

Figure 1. Outlines of the study.

and vigilance; (iv) appropriateness of material means for performing the job; (v) quality of professional training and whether it was adapted to the reality of the field; (vi) interest and variety of the job to be performed; (vii) freedom to use initiative, autonomy, and possibility or not of using personal competence; (viii) being sedentary or mobile as required by the job (frequency of travel and distance covered daily); (ix) interaction with customers, that is, characterization of the nature of relations established at the time of controls (appearance of conflicts, altercations or, on the contrary, neutrality of exchanges) and their effects on the life and socioprofessional image of the customs officers; (x) perception of risks run during job performance and the variation of this perception according to time of day or night and the prolongation of shifts; (xi) temporal dynamics of the job and variations in the rhythms of work during the course of the work periods; and (xii) effect of climatic conditions on job activity and possible influences on the temporal organization of the job.

Statistical analyses

In the 1st phase, the structure of work demands were analyzed by means of a correspondence analysis (13). The analysis was done with statistical SAS/Stat software. The aim of the analysis was to elucidate the structure of the customs officers' work experience and to identify a few variables capable of adequately summarizing that experience. The analysis included 39 variables, each having 2, 3, or 4 modalities; it produced 2 axes expressing 7.7% and 5.1% of inertia.

On the basis of this analysis, 3 of the 39 variables appeared to be the most pertinent for use in the 2nd step, which examined the respective impact of shift work and the tasks demands on health, due to their capacity to sum up within themselves a series of other variables and their capacity as valued by their contributions to inertia. The 3 variables follow:

1. "Physically demanding job" which corresponded to the question "Are you subject to physically fatiguing work conditions ?" in the questionnaire. This variable was chosen because the correspondence analysis indicated that it summarized the characteristic constraints of the typical situation of the "exposed" worker (strong job; physical, environmental, psychological constraints).

2. "Conflicting relations with travelers" which corresponded to the question "Do the interactions with travelers become exhausting after several hours?" This variable was chosen as the best indicator to represent the relational difficulties with customers (aggressive behavior, frequent disputes or altercations during customs checks).

3. "Boring, monotonous job" which corresponded to the question "How diversified do you find your job (very;

Table 1. Logistic regression analysis of the subjective health indicators, adjusted odds ratio (OR) for all factors in the table. (95% CI =

Health indicator	Gender		Age group (years)					
	Male		30—40		40—50		50—60	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep disturbances (χ^2= 67.2 - P<0.0001)					2.5**	1.09—5.89	2.5*	0.70—8.62
Sleeping pills (χ^2= 31.9 - P=0.0008)					4.7**	1.62—13.44	5.7**	1.43—22.24
Tranquillizers (χ^2= 34.7 - P=0.0003)					4.1**	1.54—10.91	8.6***	2.40—30.69
Antidepressants (χ^2= 32.1 - P=0.0007)	0.3**	0.14—0.80			4.1**	1.51—11.13	7.8**	2.13—28.32
Heart beating irregularly (χ^2= 31.4 - P=0.0009)					2.4*	1.05—5.66	6.4**	2.0—20.21
Heart palpitations (χ^2= 29.7 - P=0.002)					3.4**	1.37—8.34	5.8**	1.78—18.65
High blood pressure (HBP) (χ^2= 25.05 - P=0.0089)					2.2^{+}	0.90—5.48	2.9^{+}	0.86—9.45
Drug control HBP (χ^2= 31.40 - P<0.0001)					3.6*	1.19—11.10	6.9**	1.71—27.70
Shortness of breath (χ^2= 37.48 - P=0.001)			2.9**	1.21—7.04	4.4**	1.71—11.25	7.7***	2.26—25.67
Precordialgia (χ^2= 31.46 - P=0.001)					3.5**	1.39—8.77	4.5**	1.32—14.96
Digestion difficulties (χ^2= 42.9 P<0.0001)							2.6^{+}	0.83—8.06
Disturbed appetite (χ^2= 44.2 - P<0.0001)			0.5^{+}	0.25—1.08				
Nauseous (χ^2= 32.9 - P=0.0005)	0.5^{+}	0.20—1.05					5.4**	1.66—17.39
Bloated stomach or flatulence (χ^2= 42.1 - P<0.0001)	0.5^{+}	0.27—1.09	2.2*	1.06—4.51	3.8***	1.74—8.36	8.7***	2.62—28.66
Stomach upsets (χ^2= 56.1 - P<0.0001)								
Antacids (χ^2= 34.1 - P<0.0003)	0.4**	0.19—0.86			2.2^{+}	0.94—4.87	5**	1.59—15.44
Constipation (χ^2= 21.9 - P<0.02)							2.9*	0.96—8.65
Visual problems (χ^2= 31.52 - P=0.0009)					2.2*	1.03—4.73	4**	1.33—11.91
Leg problems (χ^2= 39.21 - P<0.0001)	0.4**	0.18—0.80			1.2	0.56—2.60	4.2*	1.13—15.08
Backaches (χ^2= 24.15 - P<0.01)	0.5*	0.23—1.01						
Pain killers (χ^2= 49.59 - P=0.0001)	0.3***	0.15—0.62			2.7**	1.22—5.84	5.4**	1.64—17.91

*** P<0.001. ** P<0.01. * P<0.05. $^{+}$ P<0.1.

somewhat; not enough)?" This variable was chosen because the result of the correspondence analysis showed that it was associated with the following items: "possibility to use individual competence", "feelings proved in the situation of time constraints", "freedom of action within work".

The use of such variables avoids having to introduce a large number of intercorrelated independent variables into the causal analyses, in which variables run the risk of mutually disputing their explicative power.

The 2nd step consisted of a series of logistic regressions to determine the effects of job demands and shift work on health. This technique gave an estimation of the relative risk in comparison with a reference group (odds ratio). It is equal to 1 if the considered factor is not linked to the studied health problem. If it is more than 1, it means that the factor provokes a rise in the occurrence in the studied problems, a rise all the more important when the odds ratio is high. The increase or decrease of the risk is reflected by the value of the odds ratio (OR). The independent variables were the type of work schedule (3x8 hours, 4x6 hours, 2x12 hours, day work), the 3 job variables ("physically demanding job", "boring, monotonous job", "conflicting relations with travelers") and the 2 individual characteristics gender and age (20<30, 30<40, 40<50, 50<60 years). Shiftwork experience was not included as an independent variable because, in this population, it was strongly linked with age. The dependent variables were the different complaints concerning gastrointestinal, sleep, cardiovascular and nervous problems. For this study, the reference group comprised 20- to 30-year-old female day workers who were not subject to any of the 3 job variables. However, it must be noted that the conclusions reached were not dependent on the choice of reference situation.

Results

Table 1 shows the results for the total cohort.

Effects of gender

The effects of gender showed up in a significant way only for a few items. The women suffered more from musculoskeletal problems and from some digestive symptoms (nausea, bloated stomach, flatulence). They took more medication (antidepressants, painkillers and stomach ache pills).

Effects of age

The second part of the results documented the effects of age, a classic phenomenon but one that merits attention. The probability of voicing complaints for each type of

95% confidence interval)

Shift schedule						Work conditions					
4x6 h		3x8 h		2x12 h		Physically demanding job		Relation with travelers		Monotonous	
OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
3.5**	1.38—8.68	5.5**	1.79—16.73	2.2+	0.89—5.37	2.7**	1.37—5.19	4.1***	1.78—9.61	2.6*	1.14—5.89
4.7**	1.16—18.76	6.5**	1.46—28.78	.	.	.	.	1.9+	0.88—3.91	.	.
7**	1.75—27.17	6**	1.40—25.54	3.2+	0.82—12.71	.	.	.	.	.	.
5.8**	1.47—22.92	5.1*	1.16—21.98	.	.	.	.	.	.	.	.
5.5**	1.86—16.09	4.9**	1.51—15.89	.	.	.	.	1.7+	0.93—3.25	.	.
4.6**	1.57—13.57	4.2**	1.28—13.41	.	.	.	.	.	.	.	.
1.9	0.73—5.16	3.1*	1.05—9.10	.	.	2.2**	1.17—4.08	.	.	.	.
5.4**	1.32—22.22	4.9*	1.07—21.96	.	.	0.5+	0.20—1.11	.	.	.	.
2.9*	1.06—7.84	4**	1.37—11.80	.	.	.	.	2.1*	1.10—3.85	.	.
3.1*	1.02—8.83	2.7+	0.82—8.64	.	.	.	.	2.7**	1.41—5.14	.	.
2.3+	0.93—5.43	3.3*	1.19—9.11	.	.	.	.	3.1**	1.56—6.15	1.9+	0.88—3.91
2.7*	1.06—6.96	3.5*	1.21—9.67	.	.	1.7+	0.93—3.25	2.5**	1.33—4.65	.	.
3.6*	1.18—10.57	2.8+	0.85—9.26	.	.	.	.	2.8**	1.45—5.30	.	.
2.6*	1.07—6.25	3*	1.11—8.16	.	.	.	.	3.3***	1.67—6.34	.	.
.	.	3.7**	1.36—10.07	.	.	.	.	3.5***	1.81—6.86	.	.
2.9*	1.08—7.69	3*	1.03—8.57	.	.	.	.	1.8+	0.95—3.21	.	.
.	.	.	.	.	.	.	.	2*	1.09—3.66	1.9+	0.90—3.99
3.2*	1.21—8.58	3+	0.80—6.88	3*	1.14—7.77	.	.	.	.	2.2*	1.10—4.69
5.8***	2.27—14.89	5.3**	1.86—14.86	3.4**	1.36—8.26	.	.	.	.	.	.
.	.	.	.	.	.	2.3**	1.18—4.29	.	.	.	.
3.4**	1.30—8.85	2.8*	0.97—8.07	.	.	2.1*	1.08—3.92	.	.	2.9**	1.36—6.02

health problem becomes higher as age increases. For complaints concerning sleep, the effect of age comes into play in a significant way beginning at the age of 40 years with the probability being 2 times higher for perceived sleep difficulties and nearly 5 times higher for the taking of sleeping pills. It is interesting to point out that there was no notable increase in this effect for the 50- to 60-year age range. Regarding the taking of tranquilizers and antidepressants, the effect of age again comes into play at the age of 40 years, the probability being 4 times higher than that of the reference age and increasing in the 50- to 60-year age range, the odds ratios being 2 times more significant [OR 8.6, P<0.001, 95% confidence interval (95% CI) 2.40—30.69 for tranquilizers; OR 7.8, P<0.01, 95% CI 2.13—28.32 for antidepressants].

The cardiovascular problems followed the same trend. For gastrointestinal problems, the effect of age showed up later, the probability of voicing complaints being significantly higher only for the 50- to 60-year age range.

Effects of work schedule

On one hand, it appeared that the 2×12-hour rota had no significant effect on the majority of the health complaints. Regarding the difficulties usually linked with shift work, there was an increase in sleep disturbances (OR 2.2, P<0.1, 95% CI 0.89—5.37) and the taking of tranquilizers (OR 3.2, P<0.1, 95% CI 0.82—12.71) at the 0.10 level. Two other kinds of difficulties increased with the 2×12-hour rota: visual problems (OR 3, P<0.05, 95% CI 1.14—7.77) and pain in the legs (OR 3.4, P<0.01, 95% CI 1.36—8.26).

On the other hand, the 3×8-hour and 4×6-hour work schedules had their own significant effects that concerned the principal aspects of health, such as cardiovascular, gastrointestinal and sleeping problems. On the whole, for those working 3×8-hour and 4×6-hour schedules, the probability that these problems will appear was at least 3 times higher than that for the reference situation. The 4×6-hour schedule, as set up within the customs teams, also turned out to be as unfavorable for health as the classic 3×8-hour schedule. These schedules gave rise to similar effects, which were, for the most part, of the same amplitude.

However, the odds ratio for stomach pain was significant for those working a 3×8-hour schedule (OR 3.7, P<0.01, 95% CI 1.03—8.57) but not for those working the 4×6-hour schedule.

These effects had an amplitude comparable to that attributable to the 40- to 50-year age range. In effect, the odds ratios of the 2-shift schedules were generally equal to or greater than those associated with the 40- to 50-year age range. Everything also occurred as if working these schedules was equal to accelerating the aging process by approximately 10 years.

Effects of job demands

Job demands had an effect on sleep and cardiovascular and gastrointestinal problems.

Physically demanding job

Physically demanding jobs had an effect on backaches and the taking of painkillers. This relationship stemmed from the nature of the job and did not involve an examination of circadian rhythmic disturbance. On the other hand, carrying out a professional activity under physically trying conditions leads more easily to sleeping problems.

Boring, monotonous job

Monotony in work had an effect on only 4 items. Regarding sleep problems and the taking of antidepressants, an interpretation involving psychological mechanisms seemed plausible.

Conflictual relations with travelers

The conflictual relations with travelers simultaneously affected digestion, the cardiovascular system, and sleep. The probability of having sleeping problems was 4 times greater when the subjects were exposed to conflictual relations with travelers. The taking of sleeping pills was equally greater as compared with the reference situation (OR 1.9, P<0.10, 95% CI 0.88—3.91).

A confrontation with travelers had affected gastrointestinal problems in a manner similar to working 3×8-hour and 4×6-hour schedules, the odds ratio ranging between 2 and 3.5. However, the impact of this variable was greater than that of the 40- to 50-year age category.

Among the cardiovascular indicators, only shortness of breath (OR 2.1, P<0.05, 95% CI 1.10—3.85) and chest pains (OR 2.7, P<0.01, 95% CI 1.41—5.14) were shown to be sensitive to confrontation with travelers. The odds ratios obtained were inferior to those corresponding to the 40- to 50-year and 50- to 60-year age ranges, but they were of the same order as those associated with a 4×6-hour schedule. An effect of a conflicting relation with travelers was seen for arterial hypertension. The odds ratio was 2.2 (P<0.05, 95% CI 1.17—4.08), and it was of the same order as that obtained for the 40- to 50-year and 50- to 60-year age ranges, although for the latter the significance threshold was weaker.

Discussion and concluding remarks

Several aspects of the job demands of custom agents have an effect on their health. These effects manifest themselves as health problems typically found in shiftwork conditions (14, 15). The amplitude of both of these effects, job demands and shift work, were of the same order. They were comparable to the effects of age.

All 3 of the central demands identified using a correspondence analysis of the questionnaires had an effect on sleep. The odds ratios associated with conflictual relations with travelers were superior to those associated with the other 2 job-demand variables, but the difference was not significant. The influence of these 3 job variables was of the same order as that of the 3x8-hour and 4x6-hour schedules and that of those over the threshold of 40 years of age. The taking of sleeping pills, for which the probability was equally increased by working 3x8-hour and 4x6-hour schedules, did not appear to increase with exposure to a boring, monotonous job or a physically demanding job. Even stressful interactions with travelers was only responsible for an effect to the statistical threshold of 0.10.

In addition, the 3 central job-related variables each had specific impacts.

A *boring and monotonous job* increased the probability of taking painkillers and suffering from vision problems, 2 kinds of effects not usually connected with shift work. These effects could have been linked to a hidden variable associated with monotony but not included in the regression. In fact, the jobs judged monotonous by the customs agents frequently involved having to remain in fixed positions, which could have led to the taking of painkillers.

A *physically demanding job* was the only predictor variable associated with the probability of backache, an effect for which the chain of cause and effect is easily construed. This relationship stemmed from the nature of the job and did not involve an examination of circadian rhythmic disturbance. It is remarkable that, in this population, contrary to what could have been expected, age had no significance. This finding could be explained by the informal distribution of jobs within a team based on the criterion of age and seniority, as can be observed in other professional sectors (16). Nor did shift work have a significance. Physically demanding jobs increased the probability of taking painkillers. It is notable that the 4x6-hour and 3x8-hour schedules had similar effects. At the same time these variables did not have an effect on backache, but the relation between shift schedules and the use of painkillers could be explained by the influence of shift work on leg problems.

The *conflictual relations with travelers* variable had the largest and most marked influence. In addition to sleep, it played a role in the area of cardiovascular and digestive problems. Confrontation with travelers turned out to be the source of a greater probability of shortness of breath, chest pains and arrhythmias, complaints which are also frequently generated by exposure to 3x8-hour and 4x6-hour schedules. The stressful relations with travelers was a source of more frequent states of hypertension, which, in this population, was only noted in relation to the 3x8-hour schedule and appeared to be less clearly linked to an advance in age. But the other types of cardiac complaints (palpitations and the declared use of beta-blockers) were not linked to customer confrontation.

Regarding digestion, if exception is made for bloating and flatulence (which had a significantly increased probability of appearing beginning in the 30- to 40-year age range), this job demand — of a psychosocial nature — had an effect on the different aspects of the digestive problems surveyed, for which the influence of age was equivalent only in the 50- to 60-year age range. These effects were roughly similar and of the same magnitude as those of the 3x8-hour and 4x6-hour schedules. For several elements of gastrointestinal problems, the effect of the "conflicting relation with travelers" variable existed although no variation with age was discernable.

The results presented concern a population for which the phenomena of selection by exclusion over the years could not have been taken into account. Customs officers who had left the units with the shift schedules analyzed could not be included in the survey. Customs officers have civil servant status and work within the framework of a public service containing numerous units spread out over the entire country. The units use diverse shift schedules, including a "normal" or "day" schedule. Therefore, the possibility exists of workers being able to escape, after a more-or-less long period, from the most stringent atypical shift schedule. However, this possibility is limited by the phenomena of intranational migration linked to a discord between the predominant geographic zones of recruitment for customs officers (southern France) and the zones of assignment (northern France).

The aforementioned limit being noted, the first point to emphasize concerns the respective harmfulness of the 3-shift schedules analyzed: (i) the 2x12-hour schedule, as organized and practiced in this professional sector, does not itself have a negative effect; (ii) the 4x6-hour schedule is a source of health problems of the same caliber as those resulting from the classic 3x8-hour schedule.

The major result that comes from this study is that the effects of job demands on health, for this population, are equivalent to the effects resulting from shift schedules. This finding signifies that the defining of a shift system, taking into consideration established knowledge regarding chronobiology and the rhythms of family and social life, represents only half of the battle to assure the full protection of shift workers' health.

The technique of logistic regression enables the different health risk factors to be weighed together. In relation to the reference situation (women aged 20 to 30 years; normal workhours; not subject to the constraints of a physically demanding job; a boring, monotonous job; or conflicting relations with travelers), the probability of sleep problems is multiplied by 3.5 for working a 4x6-hour shift schedule, by 4.1 for difficult relations with travelers, and by 2.7 for a physically demanding job. Our survey shows that the cumulation of these conditions is not exceptional. The statistic principle of logistic regression, which enables us to multiply these probabilities together, indicates that the conjunction of a conflicting relation with travelers and a physically demanding job results in the probability of sleep problems being multiplied by 11. The result is an increase greater than that linked only to shift schedules. We therefore agree with the point of view expressed in research conducted within the framework of the same problem (9), namely, it is necessary to intervene simultaneously on the level of work schedules and on the level of job demands and to proceed systematically with an examination of the job demands.

The joint consideration of the respective effects of job demands and the work schedule practiced not only comes up within the context of intervention, but also within the context of research. The results published on the combined effects are again fewer in number, and many questions remain unanswered. Earlier results (8—9) arrive at the conclusion that stress at work is an ill-health provoking factor independent of shift work. Is this conclusion, obtained from 2 different populations, valid in a general manner or are there professional sectors in which the effects of shift work and job demands are not simply additive but could combine with one another in an interactive manner? The logistic regressions presented in this paper were first carried out within the perspective of a simple additive scheme, but further logistic regression analyses could enable the testing of the hypothesis of the eventual effects of interaction.

Finally it must be emphasized that the variable shown to have the most impact on the customs agent population is "conflictual relations with travelers". This variable is also found in other professional groups which similarly practice shift work, such as among police, prison guards, and nurses (especially in psychiatric institutions). It is possible that shift work and job demands are not simply additive constraints but also interactive constraints. For example, the effect of a job demand at night differs from the effect of the same demand during the day. The feeling of reduced security linked to darkness, reduced recourse to colleagues, weakening of capacities, and circadian variations in mood are elements which increase the difficulty of a customer-focused job. Therefore the defining of the most adequate shift system should not fail to take job demands into consideration.

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References

1. Nachreiner F, Rutenfranz J. Sozialpsychologische, arbeitsphysiologische und arbeitsmedizine Erhebungen in der Chemischen Industrie In: Nachreiner F, Frielingsdorf R, Romahn R, Knauth P, Kuhlmann W, Klimmer F, editors. Schichtarbeit bei kontinuierlicher Produktion Wirtschaftverlag. Norwest: Wilhelmhafen, 1975:83—177.
2. Folkard S, Monk TH. Shift work and performance. Hum Factors 1979;21:481—92.
3. Gadbois C, Queinnec Y. Travail de nuit, rythmes circadiens et régulation des activités. Trav Hum 1984;47(3):195—225.
4. Rutenfranz J, Knauth P. Combined effects. In: Haider M, Koller M, Cervinka R, editors. Night and shiftwork: longterm effects and their prevention. Frankfurt aM: Verlag Peter Lang, 1986:311—8.
5. Kogi K. Improving shift workers' health and tolerance to shifwork: recent advances. Appl Ergon 1996;27:5—8.
6. Fischer FM, Lieber RR. Limited work factors coverage among 17 published models of shift work effects. Shift Work Int Newsl 1995;12:116.
7. Alfredsson L, Karasek R, Theorell T. Myocardial infarction risk and psychosocial work environment: an analysis of the male Swedish working force. Soc Sci Med 1982;16:463—7.
8. Frese M, Semmer N. Shiftwork, stress and psychosomatic complaints: a comparison between workers in different shift work schedules, non-shift workers, and former shift workers. Ergonomics 1986;29:99—114.
9. Cervinka R. Night shift dose and stress at work. Ergonomics 1993;36:155—60.
10. Gadbois C, Prunier S. Unfavorable consequences of six-hour shiftwork. Shift Work Int J Occup Environ Health 1997; 3(3):53—9.
11. Gadbois C, Prunier S. Douaniers en horaires atypiques: questions sur les rythmes de vie à l'heure d'une économie sans relâche. In: Sperandio JC, editor. L'ergonomie face aux changements technologiques et organisationnels du travail humain. Toulouse: Octares, 1996:303—12.
12. Barton J, Spelten E, Totterdell P, Smith L, Folkard S, Costa, G. The standard shift work index: a battery of questionnaires for assessing shift work related problems. Work Stress 1995;9(1):4—30.
13. Greenace MJ. Theory and applications of correspondence analysis. London: Academic Press, 1984.
14. Costa G. The impact of shift and nightwork on health. Appl Ergon 1996;27(1):9—16.
15. Waterhouse JM, Folkard S, Minors DS. Shiftwork, health and safety: an overview of the scientific literature 1978—1990. London: Her Majesty's Stationery Office, 1992.
16. Florès JL. Régulations formelles et informelles des différences d'âge dans le travai: le cas des personnels des remontées mécaniques. Rev Franç Aff Soc 1994;1:137—40.

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Effects of coping strategies, social support and work-nonwork conflict on shift worker's health

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Pisarski A, Bohle P, Callan VJ. Effects of coping strategies, social support and work-nonwork conflict on shift worker's health. *Scand J Work Environ Health* 1998;24 suppl 3:141—145.

Objectives This study examines the direct and mediated effects of shift workers' coping strategies and social support on structural work-nonwork conflict and subjective health.

Methods The participants were 172 registered female nurses, aged 21 to 40 years. They all worked full-time, on rapidly rotating, 8-hour shifts in metropolitan general hospitals. All the respondents completed a self-administered questionnaire requesting demographic information and data on sources of social support, work-nonwork conflict, and coping strategies.

Results A path model with good fit (χ^2=28.88, df=23, P>.23, CFI=0.97) demonstrated complex effects of social support and coping on structural work-nonwork conflict and health.

Conclusions Structural work-nonwork conflict mediated the effects of social support from supervisors and emotionally expressive coping on psychological symptoms. Control of shifts mediated the effect of social support from supervisors on structural work-nonwork conflict. Disengagement coping had direct and mediated effects on psychological and physical health. However, it also had mediated effects, with the effect on psychological health being mediated by support from co-workers and the effect on physical symptoms being mediated by family support. Co-worker support mediated the effect of social support from supervisors on psychological symptoms. Overall, these findings support previous research and clarify the process by which coping strategies and social support affect structural work-nonwork conflict and health in shift work.

Key terms extended shifts, home-work conflict, nursing, occupational health, path analysis, rotating shift work, structural equation modeling, work schedules.

In a review of research on stress among nurses, Linder-Pelz (1) identified shift work and lack of support from management as significant sources of stress. Similarly, Seymour & Buscherhof (2) found that nurses' greatest dissatisfaction resulted from structural or institutional problems, which included problems with shifts, inflexibility, lack of support from supervisors, and negative health effects. Shift workers have generally been identified as a group at risk of acute and possibly chronic health effects.

Several theoretical models have attempted to explain the elevated risk (3, 4). According to Taylor and her co-workers (4), these models tend to be hypothetical, mapping the potential relationships in the shift work domain. Initial shiftwork models portrayed these relationships linearly, but more recent conceptions have attempted to depict the complexities of the interrelationships between shiftwork variables by incorporating psychological variables such as coping (4). These conceptual models provide a more robust and comprehensive understanding of the general processes by which shift work affects health, but they have yet to be thoroughly tested.

The changing nature of work has led to a growing concern about the interplay between work and nonwork experiences, in particular the impact of conflict between home and work roles (5). The limited evidence available suggests there may be a relationship between structural work-nonwork conflict and shiftwork tolerance (6). Structural work-nonwork conflict occurs when the *time* available for social and domestic activities is limited by work requirements. It is a particular problem for shift workers required to work on evening, night, or weekend shifts. The available evidence suggests that the psychological health effects caused by conflict between home and work roles can range from psychological strain, anxiety and depression to burnout and substance abuse (5). Bohle & Tilley (6, 7), for example, found a link between self-reports of structural work-nonwork conflict and shift

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workers' fatigue and general psychological well-being. At present, however, the variables and processes influencing work-nonwork conflict in shift work are not well understood.

Studies of occupational stress suggest that the negative effects of shift work can be mediated by social support. For instance, there is evidence that support diminishes work-related stress and that work-related social support modifies the impact of occupational stress on psychological and physical health (8, 9). Employees report receiving support from various sources, including co-workers, family or friends (10). There is also evidence that positive social support from supervisors, co-workers, family, or friends reduces structural work-nonwork conflict and symptoms and that a lack of support exacerbates these effects (11). Studies of shift workers reveal that support from supervisors predicts psychological well-being and support from co-workers predicts vigor on night shift (6, 7). Social support is likely to be particularly important for female shift workers, especially since the social and domestic responsibilities of women appear to make the adaptation to shift work more difficult than it is for men (6).

The appraisal processes used by employees influences their selection of coping strategies which, in turn, affects the type and level of support that is offered (12). Support from supervisors, co-workers, family, or friends at home or at work influences the subsequent coping strategy adopted by people at work (13). However, while coping strategies may communicate that support is needed and indicate the type of support that is desired, some forms of coping also make it difficult for people to provide support (9). Research on coping styles reveals that active, problem-focused coping generally has a positive impact on well-being and that emotion-focused and avoidance strategies result in poorer long-term psychological adjustment (14). Consequently, it is important for people to be encouraged to use problem-focused strategies. However, when problem-focused strategies are used and fail, or the problem is perceived to be too intractable, the result may be an increase in levels of stress and depression (15). Organizations therefore have a responsibility to provide sufficient support for problem-focused strategies to be successful.

Unfortunately, little research has been done on coping strategies and social support in shift work, and further investigation is needed to enhance the understanding of the relationships between these factors and health outcomes for shift workers. This study explores the relationships between structural work-nonwork conflict and health in rotating shift work and examines the direct and mediated effects of social support and coping on these outcomes. It focuses on female registered nurses working rotating 8-hour shifts and aims at developing a more sophisticated understanding of the factors affecting work-nonwork conflict and health in this population. It is expected that social support and coping strategies have both direct and indirect effects on structural work-nonwork conflict. Emotion-focused coping strategies and poor support from supervisors, co-workers, and family are expected to be linked to higher levels of psychological and physical symptoms, either directly or indirectly through increased work-nonwork conflict.

Subjects and method

Participants and procedure

The participants were 172 registered female nurses employed full-time on rapidly rotating 8-hour shifts in metropolitan general hospitals. They were between 21 and 40 (mean 27) years of age. All of them had less than 20 years' experience in shift work, 83 were single, 72 had a partner, and 17 had a partner and dependent children. Age (<40 years), experience with shift work (<20 years), job description (registered nurse), employment status (full-time), and work schedule were controlled for confounding effects on structural work-nonwork conflict and symptoms. Questionnaires and an introductory letter were distributed directly to the hospitals and returned via the mail or collected from the hospitals.

Measures

The 12-item version of the General Health Questionnaire (16) was employed to measure psychological symptoms, and the Physical Health Questionnaire (17) was used for physical symptoms. The measure of perceived structural work-nonwork conflict was based on the items devised by Shamir (18), but was modified to a 5-item scale which more explicitly measures the impact of shift work (19). The 24-item coping questionnaire developed by Spelten et al (20) was used to measure the shift workers' coping strategies. Social support from supervisors, co-workers, and family was measured using the 12-item scale developed by Caplan et al (21). Control of shifts was measured using a single item, "I have sufficient control over the shifts I work", which was rated on a 5-point scale (1= completely false, 5= completely true).

Statistical methods

Summary statistics and graphic displays of raw scores on all the variables were examined for nonnormal distributions, outliers, and missing data. Negative skewness (-1.237) in the support from family variable was corrected using the "reflex" procedure described by Tabachnick & Fidell (22) followed by square root transformation. Z scores and box plots were used to identify univariate outliers. Calculating the Mahalanobis distance for each case identified multivariate outliers. Univariate outliers were found for the family support variables, and multivariate outliers were identified for both physical and psychological symptom variables. Univariate outliers were reduced to 1 unit greater than the next most extreme score, as recommended by Tabachnick & Fidell (22). A small number of observations was missing on the structural work-nonwork conflict, coping, and social support variables. If less than 10% of the data on any variable or any individual participant was missing, the data were replaced with column means. Where more than 10% of the data was missing, the case was deleted from subsequent analyses, as recommended by Tabachnick & Fidell (22).

Table 1 shows the means, standard deviations, range, and internal consistencies (Cronbach's alpha) for all the variables after the transformations, the adjustment for outliers, and the replacement of missing data.

Results

Coping strategies can be divided into those that are problem-focused and those that are emotion-focused (13). An exploratory factor analysis was conducted on the coping responses to assess whether they had a similar structure. A principal component analysis followed by varimax rotation produced 3 factors accounting for 44% of the total variance. Each factor had an eigenvalue greater than 1, and items loading 0.40 or more were retained. Table 2 shows the eigenvalues and the percentage of the variance accounted for by each factor.

The first 2 dimensions were emotion-focused forms of coping. Factor 1, labeled "disengagement coping strategies" (12 items), comprised various strategies workers might employ to disengage from problems at work by avoiding thinking about the situation, by wishing the situation away, by self-criticism, and by social withdrawal. Factor 2, labeled "emotionally expressive coping" (6 items), included letting emotions out or talking to someone about feelings.

The third factor, labeled "problem-focused coping", consisted of 6 items. These items represented both behavioral and cognitive restructuring strategies, such as active problem solving or reorganizing the way a situation was viewed. The items in each factor were summed to form the 3 scales. There was a small correlation between problem-focused and emotionally expressive coping ($r = 0.28$), but no correlation between the other factors, indicating that the strategies were empirically distinct.

The internal consistencies (Cronbach's alpha) obtained from the disengagement and emotionally expressive coping scales were high (α=0.85, 0.81). The alpha obtained from the problem-focused coping scale was unsatisfactory (α=0.63). The low reliability of the problem-focused coping scale could be partly attributed to 2 items, but even with these items removed the internal consistency was low (α =0.66). The limited internal consistency of this scale was likely to diminish the probability of identifying significant relationships between it and other variables, and it was, therefore, not used in subsequent analyses.

Path analysis

Structural equation modeling using EQS (23) was used to confirm the utility of a model describing the relationships between coping strategies, social support from various sources, structural work-nonwork conflict, and psychological and physical symptoms. The model was drawn from the shift work and occupational stress literature cited in the introduction. EQS provides several methods for examining the efficacy of a model. The methods include a chi-square test, goodness-of-fit indices, the distribution of residuals, and the Lagrange multiplier and Wald tests for testing individual paths. The chi-square values and the comparative fit index for the proposed model are presented in table 3. They suggest that the proposed model was not a good fit. Results from the Lagrange multiplier

Table 1. Descriptive statistics and internal consistencies (Cronbach's alpha) for all the composite scales.

Variable	Mean	SD	Range	Cronbach's alpha
Disengagement coping	31.68	8.73	11—55	0.85
Emotionally expressive coping	20.66	4.82	7—30	0.81
Problem-focused coping	14.35	2.87	6—20	0.63
Physical symptoms	38.39	10.77	19—66	0.83
Psychological symptoms	13.55	5.16	3—29	0.89
Structural work-nonwork conflict	17.83	3.90	7—25	0.70
Support from co-workers	14.34	2.95	6—20	0.82
Support from family, partner and friends	1.64	.92	0-3.317	0.87
Support from supervisor	12.52	4.11	4—20	0.88

Table 2. Summary of the principal component analysis of the coping items.

Factor	Eigen-value	Percen-tage of variance	Cumu-lative percen-tage of variance
1 Disengagement coping strategies	5.4768	22.8	22.8
2 Emotionally expressive coping strategies	3.2526	13.6	36.4
3 Problem-focused coping strategies	1.8833	7.8	44.2

Table 3. Goodness-of-fit summary for the structural equation model. (CFI=comparative fit index, df= degrees of freedom)

Model	Chi-square	df	P	Chi-square change	df change	CFI
Proposed	80.40	18	<.01	n/a	n/a	0.65
Modified	28.88	23	>.23	51.52	5	0.97

test suggested that the model would be improved by adding direct paths from disengagement coping strategies to family support and physical symptoms, from emotionally expressive coping to structural work-nonwork conflict, and from supervisor support to co-worker support. The general stress literature suggests that poor social support and emotion-focused coping strategies increase the impact of stressors on health and that supervisor support can also buffer the negative effects of work overload and role conflict (13, 24—27). As the suggested paths were compatible with existing theoretical or empirical evidence, they were added to the model. The Wald test suggested that the paths from the social support variables to structural work-nonwork conflict and from support from family and supervisors to psychological symptoms should be dropped. The resultant model fit the data considerably better than the original model. The chi-square was nonsignificant, the comparative fit index was high, the distribution of residuals was symmetric and approached zero, and the standardized off diagonal was low. (See table 3.) This model, including path coefficients, is presented in figure 1.

Discussion

This study demonstrates that coping, social support, and work-nonwork conflict have complex, interrelated effects on the psychological and physical health of female nurses doing rotating shift work. The path model lends support to some of the relationships posited by Folkard (3). It also expands our understanding of the specific effects of various forms of social support and coping on structural work-nonwork conflict and health in shift work.

Social support has both direct and mediating effects on both structural work-nonwork conflict and symptoms. Social support from co-workers and family had direct effects on psychological and physical symptoms respectively, and therefore the findings of Dunkel-Schetter et al (9) received support. The effect of social support from supervisors on psychological symptoms was mediated by co-worker support, a finding indicating that a supportive co-worker milieu is dependent to some extent on the support given by supervisory staff. Interestingly, the effect of supervisory support on structural work-nonwork conflict was mediated by the control shift workers could exert over shift allocations. This finding supports previous evidence of a link between supervisor support and work-nonwork conflict (28), but it highlights the important role played by supervisors in allowing workers sufficient control over shifts to diminish structural conflict.

Coping strategies also had complex effects. The effect of emotionally expressive coping on physical health was mediated by family support. This form of coping increased support from families, which, in turn, reduced physical symptoms. There was also a series of positive paths from emotionally expressive coping to work-nonwork conflict, psychological symptoms, and then to physical symptoms. This finding indicates that the negative effect of emotionally expressive coping on structural work-nonwork conflict produced subsequent negative effects on both psychological and physical symptoms. These results support the findings of Bohle & Tilley (6) concerning the relationship between structural work-nonwork conflict and psychological symptoms, and it extends the effects to physical symptoms.

Disengagement strategies had both direct and mediated effects on both psychological and physical symptoms. The direct effects indicated that disengagement coping produced higher levels of both psychological and physical symptoms. These results are consistent with previous evidence that disengagement strategies result in poorer psychological adjustment (20, 29), and they provide additional evidence of an effect on physical health. Disengagement strategies also had effects on psychological and physical symptoms that were mediated by support from co-workers and family, respectively. Consistent with the findings of Holahan & Moos (30),

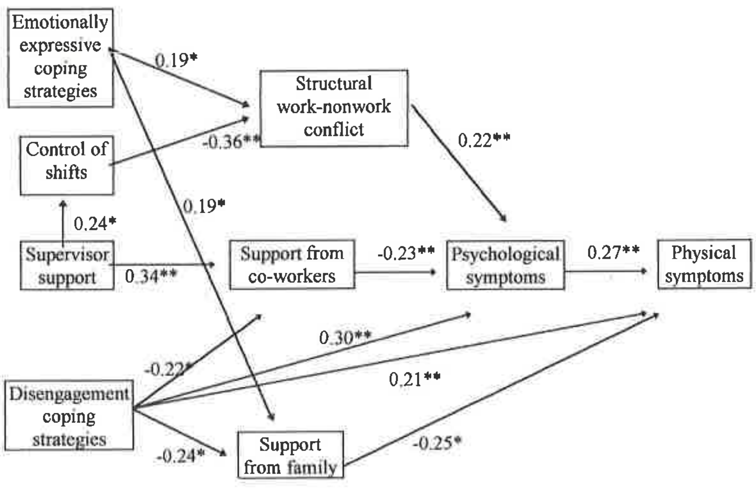

Figure 1. Standardized path coefficients for significant paths in the final model (* P <0.01, **P<0.001).

disengagement strategies were associated with lower support from both sources.

The limited internal consistency of the problem-focused coping scale resulted in an inability to use this measure in the analyses. The poor performance of the problem-focused coping scale may reflect either the unreliability of the scale or, as suggested by Terry et al (13), these strategies may be less salient when workers perceive a lack of control over the work situation which renders problem-focused coping to be inappropriate. These issues warrant further investigation because of the potential benefits to shift workers from the use of problem-focused coping strategies.

Overall, the results of this study indicate that social support, structural work-nonwork conflict, and coping strategies all influence the health and well-being of shift workers. However, the exact nature of the support, the contexts in which it is offered, and the importance of problem-focused coping have as yet to be established, as does the generalizability of the present results to men and other industries and work schedules. A better understanding of the distinctive contributions of various forms of support, such as instrumental or emotional support, to alleviating the health effects of shift work must still be investigated. This understanding should provide a stronger basis for the development of more effective organizational and individual coping strategies for shift workers in the future. Nonetheless, this study does make a significant contribution to the knowledge of the impact of coping strategies, social support, and structural work-nonwork conflict on the health and well-being of shift workers.

References

1. Linder-Pelz S. Occupational stressors and stress levels among Australian nurses: a review of research. Occup Health Aust NZ 1985;1(1):9—15.
2. Seymour E, Buscherhof JR. Sources and consequences of satisfaction and dissatisfaction in nursing: findings from a national sample. Int Nurs Stud 1991;28(2):109—124.
3. Folkard S. Effects on performance efficiency. In: Colquhoun PP, Costa G, Folkard S, Knauth P, editors. Shift work: problems and solutions. Frankfurt: Peter Lang, 1996.
4. Taylor E, Briner RB, Folkard S. Models of shift work and health: an examination of the influence of stress on shift work theory. Hum Factors 1997;39(1):67—82.
5. O'Driscoll MP. The interface between job and off-job roles: enhancement and conflict. Int Rev of Ind Org Psychol 1996;7:279—306.
6. Bohle P, Tilley AJ. The impact of night shift on psychological well-being. Ergonomics 1989;32(9):1089—99.
7. Bohle P, Tilley AJ. Predicting mood change on night shift. Ergonomics 1993;36:1—3.
8. Brand A, Hirsch BJ. The contribution of social networks, work-shift schedules, and the family life cycle on women's well-being. In: Duck S, editor. Personal relationships and social support. Newbury Park (CA): Sage, 1990.
9. Dunkel-Schetter C, Folkman S, Lazarus RS. Correlates of social support receipt. J Pers Soc Psychol 1987;53(1):71—80.
10. Thoits PA. Social support as coping assistance. J Consult Clin Psychol 1986;54(4):416—23.
11. House JS, Wells JA. Occupational stress, and social support, and health. In: McLean A, Black G, Colligan M. editors. Reducing occupational stress. Cincinnati (OH): Department of Health, 1978.
12. Wortmann CB. Social support and the cancer patient. Cancer 1984;53(10):2239—360.
13. Terry DJ, Rawle R, Callan VJ. The effects of social support on adjustment to stress: the mediating role of coping. Pers Relat 1995;2:97—124.
14. Terry DJ, Callan VJ, Sartori G. Employee adjustment to an organizational merger: stress, coping and intergroup differences. Stress Med 1996;12:105—22.
15. Vitaliano PP, Maiuro RD, Russo J, Becker J. Raw versus relative scores in the assessment of coping strategies. J Behav Med 1987;10:1—18.
16. Goldberg DP. The detection of psychiatric illness by questionnaire. Oxford: Oxford University Press, 1972.
17. Barton J, Smith L, Totterdell P, Spelten E. Does individual choice determine shift system acceptability? Ergonomics 1993;36(1—3):93—99.
18. Shamir B. Some antecedents of work-nonwork conflict. J Vocat Behav 1983;23:98—111.
19. Bohle P, Tilley AJ. Early experience of shift work: influences on attitudes. J Occup Organ Psychol. In press.
20. Spelten E, Barton J, Folkard S. Have we underestimated shift workers' problems? evidence from a "reminiscence" study. Ergonomics 1993;36(1—3):307—12.
21. Caplan RD, Cobb S, French JRP, Harrison RV, Pinneau SR. Job demands and worker health: main effects and occupational differences. Washington (DC): National Institute for Occupational Safety and health, US Department of Health, Education and Welfare, 1975.
22. Tabachnick BA, Fidell L. Using multivariate statistics. New York (NY): Harper Collins Publishers, 1996.
23. Bentler PM. EQS structural equations program manual. Los Angeles (CA): BMDP Statistical Software, 1989.
24. Kandolin I, Burnout of female and male nurses in shift work. In: Costa G, Cesana G, Kogi K, Wedderburn A. editors. Shift work: health, sleep and performance. Frankfurt: Peter Lang Verlag, 1993.
25. Singh RG, Relationship between occupational stress and social support in flight nurses. Aviat Space Environ Med 1990;61(4):349—52.
26. Cohen S, Wills TA. Stress, social support, and the buffering hypothesis. Psychol Bull 1985;98:310—357.
27. Terry DJ, Nielson M, Perchard L. Effects of work stress on psychological well-being and job satisfaction: the stress buffering role of social support. Aust J Psychol 1993;45(3):168—75.
28. Loudoun, R. Bohle, P. Work-nonwork conflict and health in shift work: relationships with family status and social support. Int J Occup Environ Health 1997;3 suppl3:S71-S7.
29. Terry DJ. Coping resources and situational appraisals as predictors of coping behaviour. Pers Individ Differ 1991; 12:1031—47.
30. Holahan CJ, Moos RH. Personal and contextual determinants of coping strategies. J Pers Soc Psychol 1987;51:389—95.

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The emotional impact of shift work on the children of shift workers

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Objectives This study compared the emotional state of children of shift and day working fathers.
Methods One hundred and ninety children (8 to 11 years of age) took part in the study. Ninety-one came from "shift working" homes, and 99 came from "day working" homes. Each child completed 2 questionnaires, The Harter Self-Perception Questionnaire and the Children's Depression Inventory.
Results The daughters of shift working fathers reported a significantly poorer perception of their ability in school-related activities and significantly greater discrepancies between their perceived overall level of competence and their ideal level of competence. In addition, more depressive symptomatology and a lower level of self-esteem were also found for the daughters of shift working fathers in comparison with the daughters of day working fathers. No such effects were found for the sons of shift working fathers.
Conclusions Parental shift working may be experienced as stressful within the family, and this stress may affect the emotional state of the child. However, the nature of expression of these emotional difficulties may vary according to the gender of the child. Further research is needed.

Key terms children's psychological health, paternal depression, work patterns, working parents.

Despite the growing interest in the work-family interface, little research has paid equal attention to both the work and the home settings. This lack may stem in part from differences in scientific disciplines in the social world, since developmental researchers are trained to conduct research in laboratories, schools, and families, but rarely in factories and offices, and organizational behavior experts rarely follow their subjects past the boundaries of the workplace (1). However, one attempt to span both environments has been to focus on the emotional state of the worker or family member as he or she moves back and forth across the settings of work and home, the emphasis being on the short-term psychological processes operating within the worker. For example, air traffic controllers returning home after a demanding shift were found to be more socially withdrawn and to exhibit less anger in marital interactions (2). Relatedly, in an examination of father-child interactions for 4- to 10-year-old children, difficult work conditions were found to be associated with lower levels of emotional involvement with the child, both positive and negative (3).

The biological and social disruption associated with work shifts is widely recognized as being problematic for many shift workers and as causing tremendous strain within the family system (4). The sorts of problems that shift workers experience fall broadly into the following 3 categories: difficulties associated with the quality and quantity of sleep (5, 6), impairment of physical and psychological health (7, 8), and social and domestic disruption (9, 10). Thus it is perhaps not surprising that elevated levels of chronic fatigue, irritability and lethargy (11), psychological ill-health (12), neuroticism (13), and depression (14) have been found among shift working populations. Despite this recognition, few attempts have been made to examine the shift working-home interface, in particular, the psychological state of the worker at the end of the day and the possible carry-over effects of mood from work to home.

In a different, but relevant body of research, the effects of parental (mainly maternal) depression on child development have been much in focus, the general conclusion being that parental depression can place the child at risk of developing some form of pathology, such as anxiety, anger, dysphoria or social withdrawal (15), a reduced sense of self-efficacy (16), and possibly even depression (17). According to Cummings & Davies (18)

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parental depression may affect children as a result of how the depression affects the behavior, cognitions, and emotions of the parent. Thus parental depression may directly affect children through, first, the emotional unavailability and thinking processes of depression, since negative ways of thinking and low self-esteem are typical of the depressed person's way of thinking and, second, indirectly by altering patterns of parent-child interaction, such as the quality and security of the attachment bond and, third, by increasing marital discord which, independently, has been shown to have potentially negative effects on child development.

When these 2 disparate bodies of research are considered together, it is perhaps surprising that little attention has been paid to familial processes within shift working families, and, in particular, to the emotional and affective state of the children. Some early research showed however that children of shift workers did less well at school than children of day workers (19) and that the children of shift workers entered into work with fewer qualifications than children of day workers (20). In trying to make sense of these findings, attention has focused on the lack of time shift workers often have to spend with their children in school and other related activities. However, in a further study, Volger et al (21) found, in a group of shift working and day working policemen, that the amount of common free time available between father and child was not necessarily related to the quality of father-child relations. Thus the quality rather than the quantity of the time spent together was suggested to be more important for good father-child relations.

The present research therefore attempts to cross scientific disciplines and draw together the following 2 disparate bodies of psychological research: first, from an organizational perspective, the impact of shift work on the emotional and affective state of the shift worker and, second, from a clinical perspective, the impact of parental depression on children. The proposed model suggests that working shifts can and does have a detrimental effect on the emotional and affective well-being of the individual shift worker, and this detrimental effect may negatively affect the behavior and cognition of the shift worker, as he or she interacts within the family, and possibly result in negative implications for the emotional and affective state of the children. The specific hypotheses to be tested were "children of shift working fathers will report more negative self-perceptions and lower levels of perceived competence than children of day working fathers" and "levels of self-reported depression will be higher among children of shift working fathers than among children of day working fathers". In addition, given that boys and girls are known to react differently to stressful events, differences in self-reported emotional state according to gender, both between and within the research groups, should be investigated.

The current research compared the emotional and affective state of children of shift working fathers with that of children of day working fathers, and it is unique in that no previous work has explored the emotional impact of shift work within the family, at the level of the child.

Subjects and methods

One hundred and ninety children, aged 8—11 years, from 2 primary schools within a predominantly shift working geographic region participated in the study. Ninety-one of the children had shift working fathers, and 99 had day working fathers. The children from day working homes were significantly older than the children from shift working homes, by approximately 6 months ($t=5.82$; $df=1,188$; $P<0.001$; 10.27 and 9.59 years, respectively). Age was subsequently controlled in the analyses. There were roughly equal numbers of boys and girls, these being distributed evenly between the 2 groups ($X^2=0.34$; $df=1$; $P>0.05$) (day working: 49 boys, 50 girls; shift working: 55 boys, 36 girls). Family variables such as parental occupation and socioeconomic class were not measured. However, all the children were drawn from 2 local primary schools, within a relatively homogeneous and contained geographic environment with a dominance of manual and semi-skilled labor force.

All the children completed 2 questionnaires. First, the Self-Perception Profile for Children (SPPC) (22), which gives a measure of children's perceptions of their global self-worth, as well as their perceived competencies in 5 separate domains (scholastic competence, athletic competence, behavioral conduct, social acceptance, and physical appearance). Higher scores are associated with greater perceived competence. In addition, discrepancies between perceived and ideal levels of competence within each domain are computed, the larger discrepancies being associated with poorer evaluations of self-worth. Second was the Children's Depression Inventory (CDI) (23), which gives an overall measure of depression, as well as scores on 5 separate subscales (negative mood, interpersonal problems, ineffectiveness, anhedonia, and negative self-esteem). Higher scores are associated with more depressive symptomatology.

Results

Children of shift workers compared with children of day workers

Multivariate analyses of variance were performed to investigate the relationships between paternal shift working, gender, and child emotional state. No significant interactions were found between whether the father worked shifts or days, and the gender of the child, and the self-reported emotional and affective state of the child. However significant main effects of gender were found for overall depression (F=4.28; df=1,157; P<0.05) and interpersonal problems (F=11.64; df=1,157; P<0.001), girls reporting higher levels than boys, and a significant main effect of paternal working on perceived academic competence was also found (F=4.81; df=1,180; P<0.05), children of day working fathers reporting higher perceived levels of competence than children of shift working fathers.

Relationship between paternal workhours and child affective state according to gender

Perceived competence. Given that gender-related differences in perceived self-competence in association with certain domains are known to exist (22), the analyses were repeated for the girls and boys separately. The daughters of the shift working fathers were therefore compared with the daughters of the day working fathers, as were the sons of the shift working fathers with the sons of the day working fathers, with respect to perceived levels of competence. The daughters of the shift working fathers reported significantly poorer perceptions of their academic competence than did the daughters of the day working fathers (F=4.40; df=1,80; P<0.05). However, no significant differences were found between the sons of the shift working fathers and the sons of the day working fathers.

Discrepancy scores (believed to be the greatest indicator of perceived self-worth) were computed and compared for the perceived and ideal levels of competence in the domains rated as important. When the girls were compared, again, only 1 significant difference was found. The daughters of the shift working fathers perceived a greater total discrepancy between their perceived and ideal levels of competence than did the daughters of the day working fathers (F=4.99; df=1,76; P<0.05). Again, no significant differences were found between the sons of the shift working fathers and the sons of the day working fathers.

The discrepancy scores between the perceived and ideal levels of competence, for the domains rated as important, were also compared for the boys and girls within each of the 2 research groups in order to assess perceptions of self-worth. Within the shift working group, there were 2 significant differences. Although the boys reported a greater discrepancy in relation to their athletic competence than did the girls (F=6.17; df=1,51; P<0.05), it was the girls who reported a total greater discrepancy in overall perceived and ideal levels of competence (F=4.44; df=1,83; P<0.05). However, within the day working group, no significant differences were found for the discrepancy ratings of the boys and girls.

Depression. The daughters of the shift working fathers were compared with the daughters of the day working fathers, as were the sons of the shift working fathers with the sons of the day working fathers, with respect to self-reported levels of depression. Although the differences were not statistically significant, the daughters of the shift working fathers reported more depressive symptomatology overall, and more negative self-esteem than did the daughters of the day working fathers (P<0.10). It is also interesting to note that the daughters of the shift working fathers scored more highly on all the subscales than the daughters of the day working fathers. Figure 1 shows a comparison of the scores. No significant differences in levels of depression were reported between the sons of the shift working fathers and the sons of the day working fathers.

The daughters of the shift working fathers were compared with the sons of the shift working fathers, as were the daughters of the day working fathers with the sons of the day working fathers. Within the shift working group, the girls reported a significantly higher overall level of depression (F=4.93; df=1,76; P<0.05), a significantly more negative mood (F=4.42; df=1,87; P<0.05), significantly more interpersonal problems (F=8.33; df=1,87;

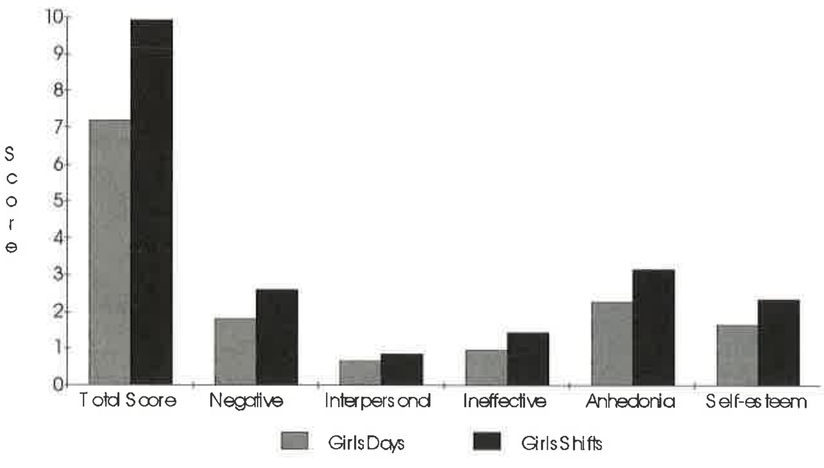

Figure 1. Total depression and subscale scores for the daughters of day working fathers and the daughters of shift working fathers.

P<0.01), and significantly more anhedonia (F=4.30; df=1,87; P<0.05) than did the boys. However, within the day working group only 1 significant difference was found. The girls reported significantly more interpersonal problems than did the boys (F=6.77; df=1,96; P<0.01).

Discussion

A relationship was found between paternal shift working and child affective state among the daughters but not the sons of the shift working fathers, and also among the daughters of the shift working fathers when compared with the daughters of the day working fathers. In particular, the daughters of the shift working fathers appeared to be the most emotionally and affectively disturbed. They reported poorer perceptions of their academic competence, their competencies overall, and their perceptions of self-worth than did the daughters of the day working fathers. There was also an indication (though not statistically significant) that they were more depressed, and held more negative views of themselves, than did the daughters of the day working fathers, and they were significantly more depressed than the sons of the shift working fathers.

Given that we did not measure the affective state of the father it was not possible to determine the extent to which the fathers' affective state may, or may not, have directly contributed to the findings. However, given the enormous biological and social disruption associated with working shifts, it has been argued that shift working families can and do experience a significantly greater number of familial stressors than do day working families (10, 24, 25), for example, the general conflicts and tensions experienced within shift working families (24, 25), the physical absence of the father from the home, and the higher rates of negative affect and psychological ill-health reported by shift workers (7, 17, 26). Stressful life circumstances and events have, for many years, been shown to be associated with the development of child behavioral and psychological disorders (27, 28), although more recently such adverse conditions have been seen as risk factors rather than as directly causal factors (29). Specific risk factors have included parental emotional disturbance (18, 30), lack of parental and social support (31, 32), and family conflict (33, 34). Thus it is perhaps not surprising that greater emotional disturbances were reported by some of the children of the shift workers than by the children of the day workers in our study.

However, as already highlighted, this effect was found only for the daughters, and not for the sons of the shift working fathers. It is important therefore to try to understand why this gender effect may occur, given the potential for increased conflict and stress across all shift working families. One possible explanation may be related to the actual nature of the variables under study. For example, it may be possible that the sons of shift working fathers may in fact also be experiencing greater degrees of emotional difficulties than the children of day working fathers, yet the expression of these difficulties may take on a different form than that of the girls, and that of the variables currently under study. For example, externalizing disorders of children (eg, conduct disorders), which have been shown to be associated with parental emotional disturbances and marital conflict (35, 36), have been found to be more common among boys than girls (37), whereas, in contrast, internalizing disorders (eg, depression) have been shown to be more common among girls than boys (27, 38). Thus the nature of the variables studied may in fact account for the gender effect produced.

This study has however numerous limitations, and therefore caution should be exercised when the results are interpreted. First, parental emotional state was not assessed. Thus it is not possible to say whether or not elevated levels of paternal distress were associated with work shifts and, in turn, were influential in the development of child emotional difficulties. Second, the focus only on internalizing as opposed to externalizing measures of emotional state may account in part for the gender effect produced. A further point to consider, since the population was drawn from a relatively small and homogeneous community, is the role of parental socioeconomic class and the development of children's competencies and problems, including academic achievement, in the interpretation of the results. Thus the lower educational achievement of some of the children of the shift working fathers may reflect a confounding effect of social class and work pattern.

In conclusion, the daughters, but not the sons, of the shift working fathers reported more negative self-perceptions, poorer academic self-competence, and more depressive symptomatology than the children of the day workers. However, the specific nature of the variables studied, that is, internalizing as opposed to externalizing expressions of emotional disturbance, may indeed account for the gender difference observed. More research is therefore needed to explore these associations further.

References

1. Crouter AC. Processes linking families and work: implications for behavior and development in both settings. In: Parke RD, Kellam, SG, editors. Exploring family relationships with other social contexts. Hillsdale (NJ): Lawrence Erlbaum, 1994:9—28.
2. Repetti RL. Effects of daily workload on subsequent behavior during marital Interaction: the roles of social withdrawal and spouse support. J Pers Soc Psychol 1989;57:651—9.
3. Repetti RL. Daily job stress and father-child interaction. Pa-

per presented at the biennial meeting of the Society for Research in Child Development, Kansas City (MO), 1989.
4. Waterhouse JM, Folkard S, Minors DS. Shift work, health and safety: an overview of the scientific literature 1978—1990. London: Her Majesty's Stationery Office, 1992.
5. Åkerstedt T. Psychological and physiological effects of shift work. Scand J Work Environ Health 1990;16 suppl 1:67—73.
6. Tepas DI, Mahan RP. The many meanings of sleep. Work Stress 1989;3:93—104.
7. Bohle P, Tilley AJ. The impact of night work on psychological well-being. Ergonomics 1989;32:1089—99.
8. Knuttson A. Shift work and coronary heart disease. J Soc Med 1989;44:1—36.
9. Colligan MJ, Rosa RR. Shiftwork effects on social and family life. In: Scott AJ, editor. Shiftwork: cccupational medicine: state of the Art Reviews. Philadelphia: Hanley & Belfus, 1990:315—22.
10. Walker J. Social problems of shift work. In: Folkard S, Monk TH. editors. Hours of work: temporal factors in work scheduling. John Wiley, 1985:211—25.
11. Estryn-Behar M, Kaminski M, Peigne E, Bonnet N, Vaichere E, Gozlan C, et al. Stress at work and mental health status among female hospital workers. Br J Ind Med 1990;47:20—8.
12. Barton J, Folkard S, Smith L, Poole CJM. Effects on health from a delaying to an advancing shift system. Occup Environ Med 1994;51:749—55.
13. Costa G, Apostoli P, D'Andrea F, Gaffuri E. Gastrointestinal and neurotic disorders in textile shift workers. In: Reinberg A, Vieux N, Andlauer P, editors, Night and shift work: biological and social aspects. Oxford: Pergamon, 1981:215—22.
14. Michel-Briand C, Chopard JL, Guiot A. The pathological consequences of shift work in retired shift workers. In: Reinberg A, Vieux N, Andlauer P, editors, Night and shift work: biological and social aspects. Oxford: Pergamon, 1981:399—408.
15. Cohn JF, Campbell SB. Influence of maternal depression on infant affect regulation. In: Cicchetti D, Toth S, editors. Rochester symposium on developmental psychopathology; vol 4, (Developmental approaches to affective disorders). Rochester (NY): University of Rochester Press, 1992:323—49.
16. White RW. Motivation reconsidered: the concept of competence. Psychol Rev 1959;66:297—333.
17. Hammen C. Self-cognitions, stressful events, and the prediction of depression in children of depressed mothers. J Abnorm Child Psychol 1988;16:347—67.
18. Cummings EM, Davies PT. Maternal depression and child development. J Child Psychol Psychiatry 1994;35:73—112.
19. Jugel M, Spangenberg B, Stollberg R. Schichtarbeit und Lebensweise. Berlin: Dietz-Verlag, 1978.
20. Maasen A. The family life of shift workers and the school careers of their children. In: European Foundation for the Improvement of Living and Working Conditions, editor. The effects of shift work on health, social and family life. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1980.
21. Volger A, Ernst G, Nachreiner F, Haenecke K. Common free time of family members under different shift systems. Appl Ergon 1988;19:213—8.
22. Harter S. Manual for the Self-Perception Profile for children. Denver (CO): University of Denver, 1985.
23. Kovacs M. Children's Depression Inventory, manual. New York (NY): Multi-Health Systems Inc, 1992.
24. Monk TH, Folkard S. Making shift work tolerable. London: Taylor & Francis, 1992.
25. Mott PE, Mann FG, McLoughlin Q, Warwick DP. Shift work: the Social, psychological and physical consequences. Ann Arbor (MI): The University of Michigan Press, 1965.
26. Barton J, Folkard S. Advancing versus delaying shift systems. Ergonomics 1993;36:59—64.
27. Harrington R. Affective disorders. In: M Rutter, E Taylor, L Hersov, editors. Child and adolescent psychiatry. Oxford: Blackwell, 1994:330—50.
28. Rutter M. Commentary: some focus and process considerations regarding the effects of parental depression on children. Dev Psychol 1990;26:60—7.
29. Garmezy N, Masten A. Chronic adversities. In: M Rutter, E Taylor, L Hersov, editors. Child and adolescent psychiatry. Oxford: Blackwell, 1994:191—208.
30. Dix T. The affective organisation of parenting: adaptive and maladaptive processes. Psychol Bull 1991;110:3—25.
31. Harter S. Causes and consequences of self-esteem in children and adolescents. In: RF Baumeister, editor. Self-esteem: the puzzle of low self-regard. New York (NY): Plenum Press, 1993:87—116.
32. Wertleib D, Weigel C, Feldstein M. Stressful experiences, temperament, and social support: impact on children's behavior symptoms. J Appl Dev Psychol 1989;10:487—503.
33. Rutter M, Quinton D. Parental psychiatric disorder: effects on children. Psychol Med 1984;14:853—80.
34. Downey G, Coyne JC. Children of depressed parents: an integrative review. Psychol Bull 1990;108:50—76.
35. Olweus D. Familial and temperament determinants of aggressive behavior in adolescent boys: a causal analysis. Dev Psychol 1980;16:644—60.
36. Earls F. Oppositional-defiant and conduct disorders. In: M Rutter, E Taylor, L Hersov, editors. Child and adolescent psychiatry. Oxford: Blackwell, 1994:308—29.
37. Rutter M, Tizard J, Whitemore K. Education, health and behavior. London: Longmans, 1970.
38. McGee R, Feehan M, Williams S, Anderson J. DSM-III disorders from age 11 to age 15 years. J Am Acad Child Adolesc Psychiatry, 1992;31:50—9.

Guidelines for the medical surveillance of shift workers

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Costa G. Guidelines for the medical surveillance of shift workers. *Scand J Work Environ Health* 1998;24 suppl 3:151—155.

Occupational health physicians should evaluate workers' fitness for shift and night work before their assignment, at regular intervals, and in cases of health problems connected with night work. The evaluation should be accompanied by a careful job analysis to ensure that shift schedules are arranged according to ergonomic criteria. This arrangement can reduce health problems and make coping with irregular workhours possible, even for people suffering from contraindicative illnesses. Both health disorders representing absolute or relative contraindication and actual work conditions should be taken into account. Health checks should be aimed at detecting early signs of intolerance, such as sleeping and digestive trouble, drug consumption, accidents, and reproductive function. Their periodicity should be set in relation to specific work conditions, individual characteristics, and social factors known to influence tolerance to shift work. Shift workers should receive clear information on the possible negative effect of shift work, and also counseling for coping with shift and night work.

Key terms counseling, night work, occupational health service, shift work.

The usefulness and necessity of preventive and periodic health assessments of shift and night workers have been stressed by many international directives and recommendations, as well as by national laws and regulations.

In particular, both convention no 171 of the International Labour Organisation (ILO) concerning night work (1) and European directive no 93/104/EC, *Concerning Certain Aspects of the Organization of Working Time* (2), state that workers should have appropriate safety and health protection, in particular the right to undergo free health assessment before their assignment to night work, and thereafter a free health examination at regular intervals and also if they experience health problems because of their night work. Moreover, night workers suffering from health problems recognized as being connected with night work should be transferred, whenever possible, to day work for which they are fit. Furthermore, employers and workers' representatives should be able to consult occupational health personnel about the consequences of various forms of night work.

In fact, shift work, in particular that including night work, is a well documented risk factor for health and well-being, as it interferes with biological functions and social life due to a mismatch between the person's circadian rhythm and environmental synchronizers. This mismatch can have a negative influence on work performance (errors and accidents), social relations (difficulties in marital relations, care of children and social contacts) and health (mainly with respect to sleep disorders, chronic fatigue, neuropsychological problems, digestive and cardiovascular diseases, and women's reproductive function) (3—5).

Preventive and compensative measures

Occupational health physicians have the duty to protect workers' health from occupational stress factors, and they also have the responsibility of defining people as "fit" or "unfit" for shift or night work, with consequent implications on both individual life and work organization.

Therefore, the evaluation of a worker's fitness for shift and night work should be strictly connected with a careful job analysis of work organization, in particular shift systems. In fact, it appears unreasonable, and also uneconomic, to define a plan for the medical surveillance of people obliged to work in unfavorable shift systems or to declare a person "unfit" for "bad" shift systems.

On the other hand, it must be stressed that shift work cannot be a discriminating criterion for worker selection.

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Instead the primary requisite is to arrange shift schedules according to ergonomic principles and to assure suitable compensative measures for shift and night workers to avoid significant perturbations in circadian rhythm, performance decrement, accumulation of sleep deficit, and marked interference with family and social life so that almost everyone can cope with shift work without impairment to health.

Consequently, occupational health physicians should strongly advise both employers and employees to consider and implement of the best possible shift schedules according to the general recommendations given in recent years. These recommendations particularly refer to the adoption of quickly rotating shift systems with clockwise rotation (morning → afternoon → night), the reduction of night shifts in succession to the minimum, delayed starting hours of morning shifts (at 0700 or 0800), flexible worktime arrangements with some free weekends, and length of the shifts connected with work load and environmental pollution (6).

However, it should be kept in mind that there is no best shift system suitable for all workplaces; instead each shift system should be tailored according to the specific work and social conditions of the work force involved. This arrangement implies, on one hand, a precise examination and evaluation of job demands and characteristics and, on the other, a careful strategy for modifying shift schedules that requires the participation of the workers in the analysis, design, implementation and assessment of the shift system chosen (7). This is not only a basic condition of democratic participation of the persons who must bear the consequences of the decisions, but it is also the only way of properly motivating them to accept the changes and therefore the only way to develop higher tolerance to unusual workhours.

In fact, from the individual point of view, changes in worktime arrangements often clash with living habits, in particular with domestic (meal and sleep times, housework, relationships with other members) and social (leisure-time activities, involvement in social groups, commuting times, etc) life (8).

Moreover, according to chronobiological and physiological principles, "ergonomic" shift schedules certainly have less negative effects on health and well-being and thus reduce medical problems and needs for control or intervention. Such schedules can make coping with irregular workhours possible even for people suffering from illnesses that may be, in principle, contraindicative for shift and night work.

In addition to the organization of shift schedules, other useful countermeasures that have proved beneficial for tolerance to shift work should be supported by occupational health physicians.

According to Thierry (9) intervention that is apt to compensate for the inconveniences of shift and night work can be represented by "counterweights" and "counter values". The first forms of compensation are only aimed at providing a reward for the troubles caused. One good example is monetary compensation, which is a simple translation of the multidimensional aspects of the problem into money. Its value varies according to several factors, some of which may not be strictly related to the seriousness of the inconvenience (eg, union power, economic conditions, productive needs). Another counterweight is, for example, intervention aimed at improving general work conditions (work environment, job enrichment). The second forms of intervention are aimed at reducing or eliminating the inconveniences. They can be directed towards both the causes and the consequences, such as the reduction of workhours, the restriction of night shifts, more compensative rest days or extra time off, additional pauses for meals and naps, sleep and canteen facilities, social support (eg, day nursery, transportation, extended school and shop hours), physical and psychological training, transfer to day work after a certain number of years, early retirement, counseling, and health surveillance (10). Obviously, the second types of intervention should be preferred and adopted according to the particular conditions and characteristics of the work groups.

Criteria for medical surveillance

Occupational health physicians should evaluate workers' fitness for shift and night work before the workers are assigned to shift work, and also at regular intervals thereafter. They should also make such evaluation in cases of health problems connected with night work.

On the basis of earlier proposals (11—15), derived from epidemiologic studies concerning the possible short- and long-term effects of shift and night work and the related physiopathological pathways, it appears reasonable to consider exemption from night work for people suffering from severe disorders and diseases that can be either directly connected to or worsened by irregular workhours; of particular concern are (i) chronic sleep disturbances, as they are the main consequence of disrupted sleep-wake cycles; (ii) severe gastrointestinal diseases such as chronic gastritis and peptic ulcer (as their prevalence among shift and night workers is 2 to 6 times higher), as well as chronic active hepatitis, cirrhosis and chronic pancreatitis, due to the necessity of proper diet and life regimen; (iii) ischemic heart disease (eg, myocardial infarction up to 12 months after the event or with impaired heart function, angina pectoris), hyperkinetic syndromes and severe hypertension, both for the direct negative influence of the disruption of hormonal, neurovegetative and biochemical homeostasis and for the "indirect" effect connected with more stressful work and living conditions; (iv) insulin-dependent diabetes, as regular and proper food intake and correct therapeutic timing is needed; (v) severe thyroid (thyrotoxicosis and thyroidectomy) and suprarenal pathologies, since they require regular drug consumption strictly connected with the activity-rest cycles; (vi) epilepsy requiring medication, as the seizures can be favored by sleep deficit and the efficacy of the treatment can be hampered by irregular wake-rest schedules; (vii) brain injuries with sequelae and severe nervous disorders, in particular chronic anxiety and depression, as they are often associated with a disruption of the sleep-wakefulness cycle and can be influenced by light-dark periods; (viii) spasmophily, as temporal changes can be a promoting factor of tetanic crisis; (ix) chronic renal impairment, as the disruption of circadian rhythms can further impair renal function; (x) malignant tumors, to avoid further stress and facilitate medical treatment; and (xi) pregnancy, because of the possible increased risk of abortion or abnormal fetal development.

Moreover, particular attention should also be paid to specific work groups or conditions since shift and night work may represent a possible risk factor under certain circumstances, in particular (i) for women with menstrual disorders, or who have small children, as they suffer from shorter sleep duration and poor sleep quality; (ii) for workers exposed to toxic substances, as a desynchronization between times of exposure and the circadian rhythm of metabolic functions can make them more vulnerable to xenobiotics (16); (iii) for people with mild digestive disorders (eg, gastroduodenitis and colitis) as the disorders can be chronicized and aggravated; (iv) for persons suffering from asthma and chronic obstructive bronchitis, as crises are influenced by circadian fluctuations of cortisol levels and bronchial patency; (v) for people with a high intake of alcohol or other drugs affecting the central nervous system (eg, benzodiazepines), for their negative influence on vigilance and performance efficiency; (vi) for persons afflicted by marked hemeralopia or visual impairment, which can make night work difficult or dangerous in cases of reduced illumination; and (vii) for people with unsatisfactory housing conditions (particularly as concerns noise in bedrooms) and with long commuting times, as they can suffer sleep deprivation and chronic fatigue. All these conditions may represent, in principle, absolute or relative contraindications to night and shift work and thus require a temporary or permanent transfer or assignment to day work, and physicians should point out the contradictions to the worker and the employer. However, occupational health physicians should evaluate each case very carefully in light of actual work situations, the perspectives of the worker, and the specific health conditions of the worker.

Nevertheless, it cannot be directly assumed that the sole removal of such risk factors can be certainly or totally beneficial to a worker's health. In fact, most of the health disorders reported by shift workers pertain to the psychosomatic domain and often have a multifactorial origin related to family heritage, life-styles, general social conditions, other occupational risks, and intervening illnesses. In this context, shift work may represent an additional stress factor due to both conflicts between endogenous rhythms and external synchronizers and to greater interference and difficulties in family and social life.

Consequently, maladaptation and intolerance to shift work are the result of sometimes complex interactions. In fact, they can act differently on shift workers, both in terms of severity and appearance in the course of worklife and according to the specific personal and social situations (16).

Therefore, it is possible that, for some persons, positive results can be obtained more through intervention with shift schedules and compensative measures than with simple transfer to day work.

Moreover, advances in clinical diagnosis, pharmacology and rehabilitation now offer better possibilities for treating some illnesses (eg, peptic ulcer, some forms of insulin-dependent diabetes, hypertension and myocardial infarction) and, therefore, may permit workers to continue in shift work when a transfer to day work is problematic, due either to other risk factors or to personal resistance to job change.

The situation as a whole must be evaluated very carefully by occupational health physicians, who, on the other hand, also have to remember that sometimes shift workers do not completely report their health problems as considered "part of the job", or they even mask them since they are more afraid of losing the economic benefits connected with shift and night work.

Factors influencing tolerance to shift and night work

Occupational health physicians should also pay particular attention to individual factors dealing with physiological functions, personality traits, and behavioral characteristics that may influence adaptation and tolerance to shift work (17).

Aging can favor progressive intolerance, as it is generally associated with an instability of circadian rhythms, sleep disturbances, depression, and a decline in physical fitness and health. On the other hand, young people can find it difficult to adapt to night work either because they are more sensitive to acute sleep loss or because it hampers the possibility of participating in and integrating to social groups.

Women can be more vulnerable to shift and night work because of their more complex circadian and infradian hormonal rhythms connected with reproductive function and the extra demands related to family life and domestic commitments. Perturbation of the menstrual cycle, more sleep problems, cumulative fatigue, and negative effects on pregnancy (lower rates, higher frequency of miscarriages, preterm deliveries, and child's low birthweight), have been recorded for some groups of female shift workers (18).

People with higher levels of neuroticism, rigid sleep habits or difficulty to overcome drowsiness have also been reported to have more difficulties in adapting to irregular work schedules, as do persons who show a less stable circadian structure and proneness to internal desynchronization (19). Moreover, the characteristics of "morningness", based on advanced phases of circadian rhythms and the sleep-activity cycle, generally induce more difficulties with short-term adjustment to night work, whereas "evening" types may have more trouble on early morning shifts.

On the other hand, good physical fitness can favor tolerance to shift work, as it can increase performance efficiency, lessen fatigue, and improve sleep and recovery mechanisms (20). Another important factor in this sense is "commitment to shift work", as in cases of workers willing and able to schedule their daily activities, in particular their sleep habits, according to irregular workhours. It is desirable that such factors or characteristics be considered not only in the evaluations of negative effects, but also in the positive sense, both in respect to the primary assignment (when possible) to night work for those expected to be more adaptable and to combining shift scheduling with individual preferences deriving from both the psychophysiological characteristics and living conditions of workers (eg, morning types and elderly people can cope better with morning shifts). However, occupational health physicians must proceed carefully in order to avoid a risky attitude towards a-critical selection that would reduce workers' possibility or probability of finding a job (a situation that could be more dangerous for their health and well-being).

In fact, it is not yet completely clear to what extent personal characteristics influence long-term tolerance to night work and, consequently, can be used as possible predictors of such tolerance. Many other factors can also play a prominent role in long-term tolerance, in particular a worker's family situation (eg, number and age of children, housing, partner's job) and social conditions (eg, socioeconomic level, community support and services, the labor market, moonlighting), in addition to the specific job demands and the organization of workhours. Such factors can explain the high interindividual variability in tolerance to shift work that has been found in epidemiologic investigations.

Of course, some factors are difficult or impossible to modify (eg, age, personality traits, family), while others can be more easily changed to provide for better coping with shift work (eg, shift schedules or some personal lifestyle factors).

Problems connected with the short-term adjustment of circadian rhythms, including sleep, are presumably the main causes of intolerance to night work in the first 1 or 2 years of shift work, whereas long-term intolerance is more related to other personal, work and social factors. Both factors influence the process of self-selection that occurs among these workers and, due to the "healthy worker effect", sometimes masks the results of epidemiologic inquiries.

Periodic health checks and counseling

Regular health checks are also important tools aimed at protecting shift workers' health. They should be a part of periodic evaluations of fitness to work that occupational physicians have to plan in relation to different risk factors. They should be aimed at detecting early signs or symptoms of difficulty in adjustment and, consequently, intolerance to night work, which may require prompt intervention both with the organization of the workhours and with individual factors (eg, correcting or improving coping or temporary or permanent transfer to day work). Therefore, they should focus primarily on sleep times and troubles, eating and digestive problems, psychosomatic complaints, accidents, reproductive function of women, drug consumption, housing conditions, commuting problems, work loads, and leisure-time activities.

Health checks should be carried out preferably using standardized questionnaires or checklists that make possible a comparison of a worker's health with later health status and with the health of reference groups of day workers. Sleep logs, diaries of daily activities, and recordings of circadian rhythms of some physiological parameters (eg, body temperature, cortisol level, melatonin level, performance) can also be helpfully used in evaluating the level of a worker's adaptation. In cases of exposure to toxic substances, biological monitoring should also take into account both the timing of exposure and time-qualified reference values (19).

The periodicity of health checks should not be set a priori; instead it should be established in relation to several factors concerning work conditions (eg, shift rota, environmental conditions, combined risk factors, compensative measures) and individual characteristics (eg, age, health, personal characteristics).

According to some proposals (12, 14, 15), the following general scheme appears advisable: a second health check not later than 1 year after the start of night work (as the 1st year is crucial for adaptation and coping), and successive health checks every 3—5 years for those under 45 years of age and every 2—3 years for those over 45 years of age.

Further clinical controls should be carried out whenever the workers complain of problems or disorders in relation to shift and night work or they suffer from other intervening illnesses that can hamper tolerance and work capacity. In such cases, as well in cases of severe difficulties in family or social life, temporary exemption from night work should be considered.

Moreover, fitness for shift work should be reevaluated when important changes in work activity occur, in particular when physical work load, chemical pollution and high mental strain changes. Furthermore, long-term medical surveillance should be arranged for people who quit nightwork for health reasons, as they may have a higher prevalence of sleep, gastrointestinal or cardiovascular disorders several years after the cessation of shift work.

Last but not least, it is necessary that shift workers be aware of the possible negative consequences of shift work and given useful information, suggestions, and guidelines on how to cope with shift and night work. Counseling and training should be done at the individual (before assignment to shift work and during periodic health controls) and the group (through educational programs) level (21, 22). They should deal with improving self-care strategies for coping, in particular for sleep (eg, tight scheduling of sleep hours, use of naps, arrangements to avoid disturbances, abuse of sleeping pills or caffeinated drinks), diet (eg, meal times, pauses, food quality, snacks, alcohol), stress management (eg, relaxation techniques), physical fitness (eg, regular exercise, smoking), leisure-time activities, and exposure to bright light (23—26).

Most useful solutions or coping strategies can be learned by shifty workers through their own direct experience, and they should be advised and supported also from the scientific point of view in maintaining, extending, and adjusting their solutions and coping strategies to their specific problems and conditions.

References

1. International Labour Office (ILO). Night work convention no 171. Geneva: ILO, 1990.
2. European Council. Concerning certain aspects of working time. Off J Eur Commun 1993;L307:18—24. Council directive 93/104/EC.
3. Waterhouse JM, Folkard S, Minors DS. Shiftwork, health and safety: an overview of the scientific literature 1978—1990. London: Her Majesty's Stationery Office, 1992.
4. Costa G. The impact of shift and night work on health. Appl Ergon 1996;27:9—16.
5. Costa G. The problem: shiftwork. Chronobiol Int 1997;14:89—98.
6. Knauth P. Designing better shift systems. Appl Ergon 1996;27:39—44.
7. Wedderburn A, editor. Instruments for designing, implementing and assessing working time arrangements. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1994. Bulletin of European studies on time, no 7.
8. Rosa RR, Härmä M, Pulli K, Mulder M, Nasman O. Rescheduling a three shift system at a steel rolling mill: effects of a one hour delay of shift starting times on sleep and alertness in younger and older workers. Occup Environ Med 1996; 53:677—85.
9. Thierry H. Compensation for shiftwork: a model and some results. In: Colquhoun WP, Rutenfranz J, editors. Studies of shiftwork. London: Taylor & Francis Ltd, 1980:449—62.
10. Wedderburn A, editor. Compensation for shiftwork. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1992. Bulletin of European studies on time, no 4.
11. Harrington JM. Shiftwork and health: a critical review of the literature. London: Her Majesty's Stationery Office, 1978.
12. Rutenfranz J. Occupational health measures for night and shiftworkers. J Hum Ergol 1982;11 suppl:67—86.
13. Scott AJ, LaDou J. Shiftwork: effects on sleep and health with recommendations for medical surveillance and screening. In: Scott AJ, editor. Shiftwork. Philadelphia (PA): Hanley & Belfus, 1990:273—99. Occupational medicine: state of art review.
14. Colquhoun WP, Costa G, Folkard S, Knauth P. Shiftwork: problems and solutions. Frankfurt aM: Peter Lang, 1996.
15. Koller M. Occupational health services for shift and night work. Appl Ergon 1996,27:31—7
16. Haider M, Cervinka R, Koller M, Kundi M. A destabilization theory of shiftworkers effects. In: Hekkens JM, Kerkhof GA, Rietveld WJ, editors. Trends in chronobiology. Oxford: Pergamon Press, 1988:209—17.
17. Härmä M. Interindividual differences in tolerance to shiftwork: a review. Ergonomics 1993;36:101—9.
18. Nurminen T. Female noise exposure, shift work, and reproduction. J Occup Environ Med 1995;37:945—50.
19. Smolenski MH, Reinberg A. Clinical chronobiology: relevance and applications to the practice of occupational medicine. In: Scott AJ, editor. Shiftwork. Occupational medicine: state of art review. Philadelphia (PA): Hanley & Belfus, 1990:239—72.
20. Härmä M. Ageing, physical fitness and shiftwork tolerance. Appl Ergon 1996;27:25—9.
21. Tepas DI. Educational programmes for shiftworkers, their families, and prospective shiftworkers. Ergonomics 1993;36:199—209.
22. Kogi K. Improving shift workers' health and tolerance to shiftwork: recent advances. Appl Ergon 1996;27:5—8.
23. Eastman CI, Boulos Z, Terman M, Campbell SS, Dijk DJ, Lewy AI. Light treatment for sleep disorders: consensus report, VI: shift work. J Biol Rhythms 1995:10:157—64.
24. Wedderburn A. Guidelines for shiftworkers. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1991. Bulletin of European studies on time, no 3.
25. Monk T, Folkard S. Making shiftwork tolerable. London: Taylor & Francis 1992.
26. Akerstedt T. Wide awake at odd hours. Stockholm: Swedish Council for Work Life Research, 1996.

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