Research Project 461 APPENDIX 1

FATIGUE, HEALTH & INJURY AMONG SEAFARERS & WORKERS ON OFFSHORE INSTALLATIONS: A REVIEW

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September 2000

ISBN: 1-900174-12-X

The analysis presented in this publication is the author's

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A REVIEW OF RESEARCH ON FATIGUE, HEALTH AND INJURY OFFSHORE

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EXECUTIVE SUMMARY:

The purpose of this literature review was to identify existing research into fatigue, health and accident rates among employees engaged in exploration, production and support roles in the offshore oil industry. Although the contribution of fatigue to accidents has been extensively researched in other industries, findings cannot automatically be applied to the offshore industry. This is because of the unique combination of conditions offshore workers cope with, including motion, extreme weather, noisy working conditions and demanding work and rest patterns. The offshore oil industry has gone through major economic, structural and technological changes in recent years, leading to reduced manning of rigs and ships, increased automation, increased workload and decreased job security (e.g. Collinson, 1998; NUMAST, 1992). This has put increased pressure on both seafarers and oilrig workers who often feel obligated to work extra hours and shifts in order to keep their jobs.

More research has been carried out amongst oilrig workers than seafarers, although even the oilrig research is not extensive. The main findings of the oilrig research show:

- Tours exceeding 2 weeks, with shift durations over 8 hours and including night shifts all appear to have serious implications for workers in terms of increased accident rates.
- Environmental factors are related to adverse subjective and objective health outcomes.
- Elevated levels of self-reported anxiety, perceived risk and workload, dissatisfaction with shift schedules, living conditions and sleep problems are evident and reflected in formal health and absenteeism records.
- Performance and alertness levels are affected by rotating shift schedules.

- Circadian adaptation possible on nightshifts, especially for fixed shift schedules.
- Adverse physiological changes related to tour lengths exceeding 1 week.

Seafaring research indicates that:

- Accident risk is greatest during the early hours of the morning, suggesting a circadian influence. Fatigue has been proposed as a contributory factor.
- Seafarers report elevated levels of anxiety, perceived work load, dissatisfaction with shift schedules and sleep problems.
- Environmental factors are related to sleep disturbances, fatigue and stress.
- Motion adversely affects cognitive and psychomotor performance.
- Circadian adaptation can only be partially achieved at best on 4-on/8-off shift pattern.

The literature also highlighted an important difference between oilrig workers and seafarers:

- Oilrig workers show circadian adaptation to night shifts while seafarers do not.
- Accident reporting is more detailed for the oilrigs than on support vessels.

Unfortunately, direct comparisons between oilrig workers and seafarers cannot be made since there have been few studies of seafarers, and these few have been limited and focused on different aspects of work patterns and the working environment. Furthermore, accident and injury studies of seafarers have paid little attention to factors such as:

- Hours-into-shift, days-into-tour, job area, risk perception, personality characteristics, time of day of the incident.

However, on rigs and vessels alike, reporting of accidents needs to be more formal and systematic with enough detail to enable investigation of the underlying causes of accidents and make comparisons between the different aspects of the offshore oil industry. One of the major problems for both industries is the lack of exposure data, which makes it impossible to calculate accurate accident rates.

Studies to date have tended to focus on one sector of the offshore oil industry, namely rigs, and when this is coupled with methodological differences between studies it fails to give an accurate picture of the offshore oil industry as a whole. Sample sizes also tend to be very small which makes it hard to draw firm conclusions. Future research needs to encompass a range of issues that affect offshore workers because it is the combination of factors that make the offshore oil industry unique.

Aims

Our main objective therefore in compiling this review follows from Brown's (1989) assertion that long hours are a major contributor to fatigue and accidents at sea. We seek to identify any existing literature that examines the nature of fatigue, health and injury in the offshore oil industry. More specific aims are as follows:

1. To identify the extent and nature of research into accident and injury occurrence in seafarers and oil rig workers and to determine to what extent fatigue can be considered a causal factor;

2. To examine self-reports of stress, health and fatigue and identify the scale of the problem in these various occupational groups;

3. To identify environmental factors contributing to stress, poor health and fatigue;

4 To identify any objective studies of the effects of work schedules, stress and fatigue on performance, and physiological state;

5 To draw comparisons between the literature available on offshore platforms and vessels, and identify any gaps in current knowledge.

Nature of Search

In order to identify as many suitable sources of information as possible, a number of on-line searches were undertaken. The following were entered as search terms on ‘Psychlit’, ‘Ergonomic Abstracts’, ‘BIDS’ and ‘Medline’*: seafarers, seafaring, sea, maritime, sea pilots, fatigue at sea, offshore fatigue, accidents at sea, short sea shipping, shipping, Ivan Brown.* Web sites for the following organizations were also searched for relevant information: The Marine Accident Investigation Branch (MAIB), The Australian Maritime Safety Authority (AMSA), The US Coastguard, The Department of Environment and Transport for the Regions (DETR), The UK P & I Club, and Lloyds. In addition, bibliographies of existing studies and IMO Library Information Services Searches were consulted for informal sources (for full citations, see references section).

BACKGROUND*:*

The Offshore Industry

The offshore oil industry can be generally divided into two occupational groups, namely personnel working aboard ships, and those working on installations. Although both industries are similar in terms of working away from home, the inhospitable weather conditions, and the demanding work and rest patterns, many differences do exist between them such as the differing tour lengths, shift and rest patterns, vessel structure and physical conditions. Furthermore, the research areas covered within the two industries vary enormously. For the purpose of this study, in which a comprehensive comparison of the two groups will be made in terms of fatigue, health and accidents and injuries, both sectors will be considered individually. An evaluation of the relevant - albeit limited in some areas - research into the issues described will follow for both areas. The review will encompass reports of accident and injury data, questionnaire surveys of fatigue, health & stress; objective measures of performance effects; and physiological measures of stress, fatigue & circadian adaptation.

The Problem of Fatigue

A great deal of evidence exists regarding the effects of fatigue in industry generally. It is widely accepted that night shiftwork, circadian disruption, sleep loss, long working hours, monotonous and unstimulating tasks lead to lowered alertness, decreased vigilance and a build-up of fatigue (May & Kline, 1987; Finkelman, 1994). Most studies identifying the problem of fatigue in the transport industry have supported this assumption, and have linked the effects of fatigue to performance deficits, human error, and accidents (May & Kline, 1987; Buck & Lamonde, 1993; Brown, 1994; Rosekind et al, 1994; Dinges, 1995; Horne & Reyer, 1995; Folkard, 1997). However, these results cannot simply be generalised and applied to the offshore oil industry. For example, it has been shown that contrary to onshore workers, offshore platform personnel can adjust to night shift work (e.g. Arendt & Deacon, 1997; Barnes, 1998a/b) indicating that once offshore, circadian rhythms adapt to the environment. The offshore oil industry is vastly different from other transport industries and is unique in terms of the various combined effects of the specific offshore conditions. According to Smith (1999), the magnitude of effects depends upon the combination of a number of factors such as design of the vessel, motion, vibration, visual and manual problems associated with motion, motion sickness, workload, shiftwork, loss of sleep, lighting, noise and other aspects of the physical environment. These factors in addition to other variables such as health status, experience, psychosocial occupational stressors, and stressors associated with the conflicting demands of work and home, are potentially suggestive of chronic fatigue effects with dire consequences, culminating in performance deficits, human error and compromised health and safety. Relative to the offshore oil industry, research into other industries does not reflect the number of potential risk factors and their cumulative effects in terms of fatigue and detrimental outcomes. It is clear that in order to obtain an accurate picture of the extent of fatigue and its effects on rigs and support vessels, more specific research needs to be conducted in the field.

Anecdotal Evidence

There are a number of areas specific to platforms that have been linked with fatigue, performance efficiency, health, and injury (Parkes, 1994; Dinges, 1995; Spurgeon et al., 1997; Smith, 1999). Due to the nature of the work, it is well documented that occupational factors such as arduous shift systems, excessive hours, sleep disturbance, high workload, motion, vibration, noise, temperature variations, and social isolation are reported to be commonplace in the industry (Parkes, 1994; 1997; 1998; Parker et al., 1995; Elliot, 1985). The above factors either alone or in combination, have been proposed to contribute to the extent of the problem of fatigue, health, and accidents and injuries in the offshore oil industry albeit with limited empirical support. It is apparent that although a sizeable literature of anecdotal evidence exists, up until now little valid and reliable research has been conducted in the area.

Shiftwork

The duration of shift schedules is one of the greatest causes for concern in the offshore oil industry generally. Onshore shift work in general appears to generate a series of health problems, for example, gastrointestinal, and cardiovascular disorders, chronic sleep problems and mood disorders (Moore-Ede, 1993). In addition, onshore studies have supported the view that working in excess of 50 hours per week increases occupational stress (Spurgeon et al., 1997). It has been argued that the relationship between hours of work and ill health is mediated by stress; directly in terms of the stressor, by increasing the demands on the worker attempting to maintain performance levels whilst experiencing increasing fatigue; and indirectly through increasing the time that an individual is exposed to other sources of stress in the workplace (Spurgeon et al., 1997). Furthermore, shift work and long working hours have been cited as the cause of many industrial accidents. It has, for example, been proposed that long working hours contributed to disasters such as Bhopal, the Exxon Valdez and Chernobyl (Demos, 1995).

Excessive Work Hours

The evidence that excessive working hours, insufficient rest periods and high workload can lead to sleep deprivation, fatigue, stress, mental and physical health problems, poor performance efficiency and compromised safety onshore (Spurgeon et al., 1997) has significant implications for those working in the offshore oil industry. Statistics suggest that at least half of all seafarers work hours in excess of 80 hours per week (Rogers, 1998) and installation workers reportedly work similar hours (Parkes, 1994) with around 20% of day workers and 8% of night workers working over 100 weekly hours (Miles, 2000). Rest periods are frequently disturbed by noise, motion, vibration, fumes and the anticipation of being woken (Smith, 1999; Torsvall, 1987) and due to reduced manning on offshore installations, workloads are becoming more intensive (Parkes, 1998). These factors in combination with social isolation, and coping with the demands of fluctuations in workload, inevitably lead to an increase in fatigue and stress (Smith, 1999; Collinson, 1998; Pollard et al., 1990).

Fatigue & Accidents Offshore

Amongst others, Brown (1989) asserted that fatigue should be considered as creating an increased risk of accidents (see also Phillips, 2000). According to anecdotal reports, fatigue, and consequently lowered vigilance and alertness, has repeatedly been associated with accident occurrence (Lauber & Kayten, 1988). MAIB statistics show that in 86% of reported accidents at sea, sleep was cited as a causal factor (Phillips, 2000). As with other transportation modes, research has shown that marine accidents are more inclined to occur on night shifts (e.g. Monk, 1986), that is, after midnight and during the early morning hours (e.g. Phillips, 2000; Sanquist et al., 1996) when alertness and vigilance and performance levels are generally at their lowest (see review by Campbell, 1992). Some maritime watch scheduling systems have been found to increase fatigue and therefore accidents, more than others. A common shift system is the 6 hours on, 6 hours off schedule used on board the ill-fated oil tanker Exxon Valdez that ran aground in 1989. It has been estimated that during the 24 hours prior to the accident, the watchkeeper only obtained approximately 5 or 6 hours sleep, taken in two separate periods: fatigue was therefore suggested to be a contributory factor in the incident.

FATIGUE, HEALTH, ACCIDENTS AND INJURY ON OFFSHORE INSTALLATIONS:

Risk Factors

There are numerous potential hazards to the health and safety of personnel working in the offshore oil industry. The work combines the threat of commonplace industrial dangers with some more specific to the environment such as fires, explosions, blow–outs, and dangers associated with drilling operations and diving accidents, as well as the risks of helicopter transportation (Mearns & Flin, 1996). As discussed by Collinson (1998), since the beginning of North Sea exploration in 1975 over 400 workers have died and many others have been seriously injured in offshore accidents (Woolfson et al., 1997). However, House (1985) proposed that "most offshore accidents are due neither to unfamiliar technology nor to particular hazardous weather and climatic conditions. Rather, like accidents in other industries, they are due to human error and faulty machinery and equipment" (p.32). Given that the advancements in technology offshore has meant less equipment failures, the role of human error has become more apparent, with safety experts now estimating that 80-90% of all industrial accidents can be attributed to 'human factors' (Hoyos, 1995). Early on, Perez (1979, cited by Sutherland & Flin, 1989) proposed that the high offshore accident rate is due to the conditions and pressures associated with offshore employment. Therefore, it can be proposed that given the long working hours and demanding shift schedules, fatigue is a major factor in the cause of many incidents in the offshore oil industry attributed to human error. Objective research in the area has so far avoided the investigation of fatigue in any real detail or specificity, and linking fatigue to incidents on installations is notoriously difficult due to relevant information such as the physical and mental states of individuals involved, being left unrecorded. However, it must be understood that the concept of fatigue is tied up with the many other variables embroiled in the conditions and experience of working in the offshore oil industry, that *have* been covered. As a result of investigations up until now, inferences must be made to a certain extent from the reported effects of shift work, working hours, environmental conditions, stress and health, and their relationship to fatigue and consequently, accidents and injury, until further research warrants definitive conclusions to be drawn. For the purpose of this review, accident and injury analyses, survey data, performance assessments and physiological data will be discussed below within the context of the impact of working within the offshore oil industry on health and safety.

Changes to Work Conditions on Offshore Installations

In recent years, major economic, structural and technological changes have been implemented in the offshore oil industry, resulting in down-sizing, redundancies and job insecurity (Parkes, 1998; Collinson, 1998). As a result, remaining employees are left to cope with increased workload and work range, in addition to recognized work factors such as demanding and fluctuating work schedules, limited rest patterns, and the challenging environmental conditions associated with such an industry. Unlike many onshore shift patterns, the norm for shift schedules on offshore installations is 2-week cycles with weekly-rotated shifts involving at least 12 hours duty, alternating with 12hr rest periods (McPhereson, 1993). A shift schedule such as this is reported to discourage the opportunity for circadian adaptation, and thereby increases mental fatigue and reduces alertness in workers (Parkes, 1994; Colquhoun et al., 1987; 1988). As a result of such shift patterns, a 24 hour period of sleep loss is a recurring consequence, especially at shift changeover time when for example personnel have worked seven 12 hour night shifts, followed immediately by seven 12 hour day shifts, often resulting in sleepiness, negative mood and poor cognitive task performance (Babkoff et al., 1988; Englund et al., 1985; Mikulincer et al., 1989; Wilkinson and Houghton, 1982 – all cited in Parkes, 1994). Furthermore, rotating shift systems have been reported to cause more subjective sleep problems than fixed shift systems (Lauridsen et al. 1991). In addition to the above, Collinson (1998) acknowledged in a review of shift work and its effects within the offshore oil industry, that there is a lack of stable employment with most positions occupied by contractors and sub-contractors.

Sickness benefit, holiday provision, employment protection and privacy are also lacking. Personnel often feel obligated to work longer hours and shifts than recommended simply to hold onto their jobs. Pressures such as these can lead to cumulative fatigue, financial, psychological and emotional tensions at home and at work, and it is clear that this in turn could have unfavorable consequences in terms of health and well being and safety on installations due to lowered alertness, vigilance and performance efficiency. Having said that, conditions do seem to be changing for the better at least in some offshore oil sectors, although the same might not be true of the UK sector where workers are reported to have little faith in the safety committee system (Whyte, 1998). In two previous surveys carried out by Rundmo and colleagues (1992; 1998) to compare how stress, conditions and safety attitudes have changed in recent years from 1990 to 1994 in the Norwegian sector, it was found that personnel reported less stress, work load demands and worries about safety in 1994 compared to 1990. To determine the extent of the problem that working on installations has on the workforce, the effects of the aforementioned external and internal factors will be discussed, and the evidence for their relationship with fatigue, health, stress, accidents and injuries will be evaluated.

ACCIDENT DATA AND ANALYSES:

Table 1. Annual Incident Numbers prepared by MaTSU for the HSE.

Year	Fatalities and Serious Injuries	Over 3 day Injuries	Totals
1991	92	638	730
1992	87	510	597
1993	63	456	519
1994	45	280	325
1995	48	352	400
1996*	46	319	365
1997	66	298	364
1998	86	236	322
Totals	533	3089	3622

* Two database reports: OIR9A and 9B data combined for 1996

Reference: HSE Offshore Technology Report OTO 2000 002

Accident and incident statistic reports prepared by the HSE examining accidents and injuries occurring annually on fixed and mobile installations in UK waters (refer to Table 1 above), indicated that accident and injury incidence rates (per 100,000 employees) have fallen since 1991, with 7.4 fatalities in 1996/97 compared to 39.2 in 1991/92 and major injuries falling from 219.9 to 93.1. Injuries over 3 days have also fallen from 1991's 1719.9 to 1997's 1221.5. However, the number of fatalities and injuries over 3 days have risen since the all time low between 1993 and 1995 of around 3 and 1000 respectively, per 100,000 employees. It must be stated though, that this pattern merely reflects the particularly low number of incidents in 1994. On the whole, excluding 1994, incidents have shown a year-by-year decrease from 1991, with 730 incidents, to 1998, with 322 incidents. While one can draw the general conclusion that incidents are on the decline in the offshore oil industry, overall, one cannot rule out the effect that different or poor methods of reporting incidents, and unavailable data could have on the accuracy of reports such as those above. There is an obvious need for more research in the area to determine the underlying cause of accidents and injuries on installations. Recent studies have endeavoured to pinpoint the causal factors of accidents and injuries and therefore propose methods of reducing the extent of the problem.

Accident Investigation

Several reports exist that have recently examined accident and injury data in relation to temporal and occupational factors (e.g. Parkes & Swash, 1999; Jeong, 1999; Hanecke et al., 1998; Williamson & Feyer, 1995; McNabb et al., 1994; Laundry & Lees, 1991; Sutherland & Cooper, 1991). The literature to date has taken two forms of investigation. Self-report surveys, the results of which must be interpreted with caution due to the weakness of circular causation inherent, and analysis of industry wide databases, a method also with associated weaknesses; i.e. absolute injury and/or accident rates cannot be calculated, as estimation of the size of the exposed population is usually impossible. As a result, researchers must attempt to estimate exposure data, or assume correlations where comparisons are unequivocal, thereby producing somewhat questionable results that may not reflect actual circumstances. However, these problems can and have been overcome, and it is evident overall that certain significant trends in the accident and injury data do exist. Furthermore, it is apparent that the rise in accidents and injuries on offshore oil and gas installations has clear links to certain tour lengths, shift systems and schedules, excessive working hours, environmental factors and the personal characteristics of the work force involved. The evidence for the above factors will be discussed below.

Days into Tour

The majority of personnel working on offshore installations work tours of two weeks on and two weeks off, though work duties can vary from one week to more than 2 weeks offshore. Forbes' (1997 – cited by Parkes and Swash, 1999) study into the relationship between accidents on the drill floor of a major offshore installation and days-into-tour showed that accidents decreased in the second week, with accidents initially showing a marked increase on the first day after a shift change, among those working rollover patterns. This finding indicates the adverse effects of rotating shift patterns most probably through adaptation difficulties and sleep loss following the shift switch. Surprisingly, there was also a trend for those working fixed shifts to show an increase in accidents on days 5 and 6. A report by Parkes and Swash (1999) for the HSE based on 3 large industry injury databases, showed that there was an increased risk of serious injury relative to less serious injuries lasting 3 or more days, with increasing days into tour ($p<0.0005$) and the same was true for fatalities and 3 days plus injuries ($p<0.05$). Furthermore, where days into a tour exceeded 2 weeks in duration, the ratio of fatalities and serious injuries to injuries lasting more than 3 days, increased significantly. This highlights the possibility that the longer the tour of duty, the more likely personnel are to feel fatigued, less alert, and therefore more inclined to make more serious errors and cause accidents as a result. The study indicated the significance of working beyond the 2-week marker. However, the statistics must be viewed with caution given that absolute injury rates could not be calculated due to the absence of exposure data.

Shift Schedule & Injury

Most data from offshore installations relate to the 12-hour shift pattern that is standard. Laundry and Lees (1991) used accident and employment records in a comparison of 10 years before and after a shift change from 8-hour to 12-hour shifts. They and found that although on the whole, on-the-job injuries decreased with the 12-hour shift system, in both systems, accidents occurred more frequently during the day even though production and work rates remained at the same level. Furthermore, injury occurrence was not related to time-into-shift. However, it must be stated that injuries in this instance referred only to minor work-related injuries and it will be shown that other studies have found significant results when more serious injuries are considered. In contrast to Laundry and Lees (1991) findings but in agreement with Jeong, (1999) and Williamson and Feyer, (1995), Parkes and Swash (1999) found that the distribution of injury severity was significantly different on the night shift as opposed to the day shift ($p<0.0005$). Twice as many fatalities and serious injuries were found to have occurred on the night shift. Furthermore this effect was found to be independent of days into the tour. Miles (2000) cites an HSE research project investigating drill floor accidents with regard to shift patterns, time of day and time of year for the following shift patterns: 0000-1200/1200-0000 and 0600-1800/1800-0600. It was found that there was no difference in the number of incidents between the two shift patterns, though season did significantly affect the number of incidents on both shifts ($p<0.05$). It was also shown that time of day affected the results ($p<0.05$) with more incidents occurring around midday for both shift patterns and around crew changeover days (50% more incidents occurred around this time though the number of incidents was a low 16), with an increase around midnight for the 12-12 shift in winter. It was further shown that more well kicks (dangerous well-control incidents that are costly in terms of lost production time) are taken in darkness and between 1800 and 0600 by the 12-12 shift, than the 6-6 shift where no kicks in darkness were reported for summer. This latter discovery is significant in its support for the argument that adjustment issues should be paramount in shaping shift schedules and patterns.

Injury & Hours into Shift

Parkes and Swash (1999) observed that with regard to the relationship between injury and hours into shift, injury severity was generally independent of hours into shift until divided into 2 groups of the first and second 12 hours of the day, whereby it was apparent – especially for drillers ($p<0.05$) - that more serious injuries and fatal injuries occurred in the latter half of the day ($p<0.01$). This indicates that drillers are particularly susceptible to serious accidents if their shifts exceed 12 hours. In another recent study, Hanecke et al (1998) analysed a large sample of German accident data (1.2 million accidents from 1994) and estimated exposure rates from the available survey data. Again, in accordance with Laundry and Lees (1991), the results did not indicate an increased risk of accidents with night work. The findings did however show that accident risk gradually increases over the first 5 hours of the working day, then decreases between the 6th and 7th hour before increasing in an exponential fashion beyond the 8th or 9th hour. This result was particularly significant given that there is a 12-hour shift schedule norm on offshore installations. Furthermore, an interaction between time of day and hours at work was evident and demonstrated that the risk of having an accident after a certain number of hours at work depended on the work start time. The results indicated that the further displaced the start time was from a normal work schedule, the higher the risk of accident incidence (i.e. 14:00 and 22:00 rather than 06:00). This is significant if it is considered that drillers for example, usually change shifts at noon and midnight, both start times being significantly displaced from the 'norm'. However, Forbes' (1997 – cited by Parkes & Swash, 1999) study showed that injury rates among drillers although elevated in the first hour, tended to decrease over the successive 12 hours of the shift. Parkes and Swash (1999) found that in terms of clock hours, serious injuries were relatively more frequent around shift handover periods. Furthermore, for all 2-hour time periods (except 23:00-01:00) more injuries with duration in excess of 3 days occurred than serious injuries. This pattern was reversed between the hours of 23:00 to 01:00 due to a high rate of serious and fatal injuries in this time period. Unfortunately, the relationship between injuries and clock hours was not investigated with relation to job type or work area.

Injury Rate, Severity & Injured Body Parts

In the report by Parkes and Swash (1999), the trend shows that the proportion of injuries in the most severe category increases with tour length ($p<0.0005$). Furthermore, the risk of serious injury increased significantly if tour length exceeded the 2-week marker. The body parts most likely to be injured were the arms, hands and shoulders, accounting for 32%, 38.6% and 31.4% of total injuries respectively. These areas accounted for the majority of the crush injuries. Leg injuries were the next frequent category, with sprains and strains accounting for the majority of the injuries to the legs. It was apparent that injury types differed across jobs and shift types. The most common incident types were found to be slips/trips/falls, handling, use of machinery, and lifting/crane operations, which were distributed differently across work areas.

Job Area

McNabb et al. (1994) examined a large database of 5251 accidents occurring on the drill floor between 1988 and 1990 from a worldwide association of drilling contractors, which included exposure data. It was found that floormen, roustabouts and derrickmen accounted for 74% and 64% of non-fatal and fatal injuries respectively when compared with other occupations, with injuries to the upper extremities occurring most frequently. According to Parkes and Swash's (1999) report, drillers accounted for 17.6% of the proportion of fatal and serious injuries, which was higher than other work areas such as construction/modifications/ deck work and production/maintenance work with proportions of 14% and 8.4% respectively. This could possibly support Laundry and Lee's (1991) proposal that more injuries occur as a function of shift start-time displacing from the norm, which was held as particularly significant for drillers. Further analysis by Parkes and Swash found that injury severity as a function of hours into shift only differed with the drilling personnel and not other work areas. It was shown that drillers had an increased risk of serious injury if their shift exceeded the 12-hour mark although during the normal 12-hour shift, injuries in general showed a peak occurrence between the hours of 02:00 and 06:00. This was in contrast to Forbes' (1997) finding that accidents decrease over the hours of a 12-hour shift, and does not support Haneckes' (1998) model of higher accident occurrence beyond the 9-hour mark. Parkes and Swash also found that among drillers, tour lengths greater than 2 weeks did not give rise to a higher proportion of injuries, as the ratio of injuries to drillers in general was more pronounced in the first 2 weeks. It is more likely that the results point to the high risks generally associated with drilling work and increased machinery handling and therefore a higher likelihood of accident occurrence as indicated by previous data (e.g. Hellesoy, 1985; Forbes, 1997; McNabb et al, 1994).

Personal Factors

According to Rundmo et al (1998) in addition to external factors on installations, job stress and physical workload may impair personnel's ability to avoid dangers and increase perceived risk due to the threat of working in such an environment (Caplan et al., 1975). In combination these factors may result in risk behaviour and accidents. The discovery that Norwegian sector personnel reportedly felt safer in 1994 (n=915) than in 1990 (n=1138, p<0.0001) (Rundmo, 1996) is, according to Rundmo (1998), a reflection of the changes in organizational and safety factors that have been implemented since the Piper Alpha disaster, and furthermore due to worker's satisfaction with the changes that have taken place. Similar results have been noted in the UK sector (Alexander et al., 1995; Flin et al., 1996a, 1996b, all cited by Mearns et al., 1997). Mearns et al. (1998) note that expectations, assumptions, values, norms and experiences of individuals may play a greater part in safety than a cohesive safety culture, and so must be addressed accordingly to create a good safety climate. In support of previous proposals, a subsequent survey by Rundmo (1998) demonstrated that where offshore personnel reported greater satisfaction with (as opposed to presence of) safety and contingency measures (i.e. personal protective equipment, alarm systems, safety training) in 1994 compared to 1990, a corresponding risk perception and reduction in risk behaviour among the personnel followed. Although any number of reasons may exist to explain the results of such studies, (i.e. the limitations of self-report measures) despite high response rate of 87-92% in Rundmo's (1998) study, the results do not tie in with the reduction in accident statistics observed in 1993/94 compared to 1990/91 as reported by the HSE. However, this may simply reflect the better safety standards and technological developments on the whole within the industry.

Personality Characteristics

In terms of the impact of personality characteristics, Sutherland and Cooper (1991) investigated the 'personality-variables' that mediate the response to stress and health outcomes or accident involvement by conducting a self-report 1-year follow up postal survey among 360 personnel in the offshore oil and gas exploration industry. Based on the present recession in the industry, added to the increased use of technology and characteristics of the job such as social isolation, hazardous, dangerous and 'unnatural' living conditions, Sutherland and Cooper (1991) proposed that conditions of uncertainty and insecurity have arisen within the workforce and the resultant circumstances are rife for a higher likelihood of accident occurrence. It was found that of 91 incidents, 29% of the offshore population reported involvements in an accident leading to personal injury. Of those, 53% reported injuries of more than 2 days duration, and 56% required a hospital visit. Furthermore, consistent with a previous study (Sutherland and Cooper 1986; Cooper and Sutherland, 1987), although most of the study population (73%) were observed to have a Type B pre-disposition, those individuals reporting Type A behaviour characteristics and neuroticism (with distributions similar to Type A) also reported higher accident involvement in terms of frequency and repetitiveness. The explanation for the Type A association is unclear. It was suggested, in line with Ward and Eisler's (1987, cited in Sutherland & Cooper, 1991) rationalisation, that Type A's tend to set personal goals in excess of performance potential and that Type A workers may take on more work load and are therefore more likely to have an accident than type B's. Sutherland and Cooper (1991) stated that improved person-job fit in the form of selection, assessment and training would cut down the negative costs of working in the offshore oil industry. Although observations from this study provide some insight into the possible cause of accidents and injuries in the offshore oil industry and may lead to suggestions for improvement, one must be wary of interpreting the results, especially with the resultant low response rate of just 32%. Questionnaire investigations and therefore the relationships observed in the study cannot be taken as linear.

Summary Of Accident & Injury Analyses

On the whole, reports indicate that numerous accidents and incidents offshore can be attributed at least in part to human causation in addition to environmental and external causes, and in some cases, can be associated with factors inherent in the person. More importantly, the findings highlight the potentially adverse effects of tour durations longer than the normal pattern of two weeks, and of shift lengths extending beyond 12 hours. It has become evident that stricter regulations are necessary to enforce a maximum of 12-hour shift schedules, and limit the length of tour duty to ensure the safety of the installation workers and the environment. However, although the benefits of shorter tour durations and shift schedules have been outlined, one must bear in mind that personnel are often more than willing to work excessive hours for tour periods longer than deemed safe, simply because whilst offshore, they would rather work and earn extra money than spend free time with limited recreational facilities. Furthermore, two weeks spent offshore means two weeks of allocated leave – often viewed as the main attraction of working in the offshore oil industry (Collinson, 1998). In addition, it must be stated that there are many deficiencies in the reporting of accident data, on which analyses are based. In order to identify risk factors in the offshore oil industry, better accident and injury reporting methods and estimates of the working population need to be installed and enforced, to ensure that all the relevant figures are available to enable accurate reporting of accident and injury statistics. Furthermore, at present nothing is known about the incidence of accidents and injuries during leave time, even though these may well indicate the after-effects of fatigue. Future reporting methods should incorporate this information to gain an idea of the extent of the consequences of working on offshore installations.

SURVEY REPORTS OF FATIGUE, STRESS, HEALTH AND ILLNESS:

Self-Report

Working in the offshore industry has often been associated with higher levels of self-reported stress due to factors such as social isolation and confined living space, the physical environment, arduous shift patterns, and fluctuating workload demands among many other variables (see the review by Parkes, 1998). However, in recent years, changes within the industry have demanded more of the remaining workers in terms of efficiency and flexibility. Therefore, it is necessary to review more recent evidence of the incidence of self-reported health, stress and fatigue in installation workers. Although platform personnel are often described as forming a 'healthy worker' group reflecting the high medical standards required of them, when compared to onshore occupational groups, they reportedly have significantly higher levels of free-floating anxiety (Cooper and Sutherland, 1987) and higher symptom scores on the GHQ (Banks et al, 1980, cited in Parkes, 1998), despite the evidence that installation workers on the whole show ‘stable extravert’ personality characteristics (Parkes, 1993), a supposedly adaptable personality trait. Parkes (1993) found evidence in support of this from a questionnaire survey of 172 control room operators offshore, whereby workers showed greater anxiety, sleep problems, dissatisfaction with shift schedules and higher perceived workload. This suggests “that psychosocial stressors in the offshore environment may play a significant role in mental health” (Parkes, 1998). However, Gann et al (1990) administered a short anxiety and depression questionnaire to 796 workers on an offshore oil installation and compared the results with some taken from their onshore counterparts, and found no significant differences between the two groups. It should be noted that the questionnaire used by Gann et al (1990) was Goldberg et al.’s (1988) brief anxiety and depression scale, which did not differentiate between work and leave-time, measuring only ‘general feelings’ which may have produced misleading results. Future self-report questionnaires should treat both work and home areas as separate, and compare the results to identify stressful episodes.

Survey research has found that ‘strain conditions’ such as job dissatisfaction, lack of social support, perceived risk and dissatisfaction with the living and working conditions on installations are likely to be reflected in reports of sleep, rest and alertness (Hellesoy, 1985). In addition, adjustment problems to the continual work-leave cycle are frequently reported (Hellesoy, 1985). Furthermore, there is a significant association between absenteeism and ratings of physical and psychosocial factors on rigs and platforms (Iversen, 1991; 1986 both cited by Parkes & Swash, 2000) possibly indicating that the effort of coping with unfavourable work conditions may bring about illness, though the direction of causality cannot be determined by this type of investigation.

Table 2. Accidents and Injury Data from Offshore Installations

Source	N/ data	Accidents/ Injuries	Time of day	Days into tour	Other factors
HSE rep (Miles 2000)	HSE database	N/A	More incidents occurred around midday (p<.05).	50% more incidents around crew changeover days.	Season effects (p<.05) with more incidents in Winter.
Parkes &Swash (1999)	2602 – HSE database	Accident rates as follows: Fatalities .6%; lost time injury** 24.9%; restricted work case*** 11.8%; medical treatment 40.2%; first aid case 22.4%.	Hours into shift: 0-12 hours: Accident rates are as follows: Fatal .5%; Serious 12.3% 3 day +* 87.2%. 12+ hours: Fatal 3.8%; Serious 15.2% 3 day+ 81%. Shift: Day 0700/1900: Serious - 24.7% Night1900/0700 Serious - 31.7%.	<7 days: Accident rates are as follows: Fatal .5%; Serious 10.2%; 3 day +*89.3%. 8 -14 days: Fatal .5%; Serious 11.6%; 3 day +*87.9%. 15 or more days: Fatal 1.7%; Serious 30.7%; 3 day + 67.6%.	Job area associated with injury rate. Drillers accounted for 17.6 % of fatal and serious injuries. Body parts most likely to be injured: Arms 32%; Hands 38.6% Shoulders 31.4% of total injuries.
Parkes & Swash (1999)	HSE database + 2 Co databases	N/A	More serious injuries & fatalities in 2nd 12 hours of the day (p<.01) especially for drillers (p<.05).	Increased risk of more serious injuries with increasing days into tour (p<.0005) and the same for fatalities and 3 day+ injuries* (p<.05). Serious injuries more frequent around shift handover periods.	N/A
Forbes (1997)	-----	N/A	Accidents decrease over hours of a 12-hour shift.	Rollover shift pattern accidents increase on 1st day after shift change, and decrease in 2nd week.	N/A
Laundry & Lees (1991)	-----	N/A	Minor injuries more frequent during the day. Injury not related to time into shift.	N/A	On-the-job injuries decreased with 12hr shift system compared to 8hr.
Sutherland & Cooper (1991)	N = 360 91 accidents	29% of crew had accident/ injury. 53% had injuries of >2 days duration. 56% required a hospital visit.	N/A	N/A	36% of Type A's and 37% of those high in neuroticism had been involved in an accident, compared to 24% of Type B's and 24% of those low in neuroticism (p<0.05).
Lauridsen & Tonnesen (1990)	N = 4000 3200 injuries 1980-1987	N/A	More injuries in day than night – not for drillers - with more 0000-0600. Injury rates lower after 5.5-7.5 hours worked. More accidents after 2.5-3.5 hrs and after 8.5-10.5 hours.	Accident rate increases for both fixed and rotating shifts around crew changeover days (days 7-8). Rotating shift workers showed greater injury rates on 1st day of work in comparison to fixed shift workers.	N/A

Objective Evidence

Formal records show some support for the incidence and effects of psychosocial stressors. Reports of medical evacuations from installations have shown that mental health and stress-related problems accounted for 5% of evacuations due to illness (Parkes, 1998) and while injury evacuation levels have fallen over the past two or so decades, the proportion of illness evacuation levels have risen (Horsley, 1997, cited by Parkes & Swash, 2000). Formal records have also shown that up to 15% of sickbay consultations were for personal concerns (Gogstad et al., 1985). It is noted however, that these figures are low given the incidence of psychosocial problems indicated by most surveys, though the researchers concluded that this might be due to the workers reluctance to discuss personal matters with the rig medic. A more recent analysis by Parkes and Swash (2000) of sickbay consultations made by personnel on 3 offshore installations between 1993 and 1998, in relation to personal and job related factors, found in support of previous studies (e.g. Hellesoy, 1985) that respiratory and musculo-skeletal disorders accounted for the majority of diagnoses, with 15.3% relating to accidents and 6.7% to ‘other’ diagnoses, including mental disorders. In relation to job type and job level, maintenance personnel showed disproportionately high consultation rates compared to production and drilling personnel, who showed higher accident rates, and exhibited a marked relationship between job level and consultation rates for all diagnostic categories. Furthermore, it was found that personnel working day and night shifts showed a higher proportion of sickbay consultations compared to day only workers mostly due to accidents rather than illness. In relation to self-reported health problems, a significant association between the total number of health problems and type of diagnosis (to a certain extent e.g. for musculo-skeletal problems) and overall sickbay consultations was evident. However, this did not indicate whether a self reported health problem was more likely to receive a similar diagnosis in the sickbay consultation reports. Interestingly, musculo-skeletal diagnoses was also correlated with poorer mental health, according to the authors, indicating either a direct causal relationship, a reciprocal relationship, or a tendency to complain (Parkes and Swash, 2000). However, although certain conclusions can be drawn from this study, its limitations, such as the over-simplification of diagnostic categories from the consultation records and absence of a comparable diagnostic category and a similar time period in the survey, mean that certain correlations must be considered with caution. In addition, where there are reports of personnel health and well being, they only refer to work-time. There is little evidence reporting ill-health consultations during leave-time, which would serve to reflect the impact of working on installations on the individual and demonstrate the interaction between offshore factors and home-life factors. It is clear that leave-time is a neglected but important area to consider, if a complete picture is to be produced.

SURVEYS OF STRESS AND HEALTH IN RELATION TO ENVIRONMENTAL FACTORS:

Physical characteristics of offshore installations such as the size, type and location, as well as the implemented work and rest schedules have been associated with health, well-being and psychosocial outcomes among personnel (Parkes, 1998). Sutherland (1993) found that fixed platforms and smaller installations were linked with reports of better mental health in comparison to drilling rigs and larger installations. The symptom level reported showed a sharp increase where there were more than 60 personnel onboard, with the most detrimental effect to symptom reporting occurring on platforms of 60-180 personnel. In terms of mental health and job satisfaction, installations in the southern UK sector compared favourably with those in the more remote Northern and Central sectors. Personnel working on newer installations report greater satisfaction and lower physical environmental stressors than those on older installations (Iverson et al., 1986, cited by Parkes, 1998) probably due to the higher design specification on more recent models.

Table 3. Shift Type and Length and Tour Length on Offshore Installations

Source	N	Schedule	% Worked	
			Platform	Rig
Parkes & Clark (1997)	1394	2-2	48 %	19.7%
		2-2+	3.4 %	--
		2-3	40.5%	0.3%
		Equal 6's	10%	--
		3-3	6.5%	7.1%
Flin & Slaven (1992)	134	1 week on	25.3%	N/A
		2 weeks on	54.5%	
		3-4 weeks on	14.2%	
		Variable system	2.2%	
Parkes & Clark (1997)	1462	Day shift	47.6%	N/A
		Day/night	45.5%	
		Other	6.9%	
Hellesoy (1985)	~500	Day shift	31%	N/A
		Night shift	37%	
		Day/Night	32%	
Cooper & Sutherland (1987)	194	Day – 7 hours on/ 7 hours off	32%	N/A
		Day/Night – 14 on/14 off	48%	
		12 hour shifts	100%	
Parkes (1999)	1320	12 hour shifts	100%	N/A

Key: 2-2 = 2 weeks on duty/ 2 week leave; 2-2+ = 2 weeks on/2 weeks off plus holidays; 2-3 = 2 weeks on/ 3 weeks leave; Equal 6's = 6 weeks of 2-2/ 6 weeks leave; 3-3 = 3 weeks on/ 3 weeks leave.

The norm for shift duration on installations is 12 hours and the most common tour length is two weeks offshore and two weeks leave (Cooper & Sutherland, 1987; Parkes and colleagues, 1997, 1999; Flin & Slaven, 1992). In a survey of rig workers by Cooper & Sutherland (1987), all those questioned worked 12-hour shifts (n=194). Parkes & Clark (1997) surveyed 1462 personnel on both rigs and platforms, and found that over 68% of workers worked 2-2 schedules, and a similar pattern was noted in Flin and Slaven's (1992) survey of offshore installation managers. The tours are either divided into a week of night shifts followed by a week of day shifts (7 nights/7 days) or vice versa (7 days/7 nights), or two weeks of fixed day or night shifts (14 nights/14 days). According to Parkes (1997), rotating shifts have been more widely adopted than fixed shifts, although earlier research by Cooper and Sutherland (1987) showed that fixed shifts were more common, and better favoured by employees (Parkes et al, 1997). In terms of hours of work, Parkes and colleagues (cited by Miles, 2000) found that 20% of day workers and 8% of night workers report in excess of 100 hours work per week. Parkes and Clark (1997) report that overall, 38.4% of the sample of 1462 installation personnel work longer hours than the standard 12-hour shifts. At the most senior level, 60.8% of personnel work in excess of 100 hours per week.

Shift Work & Sleep Problems

Table 4. Weekly Working Hours on Offshore Installations

Source	N	Sample	84 hours	85-93 hours	94-100 hours	100+ hours
Parkes & Clark (1997)	1462	Total	62.4%	10.2%	13.7%	13.8%
		Day workers	-	-	-	>20%
		Night workers	-	-	-	>8%

Shift work is reportedly a significant predictor of adverse health effects and sleeping problems. Parkes (1999) conducted a survey of 1598 male personnel on 17 offshore installations which revealed shift pattern significantly correlated with sleep and gastric problems ($p<0.01$), GHQ caseness and injuries ($p<0.05$). Sleep duration and quality were found to be unfavourably affected by rotating shift schedules ($p< 0.001$ and $p<0.025$ respectively) in a study by Parkes et al. (1997) of 95 production personnel onboard 4 North Sea production installations. Furthermore, the number of years of shiftwork was negatively related to sleep duration, over and above the effect of age, indicating a cumulative effect of rotating shiftwork on health. It is clear that significantly more installation workers report sleep problems than their onshore counterparts even though workers are more likely to adapt to night shift work offshore than onshore (Parkes, 1994). According to a survey (n=1462) by Parkes and Clark (1997), the work/leave cycle was found to be the strongest predictor of satisfaction with 2-2 and 2-3 in preference to 3-3 schedules ($p<0.001$). Lauridsen et al. (1991) found that the least favourable rotating shift schedule of 0000-1200 and 1200-0000 was related to more self-reported adverse health effects. Furthermore, Parkes (1997) found that gastric problems and sleep disturbance were predicted by rotating shiftwork ($p<0.05$ and $p<0.001$ respectively) but not job type, although the opposite was true of headaches and musculoskeletal problems.

Table 5. Sleep Duration, Quality and Deficits in Terms of Shift Type in Offshore and Onshore Populations.

Source	N	Population/ Shift Type	Day shift (mean)		Night shift (mean)		Leave time (mean)	
			Quality rating	Duration hours	Quality rating	Duration hours	Quality rating	Duration hours
Parkes 1994	172	Rotating shift						
		Offshore	3.20*	6.99	3.66	7.20	4.85	7.74
		Onshore	4.25	7.07	3.21	5.86	4.74	7.59
Parkes & Razavi (1997)	104	Rotating shift						
		Offshore	-	-	-	<6	-	-
		Onshore	-	6.5 - 7	-	6.5-7	-	-
Parkes et al (1997)	260	Offshore			Weekly Deficit			
		Forward Rotating			17.7			
		Backward Rotating			20.3			
		Fixed shift			14.5			

*Scale usually 1-5 (1=poor quality, 5=good quality).

Environmental Stressors

Noise, vibration, poor lighting and ventilation, confined living and workspace and adverse weather conditions are commonplace physical stressors in the offshore oil industry (see reviews by Sutherland and Flin, 1989; Parkes 1998) with personnel of certain job areas and levels (e.g. drilling crews) being most affected (Parkes, 1997). These environmental stressors have been associated with reports of adverse physical and psychological well-being and sleep disturbance (Hellesoy, 1985; Sutherland and Cooper, 1986). In a survey by Hellesoy (1985) of 504 offshore platform personnel in the Statfjord field in Norway, it was found that 20-25% were dissatisfied with noise, heat, ventilation and humidity aspects of the environment. Lauridsen et al. (1991) reported that 50% of installation workers found sharing cabins difficult, 47% were troubled by noise, and 40% of those considered it to be a cause of their sleeping problems. Furthermore, it is perhaps not surprising, given that drillers are involved in the most physical work under the most adverse conditions, that Hellesoy (1985) found that they report tiredness followed by sleep disturbance as their most significant health complaints. Psychosocial stressors identified by those in the offshore oil industry as being associated with adverse health outcomes, include perceived risks, job characteristics and job insecurity and concerns about relationships at work and at home and the interface between the two (Parkes, 1997; Cooper & Sutherland, 1987; Parkes, 1993; Lauridsen et al., 1991; Rundmo, 1992). In addition to which, poor health-related behaviours adopted on rigs may reflect the coping strategies used by personnel to deal with the demands of offshore work, and the social isolation and lack of adequate support (Ulleberg and Rundmo, 1997).

Health Behaviours

Research shows that in relation to onshore workers, a higher proportion of installation workers smoke and drink alcohol (37% and 32% respectively, compared to 31% and 24% in the general population), in some case excessively use and abuse drugs, and have adopted unhealthy eating patterns culminating in overweight personnel who may prove to be a liability in an emergency (Parkes, 1997; Horsley & MacKenzie, 1996, cited by Parkes & Swash, 2000; Cox and Norman, 1987; Burke, 1985; Light & Gibson, 1986; Cox, 1987). However, more recent research has shown that healthy eating is now encouraged and eating patterns are changing for the better (Horsley & MacKenzie, 1996; Oshaug et al., 1995).

Table 6. Subjective Health Effects on Offshore Installations

Source	N	Mental Health	Physical Health	
		Offshore	Offshore	General population
Parkes (1999)	1320	GHQ* cases = 14%.	Musculoskeletal - 47%; Gastric - 31% Headache - 38%; Work injuries - 10% Sleep problems - 45%	N/A
Parkes & Razavi (1997)	104	Significant increase in GHQ anxiety scores between 1990-1995 (p<.001)	Crewmembers reporting major health problems – 14% Headaches – 34%; Sleep problems – 77%.	Onshore group 21.3%; 57%; 57%.
Horsley (1996)	507	Job satisfaction (1 =poor/5=good): 28.3% = 5; 71.7% >5 Mental health disorders account for 4-5% of total medical evacuations.	Drink >21 units per week- Single personnel 46%; Attached 30%. Drink >30 units per week: Single - 20%; Attached - 13%. Smoking - Smokers - 37.2%: Exercise - offshore - 41%; onshore - 49%: Healthy eating: Offshore - 28%; Onshore - 37%.	Drinking 27% UK; 24% Scotland. Smoking 31% UK 34%Scotland.
Parkes (1992)	172	Mean GHQ* scores higher offshore: p<0.05. (Mean=8.75 compared to 7.64 onshore). Anxiety mean = 3.62 (onshore = 2.43, p<0.01)	N/A	N/A
Gann (1990)	796	Critical anxiety score – 14.6% (onshore – 15.6% ns**) Critical depression score – 24.6% (onshore – 29.8% ns)	N/A	N/A
Cooper & Sutherland (1987)	194	Mental health CCEI***. Mean score offshore = 22.6 compared with 21.1 onshore (statistically significant). High free-floating anxiety (p<0.001) TAB****, home/work relationships, marital status & environment explained 35% of the variance in mental health.	N/A	N/A
Gann (1989)	723	N/A	BMI***** = 25.65 (7% higher than onshore group).	BMI= 23.96.
Light & Gibson (1986)	419	N/A	BMI mean = 24.80; Overweight – 40.1% Obese – 5.5%.	N/A
Anderson & Cox (1987)	---	N/A	Reasons for sick-bay visits: Medical cases - 40%; Skin problems – 10%; Minor trauma – 5-10%; Musculoskeletal – 5-10%; Ear/nose/throat – 1-15%; Eye problems – 10-15%.	
Hellesoy (1985)	~500	Reasons for sick-bay visits: Personal concerns 15%	Reasons for sickbay visits: Somatic complaints - 47%; Accidents & injuries – 16%.	

OBJECTIVE MEASURES OF PERFORMANCE AND ALERTNESS:

Factors affecting performance on offshore installations can be roughly compared to those onboard shipping vessels.

Motion

Although human performance degradation has previously been associated with ship motion, in the form of postural instability, the incidence of motion sickness, motion induced fatigue and whole body vibration (Colwell, 1989, cited in Powell & Crossland, 1998), this phenomenon in floating production storage (a combination of an oil rig and a vessel) and offshore installations has been largely ignored. However, Smith (1999), identified that the above factors as well as visual and manual problems induced by motion and the many motion-related combined effects can induce fatigue and affect performance on floating storage production and off loading vessels and may endanger operational efficiency and safety. Contrary to the belief that motion is negligible on such vessels, Lewis and Griffin (1997) found that horizontal motions at the drill floor of a semi-submersible platform exceeded the ‘average threshold of perception’ (ISO 6897, 1984) for general purpose buildings, and standards predicted that the vertical motion would cause vomiting due to motion sickness in around 5% of poorly adapted adults within the first 8 hours of exposure. Such motions were suggested to be associated with the acceleration of muscle fatigue accumulation and therefore impaired performance after a long shift. Although the trends did not signify a significant decrement, the authors consider current standards insufficient to predict the effects that motion has on crew performance.

Drawing from research into the effects of ship motion on performance, Powell and Crossland (1998) brought attention to the fact that although motion is limited, through vibration (caused for example by severe slamming), the task performance of crewmembers onboard FPSOs can be affected by two significant factors. Direct mechanical disruption and progressive impairment (possible due in part to physiological effects) have been associated with impaired performance, and both may be positively or negatively moderated by habituation (e.g. to motion sickness) or cumulative effects.

Fatigue and Performance

McPherson (1999) conducted an adapted Stroop task study with 20 personnel onboard an offshore production platform in the North Sea in order to investigate the impact of fatigue as a result of tour length, on cognitive processes such as automatic and attentional processing. Albeit a limited piece of research, his is one of the few that have examined performance specifically in regards to alertness and fatigue. Tests were performed on day 3 and day 11 of a tour of duty, where personnel were regarded as alert and fatigued respectively. Workers were required to undertake a control condition and the experimental 'stroop' condition. It was found that 'fatigued' personnel were significantly slower at responding to both control and stroop conditions than the 'alert' personnel with reaction times of 18 and 24.5 seconds when alert and 22.6 and 31 seconds when fatigued for control and stroop tasks respectively. Furthermore, the fatigued group made more errors than the alert group. Although the results were not reported in statistical form, the methodology was unclear as to practice and order effects, and details such as time of testing and number of tasks, were omitted, it is evident from the results that tour length does have an impact on attentional processes and warrants further and more sophisticated research.

Table 7. Performance Effects in Relation to Tour, Shift and Time of Day

Source	N	General Effects	By Shift/Tour	By Time of Day
Lewis & Griffin (1997)	N/A	Horizontal motions on drill floor affect comfort & activities of crew by exceeding the 'average threshold of perception' (ISO 6897) by a factor >2. Vertical motions predicted to cause motion sickness in <5% of unadapted adults in 1st 8hrs of exposure. No crew performance measures.	N/A	N/A
Powell & Crossland (1998)	N/A	Direct effects of vibration proposed via mechanical disruption & progressive impairment. Indirect vibration effects proposed to affect cognitive performance through motion illness and physical & mental fatigue. No data though.	N/A	N/A
Mcpherson (1999)	20	Attention affected by fatigue after 11 days on tour.	Performance on Stroop task degraded after day 11 compared to day 3 (mean = 31.05 to 24.5). More errors in fatigued group (26 to 6) but not noticed by subjects. Best RT occurred in initial week of 7 days+7 nights.	N/A
Parkes et al (1999)	95	14days vs. 7 days+7 nights: Alertness affected by shift rotation (p<.001) and by time (p<.05); RT* affected by shift rotation (p<.001) and by time within shift (p<.01); MCRT** affected by rotation, shift & time (p<.002). 14 nights vs. 7 nights + 7 days: Alertness affected by shift rotation (p<.05) and by time (p<.025); RT affected by time within shift (p<.02); Simple Memory affected by rotation and task difficulty (p<.03). 7 days+7 nights vs. 7 nights +7days: RT affected by direction, shift & time (p<.06).	7 days + 7 nights – mean RT increased by over 10.7% during following shifts compared to 14-day fixed shift group. 7 nights+7 days mean RT increased by 5.2% compared to 14-night fixed shift group. 14-day – trend for RT to decrease over successive shifts.	Rotating shift workers: RT increased from start to end of shifts. Shift change has short-term adverse effect on simple memory task (p<.03). More RT gaps (>1sec) following rollover than with fixed shift group (p<.015). No-one in fixed group had >3 gaps compared to 21% in rotating group. 14-day – trend for RT to decrease over time within shift.

* RT – Reaction time.

** MCRT – Multiple choice reaction time

Shift Duration

Previous investigations into the effects of shift duration on the performance of control room operators and field operators at a continuous natural gas processing plant, have shown that fatigue, alertness and performance (assessed by a battery of standard performance tests including measures for reasoning, response and reaction times) are adversely affected towards the end of a long shift (Rosa et al., 1985; 1989). 12-hour shifts were shown to produce more alertness and performance decrements than 8–hour shifts - more notably on the night shift - and sleep debt effects were found to be cumulative over a sequence of shifts of this length, though a day-to day recovery in performance and alertness was apparent (Rosa et al., 1985; 1989; Rosa, 1991; Rosa and Bonnet, 1991). In addition, it was shown that personnel do not show adaptation to 12-hour shifts, since in a one-year follow-up of the change from 8-hour to 12-hour shifts performance and alertness deficits were still evident, even though personnel welcomed the change because of increased leisure time (Rosa, 1991). However, application of these results to the offshore oil industry is unclear given that 'tour' durations are incomparable and that accommodation limitations offshore mean shift flexibility is unfeasible.

Parkes et al. (1997) examined the effects of shift rotation on mood and cognitive performance (reaction time, memory and reasoning) in installation personnel, and in support of previous data (Lauridsen et al., 1991), found that crewmembers working 2-week tour shift patterns involving a mid-cycle shift change showed significantly lower performance, alertness and sleep efficiency levels during the second week in comparison to those working fixed shift patterns. Personnel working rotating shifts showed mean reaction time increases of 10.7% and 5.2% for shifts beginning with 7 day shifts and 7 night shifts respectively before switching, compared to their fixed shift counterparts. Furthermore, more notably at the start of night-shift sequences, reaction time increased from the beginning to the end of individual shifts, and it was found that roll-over shift groups showed more instances of reaction times greater than 1 second (gaps) than fixed-shift groups ($p<0.015$), which was especially marked during the first two shifts following the roll-over (Parkes et al., 1997). However, although studies of shift patterns indicate that fixed patterns are less disruptive, even following confirmation that, when day shifts follow a week of night shifts, the normal level of day-shift performance is impaired and the sleep deficit is greatest (Parkes, 1997), 87% of offshore personnel welcome rotating shifts that allow them to depart for leave having adjusted back to the normal circadian cycle (Parkes et al., 1997).

PHYSIOLOGICAL STUDIES OF FATIGUE, STRESS AND CIRCADIAN ADAPTATION:

Earlier studies into the effects of night-shift work have mostly focused on land-based occupational groups working fast-rotating shift patterns, and it is generally accepted that night-shift workers cannot attain complete phase adjustment (Akerstedt, 1988). An individual's circadian rhythms play a role in determining the systems controlling hunger, digestion, body temperature, sleep efficiency and a range of mental performances, and these are therefore affected if circadian rhythms are out of line with working hours. Furthermore, it is evident that shift workers on the whole report more fatigue than day workers (see review by Akerstedt, 1988). Troughs in circadian temperature during night work and desynchronisation of circadian rhythms with the sleep/wake cycle as a result of failure to adapt to night shift work (Wever, 1979) have been associated with decreased performance efficiency and human error (e.g. Costa, 1997). Conditions in the offshore oil sector however, mean that light and social cues, i.e, factors that can affect the circadian clock (see Duffy et al., 1996), can be controlled.

Furthermore, it has been found that phase adaptation assessed by urinary 6-sulphatoxymelatonin can be attained for certain night shift schedules in rig workers (e.g. Arendt & Deacon, 1997; Barnes, 1998, a & b). Barnes et al. (1998a) found that offshore oilrig personnel (n=10 in winter; n=17 in summer) working a 2-week, 12-hour night shift (1800-0600) were able to adapt to the shift system via a phase delay, irrespective of season (with mean adaptations of 1.5 ± 0.6 & 1.32 ± 0.41 in winter and 1.77 ± 0.31 in summer). The effects were attributed to environmental and social factors, though the significance was unclear and the number of participants working night shifts was small. Barnes et al (1998a) showed that for 7-day rapid turnaround shift sequences, drill workers beginning with a night shift (1800-0600) are out of phase for the first 4-5 days and for 4-5 days of the following day shift sequence, indicating that rapid turnaround is most beneficial to those working two week fixed tours, although even then they have only around 4-6 days of total adaptation in this particular shift schedule. In a subsequent study however, Barnes and colleagues (1998b) found that when beginning with a day shift (1200-0000) then rolling on to a night shift (2400-1200), most workers do not adapt to the night shift, suggesting that the direction of rotation and particular shift pattern play an important role in circadian adaptation. Furthermore, in contrast to their previous study, seasonality proved to be an important factor in advancing phase adjustment, indicating that the early light exposure advances the melatonin rhythm in spring in contrast to winter ($p<0.05$), in which sleep duration was also significantly decreased ($p<0.005$). Previous studies have supported the role of light exposure in advancing phase adaptation. Bjorvatn et al (1998/9) have conducted studies based on the premise that light regulates the circadian pacemaker, and that its effect are dependent on the timing of light exposure relative to the lowest point of the endogenous body temperature rhythm (around 1-2 hours before habitual waking time). Light exposure before this nadir is said to cause a phase delay and exposure after the 'dip' brings forth a phase advance. Bjorvatn et al (1998/1999) introduced sleep/wake measures to male oil platform workers on 2-week fixed shift tours (1900-0700), and found that although offshore oil workers in general phase adjust quite rapidly to night work, bright light exposure significantly improved ratings of both the adaptation period to night shifts and also the readaptation period back to normal circadian function. Although the results are purely subjective, some correlations do exist between objective sleep parameters (Akerstedt et al., 1994), and these studies basically support the view that both environmental and social external cues – unique to the offshore oil industry - play an important role in circadian adaptation and the effect of shift work in general.

Shift Systems & Adaptation

Recently, researchers from the University of Surrey have carried out a pilot investigation into the physiological effects of night-shift work of personnel working 2-week tours of weekly swing shift patterns (7 nights + 7 days) onboard North Sea oil installations. Urine and blood plasma measures were taken to assess adjustment to shift work and hormonal and metabolic changes respectively, as well as self-report records of diet and lifestyle. Although due to the small number of participants and some data precision limitations the results cannot be seen as conclusive, preliminary analysis showed that circadian adjustment to night shift work was apparent in the majority of workers. However, it was seen as unlikely that workers then adapted to the subsequent dayshifts. The instances where workers did not show phase adjustment were tentatively explained in terms of the bright light exposure of the individuals in the early mornings on the rig. It was also shown that patterns of nutrient intake tended to differ according to shift changes with daytime meals consisting of higher fat content than night time meal choices. Fat content is known to influence plasma TAG, although the plasma TAG analysis showed a trend towards higher post prandial TAGs following a night shift than a day shift meal, which was most evident early in the tour of night shifts pointing toward the presence of a potential CHD risk factor. This asymmetry indicates a need for standardisation of fat content and mid-shift meals prior to blood sampling in future studies for more representative and accurate results. Data emerging from the first phase of a larger scale study of circadian adaptation, dietary intake and metabolic responses in offshore installation workers undertaken by Professor Arendt and her colleagues at Surrey University was cited by Miles (2000) as so far supporting previous studies. Whilst working 1800 to 0600 shifts, offshore drill floor and maintenance workers have been found to adjust, on the whole by means of phase delay, to consecutive nights at a rate of around 1.5 hours per day. The effects of natural light exposure were ambiguous and although there was some indication of seasonal effects, this did not impact on the overall pattern of results.

Physiological Response to Experienced Challenge

Alekperov et al. (1988) examined the physiological effects of work leave patterns in personnel (n=60) working on floating oil-drilling platforms in the Caspian Sea. Measures of heart rate, ECG, arterial blood pressure, stroke volume and cardiac output, response times, attention, muscle strength and endurance were observed in matched crews during 7-day and 15-day shifts. Reports of fatigue and weakness were apparent from day one. An increase in latent locomotor response times to audiovisual stimuli was evident toward the end of each day. Furthermore, the most pronounced prolongation was apparent on day 7 of the morning shifts and on day 5 of the night shifts ($p<0.001$), with response time increased significantly 3 and 6-hours into the day and night shifts respectively. This finding highlights the effects of night shifts in comparison to day shifts with the detriment occurring much sooner in night workers. Significant changes in the patterns of parameters of the central nervous system, muscle strength and endurance in response to experienced challenge (using audiovisual stimuli), especially of a psychoemotional nature (e.g. aggravated by stress and isolation), were most apparent after day 9 of a tour, increasing through to day 15. In addition, the parameters of hemodynamics diminished from days 9-13 during both morning and night shifts signified by an increase in systolic blood pressure and a decrease in diastolic blood pressure. As put forward by the authors, in combination, these findings are indicative of overstrain in the individual. Alekperov et al. (1988) concluded that deleterious physiological changes can be attributed to shift duration and suggest that 1-week, rather than 2-week work-rest cycles are least disruptive and should be recommended, along with two 20-30 minute recuperation breaks after 3 and

9 hours of work. It was further proposed that an additional 1-hour break at around 2-3am should be implemented for those working night shifts.

SUMMARY OF THE MEASURES TO ASSESS ACCIDENTS AND INJURIES, FATIGUE, HEALTH AND STRESS OFFSHORE:

Accidents

Accident and injury data analyses have indicated that incidents on offshore installations can be attributed to personal, temporal and occupational factors as well as environmental and external causes. Research has highlighted the implications that shift patterns and schedules have on the incidence of accidents and injuries in the offshore oil industry. It is evident that shift and tour account for the greatest proportion of variance in accident occurrence and injury severity. Accident and injury data analysis is one of the areas that has benefited from thorough analyses of both formal records and survey data, although evidence of the link between accident and injuries and fatigue in particular, is absent, due in part to inadequacies in reporting systems. It is evident from the limitations such assessment measures reflect, that one must be wary of interpreting the results where estimates of exposure rates are used, and how certain relevant causal factors could have been omitted, therefore producing misleading results. Future reporting methods of accidents must be refined and should include all relevant exposure data. This would enable incidents on offshore installations to be correctly recorded to include all factors involved.

Table 8. Assessment of Physiological Markers in Relation to Shift Pattern and Time of day

Source	N	General effects	By shift	By time of day
Barnes et al (1998a)	27	Season had no effect on circadian phase adjustment.	Those working 2 week, 12 hour tours (rotating & fixed) showed circadian adaptation to night shifts (1800-0600). Adaptation rate mean ~1.5±0.16 SEM*hour per day).	N/A
Barnes et al (1998b)	18	Seasonal effect – phase adaptation apparent in March but not November.	Rotating shift workers (7 days+7 nights:1200-0000/0000-1200). Phase adaptation is shown in Spring following changeover ($p<.05$) but not in Winter. Therefore, type of shift affects circadian adaptation.	N/A
Arendt et al – University of Surrey	11	N/A	Rotating shift workers (7 nights+7 days: 1800-0600) tend to adjust to nightwork by rate of ~1.5 hours per day.	N/A
Bjorvatn et al (1999)	7	14 12-hour fixed night shift, 2-week tours (1900-0700). Bright light treatment significantly improved subjective adaptation ratings to night work (Mean = 5.0 to 3.1) and readaptation for leave period (4.9 to 3.2).	N/A	N/A
Alekperov et al (1988)	~60	Overstrain as a result of 2-week work-rest cycles.	Detrimental changes in haemodynamics, CNS** parameters, muscle strength & endurance apparent after day 9 increasing through to day 15. Locomotor RT*** most prolonged on day 5 of the night shift and day 7 of the morning shift ($p<.001$).	Physiological effects in terms of locomotor RT increasing significantly after 3 & 6 hours, and by end of day, in response to audiovisual challenge.

*Standard error of mean.

**CNS – Central Nervous System.

****RT – Reaction time.

Survey Measures

Survey measures are plentiful and there is a wealth of studies that on balance, supporthe view that installation workers suffer from high levels of perceived risk, self-reported anxiety and depression, stress, sleep problems, dissatisfaction with shift schedules and higher perceived workloads and lack of social support as well as adjustment difficulties related either to the experience or the conditions associated with offshore work. On the whole, surveys have not tended to include measures that differentiate between feelings and well-being in work periods and leave time, which is possibly a source of the contrasting results in the literature. In addition, surveys have failed to include methods of assessing or specifying the experience of fatigue by tending to concentrate their efforts on a specific area, which make up only a part of the problem. Nevertheless all factors identified hold implications for fatigue effects if one considers the number of variables that have implications for fatigue in their various combinations, such as environmental issues, sleep problems and psychosocial concerns. In terms of linking subjective data to objective records, some cases studies have found evidence of the subjective deleterious effects of working on rigs, and linked the results to formal records of illness and absenteeism. However, this method is not conclusive especially due to weaknesses within current reporting methods. Furthermore, it is impossible to determine the direction of causation with self-report data. It is apparent that surveys should serve as a preliminary basis of analysis for studies that intend to use additional objective measures to determine the extent of the problems associated with working on offshore installations.

Performance

Studies that have investigated the performance effects of working on offshore rigs/platforms are somewhat limited. Parallels can be drawn to some extent with onshore studies and detrimental performance effects inferred, for example that night work and longer shift durations are associated with reduced performance efficiency and alertness. However, it is apparent that although hypotheses and anecdotal reports are abundant, sound objective evidence of performance deficits attributed to offshore conditions is decidedly lacking. Several reports have addressed the deleterious effects of environmental factors such as the effects of motion and vibration on performance, though with little corroboration from objective research projects. Only one study has addressed the effects of tour length on performance specifically with reference to alertness and fatigue and found a detrimental effect. Though, with the many apparent methodological faults, conclusions cannot be readily drawn. The few studies that have examined cognitive performance in relation to working on offshore installations, have concentrated on the effects of shift schedules and duty periods on reasoning, reaction time and memory. The findings indicate that performance deteriorates over the course of a 12-hour shift with rotating shifts having greater detrimental effects than fixed shifts due to the disruption of the changeover periods, though replication is undoubtedly necessary. It is clear that to draw firm conclusions regarding the impact of the installation environment on performance in general, further research is crucial.

Physiological Data

Physiological data from personnel working on rigs to reflect fatigue, stress and health is another area of research that has been inadequately covered, but this is beginning to change. Circadian adaptation is one area that has been investigated to some extent and it has been shown that contrary to results obtained from onshore shift workers, offshore installation personnel are able to adjust to night shift work on certain shift schedules, and light cues appear to play a role in advancing phase adjustment. A study investigating the physiological response to a challenge has shown that central nervous system parameters, circulation, muscle strength, endurance and various hemodynamics can be affected by shift length over 7 days. There is however, a dearth of studies that have examined cortisol levels, neuroendocrine response, hormonal and metabolic changes sufficiently to assess stress, fatigue, emotional response and dietary intake and potential health-risk factors, exclusively in rig workers. These factors are obviously necessary to assess the physiological effects of working in the offshore oil industry, and therefore, further research is again needed.

Conclusion of Research into Fatigue, Health and Stress on Offshore Installations

To sum up and present a more definitive picture, it is clear from the few studies that have been conducted in the area that shift schedules encompassing tour length and hours of work, appear to be the most dominant problematic area. Tour lengths of two weeks or more, twelve-hour or longer work shifts, and rotating shift schedules have all appeared detrimental in terms of accidents and injuries, sleeping problems, adverse physical and mental well-being, decreased performance and undesirable physiological changes. However, it is evident from the various investigations that have taken place that results are somewhat contradictory. For example, where one study has found that more accidents occur on a night shift than on a day shift, another states the opposite (e.g. Parkes & Swash, 1999 and Laundry & Lees, 1991 respectively). In order to draw conclusions, we must be able to compare the results of several studies, and of course this is not possible at present. There are other instances of seemingly contradictory results. For example it has been shown that circadian adaptation can occur in night-shift workers after 4-5 days and this is especially true for workers on 2-week fixed shift tours (Barnes et al 1998a/b; Arendt & Deacon, 1997). However, accidents have been shown to increase around days 5-6 on fixed shift tours ((Forbes, 1997 – cited by Parkes & Swash, 1999), by which time phase adjustment should have taken place. Furthermore, studies investigating performance and physiological status agree that tours over one week cause decreased performance efficiency, lowered alertness and unfavourable changes in physiological markers in response to experienced challenge (Parkes et al., 1997; Alekperov, 1988). If one were to follow the circadian rhythm adjustment studies, it would be presumed that once adaptation had taken place in night shift workers, sleep efficiency would increase during the day, and alertness and performance efficiency would increase during the night shift. Results obtained to date, do not show this however. The most likely explanation is that this merely reflects the methodological differences between the various studies and the fact that investigations have tended to concentrate on one area of a relationship between factors, meaning accurate conclusions cannot be drawn by combining the (mismatched) results. For example, the results of Landry and Lee's (1991) study referred to minor injuries, and Parkes and Swash's (1999) research referred to more serious injuries. The sample in Alekperov's (1988) investigation of the physiological effects of shift work used both day and night shift workers on one week and two week tours and so we cannot assume that any circadian adaptation had taken place on which to base any conclusions. In support of this, Parkes' (1997) investigation into performance effects identified rotating shifts as causing the detrimental impact, where of course phase adjustment was an unlikely occurrence. Alekperov's (1988) study did not address this issue. On the other hand, the results may reflect the essence of work aboard installations and the unique combination of factors, which may impact fatigue, health and injury, where straightforward hypotheses do not necessarily follow in the light of other confounding elements. Only further research could identify the reasons for the above findings and explain the complexities of offshore work.

In conclusion, research so far has shown that certain aspects of working aboard offshore installations, such as shift schedules and working hours, have detrimental effects. Support so far has been in the form of mainly accident and injury data analyses and survey reports, and to a certain extent, performance and physiological measures. However, it is evident that there are many gaps in our knowledge especially regarding the effects of fatigue, and to what extent variables identified as having an impact on rigs, in their various combinations contribute to the problem. It is clear that tangible research in the form of all-encompassing formal records of accident and injuries, objective performance assessments and detailed physiological data is extremely limited and this needs rectifying in order to gain an accurate picture of the effects of working offshore at a psychological, behavioural and physiological level.

FATIGUE, HEALTH, ACCIDENTS AND INJURY IN THE MARITIME INDUSTRY:

Fatigue in the Maritime Industry

There exists a substantial documentation on the potentially disastrous consequences of fatigue at sea, although concrete evidence of this, particularly in the short-sea and offshore sectors, is hard to come by. Studies that have been carried out have tended to concentrate on long-haul operations, particularly among the world's naval forces. Furthermore, few studies have made use of objective measures of fatigue, or attempted to define clearly what exactly it encompasses. Brown's (1989) review of hours of work, fatigue and safety at sea, draws together all of the literature then available on fatigue, particularly with regards its' relationship to accidents, and highlights the lack of sound methodological evidence.

Although Brown (1989) found little objective evidence regarding the detrimental effects of fatigue at sea, he did find substantial reports regarding personal fatigue experiences. Seafarers commented that it was not uncommon to be expected to work continuously, often under conditions of task-induced or environmental stress for excessive (in relation to other industries) periods of time. In addition, duties were often interspersed with rest periods that severely limited the opportunity for continuous sleep. Where opportunities for longer periods of sleep did exist, disturbances due to ship motion, auditory alarms and noise associated with loading/unloading often outweighed these benefits.

The main objectives of Brown's (1989) review were to ascertain whether there was justification for regulating hours of work at sea due to fatigue, and to offer guidance on the format such regulations should take. Fatigue is defined as the subjective experience of someone who is obliged to continue working beyond the point at which they feel confident of performing a task efficiently, rather than impairment of performance, which can be indexed by accidents. It is suggested that working arrangements could contribute to fatigue and impact upon continuation of performance at an "acceptable level", in terms of:

- length of continuous duty periods;
- length of time available for rest and continuous sleep;
- The arrangement of duty, rest and sleep periods within a 24-hour cycle.

Risk Factors

Seafaring is a dangerous occupation because it presents a number of workplace dangers in combination, rare in other industries. Seafarers are exposed to extreme weather conditions, rough seas and storms result in the rolling and pitching of the ship leading to an unstable environment that makes physical work difficult. They may be exposed to hazardous and/or toxic cargoes, excessively noisy machinery and vibration. The combination of noise and vibration induces fatigue and leads to hearing loss, communication difficulties and sleep problems, which may result in neurotic syndromes, gastric and duodenal ulcers, arterial hypertension, psychosomatic conditions and a decrease in immunity to pathogenic causes (Filikowski, 1989, cited in Parker et al., 1995). These workplace dangers are reflected in seafarers' mortality rates. Hansen and Pedersen (1996) found that the fatal accident rate among Danish seafarers was over 10 times the average of other Danish occupations. Similarly, mortality rates among German seafarers have been found to be higher than the national average (Meisner, 1993, cited in Nielsen & Roberts, 1999). Jaremin et al. (1997) also found that accident and mortality rates among Polish seafarers, between 1985 and 1994, were higher than in the general population. Furthermore, in a study of seafarers' fatalities worldwide, Nielsen & Roberts (1999) estimated that a total of 2,207 lives were lost at sea each year from 1990 to 1994.

Changes to Work at Sea

Changes in the nature of seafaring in recent decades may also contribute to the causation of fatigue and accidents at sea (Parker et al., 1995). Just as in other areas of the offshore oil industry (i.e. aboard rigs) where technological changes and reduced manning have resulted in increased pressure on crew and decreased job security (Parkes, 1998) seafarers are now obliged to work longer hours and are expected to cope with demands considered unreasonable in other industries. Indeed, several studies have identified the importance of organizational factors in stress and mental well-being at sea (e.g. Pollard et al., 1990). It has been suggested that it is the responsibility of management to address potential stressors occurring as a result of reduced crew sizes, such as increased workload, loneliness and social deprivation, lest these should increase stress and fatigue, and the risk of potential incidents.

FATIGUE AND ACCIDENTS AT SEA:

It has long been suspected that fatigue contributes to human error, and is a major cause of many transportation and industrial accidents. However, the connection between fatigue and accidents at sea has been hard to prove, because in many cases, the physical and mental state of the individuals involved in incidents is not reported. Although there exists substantial anecdotal evidence on the subject, there is very little objective data that directly attributes fatigue to accident causation. One of the main reasons for this is that information pertaining to accidents does not always include details of prior working arrangements of the individuals involved. Brown (1989) suggested this led the Tavistock Institute of Human Relations (1988, cited in Brown, 1989) to conclude that there was no concrete evidence of fatigue as a causal factor in collisions and groundings, although it was felt to be an underlying issue.

Accident Investigation

In recent times, greater emphasis has been placed on examination of fatigue as a contributory factor to accidents. For example, the Transportation Safety Board of Canada (1997) suggested that investigators should be trained to explore the role of fatigue in an incident. They note that fatigue is pervasive throughout society and should therefore be considered as an underlying factor in all incidents. Thus it is recommended that investigators should determine the following:

1. The time of day of the incident;
2. Whether the operator's normal circadian rhythm was disrupted;
3. The number of hours the operator was awake;
4. Whether the sleep history 72 hours prior to the incident suggests a sleep debt.

The US Coast Guard has also stressed the importance of investigating the contribution of human related causes to marine accidents. A study by Raby & McCallum (1997) examined procedures for investigating and reporting the fatigue-related contribution to casualties at sea. Investigating officers and mariners were asked to use their judgement regarding the contribution of fatigue in 98 casualty cases. Investigating officers judged that in 23% of cases fatigue was a contributor, while the mariners judged 17% of cases as having a fatigue contribution. Overall, investigating officers and mariners concurred in 86% of cases. From these subjective judgements three factors were identified as significantly contributing to casualties and were used to compute a fatigue index score:

1. The number of self-reported fatigue symptoms;
2. The total of hours worked in the 24 hours prior to the incident;

3. The total hours spent sleeping during those 24 hours.

The fatigue index score was applied to 88 casualty cases, which had been deemed to have a direct human factors contribution. Using this procedure fatigue was estimated to be contributory to 16% of critical vessel casualties and 33% of injuries to personnel. These estimates were over ten times greater than the ones obtained from the US Coast Guard marine investigations database.

Brown (1989) concluded that there was justification for regulating hours of work at sea, despite insufficient research evidence on the effects of fatigue on shipping incidents. However, few studies had been conducted on watchkeeping systems amongst seafarers. He suggested that this lack of evidence was due to the accident reporting system itself, which made it hard to assess the causal contribution that fatigue makes to accidents. He stressed the need for a complete redesign of the accident reporting system to provide information on all factors linking fatigue to safety.

Occupation & Vulnerability to Accidents

Researchers of maritime accidents have found that the occupation and status of the seafarer influences their vulnerability to incidents. Studies have however, drawn conflicting conclusions. For example, Hansen and Pedersen (1996) found that ratings were at the highest risk of fatal accidents, and officers the lowest (in a sample of approximately 24,000). In addition, the Marine Accident Investigation Branch (MAIB, 1989) found that deck and catering ratings were more prone to accidents, yet in a study of shipboard fatalities amongst Hong-Kong registered merchant ships, Nielsen (1999) found that fatal accidents were most common amongst deck and petty officers. In contrast, the official statistics of the National Maritime Board show that engineers comprise the highest risk group (cited in Bryant, 1991). Clearly, care needs to be exercised in assessing the influence of occupation on seafaring accidents.

In general, Nielsen (1999) discovered that the authorities, in this case the Mercantile Marine Office (looking at Hong Kong merchant ship fatalities), do not always investigate accidents. Of 13 incidents concerning 3 fatalities, trained inspectors investigated just two. Either embassy personnel were called upon to verify the death, or statements by the ship's master and crew were accepted as sufficient. Nielson (1999) concluded that it is impossible to use these files for detailed reviews, thus the causes of the accidents remain obscure. However, Nielsen (1999) suggested that in the majority of cases, there were signs of poor working practice and shortages of safety equipment, which may have resulted in some of the fatalities.

Days into Tour, Shift Schedules, Injuries & Individual Characteristics

Detailed analysis of accidents aboard offshore installations, in terms of days into tour, shift and injury type and individual characteristics have yielded some interesting patterns: for example, the ratio of serious injuries relative to those lasting 3 or more days significantly increases after a tour duration of two weeks (Parkes & Swash, 1999). However, systematic analyses of vessel accidents are hard to come by: the majority of sources detailing accidents occurring aboard offshore support, or indeed any vessel types, are one-off, anecdotal case studies. Even where more thorough investigations have been carried out (e.g. Nielsen, 1999) information relating incident occurrence to days into tour, shift and injury type is noticeably absent. An exception is a study by Raby and McCallum (1997) who looked at the working conditions, which contribute to fatigue related incidents. They found that hours on duty prior to casualty ($p<0.0001$) and hours worked in the 24, 48 and 72 hours preceding the casualty ($p<0.001$) contributed to such incidents. Working conditions also contributed to personal injury cases: in fatigue related incidents mariners had worked an average of 7.7 hours on duty prior to the incident in comparison to 3.2 hours ($p<0.001$) in non-fatigue related incidents. In the 24 hours preceding the fatigue related incident seafarers reported working an average of 14.3 hours, compared to 8.4 hours ($p<0.001$).

Accidents & Time of Day

Studies of workplace accidents primarily focus on time of day and in general, the night shift is associated with a greater accident risk (Dinges, 1995). Mitler et al. (1988) found that car accidents and human errors in industry were more likely to occur between 0100 and 0800, while in a review of transport accident risk, Folkard (1997) found that collisions between ships at sea were more likely to occur during early morning hours with a peak between 0600 and 0700. These data were derived from a sample of 123 collision claims made between 1987 and 1991 (UK P & I Club, 1992, cited by Folkard, 1997). Furthermore, Flaherty (1982, cited in Berger, 1987) estimated that around 45% of all shipping collisions occur between 0000 and 0600 when visibility is over two miles and radar equipment is in use. Marine pilotage accidents have also been found to show circadian variation, with two peaks occurring between 0400 and 1000, and 1600 and 2400 (Smith & Owen, 1989). Thus, it appears that high performance demands during the night may pose safety and occupational health hazards. As Bryant (1991) suggests, reported accidents may be just the observable portion of a much greater number of generally unsafe behaviours and mishaps.

The Contribution of Fatigue to Accidents

In an analysis of 100 Australian ‘Incident at Sea Reports’, Phillips, (1998) examined evidence of behaviours induced by fatigue amongst ships’ watchkeepers, using non-numerical unstructured data indexing, searching and theorising software (NUDIST). The reports indicated a diurnal distribution of collisions and groundings, with a peak during the 0000 to 0400 watch, and a trough during the day (0800 to 1200 for collisions and 1200 to 1600 for groundings). Of 62 collisions and groundings, investigators found fatigue to be a contributory factor in only 5 (8%). One such case was the cargo vessel, the Peacock, whose mate lost situational awareness and fell asleep, causing the vessel to ground. Overall, fatigue was found to be instrumental in only a small number of incidents, although throughout the 'Incident at Sea Reports', behaviours consistent with fatigue are frequently described, for example; attentional failures, perceptual limitations, information processing problems, failures to act and failures to act appropriately. Thus, Phillips (1998) suggested that fatigue might only be determined as a contributory factor where the investigator was able to demonstrate attentional failures (through decreased vigilance or alertness) by the watchkeeper. Phillips (1998) suggests that fatigue and resultant behaviours may be overlooked or attributed to another cause unless fatigue is explicitly referred to in an inquiry: this supports Brown's (1989) questioning of the Tavistock team's finding.

Wagenaar and Groeneweg (1987) analysed 100 accidents at sea, heard by the Dutch Shipping Council between 1982 and 1985 and categorised them using a checklist based on Feggeter (1982). No accident was identified as resulting from fatigue, yet the most frequent causes were classified as false hypotheses and habits, which may or may not occur as a consequence of fatigue. Overall, cognitive difficulties were reported in 70% of errors and were accounted for in 93% of accidents. It is not recorded whether explicit details of the shift system in use aboard vessels were included in the accident reports, without which it is difficult to determine the extent to which fatigue was a factor. However, if the same criteria used by Phillips (1998) were applied to these reports, it is clear that fatigue would be identified as a contributory factor in many of the incidents.

Table 9. Accident Findings

Source	N	Time of Day	Days into Tour	Hours on Shift
Nielson, 1999	123	N/A	N/A	N/A
Raby & McCallum 1997	397	N/A	N/A	Critical vessel injuries: Number of hours on duty prior to casualty* and hours worked in the 24, 48 and 72 hours preceding casualty significant**. Personal injuries: fatigue related cases – on average 7.7 hours on duty (prior to incident) compared to 3.2 hours** where fatigue was not related to an incident. Seafarers reported an average of 14.3 hours worked in 24 hours preceding injury compared to 8.4 hours where no injury occurred.
Smith & Owen 1989	43	Marine pilotage accidents: More likely to occur between 0400 - 1000 and 1600 – 2400***.	N/A	N/A
Folkard 1997	123	Ship collisions peaked between 06:00 – 0700**.	N/A	N/A
Phillips 1998	100	Collisions and groundings peaked between 0000 –0400.	N/A	N/A

* = p<0.0001

**=p<0.001

***=p<0.0

Summary of Accident & Injury Analyses

It would therefore appear that studies investigating accidents at sea attribute a large percentage of incidents to human error, with no explicit mention of fatigue as instrumental. However, lack of sleep and/or excessive work hours are characteristic of a significant proportion of reported accidents. The general picture of factors contributing to accident causation and severity is not however, as clear as is it might be. For instance, if the same methods of analysis applied to accidents on offshore platforms were used for vessels incidents, the relative contribution of fatigue would be a great deal easier to ascertain. We can presently only assume fatigue to be a factor, and infer that shift type (i.e. night work) affects relative accident risk.

SURVEY REPORTS OF FATIGUE, HEALTH AND STRESS IN SEAFARERS: IDENTIFYING THE PROBLEM

Within the last decade, several attempts have been made at identifying the underlying causes of fatigue in seafarers: the following section discusses survey and self-report measures of fatigue, as they relate to work hours, sleep, health and stress.

As early as 1978, the stressful and tiring nature of work at sea was a cause for concern. For example, Shipley's surveys of ships' pilots demonstrate that high workload, unsociable hours and unpredictability of work and rest schedules lead to stress and fatigue (Shipley, 1978; Cook & Shipley, 1980; Shipley & Cook, 1980). However, Shipley concluded that pilots appear able, at least partially, to overcome fatigue effects, and are unaware, or perhaps unwilling to admit that fatigue may affect their job performance. Nevertheless it may be possible that it is self-selection, not training as suggested by Shipley and colleagues, which accounts for this apparent resistance to stressors.

Self –Report: The Prevalence of Excessive Work Hours

As previously noted, evidence of detrimental effects of long and unsociable work hours in the short-sea and offshore shipping industries is somewhat lacking. However, Wigmore (1989) dispatched a questionnaire to the masters of 27 offshore supply vessels, and found that they tended to work longer hours than other crew members, sometimes in excess of 19 hours per day (an average of 1.66 times per month). Furthermore, some respondents noted it was often impossible to gain the recommended 6 hours of consecutive rest for weeks at a time.

Despite this evidence and Brown’s (1989) conclusion that seafarers’ working patterns increase accident risk, little appeared to have changed by the mid 1990’s. In 1995, NUMAST organized a survey of over 1,000 officers across all sectors, inviting them to comment on issues such as health and stress, in an attempt to identify the scale of the problem in the maritime industry. It was concluded that reduced crew size (and therefore increased workload) was the main cause of fatigue in seafarers: shifts of between 12-20 hours (upwards of 85 hours per week) were commonly reported. Furthermore, 77% of officers who responded to the survey felt that fatigue had significantly risen in the previous 3 to 10 years, and 84% felt stress to be more prevalent over this time period than previously. NUMAST therefore suggested that better work organization and closer monitoring of small crews might prevent unnecessary stress and fatigue ‘on the job’. However, it is not possible to ascertain from this data which ships and work systems would be optimum for achieving this aim.

In a comprehensive study of the Unites States merchant marine, Sanquist et al. (1996) conducted a field study of fatigue and alertness in 141 personnel on 8 ships, combining self-report, survey and cognitive performance measures. With regards hours of work, it was found that tanker personnel on the 0400-0800 and 0800-1200 watches work longer hours than command personnel, and that stewards work longer hours than all seafarers, with the exception of those on the third watch ($p<0.05$). On freight vessels, personnel on the 2400-0400 and 0400-0800 shifts were found to work significantly longer than dayworkers ($p<0.05$). However, phase of voyage (i.e. whether at sea or in port) did not affect mean number of hours worked per day. With regards build up of fatigue over a tour period, what little evidence there is would seem to suggest that the effects are not necessarily cumulative (Torsvall et al., 1987).

Table 10. Hours of Work/Shift Timing: Summary of Research Findings

Source	N	Av. Per Day	Over Tour
Torsvall et al., 1987	49	N/A	Fatigue indicators did not increase over tour.
Wigmore, 1989	27	Masters worked longer hours than other crew: >19hours per day (on average.1.66 times per month).	N/A
Numast, 1990	1000	Shifts of 12-20 hours common.	>85hours per week common.
Sanquist et al., 1996	141	Tankers: personnel on 0400-0800 & 0800-1200 watches work longer than command personnel & stewards work longer than all personnel, except those on the 3rd watch: $p<0.05$. Freight vessels: personnel on 2400-0400 & 0400-0800 watches work longer than dayworkers: $p<0.05$.	Phase of voyage (i.e. At sea or in port) did not affect mean number of hours worked per day.

It is worth noting that some of the effects of stress overlap with factors associated with fatigue; for example, loss of concentration and alertness, tiredness and lack of, or poor quality sleep. In a survey of stress and health among seafarers on offshore support vessels, Stringer (1998, unpublished) found that long work hours and environmental factors (e.g. poor weather) interact to produce stress. Rank was also found to have a significant effect on stress; this is perhaps not surprising, as masters reportedly worked the longest hours aboard ship (sometimes in excess of 100 hours per week). However, stress levels among seafarers were no higher than in the general population, although the former group was statistically more likely to suffer physical ailments.

Subjective Health in the Merchant Marine

Much of the available research has been conducted in overseas seafaring populations. Australasia, North America and Scandinavia in particular are concerned with the apparent rise of fatigue and poor health in the maritime industry. In a review of health, stress and fatigue in Australian offshore maritime workers, Parker et al. (1995) reiterate NUMAST'S (1995) finding that stress and fatigue occurred as a result of shipping reforms, namely reduced crew size and increased automation. However, as the authors note, fatigue does not inevitably result in measurable performance deficits.

In a later survey of health, stress and fatigue in Australian seafarers, Parker et al. (1997) analysed the responses of over 5000 participants, in a wide range of occupations. Results demonstrate that physical health in this group is generally worse than that of onshore workers ($p<0.001$) although of the cardiovascular disease risk factors assessed, only blood pressure (BP) was higher than would be expected from Australian normative data (14% of this sample suffered elevated BP compared to 10.5% of norms). The pattern of results that emerges for the mental health of pilots is particularly interesting. Although this sample generally appear more psychologically robust than onshore populations ($p<0.001$) 8.8% of the variance in the mental health of seafarers could be explained by working excessively long hours.

Parker et al. (1998) conducted two further studies, a survey and on-board analysis, examining the work and rest patterns of Great Barrier Reef (GBR) pilots. The survey reveals (n=35) that this group also appear relatively unhealthy when compared to the general population: 56% were classified as obese, potentially increasing the risk of sleep apnea. 30% of this sample were smokers, and smoking frequency and caffeine consumption were found to be higher at sea than at home ($p<0.005$), although pilots reported less fatigue ($p<0.02$) than a sample of emergency and industrial workers. Surprisingly, given evidence to the contrary, a high proportion of respondents (>50%) reported their health as good or excellent.

Subjective Health in Other Areas of the Maritime Industry: A Wider Perspective

Poor health at sea is not solely confined to the merchant marine. For example, Elo (1985) found mental health problems to be on the increase among Finnish seafarers. In fact, job insecurity and unfair distribution of workload were significantly related to depression in this sample; $p<0.001$. With regards physical health, 15.4% of the variance in perceived health status could be explained by personality factors and climactic conditions (Elo, 1985). Johnson et al. (1994) demonstrated that fishermen tended to score higher on depression and somatization scales, and reported higher levels of most stressors (salary, education and marital status were controlled for) than a comparison group of onshore workers. According to Riordan et al. (1991) depression was significantly related to age in both fishermen and the general population ($p<0.001$) but a sense of mastery significantly predicted the incidence (or rather lack of) depression in fishermen only ($p<0.001$). In a study of stress amongst the seafaring population in general, Agterberg and Passchier (1998) used a semi-structured interview technique with three port physicians. It was found that loneliness, homesickness, and 'burn out' were the main psychological problems encountered. The apparent increase in stress among seafarers is attributed in part to the shift from purely physical to mental workload and less time for 'rest and recuperation'. It is also noted that increased work pressure is a particularly serious problem on short-sea vessels. The authors themselves acknowledge however, that the study is rather limited as only three participants were interviewed.

Much of the available research looking at fatigue, health and stress in seafarers has been conducted on Navy personnel. Obviously, the demands of this lifestyle are vastly different from those of the merchant marine, yet some similarities can be drawn. Watchkeeping systems tend to be of a similar nature, as do sleep and rest patterns. Burr et al. (1993) examined the effects of 'sustained operations' (i.e. continuous periods of duty) on psychological health in US Navy personnel during the conflict in the Persian Gulf. A good degree of adaptation to the stressors associated with 'sustained operations' was observed. Contrary to predictions, self-ratings of mood (anger/hostility, tension/anxiety and depression) actually improved over time (mean scores on tension/anxiety, anger/hostility, fatigue, vigour, depression and confusion fell within 1 standard deviation of norms based on college students). However, these findings may be highly specific to the occupational group studied. It is certainly true to say that merchant seafarers are not as thoroughly trained as navy personnel, and so may be more susceptible to the effects of sustained operations.

Sleep Duration & Quality

Lack of sleep would appear to be a very real problem for ships' pilots. According to Parker et al. (1997) self-reports of sleep quality revealed that 70% of seafarers felt sleep at sea to be poor: this figure was higher still among pilots and engineers ($p<0.01$). The duration of sleep obtained at sea is also alarmingly low: over 30% of this sample slept less than 4 hours per day. In addition, stress levels were reported as high: 80% of the sample reported feeling stressed at sea, at least occasionally. It is particularly interesting to note that the greatest source of pressure occurred at the work/home interface: self-reports of sleep quality and stress levels improved gradually when ashore.

According to a survey of pilots (Parker et al., 1998) sleep disturbance was found to be significantly greater at sea than ashore ($p<0.001$), yet need for sleep was reported as less whilst at sea, despite averaging only 5.5 hours per night, compared with 7.8 at home. However, when working on the bridge, pilots felt that boredom and lack of sleep contributed to fatigue, at least some of the time, and performance deficits were noted, although not by all respondents and to varying degrees. Boredom on the job is however, unavoidable to some extent: "The life of a shipmaster has been described as hours of boredom punctuated by moments of terror". (R. Lowell, Seaways, March 1998, p. 6). It is perhaps surprising to observe that although pilots believe their sleep at sea to be sufficient, (despite being well below the population average) they do acknowledge they are sometimes vulnerable to the effects of fatigue on performance. However, any anomalies between the findings of this, and the previous survey data, (Parker et al., 1997) may be due in part to the small sample of pilots ($n=35$) studied in this instance.

In an 18-month retrospective study, Parker et al. (1998) used logbooks to record information relating to general aspects of work and rest schedules, such as timing and quality of sleep, and self-reported alertness in 23 GBR pilots. The findings show that travel to and from ship tended to be rated highest of the work factors contributing to stress and fatigue, although not statistically significant. Other main findings can be summarized as follows: sleep efficiency at sea was rated as high, although 40-50% of sleep time occurred outside the optimal period (2200-0800; $p<0.001$). No significant differences in bridge alertness were found, although the presence of acute fatigue could be identified by the high proportion of sleep latencies of less than 5 minutes. Again, caution should be exercised when drawing general conclusions from these findings, as the study population is relatively small, and the stresses and strains experienced by pilots are not necessarily representative of those experienced by seafarers as a whole. It is suggested that better reporting of accident statistics, and the provision of educational programmes on fatigue, stress, health and lifestyle would help to alleviate the problems associated with chronic fatigue. However, in a pilot study of fatigue and alertness in

Table 11. Subjective Health Effects: Summary of Research Findings

Source	N	Mental Health	Physical Health
Elo, 1895	591	Job insecurity & unfair workload distribution significantly related to depression: $p<0.001$.	15.4% of variance in perceived health status explained by personality factors & climactic conditions.
Riordan et al., 1991	211	Sense of mastery significantly related to depression: $p<0.001$.*	N/A
Burr et al. 1993	265	Mean scores on mood factors (e.g. depression, fatigue) fell within 1 standard deviation of student norms.	N/A
Parker et al., 1997	5000	Sample demonstrate better mental health than norm group: $p<0.001$.**. Long work hours account for 8.8% of variance in mental health.	14% of sample has high blood pressure compared to 10.5% of norms***. Sample demonstrate worse physical health than normative group: $p<0.001$**.
Parker et al., 1998 (survey)	35	N/A	30% of sample = smokers. Number of cigarettes smoked significantly greater at sea than ashore: $p<0.005$. 56% classified as obese. Lower levels of chronic fatigue than norms****: $p<0.02$. >50% report health as good or excellent.

* Normative data obtained from 99 ‘businessmen’.

** 22 groups of white & blue-collar workers.

*** ABS (1992).

**** Onshore industrial shiftworkers.

crews, Griffiths and Tatttersall (1997) point out the importance of distinguishing between acute and chronic fatigue: once fatigue is experienced as chronic, allowing increased time for sleep and rest will do little to mitigate its effects.

It would therefore seem that lack of sleep at sea does indeed contribute to fatigue and decreased alertness, whether or not mariners themselves acknowledge the relationship. Sanquist et al. (1996) gathered data from 'sleep diaries' and found that watchkeepers obtain less sleep than other seafarers, but that all seafarers obtain less sleep on average whilst on tour, than they would ashore: average sleep duration at sea was 6.6 hours, as compared with 7.9 hours at home. Furthermore, watch type was found to significantly affect sleep length ($p<0.001$) and sleep quality ratings were found to be highest where sleep period start time occurred before midnight. The finding of Rutenfranz et al. (1988) also supports this proposition: seafarers working days (thus starting their main sleep before midnight) rated sleep quality as significantly higher ($p<0.05$) than those working rotating shifts. However, it would appear that shift type (i.e. 4&8 or 6&6) does not impact upon ratings of sleep quality (Donderi et al., 1995). Sanquist et al. (1996) acknowledge the lack of evidence relating to fatigue in the maritime industry, but suggest that current work schedules contradict what has long been known about human need for rest and recuperation.

Disturbed Sleep & Environmental Factors

Disturbed sleep, (as opposed to lack of opportunity for sleep) is also thought to be a major contributor to chronic fatigue, although some would argue that it is not necessarily intrinsic to the maritime industry (Howarth et al., 1999). However, it is not surprising that environmental factors, e.g. noise, are disruptive to sleep obtained at sea. However, research indicates that it is not just noise per se that affects the sleeping patterns of seafarers. Torsvall et al. (1987) examined the sleep/wake diaries of 49 engineer officers in the Swedish merchant marine. Predictably perhaps, watch duty where alarms were present reduced ratings of sleep length, quality and recuperation: 28% of nights at sea were perceived as disturbed, 12% of those can be accounted for by alarms. What is interesting however, is that nights spent on watch where no alarms occurred were also perceived as disturbed: it would appear that just the possibility of interruption is enough to affect sleep quality. These nights were also unsurprisingly typified by high levels of 'uneasiness' ($p<0.05$). However, fatigue indicators did not build up over the tour of duty, suggesting that the free nights in between watches may be sufficient for recovery from fatigue. Indeed, it would appear from this data that seafarers sleep significantly longer when not on watch (mean of 5.7 hours on watch with alarms, 6.5 hours on watch with no alarms, and 7.4 hours when not on watch at all). There is, however, some evidence that seafarers sleep more than is actually necessary. Dyer-Smith and Stein (1993) noted that lethargy, and therefore an increased desire for sleep, amongst seafarers mostly resulted from chronic boredom. Although some causes of sleep disturbance are noted in the article, it is nonetheless asserted that personnel aboard ship tend to use sleep as a form of escapism, and therefore spend the majority of their leisure time asleep.

Other environmental factors may also have a role to play, or may interact with poor sleep and long shifts to produce symptoms of fatigue. Pollard et al. (1990) conducted a study of shipboard crews, using self-reports (sleep and workload logs, fatigue rating scales) and in-depth interviews with officers on five short-sea merchant shipping vessels (crew sizes 17-25). Levels of fatigue were found to be influenced by hours worked, sleep quality, and both physically and mentally stressful work situations. In addition, the following were found to interact to produce fatigue and stress: organizational factors (e.g. ship management, pay), voyage and shift scheduling factors, ship design (e.g. level of noise and vibration) and physical factors, including extreme weather conditions. However, although these findings are based on a summary of results from interviews and direct observation, information as to the relative influence of particular factors and the magnitude of effects is not reported.

Fatigue & Alertness Ratings:

It is difficult to ascertain from the available data whether alertness ratings aboard vessels are affected by hours worked or shift type. Nonetheless, there are some interesting patterns to be noted, even if they do require significant replication before a clear picture of factors impacting on alertness levels can emerge. It would appear that watch duty significantly affects alertness ($p<0.05$) but that fatigue does not increase with time spent at sea: in fact, fatigue appears to decrease slightly ($p<0.05$) the longer the period at sea (Torsvall et al., 1987). According to Donderi et al. (1995) no evidence of the cumulative effects of fatigue were found, thus supporting the results of Torsvall et al. (1987). However, Donderi and colleagues (1995) did report that shift type (i.e. 4&8 and 6&6 schedules) does not significantly affect self-reported alertness, yet Sanquist et al. (1996) demonstrated that those on a 4-8 watch system were more likely to give low alertness ratings (= 3) than dayworkers (incidence rates of 0.15 and 0.05 respectively.)

No Evidence of Fatigue?

Not all research has concluded that fatigue is endemic to the maritime industry. For instance, Reyner and Baulk (1998) examined the sleep patterns of crew-members on 2 UK short-sea ferries, using actimeters, sleep logs, and subjective ratings of alertness. Sleep disturbance was generally found to be greater for personnel working split shifts, although no real evidence was found to suggest

Table 12. Sleep Data: Summary of Research Findings

Source	N	Duration/Timing	Quality
Torsvall et al., 1987	49	Average main sleep time = 5.7hours (with alarms), 6.5hours (without alarms) & 7.4hours (no watch duty.)	28% of nights rated as disturbed: alarms accounted for 12% of sleep disturbances. Nights with alarms characterized by high levels of 'uneasiness': $p<0.05$.
Rutenfranz et al., 1988	66	N/A	Sleep quality rated as higher among watchkeepers (as opposed to dayworkers): $p<0.05$.
Donderi et al., 1995	42	Main sleep period significantly longer on 4&4 schedule than 6&6: $p<0.01$.	Sleep quality not affected by shift type.
Sanquist et al., 1996	141	Mean sleep duration at sea = 6.6 hours, compared with 7.9hours at home. Watch type significantly affects sleep length: $p<0.001$.	Sleep quality ratings are highest when sleep onset is before midnight.
Parker et al., 1997	5000	>30% report less than 4 hours sleep per day.	Pilots & engineers more likely to report sleep as poor: 70% of total sample felt sleep to be poor quality.
Parker et al., 1998 (survey)	35	Total sleep duration per 24 hours = 5.5 hours, compared to 7.8 at home.	Significantly more sleep disturbances at sea than home: $p<0.001$.
Parker et al., 1988	23	Mean sleep duration at sea = 4-5.25 hours. 40-50% of sleep occurred outside optimal period (22:00-08:00: $p<0.001$).	Sleep quality ratings did not differ between routes.

N.B. Unless otherwise indicated, no occupational norms were available for comparison.

Table 13. Fatigue and Alertness Ratings: Summary of Research Findings

Source	N	Specific to Work Period	Specific to Tour
Torsvall et al., 1987	49	Alertness significantly affected by watch duty: $p<0.05$.	Fatigue decreased slightly over tour: $p<0.05$.
Condon et al., 1988	19	Alertness rhythms show little evidence of adaptation.	N/A
Donderi et al., 1995	42	No significant differences in self-reported alertness for 4&8 and 6&6 systems.	No cumulative fatigue effects.
Sanquist et al., 1996	141	Personnel on 4&8 shift more likely to rate alertness as =3: (incidence=0.15 vs. 0.05 for dayworkers).	N/A
Parker et al., 1998	23	Alertness lower at end of bridge period. Pilot differences account for 72% of variance in alertness.	N/A

N.B. Unless otherwise indicated, no occupational norms were not available for comparison.

that fatigue is a particular problem on these ships. No objective measures of alertness or performance were employed in this study, however.

OBJECTIVE MEASURES OF PERFORMANCE AND ALERTNESS:

Research, which objectively measures performance and alertness, is severely lacking although findings from other industries go some way to estimating theses relationships onboard ship. Horne (1985) suggested that sleep is comprised of two distinct types: 'obligatory' and 'facultative'. Only 'obligatory sleep' is needed for brain restitution and comprises the first five hours sleep during the night when slow wave sleep is predominant. While 'facultative' sleep is mainly "to occupy the unproductive hours of darkness" (p.54) and does not play a role in brain restitution. However, performance does appear to be affected when nocturnal sleep is curtailed below five hours or if it is taken during the daytime (Tilley & Brown, 1992). Sleep taken during the inappropriate circadian phase is more likely to be fragmented, shallower and shorter than sleep at night, as well as being more difficult to maintain. So even though a shiftworker obtains more than five hours sleep per day there may still be a build up of partial sleep deprivation because of the poor quality of day time sleep (Tilley et al., 1982, cited in Tilley & Brown, 1992). In a review of the literature, Campbell (1992) concluded that displaced sleep is related to performance deficits in a broad range of tasks. Thus for shiftworkers, sleep disturbance arising from displaced sleep is the major contributor to impaired performance.

Fatigue is hard to define in operational terms and this is reflected by the fact that there is no generally accepted objective test for fatigue, thus researchers often rely on self-report. Thus, studies tend to consider fatigue in relation to performance and measure it indirectly in terms of performance outcome. There have been a number of studies that have looked at sleep deprivation and performance (for a review see, for example, Tilley & Brown, 1992). In general, studies, which deprive participants of one total night of sleep, show deficits on particular tasks, such as vigilance and logical reasoning, (e.g, Blagrove et al., 1995), cognitive measures (e.g, Wimmer et al., 1992) and tracking tasks (Bohnen & Gaillard, 1994). However, studies in which sleep is reduced by a few hours per night have produced mixed results. For example Blagrove et al. (1995) reduced participants' sleep to approximately 5 hours for three weeks with no deficits to auditory vigilance or logical reasoning tests, although participants did report discomfort and disinclination to continue the regime. In contrast Webb and Agnew (1965, cited in Campbell, 1992) found that reducing sleep to three hours per night for eight days did result in slight deteriorations in performance of an addition task and visual and auditory vigilance tasks. In general, a large proportion of laboratory studies found no performance deterioration, however, there is some real life evidence that sleep restriction sustained over relatively extended time periods may result in diminished performance efficiency (Campbell, 1992). The Association of Professional Sleep Societies Committee on Catastrophes, Sleep and Public Policy (Mitler et al., 1988) reviewed a number of reports relating to human error and medical catastrophes. They noted that disasters such as the NASA Challenger space shuttle accident resulted from judgement errors made in the early hours of the morning by people who had insufficient sleep due to sleep loss and working shifts. The committee concluded that "inadequate sleep, even as little as 1 or 2 hours less than usual sleep, can greatly exaggerate the tendency for error during the time zones of vulnerability" p107. The 'zones of vulnerability' include two periods from 1am to 8am and 2pm to 6pm and correspond to periods of increased sleep propensity. (Mitler et al., 1988). This is reflected in a number of studies into accidents, which have found that in general, the night shift is associated with a higher risk of incidents (e.g. Lauridson and Tonnesen, 1990; Williamson and Feyer, 1995; Folkard, 1997).

Motion

As previously noted, the effects of vessel motion in terms of motion sickness and motion-induced fatigue (Smith, 1999, Colwell, 1989, cited in Powell & Crossland, 1998) are well documented. The relationship between vessel motion and cognitive performance is less well understood, however. A number of studies examining the relationship between vessel motion and cognitive performance have been carried out, yet results differ depending on the type of ship studied and experimental tasks employed. Using a ship motion simulator, Wilson et al. (1988, cited in Powell & Crossland, 1998) examined the effects of single frequency 'heave and roll' motions on cognitive performance. Results demonstrated that cognitive processing was significantly slower as a result of motion, although no information regarding total motion exposure time was available. Furthermore, it is not possible to ascertain from these data whether the accuracy, as well as the speed of cognitive processing was affected. However, Pingree et al. (1987, cited in Powell & Crossland, 1998) found evidence to suggest that motion results in performance degradation on a psychomotor tapping task, although not on computer-based cognitive tasks. It would therefore appear that certain types of cognitive task are more sensitive to the effects of vessel motion than others.

Table 14. Performance Findings

Source	N	By Shift	By Time of Day
Cook & Shipley, 1980	7	N/A	N/A
Condon et al. 1986	68	Trend towards: test score speed peaking during 16:00 – 20:00 and 00:00 – 00:00 shifts.	Trend towards: decrease in speed and alertness during early hours. Peak during the day.
Condon et al. 1988	39	Performance speed and alertness rhythms did not adapt to shift systems.	Letter cancellation test: interaction between shift and time into working day p=0.002.
Sablowski, 1989	70	N/A	No time of day differences found.

Field Studies

In a field study of UK ships' pilots, the choice serial reaction times of 7 pilots were measured (Cook & Shipley, 1980). Reaction times were not found to be slower after or during pilotage compared with pre-pilotage periods. However, the authors suggested that the test periods of four minutes might have been too short to show effects . In contrast, Condon et al. (1986) in a study of watchkeepers, on a "4on/8off" routine and day-workers, found that the speed of a complex visual performance task, and subjective alertness ratings decreased slightly during the early hours and peaked during the day. In a further study, Condon et al. (1988) found that task speed, in relation to its peak level, is slowest at the beginning of watches starting at 0400 or after recent awakening. Thus they suggest that there should be a provision for an adequate “waking up” period before the start of the duty. Subjective alertness was also found to be at its lowest during the night, although unlike performance, it tended to decline before sleep was imminent and was depressed after it. A significant interaction between time into working day and shift was also found for the letter cancellation test speed score ($p<0.002$). Condon et al (1988) concluded that the variations in operational effectiveness could be reduced by introducing watchkeeping systems, which allow a single long length sleep per day.

In a maritime simulation study, (Sablowski, 1989) subjects were given a primary task in which they had to pilot a container vessel for two hours, and a secondary task, which involved answering mental arithmetic problems. It was found that responses during the secondary task did show a decrement towards the end of the experimental run. However, as the experiment only lasted 2 hours and the mates were used to keeping watch for at least four hours, the performance decrement may have been due to lack of motivation due to the long period of familiarization at the beginning of the task.

PHYSIOLOGICAL STUDIES OF FATIGUE, STRESS AND CIRCADIAN ADAPTATION:

Several early studies have examined the physiological status of ships’ pilots in terms of stress and fatigue, and found some interesting, if not surprising results. Shipley (1978) examined heart rate as a stress indicator and found, broadly, that as job complexity increased, so did heart rate and therefore stress levels. Berger’s (1987) study of Australian pilots also highlights the detrimental health effects of this type of work: abnormally high levels of adrenaline excretion, particularly around midnight (approximately 7 times higher than those of a normal sleeping individual) were detected amongst pilots. Irregular sleep patterns and high cardiovascular risk also emerged as characteristic of the sample. Cook and Cashman (1982) studied ECG recordings of ships' pilots and examined the incidence of ectopic beats, thought to be triggered by stress. Although the findings demonstrate that the occurrence of ectopic beats was more common under demanding or hazardous pilotage conditions, the magnitude of the effect is difficult to determine. Furthermore, there is no way of ascertaining from this data whether pilots have a higher incidence of these irregular beats than the general population. In a much later study, Parker et al. (1998) demonstrated that their sample of pilots tended to describe themselves as morning, rather than evening types, a factor which may be pertinent to the relative fatigue effects of different shift schedules.

Colquhoun and colleagues (e.g. Colquhoun et al., 1979; Condon et al., 1984; Colquhoun and Folkard, 1985; Colquhoun, 1987) undertook several studies examining the effects of watchkeeping systems on circadian rhythm adjustment, aboard merchant vessels. Despite being inconclusive, their results suggest that full adaptation to the unusual working patterns of the seafarer does not generally occur, and would continue to be problematic without the implementation of fixed watchkeeping systems (Colquhoun, 1987). However, some studies using oral temperature as a measure of circadian variation do indicate a degree of adjustment to work hours (Colquhoun et al., 1979; Condon et al., 1984).

The 4-on/8-off System

In a series of six studies, Colquhoun et al. (1988) further examined the effect of watchkeeping schedules on a range of variables, including rhythm adjustment. In all cases (except Part VI) the watchkeepers studied worked the 'traditional' 4-on/8-off system and were matched with a roughly comparable sample of day workers. In Parts I, III, V and VI of this series (Part I: Colquhoun et al., 1988;

Part II: Rutenfranz et al., 1988; Part III: Plett et al., 1988; Parts IV and V: Condon et al., 1988) the following variables were measured in various combinations: oral and rectal temperature, hormonal circadian markers (e.g. adrenaline, noradrenaline and catecholamine) heart rate, cognitive performance, and self reports of alertness, sleep quality and duration (N.B. Details of the specific measures used in each study can be found in Table 1 below). It was generally concluded from these studies that two factors contribute to performance deficits in watchkeepers: lowered alertness resulting from circadian variation, and mental fatigue resulting from sustained attention to the job.

Table 15. Colquhoun et al. (1988) Work at Sea Series
Summary of Measures Used

Study	N	Measures Used
Part I	114	Diary records, oral & rectal temperature, urine samples, heart rate, performance tests.
Part II	67	Sleep and hours of work log books.
Part III	53	Oral & rectal temperature, urine samples, heart rate.
Part IV	39	Performance tests, alertness ratings.
Part V	43	Diary records, oral & rectal temperature, performance tests.
Part VI	3	Diary records, oral & rectal temperature, urine samples, heart rate, performance tests.

The results of Part III (Plett et al., 1998) demonstrate that there is a significant interaction between group (i.e. dayworkers, or those on a 4-on/8-off schedule) and time into working day on oral temperature measurements: $p<0.0006$, whereas data collected in Part V (Condon et al., 1988) demonstrate an interaction between time of day, and journey direction (i.e. east or west bound, $p<0.001$). Generally speaking, alertness showed poor adaptation to work hours, exhibiting a marked circadian rhythmicity: watchkeepers were least alert at night, an effect exacerbated by having just woken from sleep. General physiological adaptation was found to be at best partial, although catecholamine demonstrated the most marked effects of adaptation to time of day and hours of work. Colquhoun and colleagues (1988) argued that seafarers might be better able to adapt to unusual work patterns than shore workers, as the influence of external 'zeitgebers' (i.e. time of day cues) may be lessened at sea. This is clearly not the case however: it appears that the unusual working environment aboard ship does nothing to facilitate adaptation of physiological rhythms.

Table 16. Physiological Data: Summary of Research Findings

Source	N	By Shift	By Time of Day
Colquhoun et al. (1988)	114	N/A	N/A
Plett et al., 1988	33	N/A	Oral temperature: interaction between group & time into working day: $p<0.0006$.
Condon et al., 1988	6	N/A	Oral temperature: interaction between time of day & journey direction: $p<0.001$.
Fletcher et al., 1988	3	Although not reported, physiological data appears to indicate poor adaptation to the new system.	N/A
Parker et al., 1998 (survey)	35	N/A	Overall, sample consisted of more 'morning' than 'evening' types.

Alternative Shift Systems

Brown (1989) felt that seafarers' tasks (particularly watchkeepers) did not require the continuous kind of attention and concentration that would rule out longer duty periods. He suggested that a shift of 8 hours, as practised by other industries, would have no adverse effects on seafarers' ability to keep watch. He drew on a number of studies to highlight the need for sleep and the consequences of shortened sleep times. For example, Colquhoun (1985) suggested that the fixed 4 hours on/8 hours off shift system fragmented sleep. In fact, Sanquist et al. (1997) reported that watchkeepers on the 4-on/8-off schedule obtained less than 4 hours sleep per day for just over a fifth (22%) of their time at sea, and in a study of vigilance performance Horne et al. (1983, cited in Brown, 1989) demonstrated that sleep deprivation impaired the ability to discriminate signals. Brown (1989) pointed out that partial sleep deprivation has serious implications for the maintenance of vigilance by watchkeepers, especially as performance on tasks that are longer, familiar and disinteresting deteriorate more than shorter, novel and interesting tasks.

Fletcher et al. (1988, Part VI of the Colquhoun et al. series) conducted a trial of an alternative watchkeeping system in the merchant marine. The 2/6 system was introduced, the main benefits of this being that duty spells are compressed into a 14-hour period, thus making it possible for watchkeepers to take just one sleep per day: measurement of variables followed the same pattern as described for previous studies. Participants were also interviewed with regards the acceptability of this new system.

There were several limitations to the study however: firstly, only three officers participated and secondly, the new system was not compatible with the traditional deck watches (an 'oversight' on the part of the experimenters). However, the results can be summarized as follows: all 3 officers found the new watch more difficult and stressful under bad environmental conditions, but only one felt that the benefits of the longer, single period of sleep afforded by the new system compensated for this. There is some subjective evidence to suggest that the officers were having trouble adapting to the new system – the latter part of the watch would have overlapped with time normally spent sleeping under the old system. The authors state that physiological measurements also show this trend, although they are not discussed in any detail, due to some difficulties analysing the data. Nonetheless, Brown's (1989) recommendation of limiting the working day to 14 hours has had some success. The watch system reported by Fletcher et al. (1988) has recently been adopted by the American Coast Guard and has proved popular with seafarers as well as improving efficiency and alertness (The Telegraph - The Journal of Numast, 2000). Nonetheless, the vessels under study by Colquhoun and colleagues (1988) ranged from submarines to oil tankers: caution should therefore be exercised in interpreting the results, as ship type is bound to impact upon factors such as fatigue and alertness. In addition, there have been significant changes in the nature of the watchkeeping task in the last ten years.

Review & Comparison of Schedules

Donderi et al. (1995) reviewed studies looking at different watchkeeping schedules, and undertook an experimental comparison (n=42) of the 4-on/8-off, and 6-on/6-off systems. With regards the 6-on/6-off system, Boulard et al. (1989, cited in Donderi et al., 1995) found that day-watch personnel performed better under this schedule. Various other combinations of work and rest hours have been examined, although not in recent years. For example, Wilkinson and Edwards (1968, cited in Donderi et al., 1995) conducted a shore-based study of a 5-on/7-off system, and demonstrated partial performance adaptation and a flattening of circadian rhythms. In a 3-day study of a 4-on/4-off schedule, Chiles et al. (1968, cited in Donderi et al., 1995) found little evidence of circadian adaptation. In an attempt to demonstrate the merits of fixed watchkeeping schedules, Colquhoun et al. (1969, cited in Donderi et al, 1995) examined a 12-

on/12-off system in 12 night, and 10 dayworkers over a period of twelve days, and found no evidence of performance differences between the two groups. Donderi et al. (1995) concluded, in their quest for an appropriate system for the Canadian Coast Guard, that longer sleep periods were attainable under the old 4-on/8-off schedule ($p<0.01$: although total sleep time did not differ between the two groups). This schedule would be most appropriate for dayworkers, whereas the 6-on/6-off system would be of more benefit to night workers. The relationship between shift system and fatigue may not therefore, be as simple as has been suggested (e.g. Brown, 1989; Colquhoun, 1984; Colquhoun et al., 1988). However, no effect sizes are reported in the Donderi et al. (1995) study, restricting this interpretation of results.

Differential Adaptation

It is worth noting at this point, that not all bodily systems adjust at the same rate (Rosekind et al. 1994); it is therefore difficult to determine the degree of adaptation to a particular type or system of work. It is also important to be aware that internal circadian rhythms can be overridden to some extent by motivation. However, there is as yet little knowledge of the long-term effects of circadian disruption and sleep loss (Rosekind et al. 1994), although it is difficult to study long term effects of any form of shiftwork, as up to 20% of workers are forced to leave due to the unpleasant nature of effects on health and well-being. Personnel currently working shifts are therefore likely to comprise a ‘survivor’ population. Individual differences in adaptation to shiftwork (Waterhouse et al., 1992) and the effects of psychological mood on fatigue are also areas lacking in investigation: mood may be affected by working unusual hours, thus exacerbating fatigue and alertness problems (Paley & Tepas, 1994).

Brown's Conclusions

Brown (1989) made the following recommendations with regards work hours in the shipping industry, although he acknowledged a need for them to be validated:

1. A minimum period of 10 consecutive hours for rest and sleep in each 24 hours;
2. A rest break of at least 10 hours before the start of first duty period and a rest break of at least one hour between a duty period and a subsequent duty;
3. A maximum variation of 2 hours in the starting and finishing times of permitted daily working hours;
4. A maximum of 6 hours of continuous duty followed by a break of at least 1 hour's duration;
5. A maximum of 10 working hours (including overtime) per day, 60 working hours per week and 200 working hours per month.

With regards recommendation 4 above, Brown provided no research evidence for this maximum time, although he did cite Grandjean (1969) who concluded that a mid-day break of 45-60 minutes was sufficient to recover from fatigue effects. Brown (1989) summarised Bartley and Chute's (1947) publication on fatigue and suggested that fatigue was cumulative, in that, "if developed on one occasion, it is likely to be experienced when similar conditions recur"(p. 20). This statement is misleading as it suggests that fatigue is a result of certain conditions and does not fit with the assertion that fatigue is experienced by individuals who are obliged to work beyond the point at which they are capable of effective performance. Cumulative fatigue is usually seen as resulting from a 'build up' over a period of time. Brown (1989) also suggested that fatigue produces the initiation of compensatory behaviour, which reduces the individual's reserves for coping with stress. He felt this led to objective and subjective strain, which he saw as a real and perceived reduction in the ability to cope. Once again however, no research evidence was offered to validate this suggestion.

SUMMARY OF THE MEASURES TO ASSESS ACCIDENTS AND INJURIES, FATIGUE, HEALTH AND STRESS IN THE MARITIME INDUSTRY:

As previously noted, Brown (1989) concluded that fatigue was a major problem within the maritime industry and asserted that working hours required urgent reform, if further accidents, ill health and stress were to be avoided. Nonetheless, when examining the literature in detail it becomes apparent that there is little concrete evidence of the detrimental effects of working at sea on health, alertness, circadian adaptation and performance.

Accidents

There is a link between fatigue, poor mental health and vessel accidents, albeit an indirect one inferred via other established relationships. For example, poor quality/lack of sleep will aggravate feelings of fatigue, and the association between sleep and accidents has already been established: accidents at sea peak in the early hours of the morning (Folkard, 1997) and appear most likely to occur when crew have had little or poor quality sleep prior to the incident (MAIB, cited in Phillips, 2000). However, methods of accident reporting and analysis require attention, if conclusions as to underlying causation are to be drawn. Accident data available for offshore platforms contains details currently missing from vessel accident data, such as days into tour and detailed shift schedule information. Nonetheless, some attention has been paid to determining the role of occupation in vessel accident vulnerability, although results are somewhat conflicting.

Survey Measures

Seafarers themselves report suffering from stress and fatigue effects: (NUMAST, 1995) as an occupational group they are more likely to suffer poor physical health than their onshore counterparts, yet are likely to be more psychologically robust (Parker, 1997; 1998). One anomaly seems particularly evident on examination of the literature: on the whole, seafarers report poor quality, disturbed sleep, yet they feel their performance remains unaffected by fatigue and decreased alertness. Perhaps the most striking feature that emerges from the self-report data is the high workload and excessive number of hours worked by seafarers as a result of industry reforms.

Performance

The relationship between fatigue and cognitive performance is a largely neglected area of research. Shiftwork and sleep studies however, have demonstrated the detrimental performance effects of nightwork and poor sleep: it is therefore highly likely that the same relationships would hold true for seafarers. There is nonetheless a more substantial body of evidence detailing the effects of vessel motion, which may in turn induce fatigue, on performance. The literature generally suggests that motion will lead to performance degradation on cognitive tasks, although relatively little is known about the necessary motion severity and task types most affected. A handful of studies in the merchant marine have demonstrated that performance on a number of seafaring tasks slows at specific times; namely directly after a period of sleep or at the beginning of shifts starting on or around the 0400 mark.

Physiological Data

There is very little explicit reference within the literature to the role of fatigue in decreased vigilance or the persistence of day-oriented rhythms. Nevertheless, time of day and shift-related patterns would seem to indicate that physiological adaptation of circadian rhythms and alertness levels are implicated, at least partially in accident rate and severity. Despite somewhat sketchy evidence of circadian adaptation to seafaring work patterns, adjustment to the 4-on, 8-off system seems to be partial at best. Other shift systems have been suggested and some researched (e.g. the 6-on/6-off schedule) yet a great deal more information is needed in order for a clear picture of physiological rhythms at sea to emerge. Indeed, the effect of circadian variations on performance in general has not been well researched, either on vessels or rigs, although there are some exceptions (e.g. Shipley and Cook, 1980; Condon et al., 1986).

SUMMARY OF FATIGUE AND HEALTH IN THE OFFSHORE SECTOR:

It would appear that the majority of research into health and stress in the offshore oil industry has concentrated on oil-rig workers, although there is scarce mention of the role of fatigue, except that it may be induced by motion (Powell & Crossland, 1998). Similar studies in the maritime industry have tended to overlook offshore sectors altogether, in favour of more intuitively demanding occupations, such as fishing (e.g. Elo, 1985, Johnson, 1994) and the Navy (e.g. Burr et al., 1993). It is certainly evident that little has been done to determine the nature and causes of fatigue at sea since Brown (1989) concluded that excessive work hours were a major contributor to accidents. Furthermore, having identified the available literature relating to fatigue, health and injury in the offshore oil industry, it is apparent that large gaps currently exist within our knowledge of a number of areas, including accident causation, physiological state and cognitive performance.

The review aims were as follows:

1 To identify the extent and nature of research into accident and injury occurrence in seafarers and rig workers and to determine to what extent fatigue can be considered a causal factor;
2 To examine self-reports of stress, health and fatigue and identify the scale of the problem in these various occupational groups;
3 To identify environmental factors contributing to stress, poor health and fatigue;
4 To identify any objective studies of the effects of work schedules, stress and fatigue on performance, and physiological state;
5 To draw comparisons between the literature available on offshore platforms and vessels, and identify any gaps in current knowledge.

The Extent and Nature of Research into Accident and Injury Occurrence Offshore

The analysis of accident data differs significantly between offshore platforms and vessels: studies of maritime accident data are in the main limited to anecdotal case studies, or straightforward reports; few researchers have examined underlying causation. Although some attempts to determine differential occupational vulnerability and the contribution of fatigue to incidents have been made, limitations in reporting methods (true of all areas of the offshore industry to some degree) tend to obscure the true nature of relationships. Some of these problems could be overcome if, for example, more explicit hours into shift and days into tour information were analysed, as they have been with regards offshore platform personnel. Currently, all that can be concluded from maritime accident statistics is that incidence is likely to be affected by circadian factors and shift length, and that the role of fatigue in causation has been hugely underestimated in the past. In contrast, although fatigue has not been explicitly examined as a causal factor in accident and injury aboard platforms, data relating to work patterns prior to an incident, risk perception and personality characteristics have been studied, where appropriate. It is important to note however, that accident exposure rate information was not available in the majority of these studies, limiting an accurate reflection of results.

Self-reports of Stress, Health and Fatigue: The Scale of the Problem Offshore

Studies of the psychological effects of working in the offshore oil industry are in the main inconclusive: there is some evidence that psychosocial stressors unique to these kinds of environments impact upon mental health (Parkes, 1998), yet other studies have either failed to examine the psychological state of participants, or concluded that they were no worse off than their onshore counterparts (Gann et al., 1990; Parker et al., 1998). There is some evidence of poor physical health in vessel crew particularly amongst pilots, although it is not clear whether this occurs as a result of stress, poor diet or a combination of factors (Parker, 1998).

Although a number of studies have been conducted into stress and health in the offshore oil industry, they rarely refer to fatigue explicitly, and the majority apply to offshore platforms. Having said that, it is apparent from the self-reported data that increased workload, excessive work hours, poor quality or lack of sleep and feelings of boredom and isolation all contribute to stress, poor mental health and fatigue. More specific information (regarding levels of anxiety and depression and the relationship between work hours, sleep and fatigue) is needed in the maritime sector, as is comparison of health records and absenteeism data, in order to bring this area in line with existing information on offshore platforms.

Environmental Factors Contributing to Stress, Poor Health and Fatigue

The combination of unique environmental stressors in the offshore oil industry- noise, ship motion, adverse weather conditions, poor lighting and ventilation, and confined working and living spaces– leads to poor psychological health and sleep habits amongst rig workers and seafarers alike. However, although some level of agreement between studies of environmental factors on platforms and vessels can be found, the volume of information available for the former category is much greater than for the latter, as indeed is the number of environmental stressors examined.

Objective Studies of the Effects of Work Schedules, Stress and Fatigue on Performance and Physiological State

Performance

It becomes evident when reviewing the research that the effects of shift factors and fatigue on cognitive performance has been somewhat neglected. Very little work has been conducted on offshore vessels, or indeed any vessel type, tackling the issue of performance, with the exception of motion studies. Although it appears that certain shift start times are more vulnerable to performance deficits than others, the relative influence of shift timing has not been examined at sea in the same way as it has on offshore platforms. For example, it has been suggested that shift rotation has a significant impact on the alertness levels and performance of rig workers, yet no such conclusions can be drawn from seafarers’ performance data.

Table 17: Summary Table - Hours into Shift/Time of Day

Sector	Days into Tour/ Shift Patterns	Hours into Shift	Time of Day	General/ Other	Source
Offshore Rigs & Platforms	Incidents increased by: Tours exceeding 2 weeks; rotating shift systems, night shifts; displacement from shift start time. Injuries more severe with increasing tour length, especially above 2 weeks.	Serious accident risk increases with hours into shift Accidents decrease over a 12 -hour shift.	Incidents more likely to occur around midday (p<.05). More injuries generally during day than night, particularly between 0000-0600 (with the exception of drillers).	Season effects: more incidents occur in winter (p<.05). Drillers accounted for 17.6% of fatal and serious injuries. Most common injuries: arm & leg area by means of slips/trips/falls. Accident victims tended to demonstrate lower mental health (p<.027) more obsessional behaviour (p<.01) and be more depressed (p<.01) than controls.	Miles (2000); Parkes & Swash (1999); Forbes (1997); Laundry & Lees (1991); Sutherland & Cooper (1987); Sutherland & Cooper (1991); Lauridsen & Tonnesen (1990).
Shipping Vessels	N/A	Critical vessel accidents: Number of hrs on duty prior to casualty (p<.0001) and hrs worked in the 24, 48 and 72 hours preceding the casualty significantly affect accident likelihood (p<.001). Seafarers reported working an average of 14.3 hrs in every 24 hours preceding a fatigue related injury (compared to 8.4 hours: p<.001).	Marine pilotage accidents: More likely to occur between 0400 – 1000 and 1600 – 2400 (p<.05). Ship collisions peaked between 0600 and 0700 (p<.001). Collisions and groundings peaked between 0000 and 0400.	Some evidence suggesting that ratings are at the highest risk of fatal accidents, and some contradictory evidence that deck & petty officers are most vulnerable. Fatigue cited as a causal factor in a very small % of incidents.	Nielsen (1999); Raby & McCallum (1997); Smith & Owen (1989); Folkard (1997); Phillips (1998).

Table 18: Summary Table - Stress, Health & Fatigue Offshore

Sector	Mental Health	Physical Health	References
Offshore Rigs & Platforms	35% of variance in mental health can be explained by type A behaviour, home/work relationships, marital status & environmental factors. 15% of sick bay visits were for psychological issues. Mental health disorders make up 4 -5% of total medical evaluations. Higher free-floating anxiety levels offshore. Greater sleep problems, perceived risk and perceived workload, dissatisfaction with shift schedules and living conditions, lack of social support. Relationship exists between psychosocial stressors and formal reports. Shift schedule is the strongest predictor of satisfaction.	47% of platform workers report muskuloskeletal problems. 14% of crew-members report major health problems (compared to 21.3% of controls): 34% of these are attributed to headaches (57% for controls), and 77% to sleep problems (57% for controls). Smoking and drinking in excess of 21 units per week more common offshore. 40.1% of offshore workers are classified as overweight.	Parkes (1999); Parkes & Razavi (1997); Parkes & Clark (1997); Horsley (1996); Parkes (1992); Gann (1990); Cooper & Sutherland (1987); Gann (1989); Light & Gibson (1986); Anderson & Cox (1987); Hellesoy (1985).
Shipping Vessels	Job insecurity & unfair workload distribution are significantly related to depression: $p<0.001$. Over ¾ of Officers felt fatigue and stress had risen significantly in previous 3-10 years. Sample demonstrates better mental health than norm group (22 groups of white & blue-collar workers): $p<.001$. Long work hours account for 8.8% of the variance in mental health. Increased workload and dissatisfaction with shift schedules due to shipping reforms (i.e. reduced manning.)	14% of sample have high blood pressure compared to 10.5% of norms (ABS, 1992). Sample demonstrates worse physical health than normative group (22 white & blue-collar workers): $p<.001$. 56% classified as obese. Lower levels of chronic fatigue than norms (onshore industrial shiftworkers):$p<.02$. 50% report health as good or excellent.	Elo et al. (1985); Riordan et al. (1991); Burr et al. (1993); Parker et al. (1997); Parker et al. (1998).

Table 19: Summary Table - Environmental Factors & Sleep Offshore

Sector	Duration/Timing	Quality	Environmental Factors	References
Offshore Rigs & Platforms	Sleep offshore tends to be significantly shorter than sleep on leave (and that of onshore workers). Weekly sleep deficits are estimated at between 14-5-20-3 hours.	Sleep quality ratings significantly higher on leave: appears to be the case for both on- and offshore workers, with little difference between the two for night and day shifts.	Environmental stressors related to adverse health outcomes, perceived risks, job characteristics and insecurity, home/work interface problems/concerns and sleep disturbance. Drilling crews most affected.	Parkes (1994); Parkes & Razavi (1997); Parkes et al. (1997)
Shipping Vessels	Average sleep duration at sea = 6.6 hours, compared with 7.9 hours at home. Watch type significantly affects sleep length: p<.001. 30% of sample reports less than 4 hours sleep per day. Total sleep duration per 24 hours = 4-5.25 hours. 40-50% of sleep occurs outside the 'optimal period' (2200-0800: p<.001).	Sleep quality not affected by shift type (Donderi et al., 1995). Pilots & engineers more likely to report sleep as poor: 70% of total sample felt sleep at sea to be of poor quality. Seafarers obtain significantly less sleep than onshore workers, although self-reported alertness remains relatively high.	Noise, or possibility of noise disturbs sleep. Noise, vibration & extreme weather interact with organisational and shift factors to produce stress and fatigue.	Torsvall et al. (1987); Rutenfranz et al. (1988); Donderi et al. (1995); Sanquist et al. (1996); Parker et al. (1997); Parker et al. (1998).

Table 20: Summary Table – Performance Effects Offshore

	By Shift/Tour	By Time of Day	General Effects	References
Offshore Platforms Rigs &	Fasted reaction time occurred in initial week of 7 days & 7 nights. 14-day shift: there is a tendency for reaction time to decrease over successive shifts. Objective performance and alertness affected by shift rotation.	Rotating Shift Workers; Reaction time increased from start to end of shifts. Shift change has short-term adverse effects on simple memory. There is a trend for reaction time to decrease over time within shift.	Suggestion that horizontal motions could cause acceleration of muscle fatigue and impaired performance on long shifts – though no real evidence. Vibration disrupts performance through mechanical disruption and progressive impairment – again, no real evidence.	Lewis & Griffin (1997); Powell & Crossland (1998); Mcpherson (1999); Parkes et al. (1999).
Shipping Vessels	There is a trend towards test score speed peaking between 1600-2000 and 0000-0000 shifts. Performance speed and alertness rhythms did not adapt to shift systems.	Trend towards decrease in speed and alertness during the early hours. Peak during the day. Letter cancellation test: interaction between shift and time into working day ($p<.002$). According to some research (e.g. Sabolowski, 1989) no time of day performance differences exist.	N/A	Cook & Shipley (1980); Condon et al. (1986); Condon et al. (1988); Sabolowski (1989); Wilson et al. (1988); Pingree et al. (1987).

Table 21: Summary Table – Physiological Data

Sector	By Shift	By Time of Day	General	References
Offshore Rigs & Platforms	Most offshore night shift workers show circadian adjustment for fixed shift schedules (e.g. 1800-0600) when working 2-week tours. Adjustment affected by light exposure. Adverse changes in muscle strength, central nervous system parameters and haemodynamics in response to challenge are more apparent in 2 compared to 1-week tours. 1-week tours therefore recommended.	Physiological effects in terms of locomotor reaction time increase significantly by the end of the day, in response to audiovisual challenge.	Disagreement as to whether there are season effects of rhythm adjustment. Bright light treatment significantly improved subjective adaptation ratings to night work.	Barnes et al. (1998a); Barnes et al. (1998b); Arendt et al – University of Surrey; Bjorvatn et al. (1999): Alekperov et al. (1988).
Shipping Vessels	Circadian adaptation to the 4-on, 8-off system is at best partial. 6-on, 6-off schedule is better suited to nightworkers.	Oral temperature significantly interacts with group, time into working day & journey direction. Overall, seafarers tend to be more 'morning' than 'evening' oriented.	N/A	Colquhoun et al. (1988); Plett et al. (1988); Condon et al. (1988); Fletcher et al. (1988); Parker et al. (1998).

Physiological State

Studies of circadian adaptation reveal some interesting differences between seafarers and rig workers: according to Parkes (1994) offshore shiftworkers are more likely to adapt to their work patterns than onshore shiftworkers, although this pattern does not appear to hold true for seafarers. Colquhoun et al. (1988) found adaptation to the 4-

on/8-off system to be at best partial. Interestingly, although rig workers show best adaptation to 2-week shift schedules, this does not appear to have any performance benefits.

General Conclusion

Although many parallels can be drawn between the offshore platform and vessel environments, it is important to keep in mind the unique differences between the two sectors when interpreting results. For example, it has already been noted that platform shiftworkers adapt better than those onshore, yet this does not apply to seafarers; this is more than likely due the shift length differences between the two groups of personnel. There are many possibilities for future research on fatigue in the offshore oil industry, particularly within the maritime sector: the impact of long and unusual work hours on psychological and physical health requires considerable clarification, as can be seen from the summary tables. There are few, if any, studies that systematically measure all possible indicators of fatigue in the offshore oil industry, namely accident statistics, self-report, performance and physiological data. Research also needs to address the unique combinations of potential stressors, which may interact in various ways to produce fatigue, poor health and increased accident risk.

In conclusion therefore, the review has identified various research areas, particularly in the maritime sector, which require attention if an accurate picture of the nature and causes of fatigue is to emerge. Accident data requires closer inspection with regards hours into shift and days into tour information, although current reporting systems may not allow for this. Furthermore, information regarding exposure rates is not currently available for platforms or vessels, rendering prediction of accident likelihood beyond the scope of research until a uniform accident reporting procedure is put into place.

The effects of working offshore on health, both mental and physical, are also unclear: what research there is therefore, requires replication in the form of survey measures of both physical and mental health comparing any similarities between seafarers and rig workers, and differences between these occupational groups and onshore populations. The influence of environmental factors is also an under researched area, particularly amongst seafarers: the influence of poor weather and motion on performance, health and sleeping patterns can only be estimated from the existing literature. With regards performance data, the relative influence of shift timing requires attention in the maritime sector, if comparisons are to be drawn, and differences highlighted between seafarers and rig workers. Having said that, the effects of fatigue on performance and health in offshore platform personnel also remain to be explicitly examined.

Examination of physiological indicators of health and fatigue have been somewhat neglected in terms of offshore oil industry workers in general, particularly amongst seafarers. As is evident from the review, there exists a small selection of studies on circadian adaptation, although this has been far more thoroughly researched in platform personnel than seafarers. Furthermore, until very recently, no attempts has been made to examine disease risk factors in terms of physiological data in the former occupational group, something that requires replication and comparison with personnel working on vessels. Not only is comparison of all of the above data with onshore populations necessary, future research should aim to examine any potential differences between offshore workers at work, and on leave periods, seek to replicate current findings within larger study populations and establish a clearer picture of the relative influence of shift length and pattern on a wide range of variables. Thus, if appropriate work patterns and their regulation are to be implemented, they need to be based on concrete evidence of the nature and causes of fatigue, and not, on unsubstantiated beliefs or anecdotal evidence.

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