OTH 96 530

PSYCHOSOCIAL ASPECTS OF WORK AND HEALTH IN THE NORTH SEA OIL AND GAS INDUSTRY - Parts III and IV

Part III

Sleep, mood and performance in relation to offshore shift rotation schedules

Katharine R Parkes
Melanie J Clark and Esther Payne-Cook

Department of Experimental Psychology
University of Oxford
South Parks Road
Oxford, OX1 3UD

HSE BOOKS

Health and Safety Executive - Offshore Technology Report

Applications for reproduction should be made in writing to:
Copyright Unit, Her Majesty's Stationery Office,
St Clements House, 2-16 Colegate, Norwich NR3 1BQ

First published 1997

ISBN 0-7176-1394-1

This report is published by the Health and Safety Executive as part of a series of reports of work which has been supported by funds provided by the Executive. Neither the Executive, or the contractors concerned assume any liability for the report nor do they necessarily reflect the views or policy of the Executive.

Results, including detailed evaluation and, where relevant recommendations stemming form their research projects are published in the OTH series of reports.

Background information and data arising from these research projects are published in the OTI series of reports.

Please note that Parts I and II of the research are reported in
OTH 96 523

Part I: A review of the literature
Part II: A five-year follow-up study (1990-1995) of offshore and onshore personnel

FOREWORD

The North Sea work environment has undergone extensive change in recent years, and the effects of organizational restructuring, cost reduction, and technological innovation will continue to impact on the oil and gas industry in the future. In these changing circumstances, the health, safety, and productivity of the North Sea workforce is an issue of concern not only to personnel working offshore, but also to onshore management teams and the industry as a whole.

In this context, there is a need for current information about work and health in the offshore environment. The present research, under the general title *'Psychosocial aspects of work and health in the North Sea oil and gas industry',* seeks to contribute up-to-date findings in several areas of topical importance to the offshore oil and gas industry. The research was carried out by Oxford University with funding from the Health and Safety Executive, Offshore Safety Division; the main data collection took place during 1995-1996. The work is reported in four parts:

Part I *reviews the available research literature relating to work and health (including psychosomatic complaints, mental health and stress, and health behaviours) among offshore personnel. General aspects of the psychosocial environment on North Sea installations and specific issues, such as offshore shift rotation, are considered; areas in which information is currently lacking are highlighted.*

Part II *reports a small-scale follow-up study which evaluated changes in mental health and job satisfaction in onshore and offshore personnel over the period 1990-95. A marked feature of the findings is the significant increase in perceived workload and anxiety in the occupational group concerned (production operators), both onshore and offshore, over a five-year period of re-structuring and down-manning.*

Part III *addresses the issue of offshore day/night shift rotation patterns. Repeated assessments of sleep, mood, and cognitive performance (e.g. reaction time, memory, reasoning) over the two-week offshore work cycle clearly demonstrated the adverse effects of a mid-cycle shift change as compared with a fixed-shift schedule in which either days or nights are worked for the entire two-week period.*

Part IV *presents the main findings of a survey of the perceived physical and psychosocial work environment, safety, health and job satisfaction among offshore personnel (N=1462) on 17 offshore installations. Overall, the offshore sample did not show elevated levels of stress symptoms relative to comparable onshore groups, but job types, shift patterns, and installation characteristics were significant predictors of safety, work, and health measures.*

The research described would not have been possible without the high degree of co-operation received from the operating companies concerned, and the encouragement of the United Kingdom Offshore Operators Association. It is hoped that, in reflecting current offshore work conditions, the research findings will be of interest not only to the participating companies but also to the North Sea oil and gas industry more generally, and that the work will serve to promote greater awareness of the importance of human factors research at a time of rapid change in the industry as a whole.

SUMMARY

This report describes a study of offshore shift rotation patterns, the aim of which was to compare fixed-shift and rollover schedules in terms of sleep, mood, and cognitive performance. Two rollover patterns, night followed by days (7N+7D) and days followed by nights (7D+7N), and one fixed-shift pattern in which day and night shifts were worked on alternate tours (14D/14N), were studied.

Data were collected on four North Sea oil and gas platforms. For analysis purposes, the two-week work cycle was divided into three test phases, each covering three consecutive shifts. Prior to the first two phases, 'practice' shifts (during which data were collected but not analysed) were scheduled, and phases were separated by one or two 'rest' shifts (during which no data were collected). Assessments were carried out at the start, middle, and end of each test shift.

Individual hand-held computers, programmed to present a sequence of self-report items (measures of sleep, subjective alertness, positive mood, and workload) and cognitive performance tests (simple and choice reaction time, memory, and logical reasoning) were used for data collection. A total of 95 production personnel took part.

Rollover patterns were compared with fixed-shift schedules; the 14D *vs.*7D+7N and 14N *vs.* 7N+7D analyses were carried out separately, controlling for initial differences. The 14D group showed relatively stable responses throughout the two week work cycle, and adaptation to night work was evident in the 14N group during the second week offshore. However, rollover patterns gave rise to significant impairments as compared with the corresponding fixed-shift schedules.

For the 7N+7D group, the initial adjustment to night shifts was followed by a further 12-hour circadian change at the start of the second week; consequently, the operators concerned showed impaired alertness and performance from the start of the night shift week through to the end of the second week. The disruptive effects of rollover were also evident in the 7D+7N group as compared with the 14D condition; although normal day-shift patterns of response were evident in the first week, almost all measures showed significant decrements following the mid-cycle shift change.

Overall, the findings for sleep, mood, and performance revealed that the 14D/14N rotation pattern, which greatly reduces the frequency of circadian changes, had many advantages over rollover patterns. However, other factors are also relevant. In particular, survey data from a sample of 260 offshore personnel indicated a widespread preference for the 7N+7D rollover pattern, which allows personnel to adjust to a normal sleep/wake cycle before going on leave. Operational constraints, such as helicopter schedules and crew change arrangements, must also be taken into account.

Thus, the present study highlights the conflicting factors which underlie decisions about shift rotation schedules. There are no simple answers to these problems. The final section of the report summarises the advantages and disadvantages of the rotation patterns studied to assist managers and offshore personnel in identifying shift patterns that optimise the safety, efficiency, and well-being of those concerned, and that are appropriate to the particular circumstances in which the company operates. Within this framework, it is suggested that a strong case can be made for implementing 'fixed-shift' rotation patterns that eliminate mid-cycle rollovers and thus minimise the frequency of circadian changes to which personnel are exposed.

INDEX

1. INTRODUCTION

Shiftwork plays an essential role in many commercial and industrial activities, particularly those involving continuous production processes. However, research findings suggest that exposure to shiftwork, and the circadian adaptation that it entails, has potentially adverse implications for safety and health, including short-term impairment of cognitive performance and alertness, and longer-term impact on sleep, mental and physical health, and family life (for reviews, see, Wilkinson, 1992; Monk & Tepas, 1985; Monk & Folkard, 1992).

Published research into shiftwork relates primarily to onshore work settings, although its effects have also been studied in naval personnel (e.g. Rutenfranz *et al.* 1988; Torsvall & Akerstedt, 1988). The specific problems associated with scheduling round-the-clock work on offshore oil and gas installations have rarely been systematically investigated, in spite of the inherent difficulties involved in devising shift schedules in the North Sea environment which constrains work patterns in ways that do not apply onshore.

Thus, offshore personnel typically remain in the operating environment for continuous periods of two or more weeks, working a basic pattern of 12-hour shifts interspersed with 12-hour off-duty periods. Work schedules involving rapid rotation of work shifts and rest days (which tend to be favoured onshore) cannot be used offshore because of the isolated and remote locations, and the helicopter travel required. Furthermore, shift rotation patterns in common use offshore often involve a nights/days shift change during every tour, imposing severe adaptational demands. Environmental factors are also important; the potential for cumulative fatigue over the two-week offshore work period is further increased if sleep is disturbed by noise or vibration from production processes, or by other personnel in shared sleeping accommodation.

Findings from onshore shiftwork research which throw light on the potential effects of offshore shift schedules on health and performance, have been reviewed elsewhere (Parkes, 1993, 1994). Although research actually carried out in the North Sea environment can provide information more directly applicable to the design of offshore shift schedules, few relevant studies exist. Published research into this topic appears to be limited to survey findings focusing primarily on health and sleep problems, and a small-scale experimental study of patterns of mood and cognitive performance among offshore personnel. As a background to the present work, findings from these two types of research are outlined below, and the practical constraints which limit the design of offshore shift schedules are considered.

1.1 OFFSHORE SHIFTWORK: HEALTH AND SLEEP PATTERNS

The most extensive survey-based study of offshore shiftwork is that reported by Lauridsen *et al.* (1991). This study focused on health and psychosocial factors in relation to the main shift patterns in use in the North Sea, including 06.00 - 18.00 day work, rotating and non-rotating 06.00 - 18.00 / 18.00 - 06.00 shifts, and rotating and non-rotating 00.00 -12.00 / 12.00 -24.00 shifts (times in terms of 24-hour clock). A range of health indicators, including measures of sleep disturbance, use of sleeping medication, headaches, muscular tension, and stomach problems, was included, and the responses of employees in different occupational groups were examined.

As would be expected, shift patterns involving rotation tended to show a poorer profile on the health-related measures than non-rotating patterns. In general, the least favoured rotation pattern was 00.00 - 12.00 / 12.00 - 24.00; not only does this schedule involve an abrupt shift change at the end of the first week offshore, but neither shift represents a normal pattern of daytime work. In the study by Lauridsen *et al.*, individuals working this rotation pattern reported particularly high levels of health complaints and environmental problems (including stomach complaints, early waking, interrupted sleep, and noise disturbance).

In a comparison of onshore and offshore employees, Parkes (1993, 1994) examined sleep patterns among production operators working 06.00 - 18.00 / 18.00 - 06.00 rotating shifts. The two groups did not differ in sleep patterns during leave periods, but offshore workers reported poorer day-shift sleep quality than those working onshore. However, night-shift sleep duration was longer among offshore personnel than among those working onshore, and similar to normal sleep duration while on leave; this finding suggests that some aspects of adaptation to night-shift work may be facilitated by features of the offshore environment (e.g. the provision of meals and recreational facilities round-the-clock).

Parkes' study also examined age in relation to sleep patterns. It was found that age was negatively related to sleep duration and, to a lesser extent, to sleep quality; however, there was no evidence to suggest that older personnel who worked offshore experienced more sleep difficulties than those working onshore. A further relevant finding of this study was that number of years of shiftwork was negatively related to sleep duration over and above the effect of age, raising the possibility of a cumulative adverse effect of rotating shift work on health.

1.2 OFFSHORE SHIFTWORK: MOOD AND PERFORMANCE

Although several detailed studies of patterns of mood and cognitive performance change have been carried out in laboratory settings, and among onshore shift workers (e.g. Meijman et al. 1993; Rosa & Bonnet, 1993; Smith & Miles, 1987; Wilkinson *et al.* 1989), research of this kind has rarely been carried out offshore. In one such study, Parkes (1993) reported a small-scale investigation of mood and objective performance (reaction time, memory and reasoning) among offshore production operators working a rotating pattern of 7 night shifts followed by 7 day shifts.

The results demonstrated significant fluctuations in alertness and performance over the course of the two-week offshore work cycle. Changes over time within shifts were particularly apparent, but different phases of the work cycle (night shifts, 'rollover', i.e. shift sequences involving a mid-cycle shift change, and day shifts) also showed significant results. The most adverse effects occurred over the rollover phase during which a near-continuous period of 24 hours was worked. A limitation of this study was that only one shift rotation pattern was studied; thus, it was not possible to compare this pattern with other rotation schedules currently in use on North Sea installations. The present research, which combined an experimental study with analysis of relevant survey data, was designed to address this limitation and, in particular, to provide information about the relative merits of different offshore rotation patterns.

1.3 PRACTICAL ASPECTS OF OFFSHORE SHIFT SCHEDULING

In the light of the findings outlined above, it is important to recognise the constraints which apply to the design of offshore shift patterns, and their implications.

- As only two crews are on board at any one time, and jobs must be fully covered throughout the shift-change, offshore shift rotation (whether from nights to days, or *vice versa*) necessarily involves some form of 'backward rotation' or 'short change' system. In schedules of this kind, a change of shift involves a move to working earlier hours, involving one or two shorter shifts and shorter sleep periods; in contrast, 'forward rotation' systems move the work period later in the day, giving longer than usual rest periods over the shift-change days.

  On the basis of evidence from onshore work settings, most researchers strongly advocate forward as opposed to backward rotation (e.g. Folkard, 1992; Knauth & Rutenfranz, 1982), but in the offshore environment, with only two crews on board, forward rotation is not a feasible option. Thus, offshore personnel working rollover shift patterns are exposed not only to the demands of an intensive two-week work cycle, but also to an unfavourable 'short change' rotation sequence, particularly likely to give rise to sleep deficits and fatigue.

- In the shift rotation pattern most widely adopted on North Sea installations, a week of night work is followed by a week of day work in each two-week offshore tour. Many personnel prefer this pattern because it allows them to go on leave at the end of the two-week offshore period adjusted to a normal sleep/wake cycle. However, such a pattern requires adjustment to a 12-hour circadian change twice during each offshore tour (i.e. on working nights on arrival and changing to days at the end of the first week), with potentially adverse consequences for sleep patterns while off-duty, and for alertness and concentration while working.

  In contrast, the opposite rollover direction (seven day shifts followed by seven night shifts) involves only one 12-hour circadian adaptation offshore, but is disliked by many personnel because it necessitates their adjusting back to a normal sleep/wake cycle during the initial days of their shore leave. To avoid the circadian demands of a mid-cycle shift change some companies operating in the UK sector have implemented a system of 'fixed-shift' night and day work scheduled alternately on successive offshore tours, and this pattern was also included in the present study.

Table 1 summarises the patterns of circadian change required by the fixed-shift system, and by each of the rollover schedules, highlighting the total number of circadian adjustments per year, and whether they occur during the offshore work period or during shore leave. In particular, these data demonstrate the marked difference between the alternating fixed-shift system and the rollover patterns in terms of the frequency of circadian adaptations involved.

Table 1.1
Frequency of circadian adjustments during one year of offshore shift rotation for different rotation patterns

Rotation pattern	Number of 12-hour circadian adjustments per year of offshore employment			
	Offshore (*during work*)		Onshore (*during leave*)	TOTAL
	D→N	N→D	N→D	
7N + 7D	13	13	0	26
7D + 7N	13	0	13	26
14D / 14N Alternating	6.5	0	6.5	13

N→D indicates a nights-to-days shift change
D→N indicates a days-to-nights shift change

Note. *The table assumes a regular 2-2 work/leave cycle; for personnel with more generous leave allowances, numbers are proportionately reduced.*

1.4 PRESENT WORK

1.4.1 Offshore shift rotation: Experimental study

The research approach adopted in the study reported here extended the experimental work described by Parkes (1993) in three ways. First, three shift rotation schedules in common use on North Sea installations were compared in terms of patterns of change in sleep, mood and performance over the two-week offshore work cycle. Second, data were collected from a larger sample of participants, working on offshore installations operated by several different companies. Third, greater accuracy and flexibility of data collection was achieved by the use of individual hand-held computers to present self-report items and cognitive tasks, and to record all responses. The major features of the study design are outlined below; more technical details are given in Section 2.

- ***Shift rotation patterns studied***. The work schedules which formed the focus of the present study involved shifts of 12 hours in duration, with a rotation pattern of the type 07.00 - 19.00 / 19.00 - 07.00 (precise changeover times varied slightly. Within this framework, two different 'rollover' rotations were compared with the 'fixed-shift' sequences in which either nights or days were worked for the entire two-week offshore work period, day- and night-shift trips alternating.

  Of the two rollover schedules studied, a week of night shifts followed by a week of day shifts is the more commonly used. However, this pattern is not universally adopted and the opposite rollover direction (a week of day shifts followed by a week of night shifts) was also studied. The fixed-shift schedule of alternating night and day work between successive trips, currently used by one large operating company in the UK sector, provided an important 'baseline' condition in which adaptation over the two-week period was not subject to a mid-cycle rollover.

- ***Participants***. Most of those taking part in the study were control-room and production operators, although some production technicians were also involved. These personnel typically work day/night rotating shifts, and were therefore an appropriate focus for the present study. Furthermore, the alertness and vigilance of these operators, and their ability to carry out information-processing and decision-making tasks effectively, are essential to the safe and efficient running of oil and gas production processes. Among those concerned, therefore, fluctuations in mood and cognitive performance may have important safety implications.

- ***Data collection***. The nature of the research required that mood, sleep, workload, and other self-reported information, together with objective performance data (e.g. reaction time, reasoning, and memory), was recorded repeatedly for each participant over pre-determined test shifts during the two-week offshore work period, and on three occasions during each of these test shifts.

In the past decade, automated assessment methods have been developed to facilitate this type of field research (Kennedy *et al.* 1993; Totterdell & Folkard, 1992). One such method, the use of individual hand-held computers programmed to present test items, and to record subjective responses and objective performance data, was particularly appropriate to the present work.

This approach, which has been used in studies of shiftwork in onshore environments (e.g. Totterdell *et al.* 1995), is flexible and convenient; it also eliminates the need all tests to be administered individually on a one-to-one basis, although in the present work a researcher attended the test sessions to check equipment and ensure that the data collection ran smoothly (see Section 2.3.3).

In the present study, new programs were developed for the Psion *3a* hand-held computer. This equipment has a number of advantages over earlier models (e.g. a larger and more versatile display format), and also allowed additional circuitry to be incorporated in the system to provide greatly improved timing accuracy for the performance tasks.

1.4.2 Offshore shift rotation: Use of survey data

To provide further information about the shift rotation patterns included in the study described above, relevant data from a large-scale survey of offshore personnel (Parkes & Clark, 1996) were analysed. The data included information about actual and preferred shift rotation patterns, measures of satisfaction with shift rotation patterns, and measures of sleep duration and quality under different shift conditions. These analyses, reported in Section 6, provided an alternative viewpoint from which to assess the relative advantages and disadvantages of different shift rotation systems.

2. RESEARCH METHOD

2.1 INSTALLATIONS

Four North Sea production installations were involved in the present study. The installations were chosen primarily on the basis that they operated the particular shift rotation patterns being studied; however, from a practical viewpoint, it was also necessary to select platforms with sufficient numbers of personnel working day/night rotating shifts to take part in the work, and space to accommodate researchers.

These requirements necessitated the work being carried out on larger, 125-180 personnel-on-board (POB), second-generation platforms (in production for 12-17 years), rather than on newer installations which tend to be smaller, in terms of personnel numbers and available space. Two sets of data were collected on separate occasions on three of the platforms involved; on the fourth platform, one set of data was collected.

2.2 PARTICIPANTS

Control-room operators and production personnel, including some supervisors, acted as subjects in the study. Participation was voluntary (although some participants appeared to be ‘volunteered’ by supervisors). The start of the data collection sequences were timed to coincide with the arrival of a new crew. Most of the operators in the crews concerned were able to participate in the work; individuals who knew they would not be on board for the entire experimental sequence were excluded, but only rarely did other personnel decline to participate.

Overall, 95 personnel (including two women) from the four installations involved took part in the work. However, the analyses required that the full sequence of planned assessments was carried out, and some of those who participated in the early stages of the study were not able to complete the data collection sequence (e.g. because of an unexpected shift change, or illness). Data from approximately ten individuals had to be excluded from the analyses for this reason. The total number of subjects in the final data sets varied between 84 and 87, depending on the measure analysed.

2.2.1 Participants compared with other production personnel

Almost all the personnel who took part in the shiftwork study also participated in the large-scale survey research carried out concurrently. It was therefore possible to determine the extent to which the shiftwork study participants were representative of the occupational group concerned in the survey as a whole. Multivariate analyses of variance (MANOVA) were used to compare participants in the shiftwork study with operators who took part in the survey but were not involved in the shiftwork study.

The first analysis compared the group who participated in the shiftwork study with those who were not involved at all, while the second analysis compared participants whose data was used in the shiftwork analysis with those whose data had to be discarded because it was incomplete. In each MANOVA, a range of demographic (age, job tenure, shiftwork years), personality (extraversion, neuroticism, Type A), and job characteristics variables (e.g. workload, discretion) was included.

Neither analysis showed significant differences. Thus, the shiftwork study participants could be regarded as representative of production and control room operators in the survey sample as a whole, and those who completed the full data collection sequence did not differ significantly from those who did not do so.

2.3 RESEARCH PLAN

2.3.1 Background

The design of the study was primarily determined by the need to evaluate the effects of different shift rotation patterns on sleep, mood, and cognitive performance as rigorously as possible; however, it was also necessary to take into account the practical aspects of offshore data collection. Several general constraints had to be taken into account in planning the study.

- ***Groups.*** The two rollover shift patterns, days followed by nights (7D+7N) and nights followed by days (7N+7D), had to be tested on separate groups of operators as they were in use on different platforms. For consistency, it was decided also to test the fixed-schedule day-shift and night-shift conditions (14D and 14N) separately, giving a total of four experimental groups.

- ***Data collection schedule***. For the 14D and 14N shift conditions, a two-week offshore data collection schedule allowed the full work cycle for both the day-shift and night-shift groups to be studied; data collection started on the first day of the offshore work cycle and continued throughout the two-week period. However, on platforms working rollover schedules, one new crew comes on board each week and rotates into the first week of the shift pattern, while those already on board rotate to the second week of the pattern. Thus, two weeks' of data collection did not allow the full sequence of testing to be carried out with two crews.

  A modified data collection sequence was therefore adopted for platforms operating rollover schedules. The data which formed the basis of the main experimental design were collected from one crew studied through the entire two-week cycle; in addition, the crew already on board participated from the end of their first week offshore through the second week. These additional data were not used in the main analyses, but they formed part of the further analyses used in the direct comparison of the two rollover conditions (see below, Section 2.6).

2.3.2 Equipment

Individual hand-held computers were used to collect all the self-report and performance data used in the present study. To display the test items, and record responses, new programs were developed for the *Psion 3a* ‘personal organizer’. In addition, a separate response box with a sophisticated timing circuit was connected to the Psion through a data link (which was also used to download the data for analysis); this method provided greatly timing accuracy (±3 ms) as compared with ±50ms reported for the earlier *Psion 2* system (Totterdell *&* Folkard, 1992).

The arrangement had the further advantage of providing larger and more robust response keys than were available on the Psion keyboard. A total of nine Psions and response boxes was available. Individuals used the same Psion on each occasion, logging in at the start of each session with their individual ID number and ‘work code’ (which identified the type of work being done since the previous assessment). Data files were automatically updated after each test session with date, time, and details of all responses; at the end of the data collection period, these files were downloaded for statistical analysis.

2.3.3 Procedure

It became clear at an early stage of the work that, in order to ensure that the data were as complete and reliable as possible, it was necessary for a researcher to be present during each session. The researcher was responsible for checking that all equipment was functioning correctly, that participants understood the procedures for operating the *Psions*, and that they used the same machine on each occasion. As far as possible, assessments were carried out in a room readily accessible to (but separated from) the control-room area, and interruptions were kept to a minimum. In general, these conditions were maintained, although inevitably some sessions were disrupted by unexpected operating contingencies, or general alarms.

Some flexibility in the test schedule was achieved by allowing participants to carry out the assessments any time within the two-hour sessions; if possible, participants attended in the same order on each occasion, thus ensuring that the intervals between testing were approximately the same in each case. The *Psion* program guided the participant through the entire sequence of data collection with no direct experimenter intervention; following initial training sessions, individuals normally required 10-12 minutes to complete the program on each occasion

2.4 MEASURES

Self-report items were used to assess subjective alertness, positive mood, sleep quality and duration, and workload. Objective alertness and concentration was assessed by cognitive performance tasks (reaction time, memory, and reasoning tasks). These tasks are simple, but the speed and accuracy with which they are carried out is affected by factors such as night work and shift patterns, paced tasks, noise, cold, workload, and other stressors (Baddeley, 1981; Enander, 1987; Meijman *et al.* 1993; Parkes *et al.* 1990; Parkes, 1995; Rosa *et al.* 1985; Wilkinson *et al.* 1989).

2.4.1 Self-report data

As shown below, two different sequences of self-report items were used, the start-of-shift items differing from those used later in the shift.

- ***Start-of-shift***

- Hours of sleep during previous off-duty period.
- Rating of quality of sleep during previous off-duty period
- Present mood: ratings were made on 12 bi-polar scales presented in a different random order on each occasion. The adjectives used to anchor the opposing ends of the scales were the same as those described by Parkes (1993); total scores, ranging from -20 to +20 were calculated for *alertness* (4 items) and *positive mood* (8 items).

- ***Mid-shift, and end-of-shift***

- Perceived workload since previous assessment
- Meals, snacks, and tea/coffee intake since previous assessment
- Present mood: 12 bi-polar rating scales (as in 'start-of-shift' sequence)

Ratings of sleep quality and mood were made by moving the display cursor across a linear scale, anchored at either end by opposing descriptors (see Figure 2.1), and pressing the '*enter*' key when the appropriate point had been selected. As a safeguard against operators pressing 'enter' before making a rating, the key did not operate until the cursor had been moved. Other information was entered on the keyboard in the form of numerical data or codes.

2.4.2 Cognitive tasks

Four cognitive performance tasks were used, presented in the same order on each occasion. The tasks assessed simple and multiple choice reaction time, memory, and reasoning ability; all the tasks are widely used in human performance research, including studies of shiftwork and working hours. Details are given below.

- ***Simple reaction time*** **(SRT)**. In this task, participants responded with a single response key to a single signal presented on the *Psion* screen. The only uncertain feature of the task was the exact time at which the signal would appear (a random delay of between 2 and 10 seconds occurred between the visual prompt and the appearance of the signal). In each test session, 50 SRT trials were presented arranged in five blocks of 10 trials. After each block of 10 trials, there was a pause, which was terminated by the participant indicating that he/she was ready to continue.

[1]ENERGETIC ______________________________ TIRED

[2]CALM ______________________________ TENSE

WEARY ______________________________ VIGOROUS[1]

[2]CONTENTED ______________________________ DISCONTENTED

UPTIGHT ______________________________ AT EASE[2]

DEJECTED ______________________________ CHEERFUL[2]

[1]LIVELY ______________________________ FATIGUED

JITTERY ______________________________ RELAXED[2]

[2]HAPPY ______________________________ MISERABLE

DROWSY ______________________________ ALERT[1]

DEPRESSED ______________________________ ELATED[2]

[2]TRANQUIL ______________________________ BOTHERED

The items appeared in a different random order on each occasion

[1] *Indicates the high-scoring end of the four scales which were summed to form the alertness dimension.*

[2] *Indicates the high-scoring end of the eight scales which were summed to form the positive mood dimension.*

Figure 2.1
Scales used in the assessment of alertness and positive mood

The SRT task took 7-8 minutes to complete; it was deliberately chosen to be boring, repetitive, and longer in duration than the other tasks. Sustained concentration is required to maintain rapid responses to the signal presented, and performance is known to be sensitive to fatigue effects in general, and shiftwork in particular (e.g. Wilkinson *et al*. 1989). The task had the further advantage of being relatively simple, and thus, after the initial practice sessions, training effects were negligible relative to the magnitude of the effects of shift rotation.

Following normal practice, two forms of '*trimming*' were applied to the SRT data to ensure that unusually short times (e.g. when the subject's response anticipated the signal) or unusually long times (usually due to lapses in attention) were excluded from the calculation of mean values before analysis.

First, responses which fell outside the range of 180 - 1000 ms. were removed prior to calculation of means for each block of 10 trials. Response times shorter than 180 ms. were rare, and those that did occur were disregarded. Failure to respond within 1000ms. was treated as an error or 'gap', and the frequencies of 'gaps' were analysed separately.

Second, values which fell outside ±2 standard deviations from the block mean calculated after the first trim, were excluded. In practice, extreme values were largely removed by the first trim, the second trim only serving to eliminate occasional values which were extreme relative to the subject's usual performance but not outside the 180-1000 ms. range.

- ***Four-choice reaction time***. This multiple choice reaction task (MCRT) required participants to respond with the corresponding response key to a target which appeared on the screen in one of four pre-determined positions. As soon as one response had been made, the target re-appeared (either in a different position or in the same one) and the response sequence was repeated. Two blocks of 80 trials were presented, with a pause between them. As in the SRT task, trimmed means were analysed, and the proportion of correct responses was also taken into account.

- ***Memory task*** (Sternberg, 1966). In the simpler version of this memory task, a single target letter appeared on the screen; when the participant had memorised it, and indicated that he/she was ready to continue, a random sequence of 40 letters was presented one-by-one. The participant's task was to indicate in response to each letter whether or not it was the one previously memorised. The more complex five-letter version of the task required five letters to be memorised rather than just one; in this case, the task was to indicate when any of the target letters appeared in the subsequent random sequence. Both speed and accuracy were recorded for each version of the task. Accuracy of response was calculated as the proportion of target letters in the random sequence that were correctly identified.

- ***Logical reasoning*** (Baddeley, 1968). The test of logical reasoning required participants to indicate whether a series of logical statements of the type “A follows B” or “A is not preceded by B” was true or false in relation to the particular letter pair (either AB or BA) that followed the statement. Both speed and accuracy of response were recorded.

  Four different types of statements were presented: *active positive* (e.g. “A follows B”); *active negative* (e.g. “B does not follow A”); *passive positive* (e.g. “A is followed by B”); and *passive negative* (e.g. “B is not preceded by A”). Using all combinations of A and B pairings, eight different items can be derived for each type of statement. These 32 test items occurred in a different random order on each occasion.

  This task was more complex than the others used in the present study; it had the advantage of acting as a challenge to participants, thus serving to maintain interest in the study. However, the complexity of the task was also a disadvantage in that performance showed continuing training effects, lasting in some cases for the entire duration of the experiment.

Knowledge of results was provided at the end of each task; the mean response time and (where applicable) the accuracy for the last block of trials was briefly displayed. However, no undue emphasis was placed on this information, and participants were discouraged from keeping records of their performance.

2.5 EXPERIMENTAL DESIGN

2.5.1 Sequence of data collection over the two-week work cycle

The two-week data collection schedule in the main experimental design was based on *phases*, *shifts*, and *times-of-shift* as described below.

- *Phases*. The two-week offshore period was divided into three *`phases',* (designated Phases I, II, and III) separated by one or two ‘rest’ shifts during which no data were collected. The initial phase covered the early part of the first week, the second phase covered the mid-cycle period (end of first week running into the beginning of the second week), and the third phase continued up to the end of the second week.

- *Shifts.* Three test shifts in each phase (designated S1, S2, and S3) were used in the data analysis. Normal shift duration was 12 hours, but to achieve the mid-cycle shift rotation in the two rollover patterns, it was necessary for operators to work one or more shorter shifts (usually 8 hours) and have shorter off-duty periods. However, the sequence of three assessments during each shift was maintained during these rollover shifts.

- *Time-of-shift*. It was important to examine not only changes across different shifts and phases but also changes across time within shifts. Therefore, three assessments were carried out during each shift of testing; the first took place within 120 minutes of the start of the shift (T1); the second within a 120 minute period, starting immediately after the lunch break (T2); and the third during the final 120 minutes of the shift (T3).

In specifying the exact schedule of testing for the 7D+7N and 7N+7D rotation patterns, the determining factor was the timing of the mid-cycle shift change; data collection was scheduled so that the shift immediately prior to the rollover was always the first test shift (S1) in Phase II, with S2 and S3 designated as the two following shifts. Phases I and III were scheduled around Phase II, so that Phase I covered a sequence of three consecutive day or night shifts in the first week, and Phase III covered the three final shifts in the second week. For the 14D and 14N conditions, the three phases of data collection were arranged to correspond as closely as possible to those of the rollover conditions (see Appendix I for details of shift sequences).

Two ‘practice’ shifts during which data were collected but not analysed were also included (one prior to Phase I, and the other prior to Phase II) and, when possible, at least one ‘rest’ shift was included between each phase. The only shift pattern which created any difficulty in this respect was the 7N+7D rotation; on the platform concerned, the start of night-shift week was delayed until the third night after arrival, operators working three short day shifts in a backward rotation sequence before moving to night work (see Appendix I, Table 1A). This arrangement left only five day shifts following the rollover, and thus precluded a ‘rest’ shift between Phases II and III. However, in other respects data collection for this group followed the same sequence as for the other groups. In all, each group participating in the work was tested on a total of nine test shifts and two practice shifts.

2.5.2 Comparison of rollover and fixed-schedule shift patterns

In the main study, data were collected in each of the three phases of the work cycle. Two separate but complementary components of the experimental design allowed direct comparison of shift rotation patterns with and without a mid-cycle rollover:

- ***7D+7N compared with 14D***. This design, shown in Table 2.1(i), allowed direct comparison of the 7D+7N rollover pattern with the 14D pattern. As both groups worked day shifts during the first phase, the 14D condition served as a baseline against which to examine the effects of the mid-cycle rollover on the 7D+7N group during the second and third phases. Thus, the design allowed two weeks of day-shift work to be directly compared with the days-to-nights rollover pattern.

- ***7N+7D compared with 14N.*** Similarly, the 14N group served as a control to examine the effects of the rollover from nights to days in the 7N+7D group, as shown in Table 2.1 (ii). In this case, both groups have to adapt to night-work when they arrive on the platform; however, only those in the 7N+7D group subsequently make a further 12-hour circadian adjustment at the end of the first week when they change to day shifts.

Taking these two components together, the design allowed a detailed examination of the effects of rollover schedules as compared with non-rollover schedules. The analysis did not depend on entirely eliminating training effects across the data collection period; the focus was on comparing the mood and performance profiles of rollover and non-rollover groups, balanced for initial performance, rather than on the absolute response levels.

Table 2.1

Experimental design for the main analyses

(i) Days vs. Days/nights			
Group	FIRST WEEK		SECOND WEEK
	Phase I	*Phase II*	*Phase III*
7D+7N	DAY SHIFTS	DAY/NIGHT ROLLOVER	NIGHT SHIFTS
14D	DAY SHIFTS	DAY SHIFTS	DAY SHIFTS

(ii) Nights vs Nights/days			
Group	FIRST WEEK		SECOND WEEK
	Phase I	*Phase II*	*Phase III*
7N+7D	NIGHT SHIFTS	NIGHT/DAY ROLLOVER	DAY SHIFTS
14N	NIGHT SHIFTS	NIGHT SHIFTS	NIGHT SHIFTS

***Note**. The total sample size for analyses using this design was 66.*
14D vs. 7D+7N, n=35; 14N vs. 7N+7D, n=31

2.5.3 Analysis strategy: Rollover vs. fixed-shift schedules

The analysis of mood and cognitive performance evaluated the effects of *phases, shifts,* and *time-of-shift* 'within subjects' (i.e. each subject provided data for all levels of each factor), while the effects of *shift rotation* were tested 'between groups' (i.e. different groups of subjects were assessed under different rotation conditions). As described in Section 2.6.2, in the main experimental design, rotation patterns were analysed in pairs. Thus, the 7D+7N schedule was compared with the 14D schedule; similarly, the 7N+7D schedule was compared with the 14N schedule.

2.5.4 Statistical issues

Specific features of the analysis of each measure are described at the start of the sections concerned. However, within the analysis framework outlined above, several general statistical points should be noted.

- ***Analysis of variance model***. The main form of analysis was a four-factor 'mixed-model' analysis of variance in which *rotation* was treated as a 'grouping' factor (i.e. scores are compared across groups), while *phases*, *shifts*, and *time*, were treated as repeated-measures factors (i.e. scores are compared across occasions of testing). The aim of the analysis was to identify ways in which shift rotation patterns influenced profiles of responses across the two-week duration of the study.

- ***Interaction terms.*** Analysis of variance evaluates not only overall 'main' effects, but also 'interactions'; statistically, a significant interaction between two variables implies that one variable modifies the effect of the other. For instance, time-of-shift may have a significant overall (main) effect on, say, reaction time, but in the present context, this result would be of less interest than a significant *rotation pattern x time-of-shift* interaction, which implies that the effect of time-of-shift on reaction time depends on the shift rotation pattern being worked.

  In the present study, therefore, it was the interaction terms which provided the relevant information about differences between profiles of responses for the shift schedules being compared. Significant interactions involving the *rotation* and *phases* factors indicated that rotation patterns had different effects across the different phases; interactions which involved the *shifts* and/or *time-of-shift* factors were also of interest. Detailed patterns of findings varied across measures, but in each case the main results were apparent in the form of significant interaction terms.

  In interpreting interaction effects, the highest-order significant term is usually taken as the starting point. Thus, for instance, if a three-way interaction, e.g. *rotation x phase x shift,* is significant, this higher-order term provides a more complete picture of the results than lower-order terms, e.g. *rotation x phase*.

- ***Significance levels***. In some of the analyses presented, very high levels of statistical significance were obtained. The practice adopted in this report is that probability levels less than .001 (i.e. the probability of the observed result being obtained by chance is less than 1 in 1000) are reported as p<.001, irrespective of the actual level of significance achieved which was sometimes much higher (i.e. a smaller probability value reflecting a more highly significant result). Probability levels which reached the value of p<.05, (the level conventionally considered to be 'significant') but which did not reach the p<.001 level are quoted precisely. 'Marginal' significance levels (i.e. those for which .05 < p <.10) are noted if the trends are of particular relevance.

- ***Control for prior differences between groups***. It could not be assumed that the groups exposed to different shift rotation schedules were equivalent in terms of personal and environmental factors unrelated to shift conditions which might affect test responses. Statistical methods were used to control possible extraneous differences (e.g. due to testing conditions on particular installations, or to demographic/personality differences) between groups which might otherwise have distorted the observed effects of shift rotation.

  Initial balancing of groups was achieved by the use of a single covariate in the analyses which had the effect of equating, in the two groups being directly compared, the overall level of response (averaged across shifts and times) in the first phase. This process was carried out separately for the two analyses, 7D+7N *vs.* 14D, and 7N+7D *vs.* 14N. The rationale for this approach was that any differences observed in the first phase were not due to the shift pattern being worked as, in each case, the comparison was between groups exposed to the same initial shift condition (i.e. day work for the 7D+7N *vs.* 14D analysis, and night work for the 7N+7D *vs.* 14N analysis).

  This method of controlling extraneous differences did not influence the pattern of responses across shifts and times within the shift rotation groups, but it allowed effects in the second and third phases to be examined free of possible differences in overall levels during the initial phase that were unrelated to shift rotation patterns. The question being asked therefore was *"Relative to equivalent overall levels of response when working under the Phase I shift condition, what differences are observed in Phases II and III for the rollover vs. fixed-shift conditions?"*

- ***Speed/accuracy trade-off in cognitive tasks.*** In three of the cognitive tasks used to assess alertness (multiple choice reaction time, memory task, and logical reasoning), both speed and accuracy of response were recorded. In general, faster responses tend to be less accurate, and *vice versa*; thus, it was important to take into account both aspects of performance in evaluating the effects of shift rotation patterns. In the present study, covariance methods were used to take accuracy into account in analysing speed of response. Thus, in analysing mean response times, the corresponding accuracy level was treated as a covariate. In effect, therefore, speed of response was analysed while the accuracy level of each trial was controlled.

- ***Practice effects***. Relatively little practice was required to use the self-report scales and carry out the SRT task; thus, a single initial practice shift was sufficient for reliable performance to be achieved, and the full data set for all three phases of data collection could be used in the analysis of these measures. However, for the more complex cognitive tasks (MCRT, memory tasks, and logical reasoning), the single initial shift did not provide adequate practice time for performance to stabilise sufficiently for analysis purposes. Therefore, for these more complex tasks, the formal analysis included only data from Phases II and III, Phase I being treated as extended practice.

2.6 DIRECT COMPARISON OF ROLLOVER CONDITIONS

The experimental plan shown in Table 2.1 was designed to provide a rigorous comparison of corresponding rollover and fixed-schedule shift patterns; however, it did not allow direct comparison between the 14D and 14N shift conditions, or between the 7N+7D and 7D+7N rollover patterns. These pairs of conditions involved both different subject groups and different initial shift conditions, thus precluding the use of Phase I data for statistical control of extraneous between-group differences. Although general comparisons could be made by examining the different mood and performance profiles for the different shift patterns, additional analyses based on an alternative design potentially provided a more powerful method of comparison.

This alternative design was similar to that used in an earlier study of night-to-days shift rotation (Parkes, 1993). Data from the fixed-schedule groups (14D and 14N) were not relevant to these analyses, and the method was not appropriate to the complex cognitive tasks for which only data from Phases II and III were used in the main analyses (see Section 2.5.4). Thus, these additional analyses were applied only to the measures of alertness and positive mood, and to the simple reaction time data.

2.6.1 Experimental design

The experimental design for these analyses distinguished between 'stable' phases (i.e. a sequence of day- or night-shifts) and the rollover phase (a sequence of shifts involving a change from nights to days or vice versa) of the work cycle. For each direction of rollover, the design (shown in Table 2.2) combined two sets of data, each set including data from two phases only, either Phases I and II, or Phases II and III. The order of testing rollover and stable phases was an important feature of the design.

Order 1 referred to a data collection sequence in which the rollover phase followed the stable phase (Groups A and C), while *Order 2* referred to a data collection sequence in which the rollover phase preceded the stable phase (Groups B and D). *Order 1* data were taken from Phases I and II of the main study. *Order 2* data were not part of the main study. but were obtained from separate crews in Phases II and III only (see Section 2.3.1).

As shown in Table 2.2, by combining data from the 7N+7D and the 7D+7N rotations, the design was balanced with respect to the comparison between stable and rollover phases, and with respect to the comparison between nights-to-days rollover and days-to-nights rollover.

Table 2.2
Experimental design for comparison of 7D+7N and 7N+7D rotations

GROUPS*	ORDER	First period of data collection	Second period of data collection
‘Nights‘ A	1	STABLE PHASE Nights	ROLLOVER Nights → Days
B	2	ROLLOVER Days → Nights	STABLE PHASE Nights
‘Days’ C	1	STABLE PHASE Days	ROLLOVER Days → Nights
D	2	ROLLOVER Nights → Days	STABLE PHASE Days

Notes: *N=50. [Data from groups B and D were additional to the main data set.]*

** Groups were designated ‘Nights’ or Days’ according to whether day shifts or night shifts were worked during the stable phase of data collection.*

2.6.2 Analysis strategy: Comparison of rollover directions

A four-factor analysis of variance with two ‘between-group’ factors (Order 1 *vs.* Order 2, and ‘Days’ *vs.* ‘Nights’), and two ‘within-subject’ factors (stable phase *vs.* rollover, and first *vs.* second period of data collection) was used to analyse the data. As in the main experimental design, interaction terms were the primary focus of interest. The overall comparison between rollover and stable phases was represented by the *period x order* interaction, but the more important comparison between nights-to-days and days-to-nights (i.e. the effect of direction of rollover) was represented by the three-way interaction *period x order x nights/days.* This three-way term also occurred in the form of higher-order interactions involving *shifts* or *time-within-shifts*.

Covariance methods were used to balance training effects across corresponding groups, and to take into account initial differences unrelated to shift rotation patterns. Thus, responses in the rollover phase was statistically controlled to the same overall level in Groups A and D, and, separately, in Groups B and C. The rationale for this method was that groups in these two pairs were working the same shift pattern, and thus response differences during the rollover phase were due to training effects and/or to pre-existing differences between the groups, rather than to shift rotation effects.

3. SLEEP, MOOD, AND WORKLOAD

3.1 SLEEP DURATION AND QUALITY

3.1.1 Data analysis

Sleep duration (in hours) and *sleep quality* (rated on a 0-10 scale) were assessed at the start of each shift. The two measures were analysed separately, using the analysis of variance model detailed in Section 2.6, except that there was no 'time-of-shift' factor as only one assessment of sleep was made during each shift.

3.1.2 Sleep duration

The relevant terms in the analysis of sleep duration are shown in Table 3.1. The *phase x shift x rotation* term was significant in both the 14D *vs*. 7D+7N and the 14N *vs*. 7N+7D analyses; these results indicate that, in both comparisons, duration of sleep differs for rollover and fixed shift rotations, and that these effects vary across phases, and across the three shifts within each phase (see Section 2.5.1 for details of the data collection schedule, and the notation used to designate '*phases*', and '*shifts').*

In Phase I, sleep duration in the rollover groups did not differ from that in the corresponding groups working fixed-shift patterns. The significant effects occurred in Phase II (the shift-change phase for rollover groups) and, in the 14N *vs.* 7N+7D comparison only, in Phase III (post shift-change). Figures 3.1 and 3.2 illustrate the data for 14D *vs*. 7D+7N and 14N vs. 7N+7D comparisons, respectively.

Table 3.1
Sleep duration: Significance of shift rotation effects

	Rotation x phase x shift	*Rotation x phase*
14D *vs*. 7D+7N	F = 11.41 df = 4,128 p<.001	F = 18.36 df = 2,64 p<.0001
14N *vs*. 7N+7D	F = 9.40 df = 4,112 p<.025	F = 10.13 df = 2,56 p<.001

As shown in these Figures, the fixed-shift patterns result in relatively stable sleep duration over the two-week work cycle. In contrast, both rollover groups report short sleep durations immediately following the rollover in Phase II. In Phase III, the 7D+7N group show some indication of compensating for sleep lost earlier. However, this pattern does not apply to the 7N+7D group, who continue to show significant sleep deficits until the final shift in Phase III.

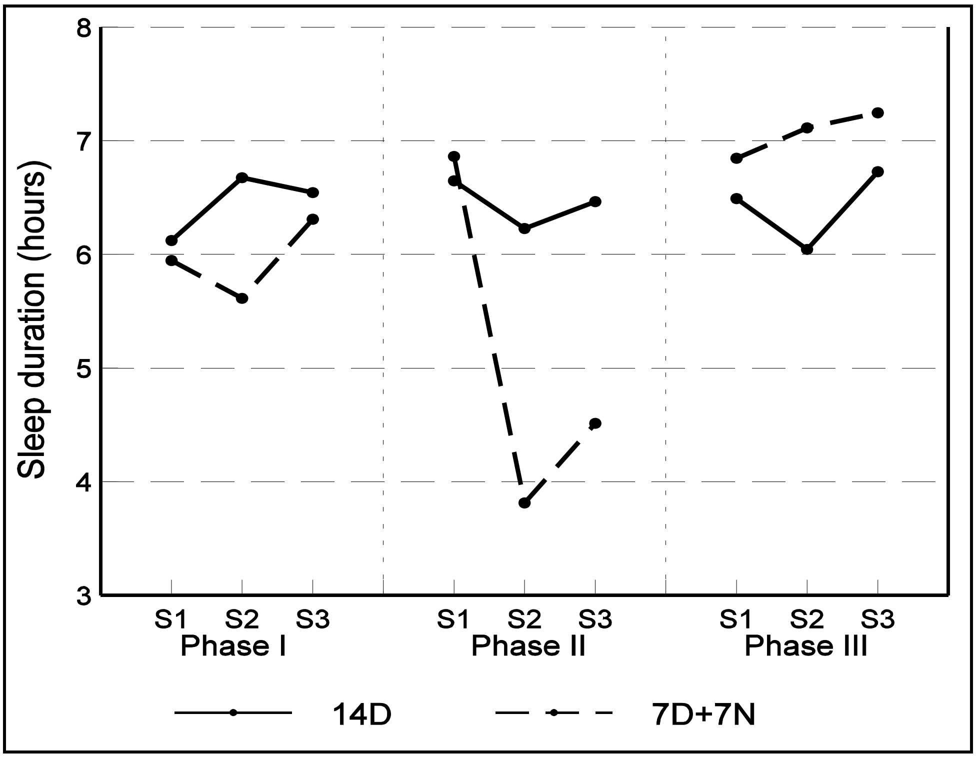


Figure 3.1
Sleep duration in relation to shift rotation: Days vs. Days/nights

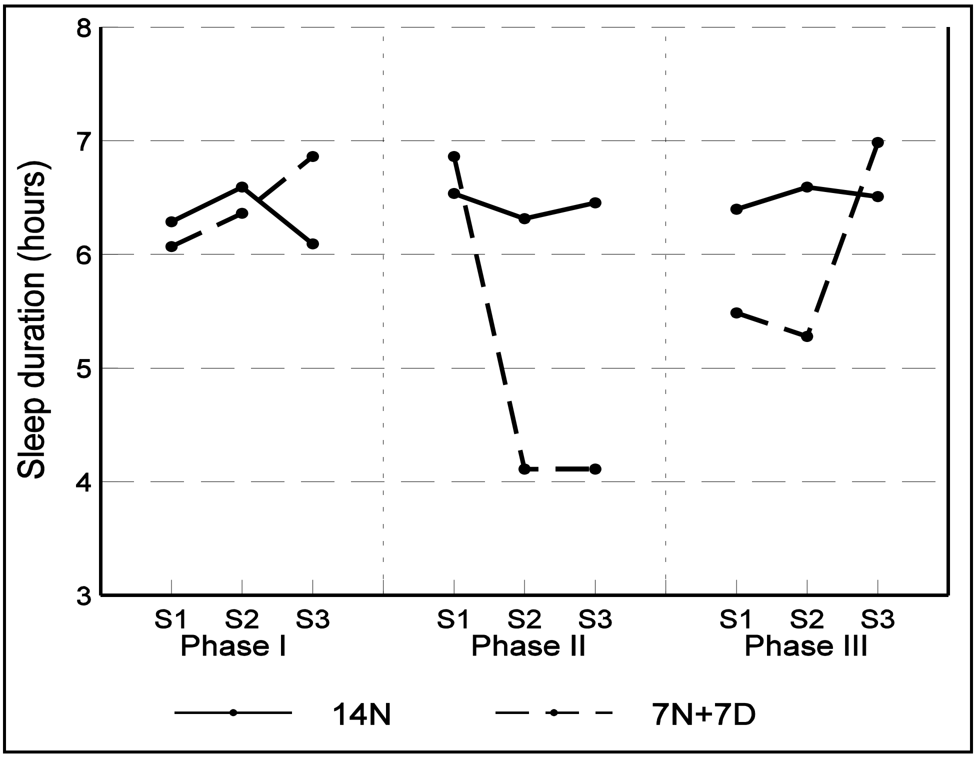


Figure 3.2
Sleep duration in relation to shift rotation: Nights vs. Nights/days

3.1.3 Sleep quality

For sleep quality, as shown in Table 3.2, the 14N *vs*. 7N+7D comparison gave rise to significant effects of shift rotation, which differed across phases and across shifts; however, the *rotation x phase x shift* term in the 14D *vs*. 7D+7N analysis did not reach conventional significance level, although it showed a similar trend. The data for the 14N *vs*. 7N+7D comparison, shown in Figure 3.3, reveals a pattern similar to that found for sleep duration

Table 3.2
Sleep quality: Significance of shift rotation effects

	Rotation x phase x shift	*Rotation x phase*
14D *vs*. 7D+7N	*F = 1.90* *df = 4,132* *[p=.11]*	*ns*
14N *vs*. 7N+7D	F = 3.00 df = 4,112 p<.025	*F = 2.55* *df = 2,56* *[p<.10]*

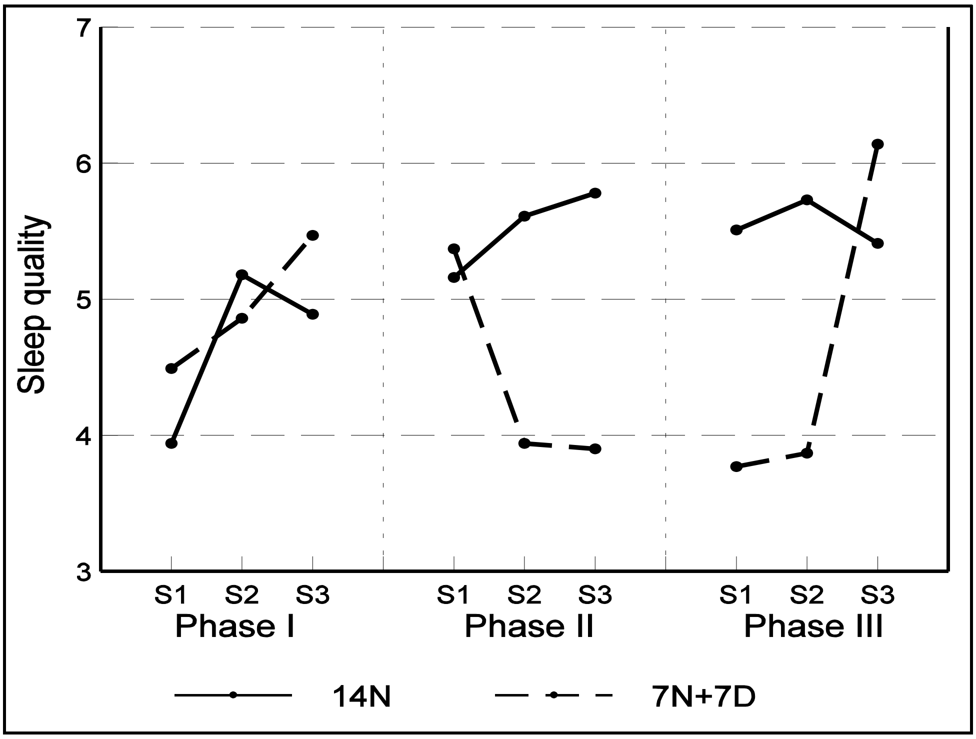


Figure 3.3
Sleep quality in relation to shift rotation: Nights vs. Nights/days

In Phase I, both the rollover (7N+7D) and fixed-schedule (14N) groups show a trend of increasing sleep quality across the three shifts, indicating progressive adaptation to night shift work. In Phase II, sleep quality continues to increase in the fixed-schedule group, but declines markedly in the rollover group. Only at the end of Phase III does sleep quality in the rollover group catch up with that in the fixed-schedule group. In both Phase II and Phase III, the *shift x rotation* interaction is significant, F(2,56)=4.10, p<.025, and F(2,56) = 5.92, p<.001 respectively.

3.2 ALERTNESS AND POSITIVE MOOD

3.2.1 Data analysis

As described in Section 2.4.1, on each occasion of testing, participants rated their current mood on 12 separate scales; scores were summed to assess *alertness* (4 items) and *positive mood* (8 items). The range on each scale ran from -20 to +20, high scores representing high levels of alertness and positive mood. Data analysis followed the strategy set out in Section 2.6, alertness and positive mood being treated separately. In contrast to the sleep measures which were only recorded at the start of a shift, mood measures were made three times during each shift; thus, the analysis of alertness and positive mood involved three factors, *phases*, *shifts* and *time-of-shift* (see Section 2.5.1 for details of the data collection schedule, and the notation used to designate '*phases*', and '*shifts'* and *'time-of-shift')*.

3.2.1 Alertness

Rollover *vs*. fixed-schedule shift patterns were found to affect alertness levels in both the 14D *vs*. 7D+7N and the 14N *vs*. 7N+7D comparisons. The effects found involved *phases, shifts*, and *time-within-shifts*. The significance levels of the relevant interaction terms are summarised in Table 3.3, and the results are illustrated in Figures 3.4 and 3.5.

Table 3.3
Alertness: Significance of shift rotation effects

	Rotation x phase x shift	*Rotation x phase x time*	*Rotation x phase*
14D *vs*.7D+7N	F =6.50 df = 4,132 p<.001	F =2.80 df = 4,132 p<.05	F = 3.70 df=2,66 p<.05
14N *vs*.7N+7D	F =2.85 df = 4,116 p<.05	F =2.98 df = 4,116 p<.025	F = 3.57 df = 2,58 p<.05

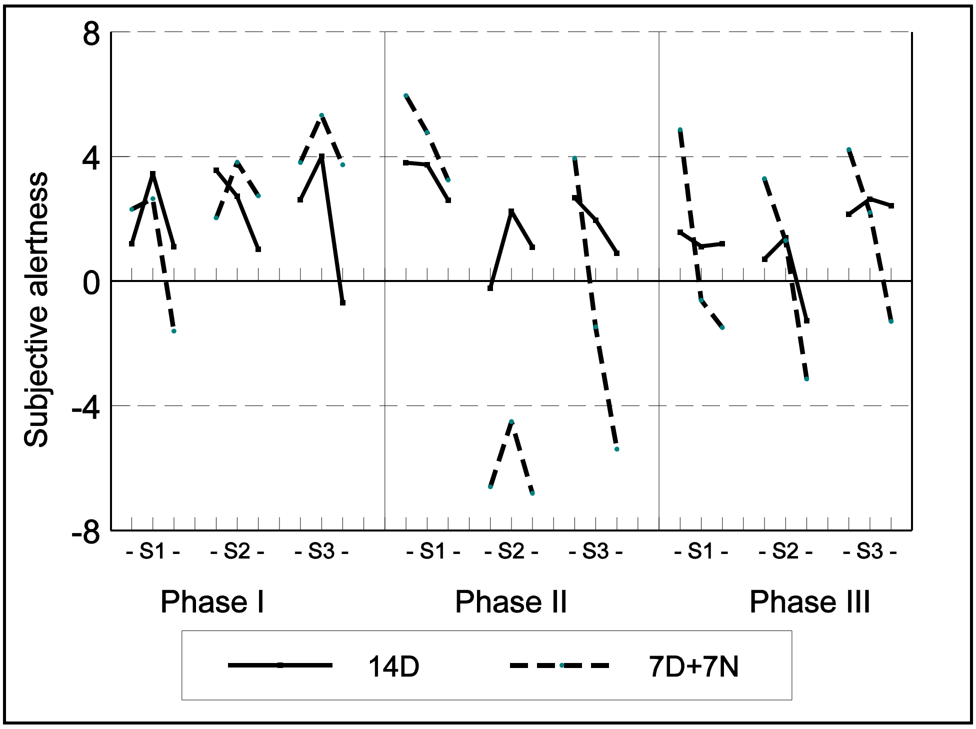


Figure 3.4
Alertness across phases: Days vs. days/nights

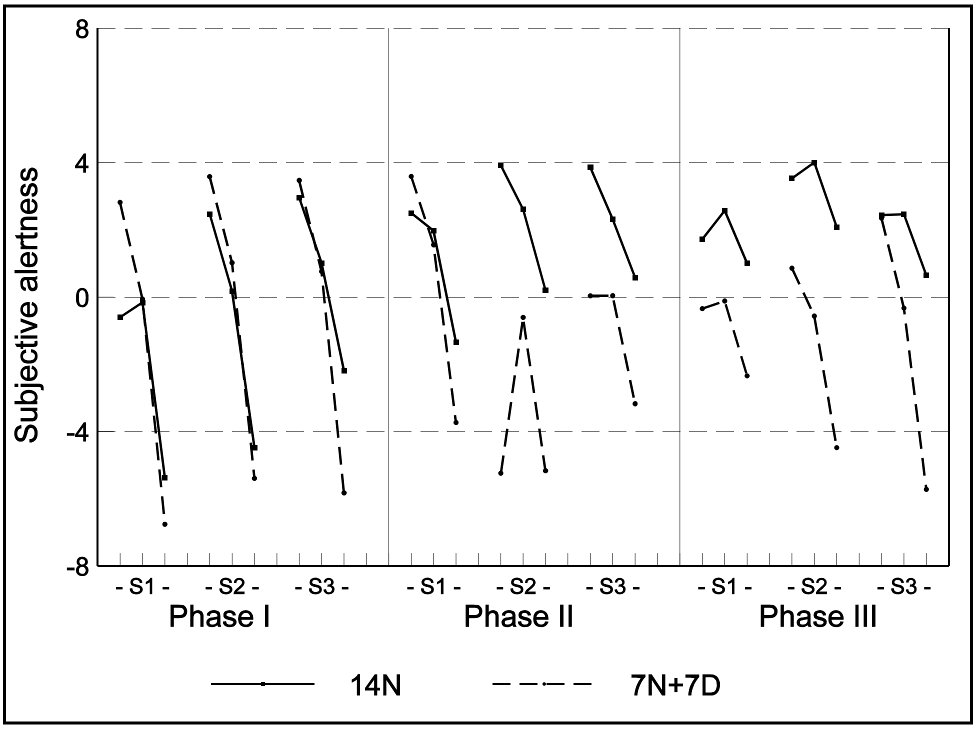


Figure 3.5
Alertness across phases: Nights vs. nights/days

Note. *In these diagrams, three points are plotted for each shift, representing the three times (start, middle, and end of shift) at which assessments were made.*

For the 14N *vs.* 7N+7D comparison, the significant interaction terms were reflected in the sharp decline in alertness throughout the shift immediately after the rollover and the marked reduction in alertness from the start to the end of the following shifts. Even more marked effects of rollover are evident in the results for the 7D+7N group as compared with the 14D group. Whereas the 14D group shows a relatively stable and positive level of alertness throughout the two-week work cycle, for the 7D+7N group alertness throughout the shift immediately following the mid-cycle rollover is particularly low. Although there is some recovery by the start of the next shift, the marked reduction in alertness from the start to end of shift persists throughout Phase III.

In statistical terms, the *rotation x shift* interaction (which indicates that rotation pattern influences change in alertness over shifts) is significant in Phase II in both analyses; F(2,66) = 12.76, p<.001 for the 14D *vs.* 7D+7N comparison, and F(2,58) = 4.70, p<.001 for the 14N *vs.* 7N+7D comparison. In Phase III, the 14N group tends to show a higher overall level of alertness than the corresponding rollover group F(1,28)=3.56, p<.10. For the 14D *vs.* 7D+7N comparison, there is a significant *rotation x time* interaction, F=4.36, df=2,66, p<.02 in Phase III, the rollover group showing greater reduction in alertness over each shift than the fixed-shift group.

Direct comparison of the 14D *vs.* 7D+7N data in Figures 3.4 with the 14N *vs.* 7N+7D data in Figure 3.5 is not strictly within the experimental design, as extraneous differences between the groups in the two analyses cannot be controlled. Such comparisons must therefore be interpreted cautiously. However, it is of interest to note that both the fixed-schedule groups show predominantly positive levels of alertness (i.e. above the neutral point on the scale used) throughout Phases II and III, whereas following the rollover, both the 7D+7N and the 7N+7D groups generally show negative levels of alertness, except at the start of shifts.

3.2.2 Direct comparison of 7D+7N and 7N+7D rollover conditions

The main experimental design did not allow direct comparison of the two rollover conditions; however, additional data collected from other crews during the rollover and the subsequent week, allowed a form of analysis designed to compare the 7D+7N and 7N+7D rollover shift patterns. Details of this experimental design (which did not include the fixed-shift 14D and 14N data) are given in Section 2.6. The analysis was primarily intended to examine whether the direction of rollover significantly affected patterns of alertness.

The significance levels of the relevant terms in the analysis are shown in Table 3.4. Overall level of alertness during the rollover phase was significantly different from that during the stable phases (i.e. sequences of days or nights with no shift change). However, the higher-order interactions involving the days/nights factor represented the effects of direction of rotation, i.e. with the nights-to-days schedule as compared with the days-to-nights schedule.

The effect of rotation direction was apparent in the different patterns of change over time-within-shift for days-to-nights as compared with nights-to-days (indicated by a significant *direction of rotation x time* interaction). However, the corresponding interaction involving shifts was non-significant; thus, the pattern of change over time did not differ significantly across the three shifts within each phase.

Table 3.4
Alertness: Analysis of the effects of rollover direction

	Rollover vs. stable phases	**Direction of rollover**	
		Direction x shift	*Direction x time*
7D+7N *vs.* 7N+7D	F = 9.37 df = 1,46 p < .004	ns	F = 4.59 df = 2,92 p < .015

Alertness levels in relation to direction of rotation are shown in Figures 3.6 and 3.7; for clarity, results for the two rotation directions are shown in separate diagrams although both derive from the single analysis the results of which are shown in Table 3.4. Each diagram is based on data from two separate groups, both of which were assessed during the rollover phase (Phase II) and during one other phase, either before or after the rollover (Phases I and III, respectively). Thus, as shown in Figures 3.6 and 3.7, there are two sets of data for the rollover phase, and one set of data for each of the other phases.

During the initial day-shift phase, alertness is relatively high throughout each shift; in contrast, Phase II reflects the circadian disruption associated with the rollover, and the night-shift phase is marked by a sharp reduction in alertness from start to end of each shift. The main difference between this rotation direction and the opposite direction shown in Figure 3.7 is that alertness among those working a nights-to-days rotation shows no benefits of day-shift work.

Thus, a sharp reduction in alertness occurs across shifts in both the initial week of nights and the subsequent week of days. Indeed, alertness patterns during day shifts in the nights-to-days rotation are very similar to those during nights in the days-to-nights rotation, illustrating that the adverse effects of the mid-cycle rollover eliminate the usually favourable effects of working a normal circadian sleep/wake pattern.

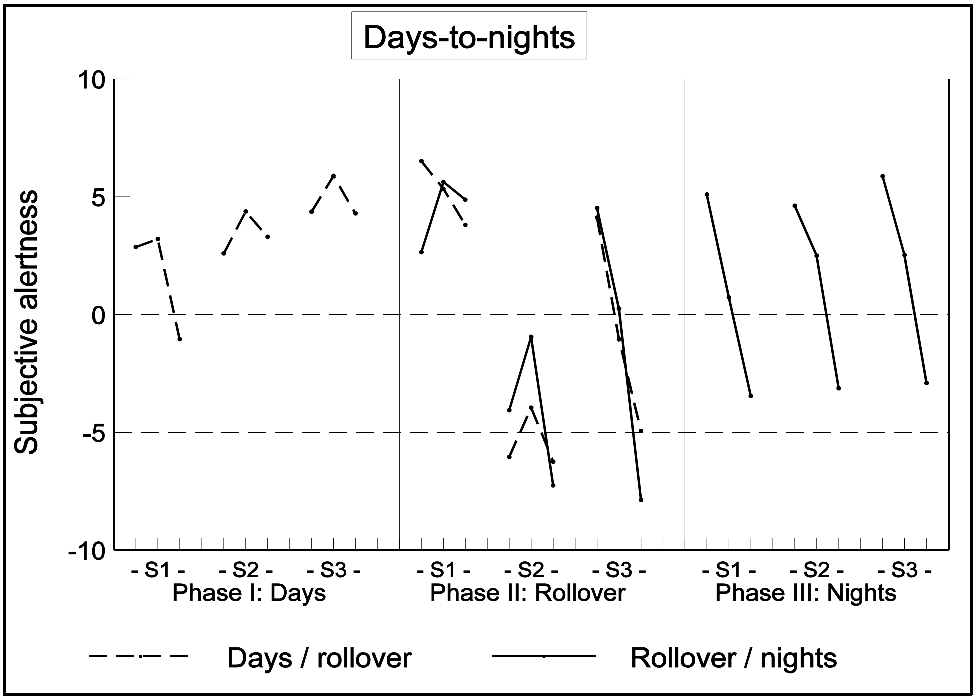


Figure 3.6
Days-to-nights rollover in relation to alertness

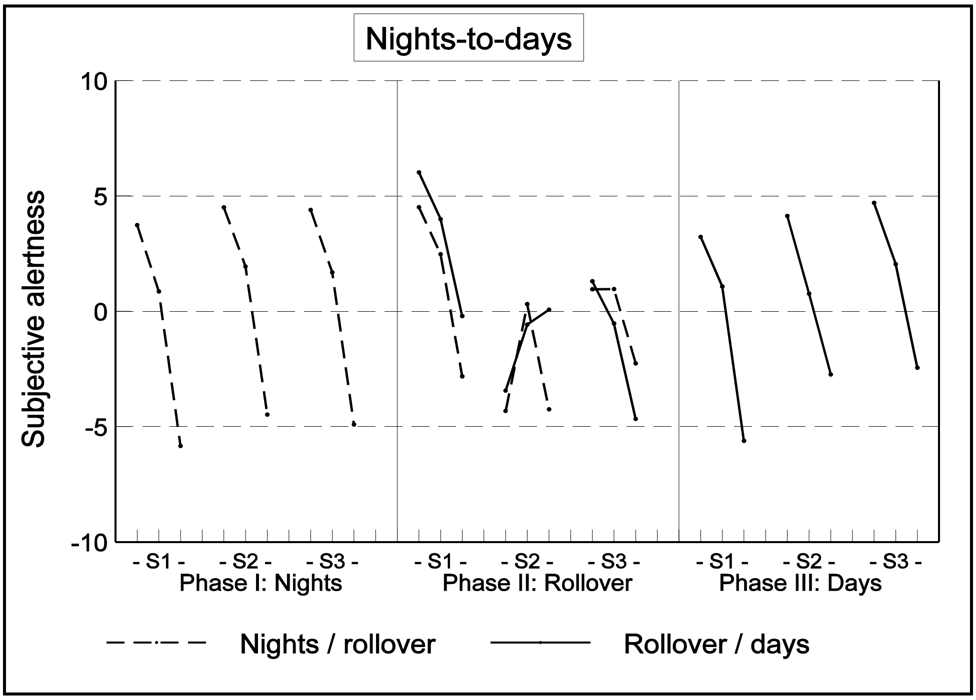


Figure 3.7
Nights-to-days rollover in relation to alertness

***Note**. In these diagrams, three points are plotted for each shift, representing the three times (start, middle, and end-of-shift) at which assessments were made*

3.2.3 Positive mood

Results of the analysis of positive mood comparing the corresponding fixed-shift and rollover rotations are summarised in Table 3.5. Significantly different patterns of change in positive mood were found in the 14D *vs*. 7D+7N analysis (*rotation x phase x shift* interaction), but in this analysis there was no significant pattern of change over the three time points in each shift. In the corresponding 14N *vs*. 7N+7D analysis, the results were more complex in that the four-way *rotation x phase x shift x time* interaction was significant, indicating that differences associated with both shifts and time-within-shifts were involved.

Consistent with the design of the study, there were no significant differences between corresponding rollover and fixed schedule conditions in Phase I. However, the effects of rollover were apparent in the later phases. As shown in Table 3.5, in Phase II, both analyses show a highly significant *rotation x shift* effect, implying that the pattern of change in positive mood over the shifts within each phase is significantly different for the rollover and fixed-shift conditions. For the 14N vs. 7N+7D only, there is also significant *rotation x shift* interaction in Phase III.

Table 3.5
Positive mood: Significance of shift rotation effects

	OVERALL		PHASE II	PHASE III
	Rotation x phase x shift x time	*Rotation x phase x shift*	*Rotation x shift*	*Rotation x shift*
14D *vs.* 7D+7N	ns	F = 4.27 df = 4,132 p<.005	F = 6.48 df = 2,66 p<.005	*ns*
14N *vs.* 7N+7D	F = 3.42 df = 8,232 p<.001	*ns*	F = 9.33 df = 2,58 p<.001	F = 7.49 df = 2,58 p<.002

To allow direct comparison, Figures 3.8 and 3.9 show the patterns of positive mood across shifts and phases for the 14D *vs.* 7D+7N and the 14N vs. 7N+7D analyses, respectively. For the 7D+7N group, the days-to-nights rollover gives rise to an abrupt fall in positive mood in Phase II, but the previous level is largely restored in the following shift. In contrast, the 7N+7D group show an increasingly low level of positive mood into Phase III (although the markedly low mood during the final shift of Phase III should be interpreted with caution as, in both the crews involved, this assessment was affected by problems unrelated to the present study).

Patterns of positive mood in the 14N and 14D groups also show some interesting features. In the 14N group, there is a continuing trend towards improving mood throughout the two week work period consistent with the combined effects of adaptation to night work, and progress through the two-week cycle towards the end of the offshore tour.

In the analysis of the 14D data, there is some evidence of a cyclic pattern; thus, positive mood increases at the beginning of Phase II and falls to a low point at the beginning of Phase III, before improving steadily until the end of the trip. This pattern is consistent with the widely-held view that offshore personnel tend to experience low mood about 10 days into a two-week tour. It is likely that in the present data set these effects were only apparent for the 14D group, because in any other shift sequence, any cyclic pattern of this kind is distorted by the more immediate and obvious effects of circadian disruption.

3.2.4 Positive mood: Comparison of rollover directions

The effects of direction of rotation on positive mood were compared using the same form of analysis as that described for alertness in Section 3.2.2. None of the relevant terms in the analysis were found to be significant. Thus, there is no evidence that direction of rotation, i.e. whether nights or days are worked during the first week, affects patterns of positive mood over the two-week work cycle for those working rollover shift patterns.

3.3 WORKLOAD

3.3.1 Data analysis

Assessments of perceived workload were made at the middle and end of each test shift (T2 and T3). Thus, in these analyses, there were only two time points in each shift; otherwise the analyses followed the same model as for the mood measures. The main aim in analysing workload ratings was to determine whether there were significant patterns of workload change associated with rollover as compared with fixed schedules.

3.3.2 Workload in relation to shift rotation

The results of the workload analyses are summarised in Table 3.6. The *rotation x phase x shift* interaction was significant for the 14N *vs*. 7N+7D analysis but not for the corresponding 14D *vs*. 7D+7N analysis. However, in both analyses, the *rotation x phase* interaction was significant indicating that patterns of workload across phases differed for the rollover and fixed-schedule groups. These results are shown graphically in Figures 3.10 and 3.11.

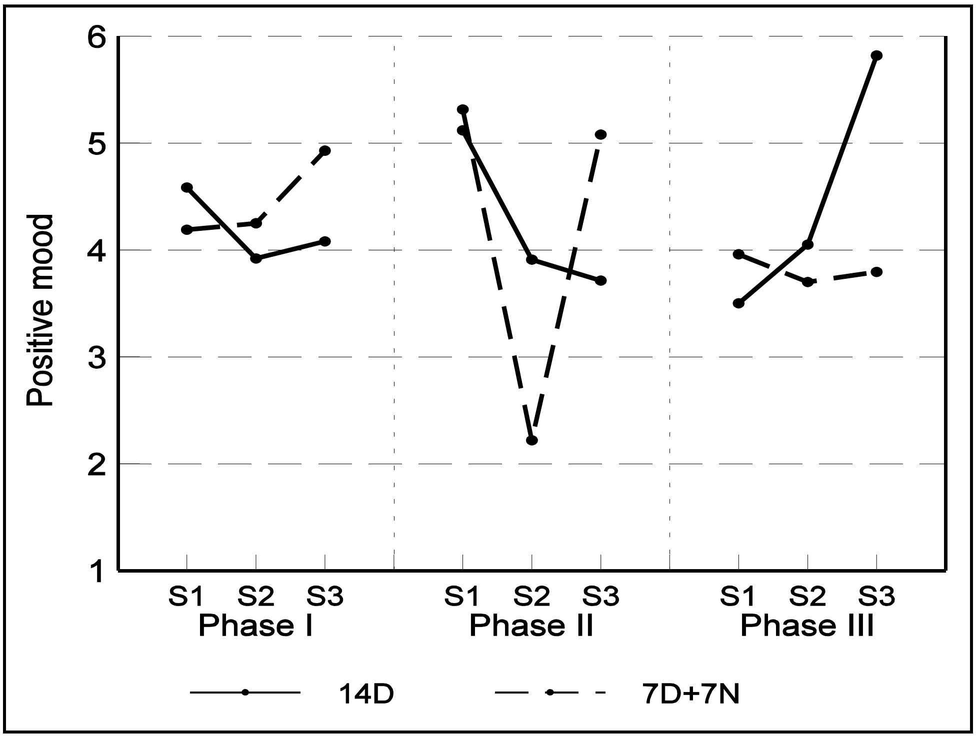


Figure 3.8
Positive mood in relation to shifts and phases: Days vs. days/nights

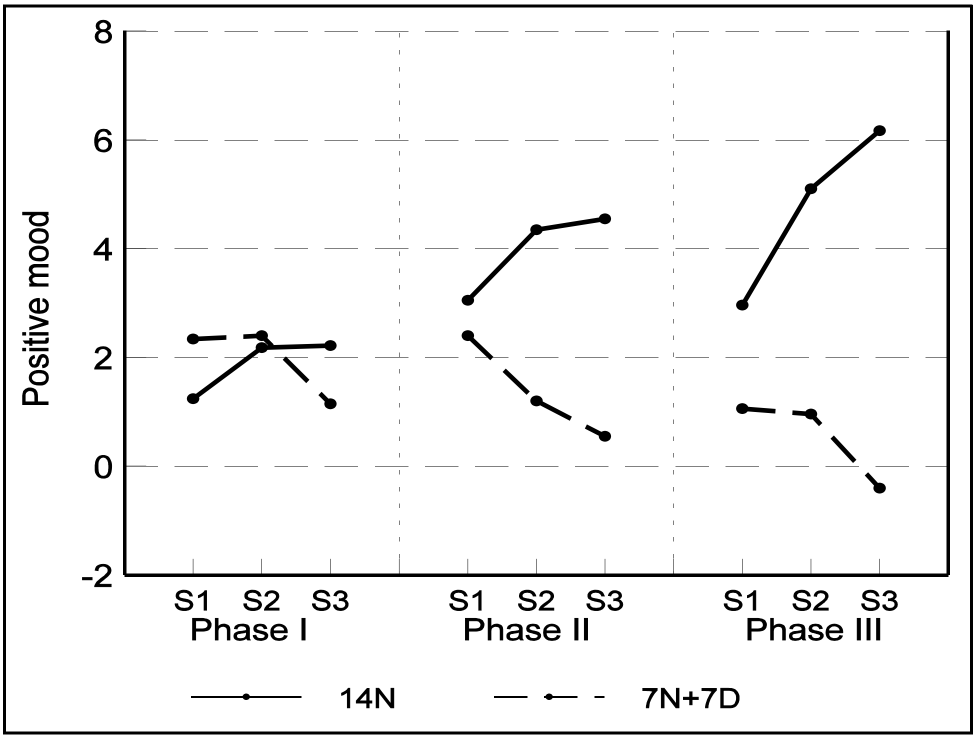


Figure 3.9
Positive mood in relation to shifts and phases: Nights vs. nights/days

Table 3.6
Perceived workload: Significance of shift rotation effects

	Rotation x phase x shift	*Rotation x phase*
14D *vs*. 7D+7N	*ns*	F =8.60 df = 2,66 p<.001
14N *vs*. 7N+7D	F = 5.31 df = 4,112 p<.001	F = 4.36 df = 2,56 p<.025

In both fixed-schedule groups (14D and 14N), workload shows a decreasing trend across phases, but this is not true of the rollover schedules both of which show a marked increase in perceived workload during Phase III as compared with Phase II.

One likely factor contributing to this effect is that, as far as possible, shift teams prefer to minimise workload during the rollover period; this lower level of workload is compensated by an increased level during subsequent shifts. Whilst these results suggest that there is some tendency for workload to be adjusted in relation to shift rotation, it should be noted that contingencies outside the control of the operators concerned (e.g. unexpected shut-down of production plant) also play a role, and often the major role, in determining workload.

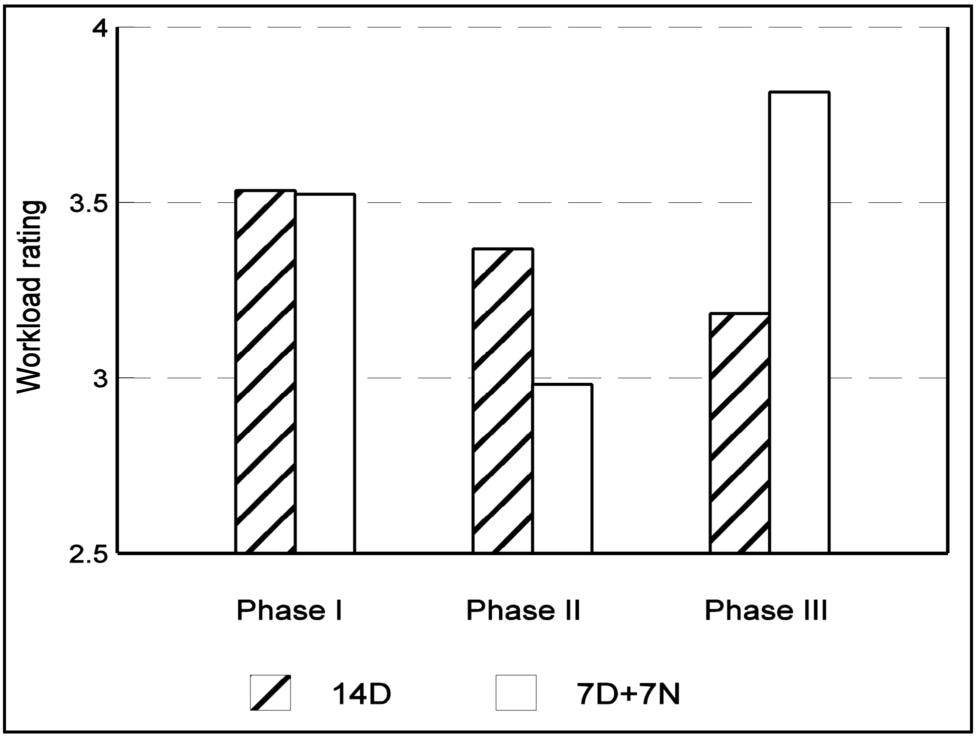


Figure 3.10
Perceived workload across phases: Days vs. days/nights

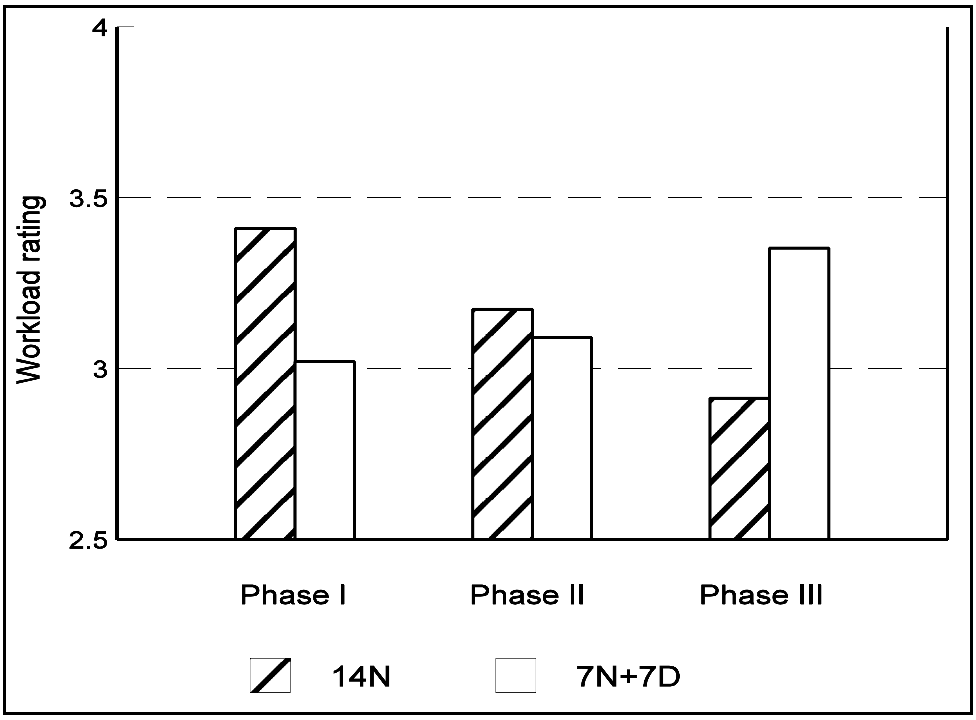


Figure 3.11
Perceived workload across phases: Nights vs. nights/days

SUMMARY

3.4 SLEEP, MOOD, AND WORKLOAD

- Rollover rotation patterns had adverse effects on sleep duration and quality, as compared with the corresponding fixed-shift conditions. The short off-duty periods associated with rollover schedules were reflected in significantly reduced sleep hours; for the 7N+7D rotation, impaired sleep continued almost to the end of the second week offshore.

- Personnel working day-shifts in the first week showed a relatively constant and favourable pattern of subjective alertness; among those working two weeks of day shifts, this stable pattern continued throughout the tour.

- Adjustment to nights shifts, either at the start of the first week or following rollover, resulted in significantly decreased alertness from the start to end of individual shifts; however, the 14N group working two weeks of night shifts showed progressive adaptation, resulting in relatively stable alertness in the second week, comparable with that of the 14D group.

- Rollover, irrespective of direction, had markedly adverse effects on subjective alertness during the first two shifts following the shift-change, persisting throughout the second week in the nights-to-days rollover group.

- Positive mood in the 7N+7D group, relative to the 14N group, was adversely affected by the rollover for the remainder of the work cycle, but the adverse effects in the 7D+7N group occurred only during the first shift after the rollover.

- In the 14D group, some evidence of a possible cyclic effect of positive mood was found; low mood occurred early in the second week but recovered before departure.

- Perceived workload level decreased across the two-week tour in both the fixed-shift groups whereas, in 7D+7N group, significantly reduced workload over the rollover was compensated by higher subsequent levels.

4. COGNITIVE PERFORMANCE: REACTION TIME

4.1 MEAN SPEED OF RESPONSE

4.1.1 Data analysis

In the analysis of the reaction time (RT) data, the overall mean RT value for each test occasion was calculated as the average of the trimmed means of the five blocks of 10 trials (see Section 2.4.2). To compare rollover and fixed shift rotation patterns, analyses were carried out within the framework of the main experimental design described in Section 2.6; in the subsequent comparison of the two rollover conditions, additional data were analysed using the model described in Section 2.6.

4.1.2 Comparison of rollover and fixed-shift rotation patterns

Results of analyses comparing corresponding rollover and fixed rotation patterns are shown in Table 4.1.

Table 4.1
Reaction time (RT): Significance of shift rotation effects

	Rotation x phase x shift	*Rotation x phase x time*	*Time within shift*
14D *vs.* 7D+7N	F = 8.82 df = 4,132 p<.001	*F = 2.32* *df = 4,132* *[p<.06]*	F = 5.39 df = 2,66 p<.01
14N *vs.* 7N+7D	*ns*	F = 2.56 df = 4,116 p<.05	F = 4.79 df = 2,58 p<.02

In the 14D *vs*. 7D+7N comparison, mean RT changed over the three shifts within a phase; this effect was different in the three phases, and for the rollover and fixed-shift groups (significant *rotation x phase x shift* interaction). There was also a significant effect of *time-of-shift*, and a marginally significant *shift x phase x time* interaction, indicating that the time-of-shift effect tended to differ across phases and groups.

In the analysis of 14N *vs.*7N+7D data, the *rotation x phase x time* interaction was significant, again indicating that the *time-of-shift* effect varied significantly across phases, and was different for the rollover and fixed-shift groups. This result was partly attributable to the initial adaptation to night shifts, and partly to the effects of shift change in the 7N+7D rollover group, both of which were associated with longer RT times at the end of shifts. Figures 4.1 and 4.2 illustrate the full pattern of results for each analysis.

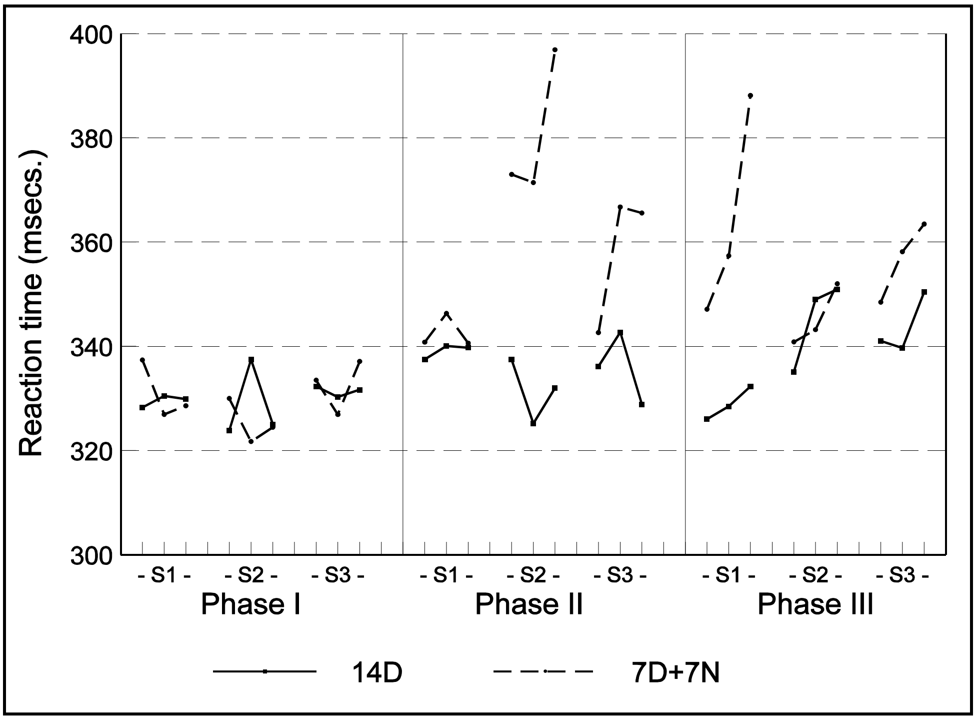


Figure 4.1
Reaction time across phases: Days vs. days/nights

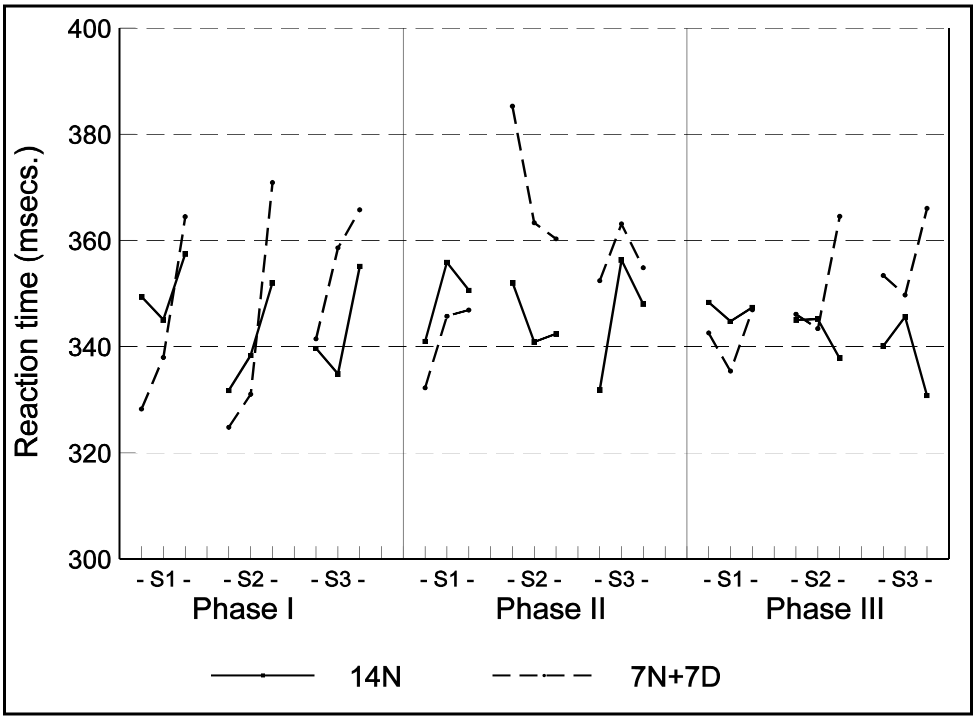


Figure 4.2
Reaction time across phases: Nights vs. nights/days

In these diagrams, three points are plotted for each shift, representing the three times (start, middle, and end-of-shift) at which assessments were made.

Several more detailed points illustrated in Figures 4.1 and 4.2 are noted below:

Phase I. In this phase, RT shows a stable pattern for those working days in the first week (14D and 7D+7N groups), with no significant variation across either shifts or the three times within shifts (Figure 4.1). In contrast, in the 14N *vs.* 7N+7D analysis, there is a marked *time-of-shift* effect in Phase I (F = 18.36, df =2,58, p < .001), which applies to both the groups who work nights in the first week offshore (14N and 7N+7D). As shown in Figure 4.2, RT increases from the start to end of each shift, reflecting the demands of circadian adaptation to night work, mitigated by recovery over the off-duty sleep period.

Phase II. Both the 14D *vs.* 7D+7N and the 14N *vs*. 7N+7D analyses show the adverse effects of mid-cycle shift changes. In both analyses, immediately prior to rollover, the RT values continue the pattern of Phase I; in particular, the 14N and 7N+7D groups show continuing adaptation to night work. However, there is marked disruption of the pattern immediately following the rollover.

Adverse effects on RT (relative to the corresponding fixed-shift groups) occur irrespective of the direction of rollover, although they are more marked for those changing from days to nights (Figure 4.1) than for those changing from nights to days (Figure 4.2). Consistent with sudden disruption of circadian adaptation, the slowing of performance is most apparent immediately after the rollover, but the effect persists into the following shift for the 7D+7N group.

Phase III. Following the rollover, the performance of the 7D+7N group does not become comparable to that of the 14D fixed-shift group until the second shift of Phase III (i.e. two days before the end of the offshore period). In contrast, the 7N+7D group achieve performance levels similar to the 14N group in the first shift of this phase, but tend to show slowing of performance at the end of the last two shifts of Phase III. This pattern suggests that, over the two-week offshore work cycle, the cumulative adaptational demands of changing to day work for the second week are greater than those of two weeks of night work.

More generally, findings from the analyses of mean reaction time, an objective indicator of alertness, parallel those obtained from the subjective alertness measure in that the disruptive effects of the mid-cycle shift change are clearly evident when the rollover groups are compared with the corresponding fixed-shift groups, and that the demands of adaptation to night work are reflected in both measures.

4.1.3 Direct comparison of 7N+7D and 7D+7N rollover conditions

This analysis was similar to that described for the subjective alertness measure in Section 3.2.2; the aim was to compare the two rollover conditions directly, using the experimental design described in Section 2.6. The significance of the relevant terms in the analysis are shown in Table 4.2, and the reaction time profiles for the days/nights and nights/days rotation directions are plotted in Figure 4.3 and 4.4 respectively.

The significance tests showed that both shifts and time-within-shifts contributed to the pattern of differences between the two rotation directions; the separate interaction terms, *direction of rotation x time-within-shift* and *direct of rotation x shift* were both significant, although the more complex pattern represented by the interaction involving both these factors was only marginally significant.

Table 4.2
Reaction time: Analysis of the effects of rollover direction

	Direction x shift x time	*Direction x shift*	*Direction x time*
7D+7N *vs.* 7N+7D	*F = 2.34* *df = 4,184* *[p < .06]*	F = 3.65 df = 2,92 p < .03	F =7.02 df = 2,92 p < .002

The results shown in Figures 4.3 and 4.4 closely parallel those reported for the subjective alertness measure. Thus, the fastest and most consistent responses occur during the initial day-shift week in the 7D+7N group; at no other stage in the two-week offshore work period is equally favourable performance observed in this group, and the 7N+7D group never achieves this consistent pattern.

In particular, in the 7N+7D data, the Phase III day-shift sequence following the rollover shows slower responses than the during the initial night-shift phase; thus, as for the subjective alertness measure, there is little or no apparent benefit from working a normal circadian sleep/wake cycle in the second week.

In the 7D+7N data, there is not only evidence of disruption following the rollover, but also a strong trend of deteriorating performance during Phase III (a pattern which does not occur in the 14N group, see Figure 4.2). A possible explanation for this increasing performance impairment is that the 7D+7N group are exposed to the need for circadian adaptation to night work when they have already completed a week offshore, and are therefore more susceptible to cumulative fatigue effects than those who do night work in the first week.

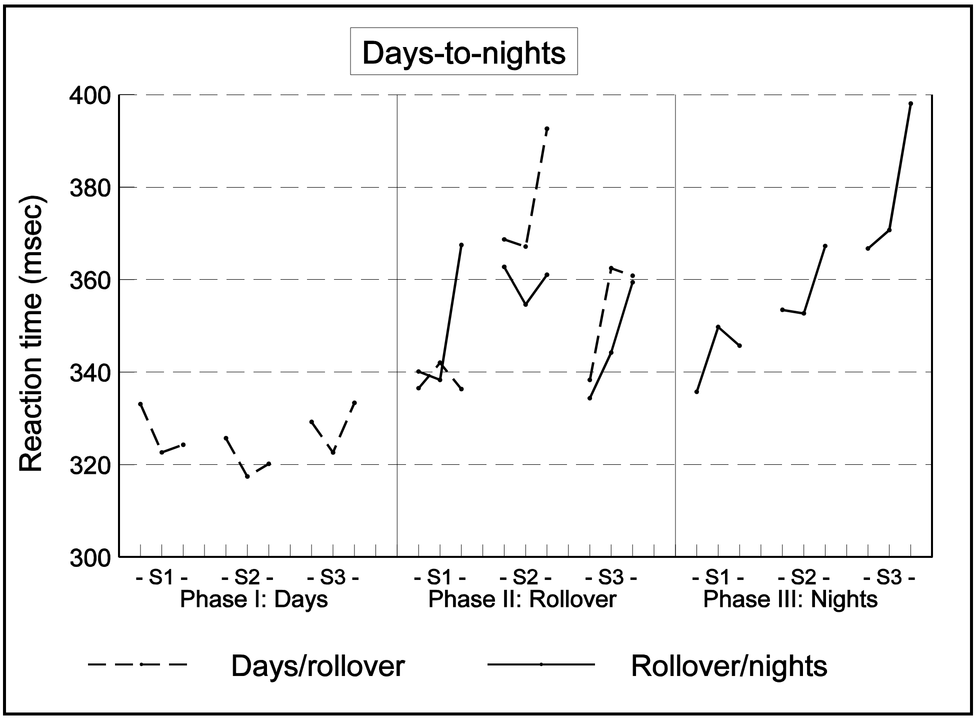


Figure 4.3
Reaction time in relation to days-to-nights rollover

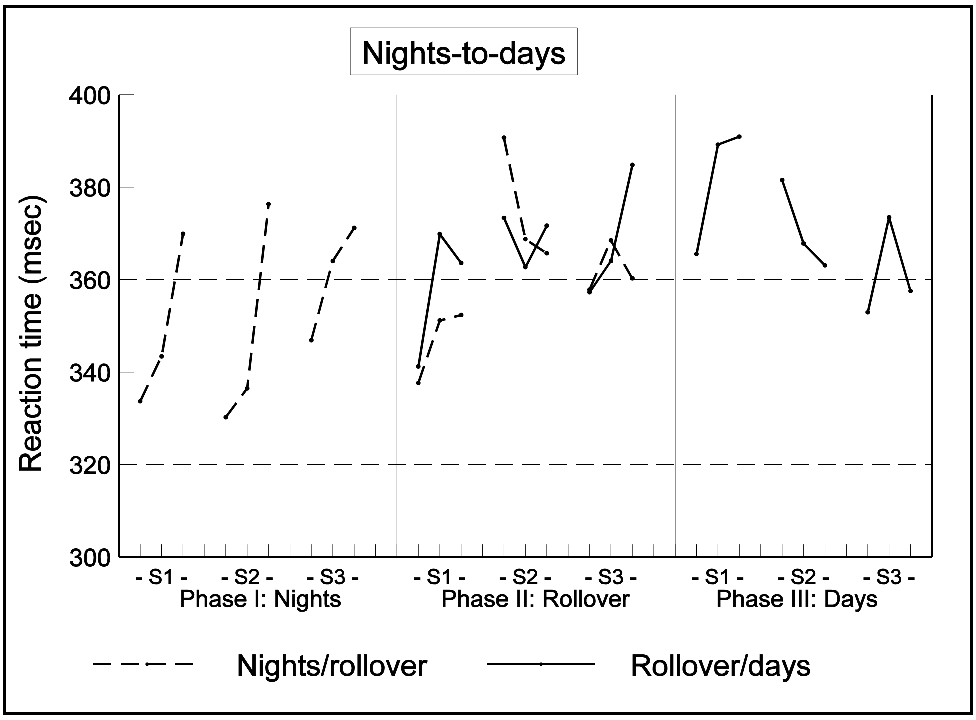


Figure 4.4
Reaction time in relation to nights-to-days rollover

In these diagrams, three points are plotted for each shift, representing the three times (start, middle, and end-of-shift) at which assessments were made.

4.2 ANALYSIS OF OTHER MEASURES OF RT PERFORMANCE

4.2.1 Variability of reaction times within blocks of trials

The analysis of mean RT values reported in Section 4.1 did not take into account the extent to which RT varied within each of the five blocks of trials carried out by an individual at each assessment; this 'within-person' variability of response is of interest in that increased variability of responses is often a sign of performance impairment.

To examine the variability of reaction time in relation to rollover *vs*. fixed shift schedules, analyses were carried out in which the standard deviation (a measure of variability about the mean of a set of values) of responses in each block of ten trials carried out by participants was calculated. These values were averaged across the five blocks in each test session, and this average value was treated as the dependent variable in an analysis following the design described in Section 2.6..

In some respects, the results of this analysis were similar to, but less marked than, those for mean reaction times. For the 14D vs. 7D+7N comparison, the *rotation x phase x shift* interaction was significant (F = 2.51, df = 4,132, p<.05). Examination of the data revealed that, in Phase II, there was a marked increase in variability of response as compared with the Phase I, and as compared with the 14D fixed-shift group. In addition, in both analyses, there were marginally significant effects of time of shift (p<.10 in each case), variability of response tending to increase over the course of individual shifts.

These results suggest that the increased mean reaction times observed under unfavourable shift rotation conditions are not simply due to a general increase in all response times, but reflect increased variability of response (particularly an increased range and frequency of longer response times). However, in each analysis, there was also a significant overall trend of increasing variability across phases irrespective of whether a fixed or rollover shift rotation pattern was worked (p<.001 in each case). This trend is apparent in Figures 4.5 and 4.6, and is consistent with a cumulative effect of fatigue across the work cycle irrespective of the particular shift pattern worked.

4.2.2 Frequency of 'gaps' in reaction time responses

Prior to the analysis of mean reaction times, RT responses slower than 1000 ms. (designated 'gaps') were removed from the data set to avoid distorting overall means by including unusually long reaction times. Nonetheless, the frequency of gaps under different shift rotation conditions was of interest in revealing lapses in concentration. In analysing gaps, it was necessary to adopt a statistical approach appropriate to the non-parametric nature of the data; thus, nearly half the participants completed all trials with no gaps at all, and of those whose data did include gaps, the frequency of such lapses was generally quite low. Consequently, the distribution of gaps was strongly skewed with many low or zero values, and only a few relatively high ones.

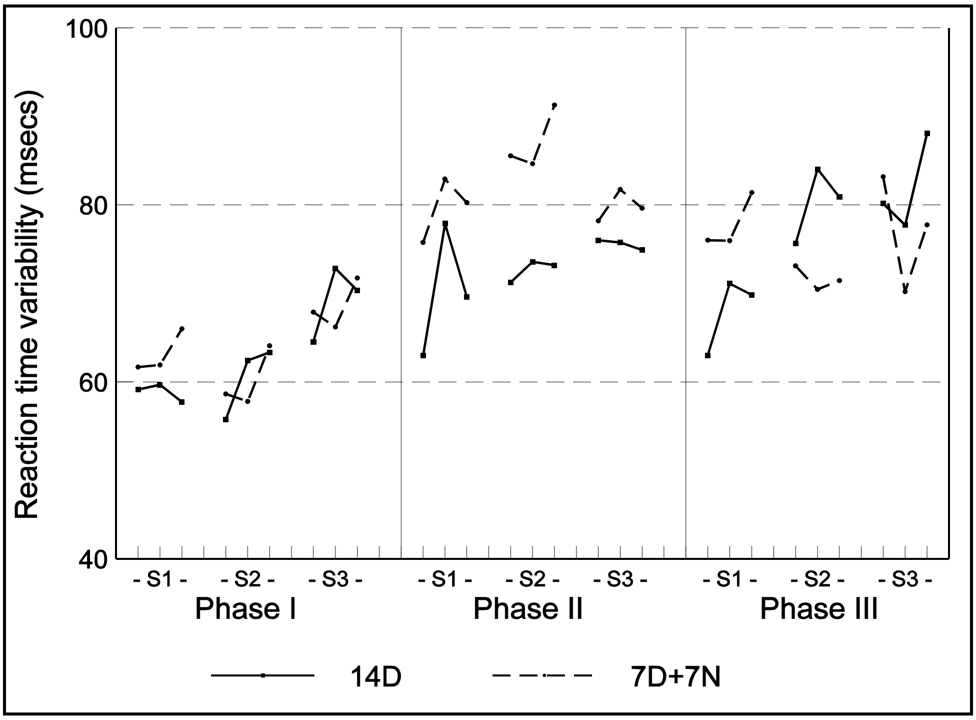


Figure 4.5
Reaction time variability across phases: Days vs. days/nights

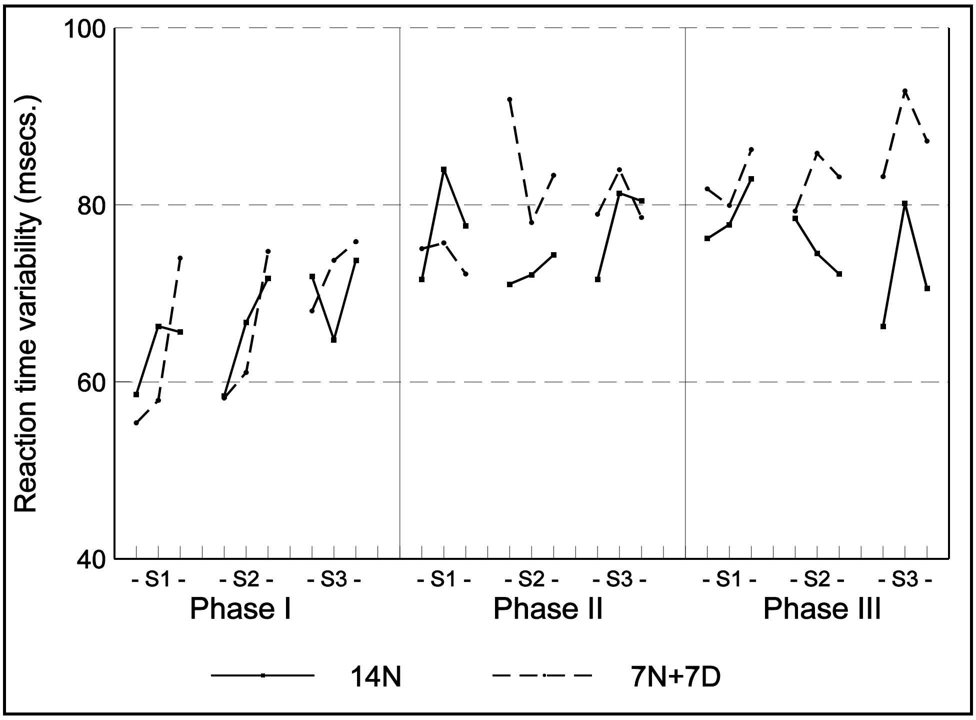


Figure 4.6
Reaction time variability across phases: Nights vs. nights/days

In these diagrams, three points are plotted for each shift, representing the three times (start, middle, and end-of-shift) at which assessments were made.

Thus, parametric methods of analysis (which require normal or near-normal distributions) could not be used. It was also not possible to use covariance methods to control initial differences between groups working different shift rotation patterns.

The approach adopted was to sum the number of gaps recorded over the three test occasions during a shift (i.e. time-of-shift was disregarded in this analysis). Thus, a single score (representing the number of gaps in 150 RT trials) for each participant for each of the nine test shifts (three shifts in each of the three phases) was derived; an overall average across the nine shifts was also calculated in each case.

The analyses compared the combined fixed-schedule groups (14D and 14N) with the combined rollover groups (7D+7N and 7N+7D). In the fixed shift groups, more than half the participants had no gaps, and no one had more than three gaps. In contrast,the distribution for the rollover groups extended over a much wider range; only 34% of the participants had no gaps, and 21% had more than three gaps, and the maximum value was 14 gaps. Figure 4.7 shows the cumulative distributions of frequencies of gaps under rollover and fixed-shift conditions.

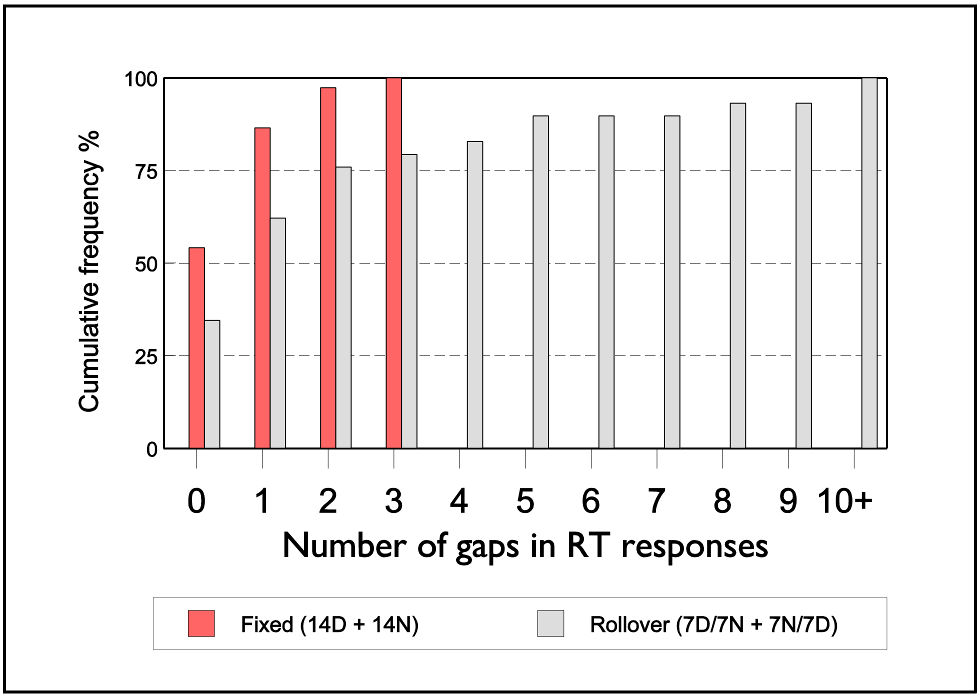


Figure 4.7
Cumulative frequency distributions of gaps in RT responses:
Fixed vs. rollover schedules

The difference between the rollover groups and the fixed-schedule groups in the number of gaps recorded was tested using the Mann-Whitney test (a non-parametric method of comparing distributions in two independent samples); this test was also carried out for each individual shift. Values of the Mann-Whitney U statistic, and one-tail significance levels, are shown in Table 4.3. The data are plotted in Figure 4.8 showing, for each shift, the proportion of each group with one or more gaps.

Table 4.3
Gaps in RT responses: Comparison of rollover and fixed-schedule groups

	ROLLOVER *vs.* FIXED SCHEDULES		
	PHASE I	PHASE II	PHASE III
Shift 1	*ns*	*ns*	*ns*
Shift 2	U=698, p< .01	U=694, p<.02	U=668, p<.05
Shift 3	*ns*	U=708, p<.01	*[U=648, p<.06]*
OVERALL	Rollover *vs*. fixed schedules: U=707, p<.015		

Overall, the rollover groups had significantly more gaps than the fixed-schedule groups; this difference was primarily due to the higher incidence of gaps in the rollover groups immediately following the shift change (i.e. in Shifts 2 and 3 of Phase II), although similar but weaker effects were also apparent in Phase III. The

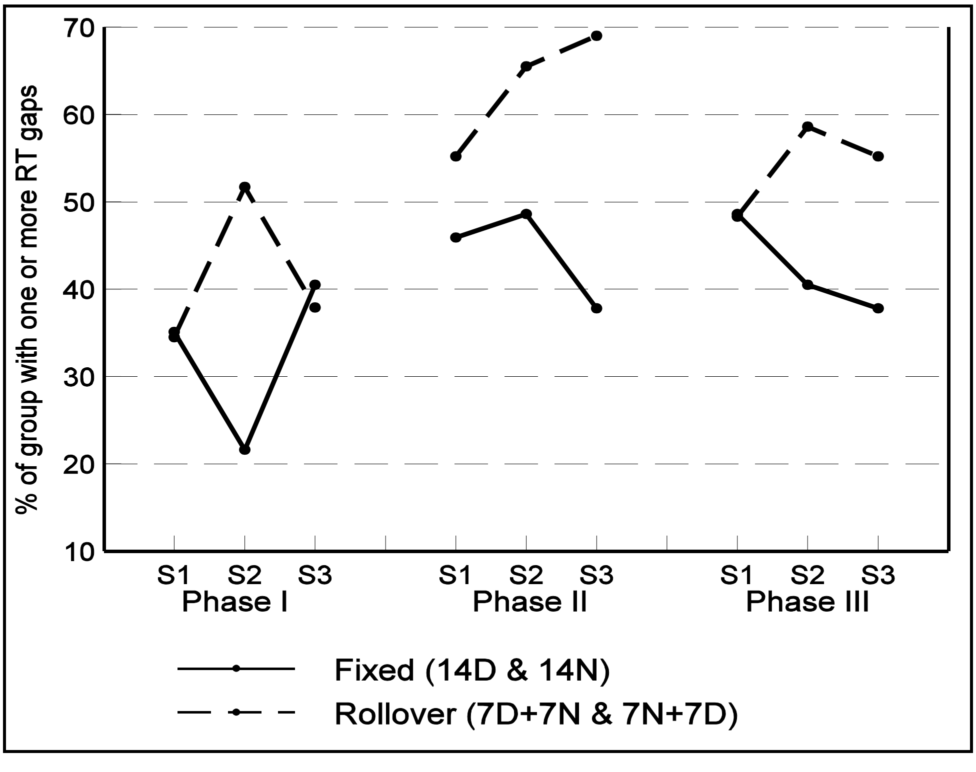


Figure 4.8
Gaps in RT responses: Comparison of rollover and fixed-schedule groups in each phase

significant effect in the second shift of Phase I is less readily explained; it appeared to be largely due to the particularly low level of gaps in the 14N group as compared with the high level in the 7N+7D group; however, the non-parametric nature of the data, and the relative infrequency of gaps in the data set as a whole, made it difficult to draw firm conclusions from more detailed separate comparisons of 14N *vs*. 7N+7D and 14D *vs*. 7D+7N conditions.

SUMMARY

4.3 REACTION TIME

- Reaction time was relatively stable in the 14D group throughout the two-week work cycle, and in the 14N group, once initial adaptation had occurred.

- Both rollover groups were adversely affected by the mid-cycle shift change, reaction time increasing sharply immediately following the rollover. In the 7D+7N group, mean RT increased by an average of 10.7% during the two shifts following the rollover as compared with the 14D fixed-shift group. The corresponding increase for the 7N+7D group was 5.2% as compared with the 14N group.

- Increased reaction time from start to end of individual shifts was particularly marked at the start of night-shift sequences.

- Within-person RT variability increased over the three phases irrespective of the shift rotation pattern being worked; this trend is consistent with cumulative fatigue effects over the two-week offshore work cycle.

- Rollover groups showed significantly higher frequencies of ‘gaps’ (reaction times greater than 1 second) than the fixed shift groups, particularly during the two shifts immediately following the rollover.

- Direct comparison of RT profiles for the two rollover conditions confirmed that, when day shifts followed a week of night shifts, the normal level of day-shift performance is impaired.

5. OTHER COGNITIVE PERFORMANCE MEASURES

5.1 MULTIPLE CHOICE RESPONSE TIME

5.1.1 Data analysis

In the multiple choice response task, a target appeared in one of four positions on the screen; the subject's task was to note the position of the target and respond with the appropriate key. Two main features distinguished this task from the simple reaction time test; first, it was a more difficult task, and showed more marked training effects; second, accuracy (i.e. whether the correct response was made to each signal) was important as well as speed of response.

Both these factors had to be taken into account in analysing the data. As described in Section 2.5.4, Phase I of the data collection was treated as an extended period of practice, and the analysis was restricted to Phases II and III; as in the analyses of other measures, the average level of performance immediately prior to Phase II was treated as the covariate to control initial differences between corresponding groups.

To take into account the trade-off between speed and accuracy (i.e. faster speeds tend to be associated with lower accuracy), the accuracy achieved in each trial (in the form of an arcsine transformation of the proportion of correct responses) was controlled in the analysis of speed. In simple terms, therefore, the analysis addressed the issue of how different shift rotation conditions affected speed of response, whilst statistically removing variation due to changes in accuracy.

5.1.2. Results

In the analysis of the combined data from Phases II and III, the 14N *vs*.7N+7D comparison revealed no significant effects of shift rotation pattern, but there were significant effects in the 14D *vs*. 7D+7N analysis. As shown in Table 5.1, the four-way interaction, *rotation x phase x shift* x *time,* was highly significant, indicating that shift rotation affected the pattern of response times over shifts and over time-of-shift, and that the pattern was different in the two phases. Further analysis of each phase separately revealed a significant *rotation x shift x time* interaction in Phase II, and a *rotation x time* interaction in Phase III.

The data are shown graphically in Figure 5.1. For the 14D group, there is a gradual trend of response times decreasing over successive shifts in both phases, and in general, over times within each shift. These results are consistent with continuing improvement in this task over time, consistent with a long-term training effect.

Although the 7D+7N group shows a level of performance similar to that of the 14D group prior to the rollover, performance is disrupted (as compared with the 14D group) during the two shifts following the rollover, particularly at the middle and end of these shifts. In Phase III, the 7D+7N group continue to show slowing of performance towards the end of each shift, in contrast to the relatively stable and improving performance of the 14D group.

Table 5.1
Multiple choice response time: Significance of shift rotation effects

	PHASES II and III *Rotation x phase x shift* x *time*	PHASE II *Rotation x shift x time*	PHASE III *Rotation x time*
14D *vs.* 7D+7N	F =3.61 df = 4,131 p<.01	F = 4.50 df = 4,131 p<.002	F = 13.07 df = 2,65 p<.001

The 14N *vs.* 7N+7D comparison yielded no significant effects of rotation pattern; however, examination of the data showed that the general level of performance of the 14N fixed-schedule group and the 7N+7D rollover group was more closely comparable to that of the 7D+7N rollover group than to that of the 14D group.

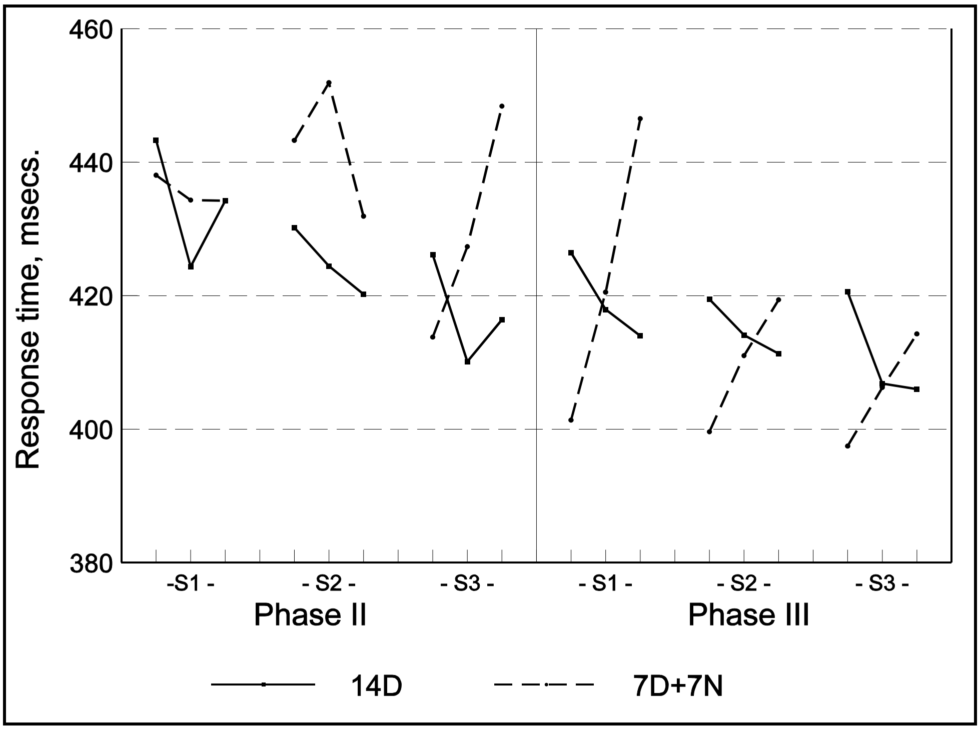


Figure 5.1
Multiple choice reaction time: Days *vs.* days/nights in Phases II and III

5.2 MEMORY TASK

5.2.1 Data analysis

The memory task was used in two forms, differing in level of difficulty. The simpler version of the task (M1) involved memorising one 'target' letter, and responding with either the *'yes'* or the *'no'* key to a sequence of random letters subsequently presented one by one. In the more difficult version (M5), the procedure was similar but the task required that five target letters were memorised, and the appearance of any one of these target letters identified in the random sequence that followed.

In analysing these data, the two levels of task difficulty were included as an additional factor in the analysis model. The dependent variable in the analysis was the mean speed of response to each of the letters in the sequence. Accuracy of response was taken into account by covariance methods; in this case, the proportion of target letters correctly identified (in the form of an arcsine transformation) in each trial was treated as the covariate. An additional covariate representing the mean performance level during the shift immediately preceding Phase II was included to control for initial differences between corresponding groups.

5.2.2 Results

In the analysis of the memory task data for Phases II and III, the overall mean performance levels across the two phases showed significant effects of shift rotation. As shown in Table 5.2, for the 14N *vs*. 7N+7D comparison, the three-way interaction term was significant indicating that response time depended on phase, on task difficulty, and on shift rotation. This term was not significant in the 14D *vs*. 7D+7N analysis, but separate analyses at each level of task difficulty (also shown in Table 5.2) revealed a highly significant *'rotation x phase'* term for the relatively simple M1 task in each analysis, but no significant effects for the M5 task.

Table 5.2
Memory task response time: Significance of shift rotation effects

	Rotation x phase x task difficulty	*Rotation x phase*	
		Task difficulty M1	*Task difficulty* M5
14D *vs*. 7D+7N	*ns*	F =8.18 df = 1,29 p<.01	*ns*
14N *vs*. 7N+7D	F=5.26 df=1,29 p<.03	F=7.69 df=1,29 p<.01	*ns*

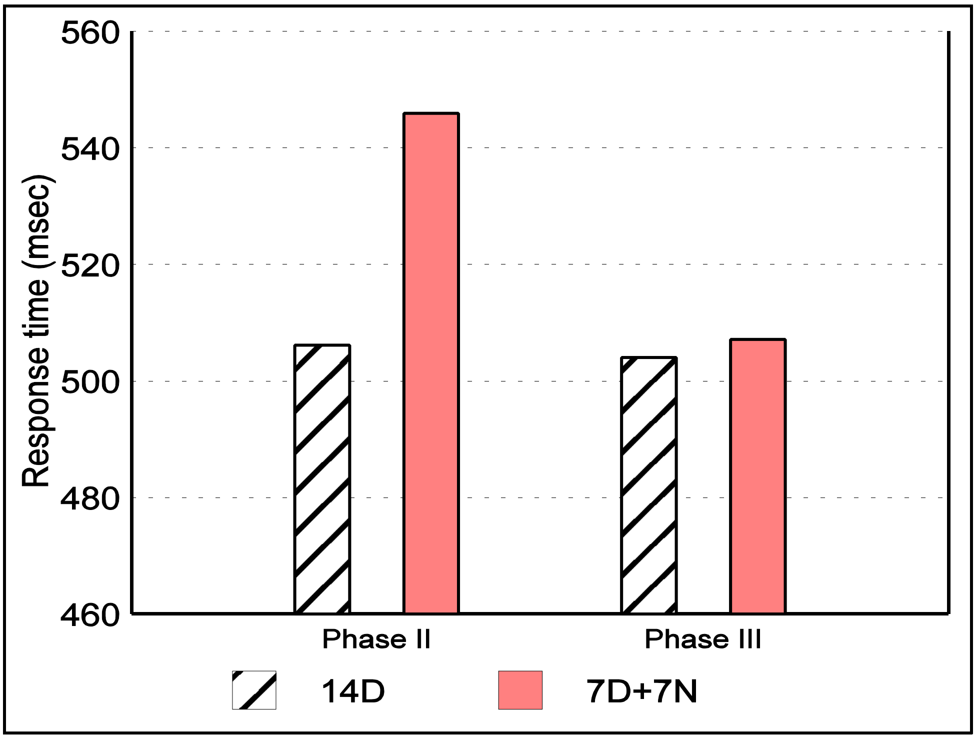


Figure 5.2
Mean response times for memory task (M1): Days vs. days/nights

Mean response times in Phases II and III are shown in Figure 5.2 for the 14D *vs.*

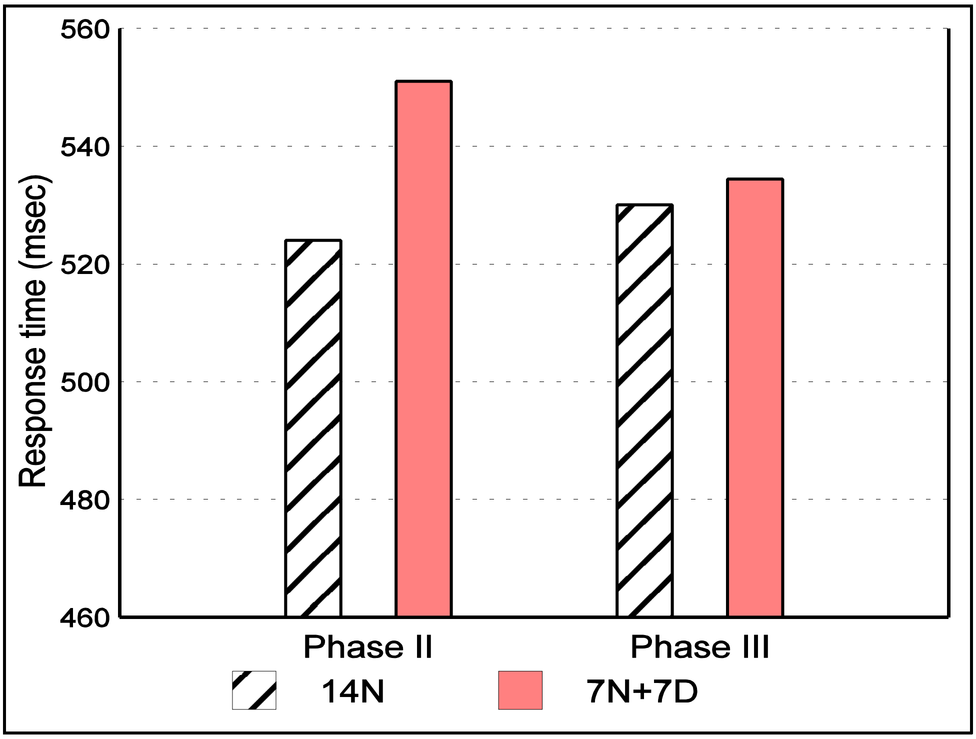


Figure 5.3
Mean response times for memory task (M1): Nights vs. nights/days

7D+7N comparison and in Figure 5.3 for the 14N *vs*. 7N+7D comparison. The results take a similar form in each case; the rollover groups show longer response times than the fixed-schedule groups in Phase II, but this difference is eliminated in Phase III. Thus, the shift change (whether from nights to days, or from days to nights) has short-term adverse effects on performance of the M1 task, but these effects do not persist into Phase III. The M5 task did not show significant *phase x rotation* effects. However, there was a significant overall effect of task difficulty; response times were significantly longer for the M5 task (which imposed the heavier memory load) as compared with the M1 task.

5.3 LOGICAL REASONING TASK

5.3.1 Data analysis

Analysis of data from the logical reasoning task was complicated by the continuing practice effect running through all the trials, and by the wide variation between individuals in speed of response, with some very long and erratic response times. These aspects of the data gave rise to particular difficulties in identifying shift rotation effects. Two steps were taken to reduce these problems. First, prior to analysis, a square root transformation was used to produce a distribution of response times approximating more closely to a normal distribution; thus, the data analysed were the square roots of response time values, rather than the actual values.

Second, to control for training effects, a method similar to that used in the analysis of logical reasoning data by Parkes (1993) was adopted. This method made use of the fact that the item set consisted of equal numbers of active items (e.g. *A follows B*) and passive items (e.g. *A is followed by B*), the latter being more difficult. In the analysis, mean response times for passive items were treated as the dependent variable, and the mean response times for the corresponding active items were treated as a covariate.

This method incorporated a ‘within subjects’ control into the data at each test occasion, thus reducing the impact of training effects; in effect, performance on the passive items was analysed relative to performance on the active items. Accuracy levels were also controlled.

5.3.2 Results

Comparison between the 14N and 7N+7D conditions yielded no significant results relevant to the issue of shift rotation. However, in the 14D. *vs*. 7D+7N analysis of the data from Phases II and III, the significant four-way interaction indicated that the pattern of results across phases, shifts, and time-within-shifts was different for the fixed-shift 14D condition as compared with the rollover 7D+7N condition. Further analyses of each phase separately showed that these significant effects derived from the Phase II data, rather than those relating to Phase III. These results are shown in Table 5.3.

Table 5.3
Logical reasoning task response time: Shift rotation effects

	PHASES II and III *Rotation x phase x shift* x *time*	PHASE II *Rotation x shift x time*	PHASE III *Rotation x shift x time*
14D *vs.* 7D+7N	F =3.89 df = 4,125 p=.005	F = 2.84 df = 4,125 p<.03	*ns*

The data are plotted in Figure 5.4. The most conspicuous feature of the results is the slow response times at the end of the two shifts following the rollover in the 7D+7N group as compared with the successively decreasing response times of the 14D group in the corresponding shifts.

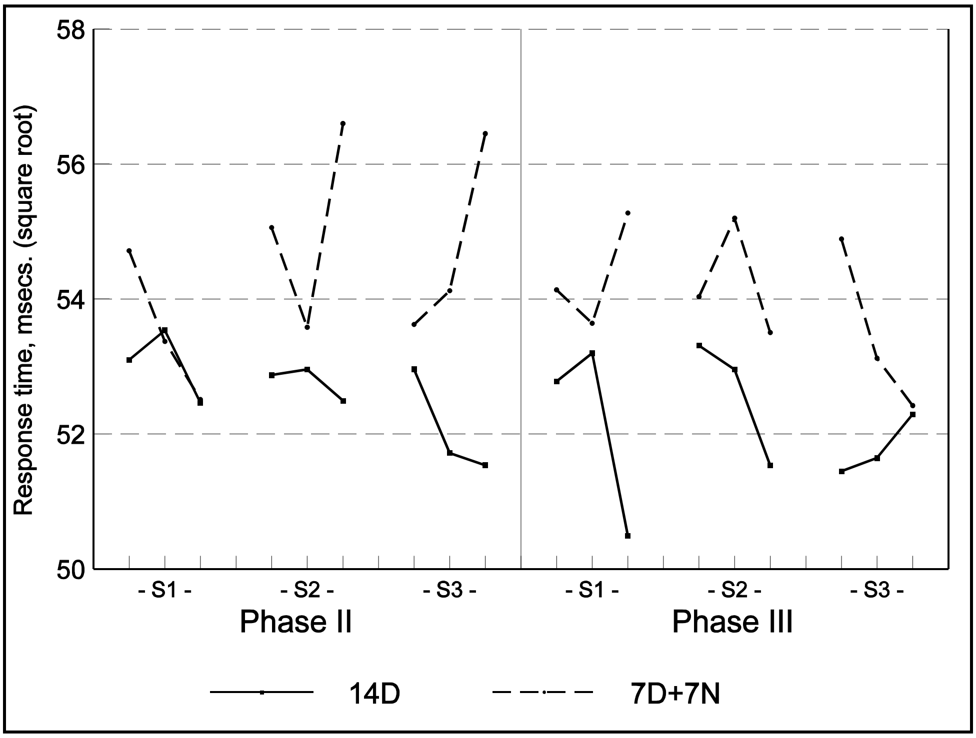


Figure 5.4
Response time in logical reasoning task: Days vs. days/nights

SUMMARY

5.4 OTHER COGNITIVE PERFORMANCE MEASURES

- This section reports findings from three cognitive tasks (multiple choice reaction time, short-term memory, and logical reasoning). To reduce analysis problems resulting from extended training effects, only data from Phases II and III were analysed. Speed of response was treated as the dependent variable, taking accuracy into account.

- The 14D *vs.*7D+7N comparison showed significant findings for each measure, except the more difficult memory task (M5). The significant results occurred primarily in the two shifts immediately following the rollover. In each case, the 7D+7N group showed a deterioration in performance, while the performance of the 14D group continued to improve. However, differences between the groups were largely eliminated by Phase III.

- Only the single-letter memory task showed a significant effect in the comparison of the 14N and 7N+7D shift patterns. Again, the rollover group showed slower responses in Phase II, but not in Phase III. Performance decrements resulting from the shift change were relatively small, but the switch to day shifts brought about no significant improvement in performance relative to that of the 14N group.

6. SHIFT ROTATION: ANALYSIS OF SURVEY DATA

To extend the information about patterns of mood and cognitive performance over time, survey data relevant to the issue of shift rotation were also examined. The sample used in these analyses was selected from the main survey data set to correspond to the sample involved in the study of mood and performance. It consisted of male personnel from production platforms who worked day/night shifts with rotation patterns of 7D+7N, 7N+7D, or 14D/14N, on a schedule of 07.00 - 19.00 / 19.00 - 07.00 hours (exact changeover times varied slightly), in jobs classified as production, maintenance, or supervisory (N=260). A total of nine platforms was involved; five platforms operated the 7N+7D pattern, one operated 7D+7N, and three operated 14D/14N. In the analyses reported here, three main topics were addressed: actual and preferred shift rotation patterns; satisfaction with current rotation pattern; and sleep duration and quality in relation to shift rotation.

6.1 ACTUAL AND PREFERRED SHIFT ROTATION PATTERNS

Table 6.1 shows the actual and preferred shift rotation patterns of the personnel in the sample.

Table 6.1
Actual and preferred day/night shift rotation patterns

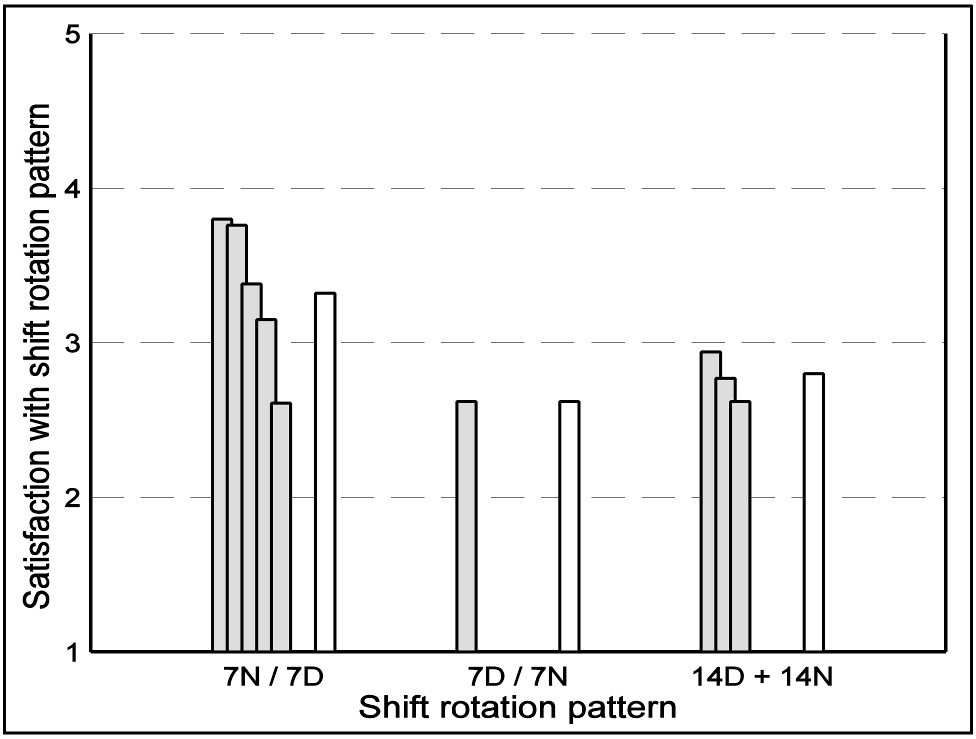
Current shift rotation pattern	N	Shift rotation preference		
		7N + 7D	7D + 7N	14D/14N
7N + 7D	93	81 87.1%	0 --	12 12.9%
7D + 7N	67	50 74.6%	11 16.4%	6 9.0%
14D/14N	100	58 58.0%	0 --	42 42.0%
OVERALL	260	189 72.7%	11 4.2%	60 23.1%

The data shown relate to male production, maintenance, and supervisory personnel working day/night rotating shifts on production platforms. Individuals who indicated no shift rotation preference were excluded.

It can be seen from Table 6.1 that there was a marked preference for the 7N+7D pattern; 72.7% of the total sample opted for this pattern. In contrast, no one who was not already working the 7D+7N pattern reported a preference for it and, of those for whom this was their actual pattern, only a small minority (16.4%) considered it to be their preference. Personnel working the fixed-shift 14D/14N pattern were more evenly split in their preferences; although more than half of them (58.0%) reported preferring the 7N+7D rotation, the remaining 42% indicated that 14D/14N was their preferred schedule.

6.2 SATISFACTION WITH SHIFT ROTATION PATTERNS

One item in the job satisfaction scale specifically assessed satisfaction with shift rotation patterns; scores ranged from 1 to 5, higher scores representing higher levels of satisfaction. The shift rotation patterns differed significantly in satisfaction scores (F=6.61, df=2,250, p=.002); the data are shown graphically in Figure 6.1.



In this figure, the darker shaded bars show the overall means for each shift rotation pattern; individual platform values are shown by the paler shading.

Figure 6.1
Satisfaction with shift rotation patterns

The significant overall effect was largely due to the higher level of satisfaction reported for the 7N+7D pattern as compared with the 7D+7N pattern, the 14D/14N schedule having an intermediate value. However, as described below, platform differences and differences in work/leave schedules were also relevant.

Platform differences. Data for the 7N+7D and 14D/14N rotation patterns were obtained from more than one platform, and some differences between platforms were found even when the same shift rotation pattern was in operation. Thus, platform differences (including, for instance, the timing and organization of crew changes) contributed to satisfaction with shift rotation over and above the rotation pattern itself. These differences were significant for 7N+7D platforms (F=4.04, df=4,89, p<.005), but not for the 14D/14N platforms.

Further analyses were carried out to examine the extent to which general satisfaction with work conditions as a whole may have contributed to the results outlined above. In this analysis, the total score on 17 job satisfaction items unrelated to shift rotation, working hours, and work/leave patterns, was used as a control variable; this measure was a highly significant covariate, but controlling for these overall satisfaction scores led to little change in the relative levels of satisfaction for the three shift rotation schedules shown in Figure 6.1.

Work/leave schedules. There was some evidence to suggest that satisfaction with shift rotation patterns may have been influenced by attitudes to a related issue, that of work/leave schedules. The sample analysed included 104 personnel working an equal-time 2-2 schedule (i.e. two weeks' offshore alternating with two weeks' leave), while the remainder (n=155, mainly operating company personnel) had more generous leave allowances (2-3, or an extended 2-2, 2-2, 2-2, 2-6 pattern). In both these groups, satisfaction was significantly affected by shift rotation pattern (p=.003 and p=.002 respectively) but, as shown in Figure 6.2, different effects were observed

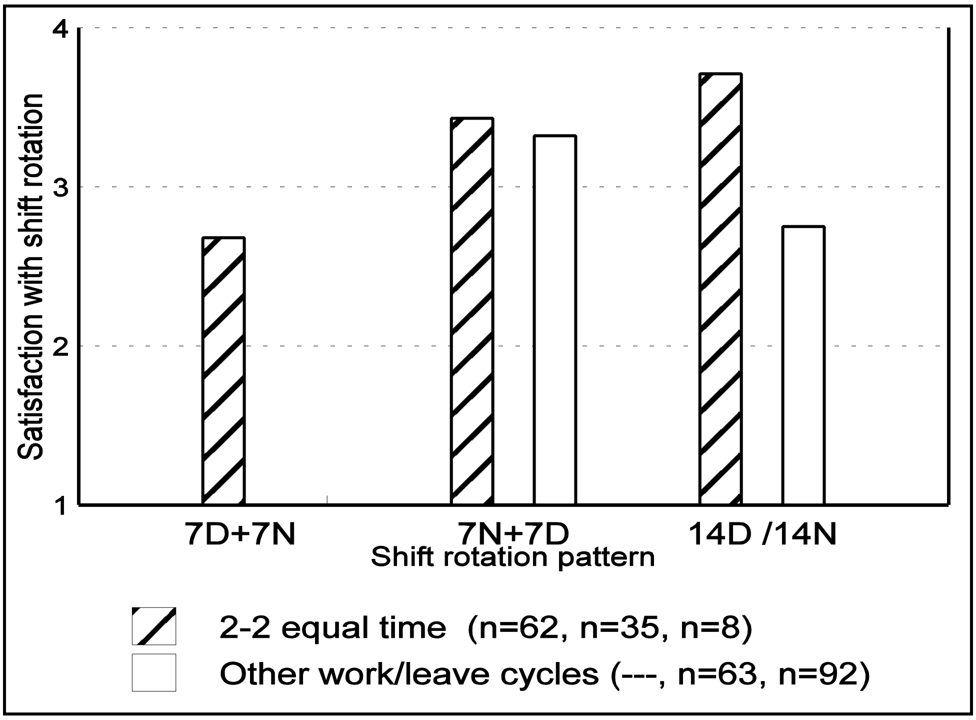


Figure 6.2
Satisfaction with shift rotation patterns in relation to work/leave cycles

in each case. Among those with a regular 2-2 work/leave cycle, personnel on platforms operating the 14D/14N shift pattern reported high satisfaction with shift rotation; in contrast, on the same platforms, those working the more generous work/leave pattern reported relatively low satisfaction with 14D/14N shift rotation.

Whilst these results must be interpreted with caution in view of the small numbers of personnel working (n=8) a 2-2 work/leave cycle with 14D/14N shift rotation, they do illustrate the diversity of opinions involved. In particular, the data suggest that negative attitudes towards the 2-2, 2-2, 2-2, 2-6 work/leave schedule among the personnel concerned (who formed the great majority of 14D/14N groups) may have impacted adversely on satisfaction with the 14D/14N shift rotation pattern.

6.3 SLEEP PATTERNS IN RELATION TO SHIFT ROTATION

The survey included separate measures of average sleep duration for day-shift weeks, night-shift weeks, and when on leave; corresponding assessments of sleep quality were also obtained. The day-shift and night-shift data were analysed in relation to the three shift rotation patterns. In order to examine whether sleep played a role in individual preference for particular shift rotation patterns, a further factor, representing whether or not the shift rotation worked was the same as the individual's preferred rotation, was also included in these analyses. Two control variables, age and the corresponding sleep measures relating to the leave period, were used as covariates. The results of these analyses are shown in Table 6.2, and in Figures 6.3 - 6.6.

Table 6.2
Sleep patterns in relation to shift rotation: Significance of effects

MEASURE	Shift rotation pattern	Preferred vs. non-preferred rotation
SLEEP DURATION		
Day shifts	F=5.44, df=2,240, p<.005†	F=5.04, df=1,240, p<.03
Night shifts	F=3.73, df=2,239, p<.03	F=5.85, df=1,239, p<.02
SLEEP QUALITY		
Day shifts	F=3.83 df=2,241, p<.03	*ns*
Night shift	F=9.90, df=2,239, p=.001	F=9.03, df=1,239, p<.005

† In this analysis, the *rotation pattern x preferred vs. non-preferred rotation* interaction was also significant, F=3.01, df=2,240, p=.05.

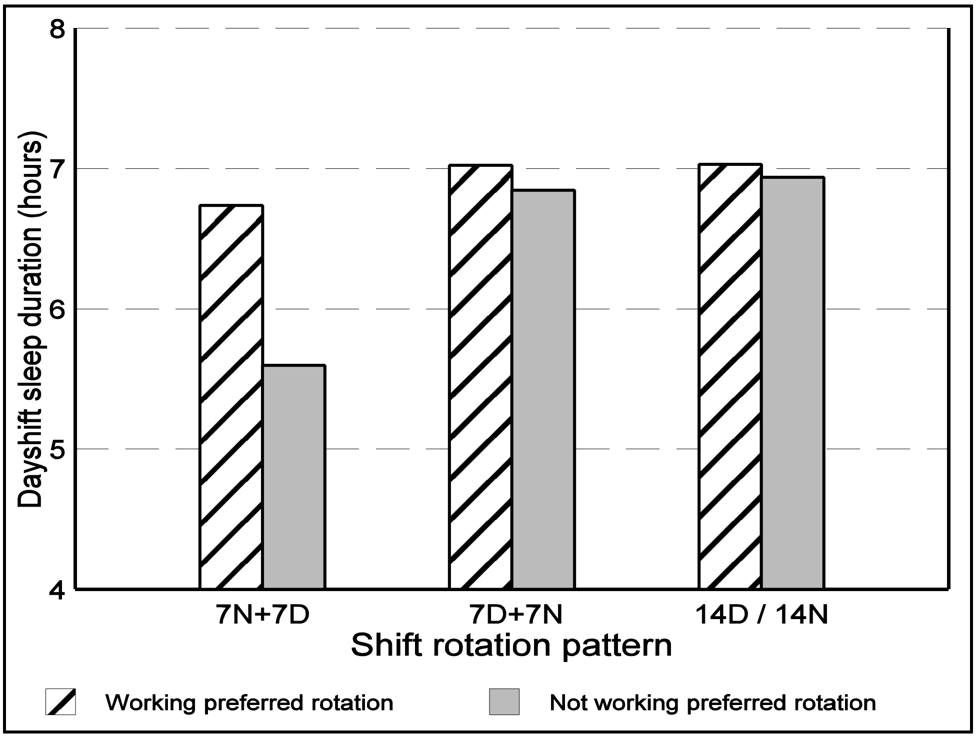


Figure 6.3
Dayshift sleep duration in relation to actual and preferred shift rotation

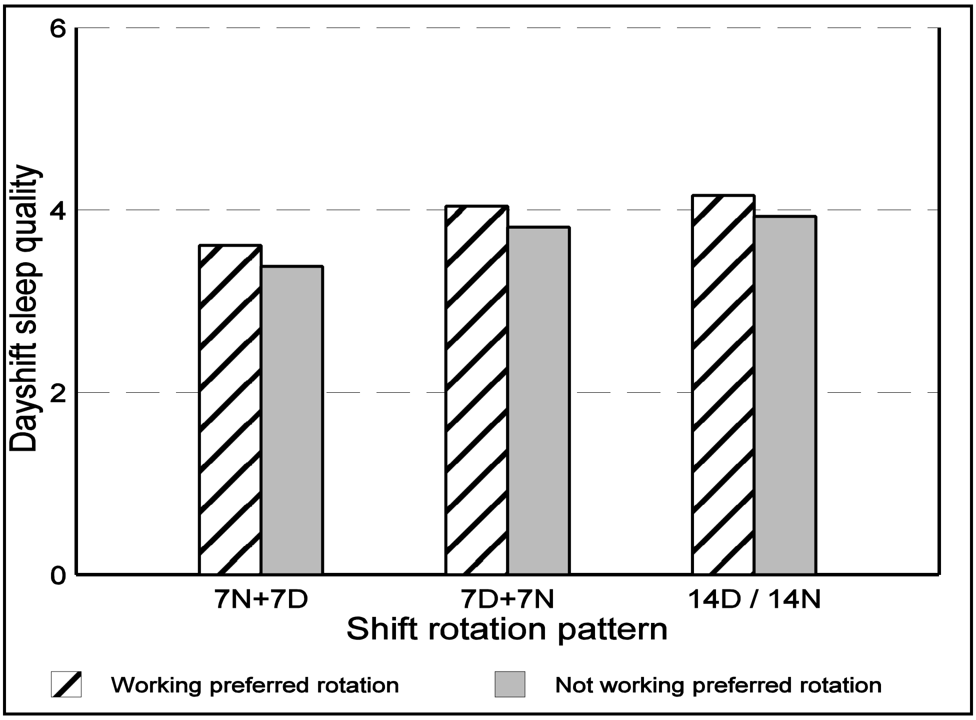


Figure 6.4
Dayshift sleep quality in relation to actual and preferred shift rotation

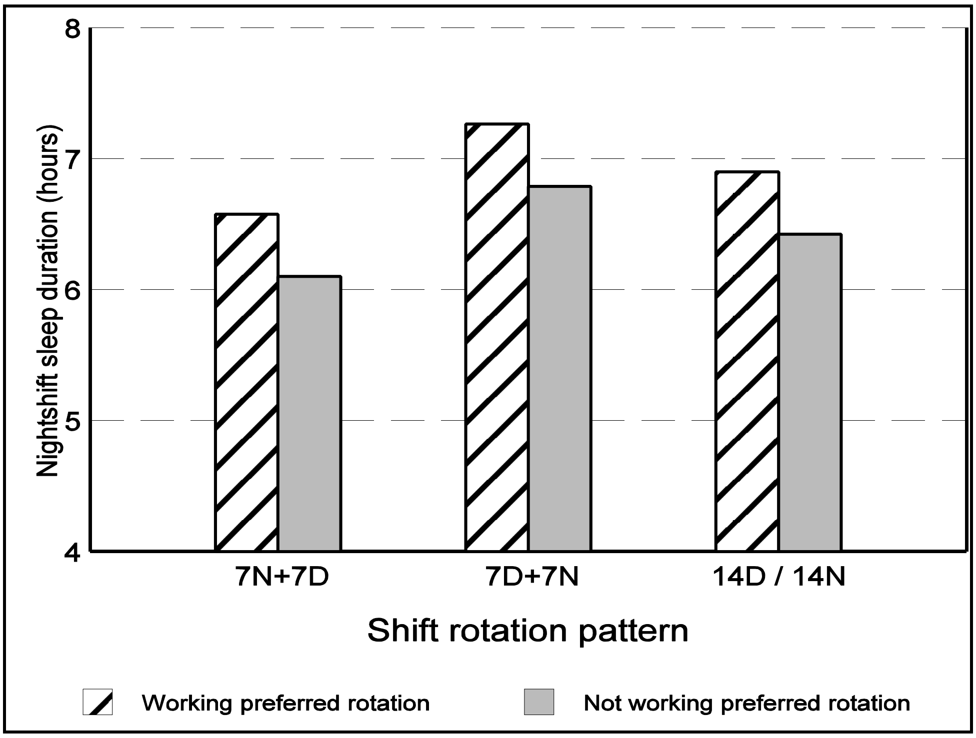


Figure 6.5
Nightshift sleep duration in relation to actual and preferred shift rotation

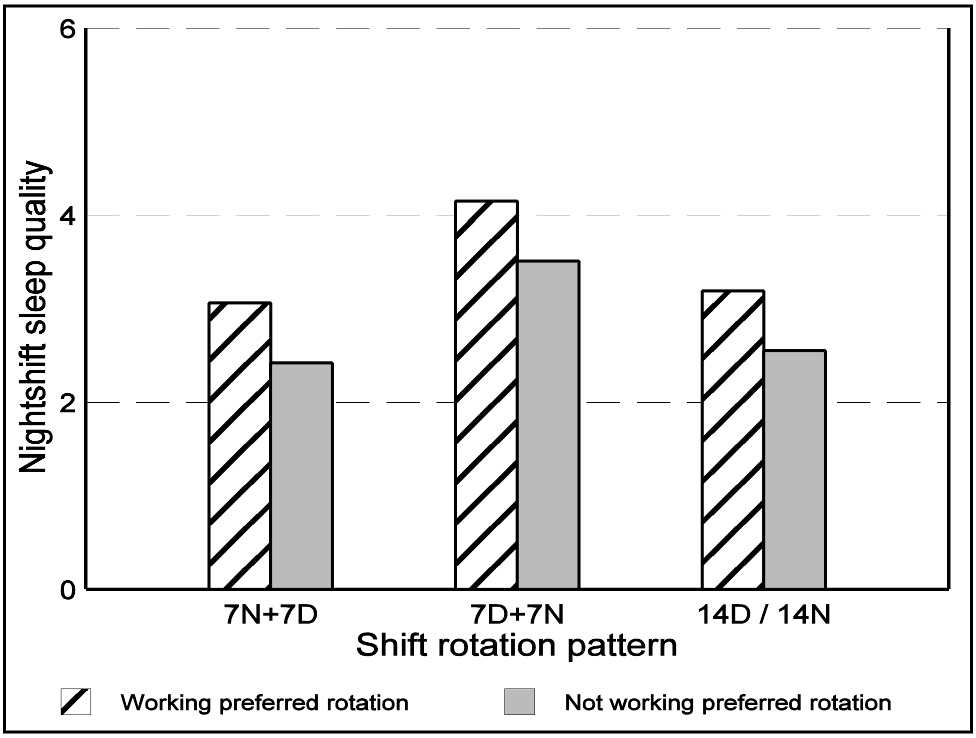


Figure 6.6
Nightshift sleep quality in relation to actual and preferred shift rotation

Actual shift rotation pattern, and whether or not individuals were working their preferred patterns, were both significant predictors of the sleep measures. In addition, the two covariates were significant in each analysis. Inclusion of these covariates allowed offshore sleep patterns to be examined relative to age (older personnel reported poorer sleep quality and shorter sleep duration than younger ones) taking into account individual differences in sleep during leave periods.

- ***Sleep duration***. For day-shift sleep duration, there was a significant interaction between shift rotation pattern and preference. Thus, as shown in Figure 6.3, the day-shift sleep duration of individuals working the 7N+7D pattern who reported that they would prefer a different pattern was particularly low. Thus, poor sleep following the nights/days rollover may have been one reason underlying the preference that these individuals expressed for the fixed-schedule 14D/14N pattern (see Table 6.1).

  However, the 7D+7N and 14D/14N rotations did not differ in day-shift sleep duration; the preference factor was also non-significant in this case. More generally, it can be seen from Figure 6.3 that even for the most favourable shift conditions, average day-shift sleep duration falls short of a normal 8-hours sleep period by approximately one hour.

  For night-shift sleep duration, shift rotation and preference showed significant and independent effects. Those who were working their preferred rotation reported longer night-shift sleep duration than those who were working a schedule different from their preferred one; longest night shift sleep duration was reported for the 7D+7N rotation pattern, while the shortest duration was for the 7N+7D rotation.

- ***Sleep quality***. Night-shift sleep quality was more markedly affected by shift rotation pattern than day-shift sleep quality. Both the 7N+7D and the 14D/14N patterns were associated with poorer night shift sleep quality than the 7D+7N pattern; for day-shift sleep quality, shift rotation was not a significant factor. Similarly, whether or not individuals were working their preferred shift rotation pattern was significantly related only to night-shift sleep quality (those working a non-preferred pattern reporting poorer sleep quality).

It is apparent from these results that the 7N+7D rotation shows relatively unfavourable sleep durations for both day shifts and night shifts, and relatively poor night-shift sleep quality; these findings directly reflect the fact that individuals working the 7N+7D rotation experience circadian disruption twice during each offshore trip (i.e. on working nights on arrival, and changing to days at the end of the first week). Furthermore, the results suggest that sleep problems may be a relevant factor among some of those who expressed preferences for shift rotation patterns other than the ones they were currently working.

6.3.1 Sleep deficits

Calculating the differences between sleep durations for leave periods and those for day and night shifts allowed estimates to be made of the overall sleep deficit (i.e. sleep hours during offshore weeks as compared with sleep hours during leave) for the two-week offshore work period. The mean deficits for day-shift work and night-shift work based on the survey sample of 260 production, maintenance and supervisory personnel are shown in Table 6.3 However, there was considerable individual variation around these mean values; some individuals reported an average night-shift sleep duration longer than that during their leave periods, whereas for others night-shift work was associated with greatly reduced sleep hours.

For day-shift work, the mean sleep deficit values for the three shift rotation patterns are significantly different (p=.012); as would be expected, the day-shift group (14D) for whom no circadian adaptation was involved, had the smallest average value. In this case, the deficit of approximately 50-55 minutes per day can be attributed to the early start to day shifts (usually 06.30 or 07.00 hours), and offshore work conditions more generally (e.g. noise disturbance from round-the-clock production, and/or shared cabin accommodation) rather than a need for major circadian adjustment to night work. Overall, the 7N/7D group had the highest sleep deficit for both day- and night-shift work, reflecting the double circadian adaptation inherent in this shift pattern.

Table 6.3
Estimated sleep deficits in relation to shift rotation patterns

Shift rotation pattern	Estimated sleep deficits			
	Day shifts (hrs. per day)	Night shifts (hrs. per day)	Rollover* (total hours)	Estimated total hours over two-week tour
7N+7D	1.31	1.33	4.5	20.3
7D+7N	1.05	1.21	4.3	17.7
14D	.90	---	---	12.6
14N	---	1.175	---	16.4
Average 14D/14N				14.5

* *The data shown in this column were derived from the sleep duration data in Section 3; they represent the total sleep deficit for the first two off-duty periods following the rollover*

Under each of the rollover conditions, additional sleep loss is experienced during the shift-change phase, when the interval between the end of one shift and the start of the next may be as little as five hours, although an eight-hour rest period is more usual. The additional deficits during the two shifts immediately following the rollover are included in Table 6.3. The overall sleep deficits for the two-week offshore work period, which are also shown in Table 6.3, indicate that in this respect the fixed-schedule 14D/14N condition (averaged over day- and night-shift tours) is most favourable, and the 7N+7D rollover is the least favourable. The difference between these two shift patterns amounted to an average of some 6 hours in a two-week tour (approximately 8 hours for a day-shift tour, and 4 hours for a night-shift tour).

SUMMARY

6.4 SURVEY DATA

The main findings from the analysis of data from 260 personnel working on nine offshore installations were:

- There was a strong preference for the 7N+7D rotation pattern; 73% of the total sample opted for this schedule. Very few individuals opted for the 7D+7N pattern, and all of them were already working this pattern.
- Of those currently working 14D/14N pattern, 42% reported a preference for it, while 58% opted for the 7N+7D rollover pattern.
- *'Satisfaction with shift rotation'* was highest for the 7N+7D pattern, and lowest for 7D+7N, but there were significant differences between installations working the same pattern. Dissatisfaction with the 14D/14N pattern appeared to be linked to an unpopular work/leave schedule.
- Shift rotation patterns significantly affected the duration and quality of sleep. The 7N+7D pattern tended to be least favourable in this respect. Individuals working this pattern who reported poor sleep in the day-shift week were more likely to report a preference for 14D/14N rotation.
- As compared with sleep during leave periods, all personnel reported sleep deficits while working offshore. Overall deficits over the two-week work cycle were greatest for the 7N+7D pattern (20.3 hours), and least for the 14D/14N pattern (12.6 hours for day-shifts, 16.4 for night shifts).

7. CONCLUSIONS

This report combines data from an experimental study of sleep, mood, and cognitive performance in relation to shift rotation patterns, with findings derived from survey data. Taken together, the results demonstrate that shift rotation patterns have significant effects on objective performance, and on subjective alertness and well-being among offshore personnel responsible for round-the-clock production processes. Whilst the findings are consistent with the large body of research on shiftwork in onshore work settings, they add to the available literature in providing information specific to the particular conditions of offshore work which constrain the design of shift rotation patterns in ways that do not apply onshore.

In seeking to integrate and interpret the findings reported, the discussion presented here is divided into two parts. First, the effects observed are reviewed in relation to relevant findings from the more general shift work literature, and some methodological aspects of the present study are noted. Second, the relative advantages and disadvantages of the shift rotation patterns studied are summarised taking into account the present findings, and practical considerations relevant to offshore shift scheduling.

7.1 FINDINGS IN RELATION TO CURRENT LITERATURE

7.1.1 Sleep

Each of the shift rotation patterns studied resulted in some degree of sleep loss over the two-week offshore work period, as compared with the sleep hours of the same personnel during leave periods. Thus, irrespective of the type of shift rotation in operation, working 12-hour shifts in the offshore environment gave rise to sleep deficits. This finding is consistent with research literature that demonstrates shorter sleep hours for shifts of 12-hour as compared with 8-hour duration (e.g. Rosa, 1991; Rosa & Bonnet, 1993).

However, among offshore personnel, environmental factors (e.g. noise, shared cabins) may contribute to loss of sleep over and above extended work hours. Lauridsen *et al.* (1991) reported that 47% of their sample of offshore personnel were troubled by noise, and 40% considered noise to be the cause of their sleeping difficulties. In addition, most of the sample in the study by Lauridsen *et al.* shared cabin accommodation, and more than half of them reported that they found sharing cabins difficult.

In the present study, the particular demands of night work were apparent in that sleep loss averaged 16.4 hours over the two-week offshore tour for night shifts (14N group) as compared with 12.6 hours for day shifts (14D group). However, those working rollover schedules showed greater sleep deficits, reflecting the effects of a mid-cycle shift change. As noted in the Introduction, rollover schedules in operation offshore are necessarily of the 'backward rotation' type, which basic research into circadian rhythms suggests is likely to be particularly unfavourable (Monk & Tepas, 1985), and which has been linked to sleep and health problems in a recent study of petrochemical workers (e.g. Jaffe *et al*. 1996). In the present study, the 7N+7D pattern, in which two circadian adjustments (from days to nights in the first week, and from nights to days in the second week) were involved showed the highest overall sleep deficit (20.3 hours) over the two-week work cycle.

In a review of the literature on shift work, Waterhouse *et al.* (1992) note that sleep loss during night-work, and its impact on performance and efficiency, is a matter of concern; in particular, the authors draw attention to the possibility of cumulative impairment arising from a series of 12-hour night shifts. However, under the shift rotation conditions operated offshore, sleep deficits associated with rollover patterns were more severe than those under the 14N night-shift condition. Waterhouse *et al*. also note that occasional 'naps' may be used by shift workers to make up for reduced duration of sleep during the main rest period; however, among offshore production personnel naps or momentary inattention during working hours could pose serious safety risks, particularly if only one operator is present in the control room.

The daily records of sleep duration and quality obtained in the present study could also be compared with data reported by Totterdell *et al* (1995) who used a similar daily method of obtaining information about sleep in relation to shift work. Comparisons showed that offshore personnel working day shifts reported shorter average sleep durations than the nurses studied by Totterdell *et al*. Thus, when working day shifts, the nurses reported an average of 7.1 hours sleep as compared with 6.2 hours for day-shift work in the present data. Corresponding values for night shifts were 7.6 hours in the data of Totterdell *et al*. and 6.5 hours in the present data.

7.1.2 Alertness and performance

Extended shift durations of 12 hours as compared with 8 hours have been found to lead to decrements in performance and alertness, and increases in subjective fatigue, among onshore production operators, especially during night shifts (Rosa *et al.* 1989; Rosa & Bonnet, 1993). In the offshore work environment, production personnel not only work 12-hour shifts but do so over the two-week work cycle, rather than over short periods (three or four days) interspersed with rest days, as is common practice onshore. Any impairment in the alertness and performance of operators responsible for the safety and smooth running of offshore production processes is a matter of potential importance, and several issues arising from the findings of the present study merit attention in this context.

Rollover vs fixed schedule rotation patterns. The main aim of the study was to compare the 14D/14N rotation pattern with two different rollover patterns. Taking the 14D condition as a 'baseline' in the comparison with the 7D+7N rotation pattern, the mid-cycle rollover to night shifts was found to give rise to significant and adverse effects on subjective alertness and on objective performance measures. Only one measure failed to show significant effects in these analyses; consistent with other research which suggests that performance of tasks with a high short-term memory load is not impaired by circadian changes (Folkard *et al.* 1976), the more difficult version of the memory task showed no significant effects in the present work.

All the other measures (subjective alertness ratings, and performance of the simple reaction time task, the multiple choice reaction task, the single-letter memory task, and the logical reasoning test) demonstrated significant decrements in the 7D+7N rollover group as compared with the 14D group. This impairment was particularly apparent in the two shifts immediately following the rollover, but it persisted into Phase III for several measures, including subjective alertness, and the simple and multiple choice reaction time tasks. These results are consistent with evidence from onshore research on the effects of shift rotation, the demands of circadian adjustment, and associated sleep disruption (for reviews, see Wilkinson, 1992; Waterhouse *et al.* 1992).

Comparison of the 14N and 7N+7D shift patterns showed less marked effects of rollover than in the 14D *vs.* 7D+7N analysis. Nonetheless, significant and adverse effects were observed for subjective alertness, for reaction time, and for the single-target memory task. Furthermore, in no instance, were levels of performance or subjective alertness in the 7N+7D group significantly more favourable than those of the 14N group who continued to work night shifts during the second week offshore. Thus, when day shifts follow the rollover, as in the 7N+7D pattern, the potential advantages of daytime work (in terms of alertness and performance levels) are lost. This result can be compared with that for the 7D+7N rollover direction for which the favourable effects of day-shift work are apparent during the first week offshore, before the adverse effects of rollover to night work occur in the second week.

Direction of rollover. The difference between the two directions of rotation in patterns of alertness was examined in further analyses of the 7D+7N and the 7N+7D patterns. Significant differences associated with rollover direction were demonstrated in the analyses of both subjective alertness and objective reaction time. However, these effects were largely attributable to responses in the first week. For the 7D+7N group, the first week was a day-shift week with relatively stable and favourable levels of response; in contrast, for the 7N+7D group, the first week was a night-shift week with sharp decrements in alertness from start to end of individual shifts.

In other respects, there was little to chose between the two directions of rotation; both groups showed impaired alertness during the two shifts following the rollover, the effects being more marked in the 7D+7N group, when contrasted with their responses during the first (day-shift) week. Findings for the 7N+7D group were generally similar to those reported by Parkes (1993), although in the earlier study the rollover involved a work period of 24 hours with only 2-3 hours rest period between the last night shift and the first day shift. In the present work, a modified system allowing 8 hours between shifts was in operation, thus providing a better opportunity for rest.

In comparing the effects of rollover direction, it should be noted that the 7N+7D rotation (which is in widespread use in the North Sea) is implemented slightly differently by different companies and on different platforms. On the platform that participated in the present study, the start of the night-shift week was delayed until the third night after arrival, operators working three short day shifts in a backward rotation sequence before moving to night work (see Appendix I for details). Thus, as compared with patterns which schedule night-shift work from the first night after arrival (see Appendix II for examples of other 7N+7D schedules in current use), the pattern which formed the basis of the present study was more favourable in that it allowed personnel time to adjust to being offshore before they started night work. Conversely, however, the number of day shifts worked following the rollover were reduced, thus allowing less time for circadian adaptation during the day-shift phase.

'Gaps' in reaction time responses. Analysis of 'gaps' in the reaction time data (i.e. responses of longer than 1 second) threw further light on the demands imposed by rollover schedules. Overall, the rollover groups had significantly more gaps than the fixed-shift groups; this difference was particularly marked during the two shifts immediately following the rollover. This result is consistent with data reported by Totterdell *et al*. (1995) who found a high incidence of gaps during the first two night shifts following rest days.

Krueger (1989) reviews evidence linking the occurrence of gaps to sleep loss and fatigue, pointing out that a large increase occurs in the duration of the slowest reaction times although subjects can still achieve some reaction times close to their best performance. This is consistent with the present findings that showed an increase in the variability of responses as well as an increase in mean reaction time under unfavourable rotation conditions; in addition, irrespective of the particular shift pattern worked, increased variability of response time occurred across the three phases of the study, suggestive of cumulative fatigue effects.

7.1.3 Safety and health implications

Safety. In discussing the relevance of cognitive performance findings to applied settings, Rosa *et al*. (1989) draw attention to the difficulty of estimating the level of 'real-world' risk associated with decrements in performance on standard tasks. They noted *"There is no heuristic available to translate, for example, a 10% change in reaction time into some safety or health consequences"*. This observation is of course also true of the present findings relating to shift rotation. Furthermore, Rosa (1991) pointed out that in spite of the sleep and performance deficits observed, there was no evidence of 'major adverse incidents' that could be attributed to fatigue resulting from the extension of shifts from 8 hours to 12 hours, which was the focus of the study.

The present study also lacks information about relationships (if any) between accidents/incidents and the alertness and performance profiles reported. Whilst it would be potentially valuable to analyse the present data in relation to accident/injury statistics from operating company records, such data have yet to be obtained. However, decision-making, vigilance, and other information-processing skills play a important role in the work of offshore production personnel, and consequently in the safety of the installation more generally, and the cognitive tasks used in the present study represent components of these more complex skills.

Kennedy *et al.* (1993) have suggested that one way of interpreting the practical significance of performance decrements under conditions of environmental stress is to examine the magnitude of such decrements in relation to the effects of alcohol intake; thus, the suggestion is that alcohol effects could be used as a standard marker stimulus against which to assess other agents. These authors report the percentage decrements in the performance of a range of standard cognitive tasks at three BAC (blood alcohol concentration) levels, relative to a zero level.

The percentage decrements observed in the present study over the two shifts immediately following the rollover as compared with the one immediately prior to the rollover, and as compared with the corresponding 14D or 14N group, were in the range of approximately 5-10%. This range is generally comparable with the percentage decrements in performance associated with BAC levels of .10 in the data of Kennedy *et al.* Parallels such as these can only be drawn very cautiously, but they do suggest the potential value of examining indicators of 'real-world' performance, such as accidents and incidents, in relation to standardized test data.

Health. Research carried out in onshore work settings highlights the potentially adverse health effects of shift work as compared with day work; Monk and Folkard (1992) review this literature. Some evidence also suggests that health impairment occurs in past shift workers (Frese & Semmer, 1986; Vener *et al.* 1989) as well as those currently involved in shiftwork. More specifically, recent studies (e.g. Olsen & Kristensen, 1991) demonstrate that shiftwork is a risk factor for cardiovascular disease. Furthermore, prolonged exposure to shiftwork over a period of years appears to have cumulative effects on cardiovascular risk (Kawachi *et al.* 1995; Knutsson *et al.* 1986), and on sleep patterns (Foret *et al.* 1981; Parkes, 1994), which are not accounted for solely by increasing age.

Consistent with these findings, Waterhouse *et al.* (1992) noted that "The evidence in favour of the view that shiftwork is associated with an increase in cardiovascular disease is now becoming more difficult to dismiss as inconclusive" (p.20). Taken together with the observation of Gann (1989) that the death rate from coronary heart disease among offshore personnel could increase six-fold by the turn of the century, cardiovascular disease and its possible link to shiftwork are issues of potential importance to the offshore oil and gas industry.

Waterhouse *et al.* also draw attention to the link between shiftwork and digestive disorders and ulcers. Whilst the mechanisms involved are not fully understood, the authors suggest that in addition to factors such as meal times and diet, it is possible that the circadian adjustment necessitated by night work, and its effects on physiological and biochemical processes, may play a role. Similarly, Vener *et al.* (1989) discuss the possible consequences of 'internal desynchrony' among shift workers with particular reference to gastrointestinal disorders.

In the context of the present study, the possibility that the process of circadian adjustment may play a role in health problems among shift workers is relevant to the issue of shift rotation, as it suggests that rotation patterns involving a higher frequency of circadian changes are likely to be less favourable from a health point of view. In this context, it should be noted that the 14D/14N pattern involves only half as many circadian changes annually as the rollover patterns studied (see Section 1.3).

Work/home interface. The present study focused on patterns of sleep, mood and cognitive performance during the two-week offshore work cycle. The study was not designed to continue into the subsequent period of shore leave. However, it is important to note that when offshore personnel go on leave directly following one or two weeks of night shifts, the implications for alertness, cognitive performance and sleep problems are essentially similar to those which apply when the need for circadian adjustment occurs offshore. In particular, the present findings raise questions about the advisability of driving immediately after leaving the heliport, particularly if personnel have had no rest period following the final night-shift of the work cycle.

Furthermore, family and leisure activities during the initial days of shore leave are potentially disrupted by the need for circadian re-adjustment. These problems are likely to be particularly resented if, as is often the case, the leave period is restricted to two weeks. The problem of re-adjusting from night shifts during shore leave is the major reason why the (otherwise unfavourable) 7N+7D system is widely preferred by offshore personnel.

However, some changes to work/leave cycles could serve to partially alleviate the problem of re-adjusting to a normal sleep/wake cycle during the initial days of shore leave. In particular, when a 14D/14N system is in operation, it would be possible in principle to arrange work/leave schedules so that the shore leave that follows night shifts is longer than that which follows days shifts, thereby explicitly recognising the extra time required to adjust from night work. This could be achieved, for instance, among the operating company personnel in the present study, by a change from the present 2-2, 2-2, 2-2, 2-6 work/leave pattern to a 2-2, 2-4, 2-2, 2-4 pattern, with the two-week break following the 14D sequence, and the four-week break following the 14N sequence.

7.1.4 Methodology

In evaluating the findings described in this report, it is important to note the differences between the methodology adopted in the present study of mood and performance patterns in relation to shift rotation, and the survey methods used in most published research into psychosocial aspects of offshore work. In survey data, comparisons are usually made across different groups, e.g. occupational groups, or age groups, using data collected at only one point in time. This approach requires relatively large samples in order to ensure that the groups are adequately representative of the larger population, and to allow between-group differences to be identified against a background of wide variation between individuals.

The methodology of the present study involved multiple assessments of each individual, rather than only a single assessment occasion. Thus, the analysis was based on patterns of change in the same individuals over time. Furthermore, the possibility that groups exposed to different shift conditions might differ in other respects (for instance, age, personality) was taken into account by statistically controlling between-group differences unrelated to shift patterns prior to analysis (see Section 2.5.4). This type of design does not necessitate samples as large as those required in cross-sectional surveys. In statistical terms, the important factor in such analyses is the total *'degrees of freedom'* (which depends on the product of the number of subjects multiplied by the number of assessments) rather than the sample size *per se*.

In the present study, the sample sizes for the main analyses was 66, while the additional comparison of the two rollover conditions was based on a partially overlapping sample of 50 participants. These samples are comparable to, or larger than, those used in other work of this kind which has been accepted as a basis for implementing changes in work conditions (e.g. Parkes, 1995). It is also relevant that the performance data analysed were mean values based on multiple trials during each assessment. For instance, the reaction time data reported in Section 4 is derived from a total of nearly 90,000 responses. Thus, the fact that experimental approaches such as that reported here tend to use smaller samples than survey work should not be seen as detracting from the present findings.

7.2 RELATIVE MERITS OF DIFFERENT ROTATION PATTERNS

This section summarises, on the basis of the information presented in this report, the relative advantages and disadvantages of the rollover and fixed-shift rotation patterns studied (see Tables 7.1 to 7.3).

It is clear from these tables, that no one rotation pattern combines all advantages and avoids all disadvantages. Thus, no single optimum pattern exists; rather, the task is to identify one or more factors to which priority should be given in determining the most appropriate rotation pattern. To some extent, this decision will depend on particular features of different installations, the operating policies of different companies, and the preferences of the personnel concerned.

However, the major issue in designing shiftwork schedules, whether onshore or offshore, is managing circadian change. The particular constraints which apply offshore make this problem especially difficult. The results of the present study, and the literature reviewed, suggest that the over-riding concern should be to minimise the number of circadian changes to which personnel are exposed. Whilst such a strategy cannot solve all the problems of scheduling offshore shiftwork, from the point of view of performance, safety, and the long-term health of the personnel concerned, a strong case can be made for implementing rotation patterns that do not require individuals to change from day to night shifts, or *vice versa*, during the two-week offshore work cycle. An important corollary to such a policy, however, would be to examine ways of reducing as far as possible the problems experienced by personnel on alternate tours when shore leave follows night-shift work.

Table 7.1
Rollover schedule: 7N+7D

ADVANTAGES

- Widely preferred by offshore personnel. 87% of those working the 7N+7D pattern, and 73% of the survey sample analysed, opted for this schedule.
- Because personnel adjust to and from night-shift work while offshore, they are not exposed to the need for circadian change during the first few days of shore leave. Avoids the need to travel while night-time adjusted.
- Ease of scheduling as everyone works the same shift sequence on each tour.
- Only one shift team leaves each week; therefore, there is always one team to cover between departure of one crew, and arrival of the new crew.

DISADVANTAGES

- Gives rise to the largest sleep deficit over the two-week offshore work period.
- Day-shift levels of sleep, alertness, and performance are not experienced during either week of the offshore work cycle; the first week is affected by adjustment to night work, and the second week by having to re-adjust from nights to days. As adjustment to a 12-hour circadian change takes more than a week (Monk & Tepas, 1985), crews working this pattern tend to show impaired alertness and performance throughout the entire work cycle.
- Marked deterioration in alertness and performance from start to end of shifts in both the night-shift and the day-shift weeks.
- Rollover schedules involve twice as many 12-hour circadian changes annually as fixed-shift schedules, with possible long-term consequences for health and sleep patterns.
- Offshore shift change schedules are necessarily of the ‘backward’ rotation type, involving short rest periods (usually 5 - 8 hours) during the rollover, which do not allow breaks of the duration (11 hours) currently specified in EU onshore recommendations.
- Each team rotates shifts with two other teams, one in the first week and one in the second week, with possible disruption to communication and co-ordination between day and night crews.

Table 7.2
Rollover schedule: 7D+7N

ADVANTAGES

- First week of day shifts requires no circadian adaptation. Therefore, personnel have time to re-adapt to the offshore work environment before they have to adjust to night work.
- Performance, alertness and sleep during the first offshore week is not impaired by a prior week of night work.
- Ease of scheduling as everyone works the same shift sequence on each tour.
- Only one shift team leaves each week; therefore, there is always one crew to cover between departure of one crew, and arrival of the new crew.

DISADVANTAGES

- Strongly disliked. Only 16% of those working the 7D+7N pattern indicated that it was their preferred pattern, and no one working other rotation systems opted for it.
- It takes longer to recover from night shifts than from day shifts at the start of shore leave. The 7D+7N pattern requires personnel to re-adjust to a normal sleep/wake cycle during the first few days of leave after every offshore tour.
- Impaired alertness and performance during shifts immediately following the rollover. Marked performance decrements at the end of these shifts.
- Tends to produce an uneven distribution of work across the two-week offshore tour to allow lower workload during the rollover phase.
- Rollover schedules involve twice as many 12-hour circadian changes annually as fixed-shift schedules, with possible long-term consequences for health and sleep patterns.
- Offshore shift change schedules are necessarily of the ‘backward’ rotation type, involving short rest periods (usually 5 - 8 hours) during the rollover which do not allow breaks of the duration (11 hours) currently specified in EU onshore recommendations.
- Each team rotates shifts with two other teams, one in the first week and one in the second week, thereby potentially disrupting co-ordination and communication between shift teams.

Table 7.3
14D/14N Fixed-shift schedule

ADVANTAGES

- Lowest overall sleep deficit for both and night shifts
- Greater stability of subjective alertness and performance over the two-week cycle. In particular, adjustment to night-shift work is not disrupted by the need for further circadian adaptation resulting from a mid-cycle shift change.
- Little or no significant deterioration in alertness or reaction time over the course of individual shifts, either during days or, after initial adaptation, during nights.
- Of the shift patterns studied, the 14D/14N pattern requires the smallest number of 12-hour circadian changes in the course of a year (5-6 in the days-to-nights direction, depending on the work/leave pattern operated, and a similar number to return to a normal cycle). Alternate offshore tours involve only day shifts, with no major circadian adjustment required.
- The 14D/14N pattern allows the same night and day shift teams to work together through the entire two-week period, thus enhancing handover and co-ordination between the night and day crews.
- The 14D/14N pattern was advocated by Lauridsen *et al.* (1991) on the basis of an extensive survey of sleep and health among offshore shift workers.
- Among employees (mainly contractor personnel) working a regular 2-2 work/leave schedule, scores on the ‘satisfaction with shift rotation’ survey item were comparable to those for the 7N+7D pattern, and significantly higher than those for the 7D+7N pattern.

DISADVANTAGES

- Operators dislike going on leave after two weeks of night shifts, because their first few days of leave are disrupted by the need to re-adjust to a normal sleep/wake cycle. A further problem is the potential danger of driving home the day after completing two weeks of night shifts.
- Fewer than half the operators (42%) working the 14D/14N schedule preferred it; the remainder opted for the 7N+7D schedule.
- Complicates the planning of work rotas as it is necessary to schedule alternating night-work and day-work tours, rather than assume that the same rollover sequence will apply to everyone concerned on each trip.
- To ensure that essential jobs are covered at all times, the 14D/14N schedule requires two helicopter flights on same day for crew-change purposes so that the incoming day-shift team arrives before the departing team leave. Alternatively, successive crew-change days are required, one or two team members leaving on any particular day, thus potentially disrupting team cohesion.
- Low ‘satisfaction with shift rotation’ rating from operating company personnel; this view may have been influenced by dislike of their particular work/leave cycle.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the following organizations and individuals whose co-operation and assistance made this work possible.

- Major funding for the study was provided by the *Health and Safety Executive, Offshore Safety Division (HSE-OSD),* under agreement MaTSU/8550/3037 with the University of Oxford. Robert Miles of HSE-OSD, Fiona Davies of MaTSU, and Angela Einon of the Department of Experimental Psychology, University of Oxford, were responsible for liaison with HSE and general administrative assistance.

- The work could not have been carried out without the generous co-operation of the following companies: *BP Exploration Operating Company Limited, Shell U.K. Exploration and Production,* and *Texaco (North Sea) UK Co.* The assistance of the offshore and onshore managers of these companies, who arranged extended visits by the research team to each of the installations taking part, greatly facilitated the research.

- The study described in this report imposed significant demands on the time and patience of the production and control-room personnel who participated in the repeated assessments of mood and performance; the high level of motivation and commitment shown by these personnel merits particular acknowledgement.

To each and all of those concerned, the authors would like to express their sincere thanks and appreciation, and the hope that the work reported here will be of interest to them and to the wider North Sea community.

REFERENCES

BADDELEY, A. D. (1968). A 3-min reasoning test based on grammatical transformations. *Psychonomic Science*, **10**, 341-342.

BADDELEY, A. D. (1981). The cognitive psychology of everyday life. *British Journal of Psychology*, **72**, 257-269.

ENANDER, A. (1987). Effects of moderate cold on performance of psychomotor and cognitive tasks. *Ergonomics*, **30**, 1431-1445.

FOLKARD, S., KNAUTH, P., MONK, T. H., & RUTENFRANZ, J. (1976). The effect of memory load on the circadian variation in performance efficiency under a rapidly rotating shift system. *Ergonomics*, **19**, 479-488.

FOLKARD, S. (1992). Is there a 'best compromise' shift system? *Ergonomics*, **35,** 1453-1463.

FORET, J., BENSIMON, G., BENOIT, O., & VIEUX, N. (1981). Quality of sleep as a function of age and shift work. In A. Reinberg, N. Vieux, and P. Andlauer (Eds.), *Night and Shift Work: Biological and Social Aspects* (pp. 149-160). Oxford: Pergamon Press.

FRESE, M. & SEMMER. N. (1986). Shiftwork, stress, and psychosomatic complaints: A comparison between workers in different shiftwork schedules, non-shiftworkers, and former shiftworkers. *Ergonomics*, **29**, 99-114

GANN, M. (1989). *Coronary artery disease in an offshore workforce.* Thesis submitted for Diploma of Membership of the Faculty of Occupational Medicine of the Royal College of Physicians, London.

JAFFE, M. P., SMOLENSKY, M. H., & WUN, C. C. (1996). Sleep quality and physical and social well-being in North American petrochemical shift workers. *Southern Medical Journal*, **89**, 3-5-312.

KAWACHI, I., COLDITZ, G. A., STAMPFER, M.J. *et al.* (1995). Prospective study of shift work and risk of coronary heart disease in women. *Circulation*, **92**, 3178-3182.

KENNEDY, R. S., TURNAGE, J. J., WILKES, R. L., & DUNLAP, W. P. (1993). Effects of graded dosages of alcohol on nine computerized repeated-measures tests. *Ergonomics*, **36**, 1195-1222.

KNAUTH, P., & RUTENFRANZ, J. (1982). Development of criteria for the design of shiftwork systems. *Journal of Human Ergology*, **11**, 337-367.

KNUTSSON, A., AKERSTEDT, T., JONSSON, B., & ORTH-GOMER, K. (1986). Increased isk of ischaemic heart disease in shift workers. *Lancet*, **2**, 89-92.

KRUEGER, G. P. (1989). Sustained work, fatigue, sleep loss and performance: A review of the issues. *Work and Stress*, **3**, 129-141.

LAURIDSEN, O., TRONSMOEN, S., BERLAND, J., GITLESEN, J .P., RINGSTAD, A. J., *et al.* (1991). *Shift-work and health: Shift-work, sleeping difficulties, psycho-social work environment and psychosomatic complaints*. Rogaland Research / Phillips Petroleum Company, Norway.

MEIJMAN, T., VAN DER MEER, O., & VAN DORMOLEN, M. (1993). The after-effects of night work on short-term memory performance. *Ergonomics*, **36**, 37-42.

MONK, T. H., & FOLKARD, S. (1992). *Making shift work tolerable*. London: Taylor and Francis.

MONK, T. H., & TEPAS, D. I. (1985). Shift work. In: C. L. Cooper and M. J. Smith (Eds.), *Job Stress and Blue Collar Work.* Chichester: Wiley.

OLSEN, O. & KRISTENSEN, T. S. (1991). Impact of work environment on cardiovascular diseases in Denmark. *Journal of Epidemiology and Community Health*, **45**, 4-10.

PARKES, K. R. (1993). *Human Factors, Shift Work, and Alertness in the Offshore Oil Industry*. Report OTH 92 389. London: HMSO.

PARKES, K. R. (1994). Sleep patterns, shift work, and individual differences: A comparison of onshore and offshore control-room operators. *Ergonomics,* **37**, 827-844.

PARKES, K. R. (1995). The effects of objective workload on cognitive performance in a field setting: A two-period cross-over trial. *Applied Cognitive Psychology*, **9**, S153-S171.

PARKES, K. R., STYLES, E. A., & BROADBENT, D. E. (1990). Work preferences as moderators of the effects of paced and unpaced work on mood and cognitive performance: A laboratory simulation of mechanized letter sorting. *Human Factors*, **32**, 197-216.

PARKES, K. R. & CLARK, M. J. (1996). *Psychosocial aspects of work and health in the North Sea oil and gas industry.* Part IV. The offshore environment in the mid-1990's: A survey of psychosocial factors. Report OTH 96 530. Sudbury: HSE Books.

ROSA, R. (1991). Performance, alertness, and sleep after 3.5 years of 12 h shifts: A follow-up study. *Work and Stress*, **5**, 107-116.

ROSA, R. R., WHEELER, D. D., WARM, J. S., & COLLIGAN, M. J. (1985). Extended workdays: Effects on performance and ratings of fatigue and alertness. *Behavior Research Methods, Instruments, and Computers*, **17**, 6-15.

ROSA, R. R., COLLIGAN, M. J., & LEWIS, P. (1989). Extended workdays: Effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables. *Work and Stress*, **3**, 21-32.

ROSA, R. R., & BONNET, M. H. (1993). Performance and alertness on 8 h and 12 h rotating shifts at a natural gas utility. *Ergonomics*, **36**, 1177-1193.

RUTENFRANZ, J., PLETT, R., KNAUTH, P., CONDON, R., *et al.* (1988). Work at sea: a study of sleep and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels. II. Sleep duration, and subjective ratings of sleep quality. *International Archives of Occupational and Environmental Health*, **60**, 331-339.

SMITH, A. P., & MILES, C. (1987). The combined effects of occupational health hazards: an experimental investigation of the effects of noise, nightwork and meals. *International Archives of Occupational and Environmental Health*, **59**, 83-89.

STERNBERG, S. (1966). High-speed scanning in human memory. *Science,* **153**, 652-654.

TOTTERDELL, P. & FOLKARD, S. (1992). In situ repeated measures of affect and cognitive performance facilitated by use of a hand-held computer. *Behavior Research Methods, Instruments, & Computers*, **24**, 545-553.

TOTTERDELL, P., SPELTEN, E., SMITH, L., BARTON, J. & FOLKARD, S. (1995). Recovery from work shifts: How long does it take? *Journal of Applied Psychology*, **80**, 43-57.

TORSVALL, L. & AKERSTEDT, T. (1988). Disturbed sleep while being on-call: an EEG study of ships' engineers. *Sleep,* **11**, 35-38.

VENER, K. J., SZABO, S. & MOORE, J. G. (1989). The effect of shift work on gastrointestinal (GI) function. *Chronobiologia*, **16**, 421-439.

WATERHOUSE, J. M., FOLKARD, S., & MINORS, D. S. (1992). Shiftwork, health and safety: An overview of the scientific literature 1978-1990. HSE Contract Research Report No. 31/1992. London: HMSO.

WILKINSON, R. T. (1992). How fast should the night shift rotate? *Ergonomics*, **35,** 1425-1446.

WILKINSON, R., ALLISON, A., FEENEY, M., & KAMINSKA, Z. (1989). Alertness of night nurses: Two shift systems compared. *Ergonomics*, **32**, 281-292.