A review of research into fatigue in offshore shipping

Research associates at the Centre for Occupational and Health Psychology at Cardiff University, Rachel McNamara, Alison Collins and Victoria Matthews are currently working with the Seafarers International Research Centre on a project looking at aspects of fatigue and health in merchant seafarers. The project is funded by the HSE, MCA and Seafarers International Research Centre.

Although seafarer fatigue is not a new concept, there has been little research to date examining work and rest schedules in the maritime industry. Seafaring is a dangerous occupation because it includes a number of workplace dangers in combination, something 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.

Increasingly, shipping regulators, owners and trade unions alike are becoming aware that such conditions, along with ship type, minimal manning, rapid turnaround, short sea passages and traffic conditions, may find seafarers working long hours without sufficient rest. These factors will undoubtedly result in fatigue, which has potentially disastrous consequences both for the individual in terms of reduced performance and poor health (for example, ulcers, hypertension and hearing loss as a result of excessively noisy machinery and vibration) and as for the environment, if accidents occur as a result of lowered alertness. The present article is based on a recent review of the literature on these topics (Collins, Matthews and McNamara, reference 3). This literature review has been the starting point of our current project, which is briefly outlined at the end of the article.

Gaps in current knowledge

Research has established a link between fatigue, poor mental health and accidents in other areas of the transport industry (e.g., Dinges, 1995). However, due to a lack of evidence, we can only infer the existence of such relationships in the maritime industry.

There is an established link between shift pattern, poor health, safety and fatigue in onshore shift-workers (e.g., Waterhouse et al, 1992). Given the added complications of working at sea, (i.e. living and working in the same environment, vessel motion, noise and poor weather) it seems fair to assume that the impact of shift pattern would be greater still on maritime crew. Concrete evidence of this, however, is currently not available.

The contribution of fatigue to personal and vessel accidents

There is little evidence of the causal influence of fatigue to accidents in the maritime industry: this may, however, be due to inadequacies in incident

reporting systems. Many files covering accidents are insufficiently detailed: for example, they often fail to provide information relating to days into tour, hours into shift, shift patterns and number of hours worked before the incident, thus causes often remain obscure.

The role of fatigue in performance deficits

Fatigue is hard to define in operational terms. This is reflected in the fact that there is no generally accepted objective test for fatigue and researchers typically rely on self-report. Studies, therefore, tend to consider fatigue in relation to performance and measure it indirectly in terms of performance outcome. With regards to the effects of sleep on performance, results are ambiguous. Furthermore, little is currently known about the effects of shift pattern on performance at sea, as the working environment is vastly different from that experienced by onshore shift-workers. Any inferences from other occupational groups must, therefore, be handled sceptically and with caution.

The effects of work hours and fatigue on physiological status

The few studies to have examined physiological indicators of fatigue in seafarers have tended to concentrate on ships' pilots. We therefore know very little about the impact of excessive work hours and lack of sleep on health outcomes such as high blood pressure, increased heart rate, and digestive disorders in this occupational group as a whole. People's ability to perform the majority of tasks is influenced by internally controlled rhythms that run to a 24-hour cycle.

Such rhythms are pervasive in human physiology and behaviour, and appear to be vital to overall well-being. Known as circadian rhythms (from the Latin "circa" - meaning about, and "dies" - meaning day) they mediate numerous systems and functions within the body, including temperature, sleep, motor and cognitive performance and digestion. Studies of onshore shift-workers have shown that night- and shift-work can lead to reduced efficiency and decrements in health, potentially as a result of disrupted circadian rhythms. However, comparable research is not yet available for seafarers. Furthermore, because seafarers' shifts tend to be shorter and more frequent than those of say, industrial shift-workers, the degree of circadian disruption may be greater; in other words, maritime crew may adapt less well to their unusual work patterns than their onshore counterparts.

The role of the environment on fatigue, health and performance

Seafarers have to contend with a number of unique environmental stressors including noise, motion, poor lighting and ventilation, adverse weather conditions and confined working and living spaces which can lead to poor psychological health and sleep habits. However, the influence of these environmental stressors is an under-researched area. There has been some investigation into how a single factor impacts on the life of seafarers but examination of the way in which these factors interact in combination has been sorely neglected.

Anecdotal evidence and extent of research

It has long been suspected from the large amount of anecdotal evidence, that fatigue contributes to human error and is a major cause of accidents and incidents at sea. Some attempts have been made to try and gauge the prevalence of fatigue and its consequences. In 1995, NUMAST organized a survey of over 1,000 officers across all sectors of the industry, inviting them to comment on health and stress issues. Many respondents reported shifts of between 12-20 hours per day. In addition, 77% of officers felt that fatigue had significantly risen in the previous three-ten years and 84% felt stress to be more prevalent over this time period than previously.

Vessel accidents

It has already been noted that information pertaining to accidents does not always include details of prior working arrangements of the individuals involved: nevertheless, in recent times greater emphasis has been placed on examination of fatigue as a contributory factor. The US Coast Guard has stressed the importance of investigating the contribution of human-related causes to marine accidents. In a study by Raby & McCallum (1997), investigating officers and mariners were asked to use their judgement in 98 casualty cases. Results show that investigating officers judged fatigue as contributory in 23% of cases, while the mariners judged 17% of cases as fatigue related. From these subjective judgements three factors were identified as significantly contributing to casualties:

- the number of self-reported fatigue symptoms
- the total of hours worked in the 24 hours before the incident
- the total hours spent sleeping during those 24 hours.

Lack of sleep has dangerous consequences as highlighted by the grounding of the oil tanker Exxon Valdez in 1989. It has been estimated that during the 24 hours before the accident, the watchkeeper only obtained five or six hours of sleep, taken in two separate periods. Furthermore, it would appear that time of day has a significant effect on accident likelihood: Folkard (1997) found that collisions at sea were more likely to occur during early morning hours with a peak between 04:00 and 07:00.

Subjective measures of health, stress and well-being

There is some evidence to suggest that the long hours worked at sea, combined with the unique pressures faced by seafarers, negatively impact on health and well-being. In a survey of health, stress and fatigue in Australian seafarers, Parker et al (1997) analysed the responses of over 5,000 participants, in a wide range of occupations. Results demonstrate that physical health in this group is generally worse than that of onshore workers, 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 with 10.5% of

norms). The pattern of results which emerges for mental health is particularly interesting: although this sample generally appears more psychologically robust than onshore populations, a significant proportion of variance in the mental health of seafarers could be explained by working excessively long hours.

It would seem that lack of sleep at sea does indeed contribute to fatigue and decreased alertness, whether or not mariners themselves are aware of the correlation. Sanquist et al (1996) gathered data from "sleep diaries" and found that all seafarers obtain less sleep on average while on tour than they would ashore: average sleep duration at sea was 6.6 hours as compared with 7.9 hours at home. It is difficult to ascertain from the available data whether alertness ratings are affected by hours worked or shift type. Nonetheless, it would appear that watch duty significantly affects alertness, but that fatigue does not increase with time spent at sea: in fact, fatigue appears to decrease slightly with tour length (Torsvall et al 1987).

The impact of fatigue on performance

There is some "real life" evidence that sleep restriction sustained over relatively long time periods can lead to diminished performance efficiency. In a review of the effects of sleepiness on accidents, Dinges (1995) concluded that the effects of sleep deprivation can be cumulative, and reductions of as little as two-three hours per night can contribute to sleepiness over a number of days. The Association of Professional Sleep Societies Committee on Catastrophes, Sleep and Public Policy (Mitler et al, 1988) concluded that reduction of sleep by one or two hours, can result in an increased likelihood to make errors during the "time zones of vulnerability" (p107) which include two periods from 1am to 8am and 2pm to 6pm.

It was further 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 working shifts and sleep loss. Indeed a number of studies into accidents have found that, in general, the night shift is associated with a higher risk of incidents (e.g., Lauridsen and Tonnesen, 1990; Folkard, 1997).

Although the effects of vessel motion in terms of motion sickness and motion induced fatigue are well documented, (e.g., Smith, 1999, Colwell, 1989, cited in Powell & Crossland, 1998) the relationship between vessel motion and cognitive performance is less well understood. 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. Indeed, it may well be the case that certain types of cognitive task are more sensitive to the effects of vessel motion than others.

Physiological status

Several early studies 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 physiological effects of this type of work: abnormally high levels of adrenaline, particularly around midnight (approximately seven-times higher than those of a normal sleeping individual) were detected among pilots. Irregular sleep patterns and high cardiovascular risk also emerged as characteristic of the sample.

In a series of six studies, Colquhoun et al (1988) examined the effect of watch-keeping schedules on a range of variables, including circadian rhythm adjustment. Generally speaking, alertness showed poor adaptation to work hours, exhibiting a marked circadian rhythmicity: watch-keepers were least alert at night, an effect exacerbated by just having woken from sleep. General physiological adaptation was found at best partial. However, there is as yet little knowledge of the long-term effects of circadian disruption and sleep loss in general (Rosekind et al (1994) although it is difficult to study long-term effects of any form of shift-work 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.

Limitations of research carried out to date

Having reviewed the available research, it becomes evident that our current knowledge of the effects of excessive hours and fatigue on seafarers is at best patchy. There is little concrete evidence, and what evidence exists is difficult to place in context given lack of comparison with onshore workers. Studies have tended to utilise relatively small samples, and the effects of factors such as sleep deprivation, hostile working environments and long hours in combination have been largely ignored.

In conclusion

There are few, if any, studies which systematically measure all possible indicators of fatigue in the maritime industry, namely accident statistics, self-report, performance and physiological data. Research is also needed to address the unique combinations of potential stressors, which may interact in various ways to produce fatigue, poor health and increased accident risk. Accident data require closer inspection with regard to hours into shift and days into tour information, although current reporting systems do not allow for this. Furthermore, information regarding exposure rates is not currently

available, rendering prediction of accident likelihood beyond the scope of research until a uniform accident reporting procedure is put into place.
The effects of working at sea 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 and differences between this occupational group and onshore populations. The influence of environmental factors is also an under-researched area: the influence of poor weather and motion on performance, health and sleeping patterns can only be estimated from the existing literature. With regards to performance data, the relative influence of shift timing also requires attention in the maritime sector.

Examination of physiological indicators of health and fatigue have again been somewhat neglected among seafarers. There exists only a small selection of studies on circadian adaptation and, until very recently, no attempts had been made to examine disease risk factors in terms of physiological data. Not only is comparison of all of the above with onshore populations necessary, but future research should also aim to examine any potential differences between offshore workers at work and on leave periods, should seek to replicate current findings within larger study populations and should establish a clearer picture of the relative influence of shift length and pattern on a wide range of variables.

Scope of our current project

The aim of our current research ("Fatigue, health and injury among merchant seafarers", Seafarers International Research Centre) is to redress the balance by assessing work and rest hours, performance duties and the physical and mental life of seafarers. The project marks the start of a series of independent studies supported by NUMAST, MCA, HSE, DETR and the Seafarers' International Research Centre, aimed at investigating the effects of seafarers' fatigue.

This study will look at fatigue and health in terms of voyage cycle, crew composition, watch-keeping, work and sleep patterns, self-report, physiological indicators of fatigue, (e.g., salivary cortisol measures) and the working environment. Its principal aims are to predict worst-case scenarios for fatigue, health and injury and to develop best- practice recommendations which will serve to reduce the incidence and effects of fatigue as well as the risk of injuries and accidents. The first phase of the project will concentrate on seafarers working in the British offshore sector, although it is hoped this will be extended to other areas of the industry on an international level.