Stress at Sea and Tiredness

Learning from the Project Horizon - Stress at Sea

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Project Horizon is a major multi-partner European research study that brought together 11 academic institutions and shipping industry organisations with the agreed aim of delivering empirical data to provide a better understanding of the way in which watchkeeping patterns can affect ships' watchkeepers. The broad spread of the project partners ensured expert objectivity of the project and its results, as well as widening routes for dissemination and exploitation of the findings. The project was established to:

- define and undertake scientific methods for measurement of fatigue in various realistic seagoing scenarios using bridge, engine room and cargo simulators
- capture empirical data on the cognitive performance of watchkeepers working within those realistic scenarios
- assess the impact of fatigue on decision-making performance, and
- determine arrangements for minimising risks to ships and their cargoes, seafarers, passengers and the marine environment.

At the heart of the project was the extensive use of ship simulators in Sweden and the UK to examine the decision-making and cognitive performance of officers during a range of real-life, real-time scenarios of voyage, workload and interruptions. A total of 90 experienced deck and engineer officer volunteers participated in rigorous tests at Chalmers University of Technology in Göteberg, and at Warsash Maritime Academy at Solent University to measure their performance during seagoing and port-based operations on bridge, engine and liquid cargo handling simulators.

The project sought to take understanding of the issues to a new level with specialist input from some world-leading transport and stress research experts. Academic experts at WMA, Chalmers and the Stress Research Institute at Stockholm University (SU) devised the simulator runs, setting the requirements for fatigue measurement and determining performance degradation measures for watchkeepers, and SU analysed the results from the week-long programmes.

Finally, in response to the research findings, the Project Horizon partners have developed a fatigue management toolkit for the industry, which seeks to provide guidance to owners, operators, maritime regulators and seafarers to assist them in organising work patterns at sea in the safest and healthiest way possible.

Shipping is the ultimate 24/7 industry. Inherently globalised in its nature, the industry is complex, capital-intensive, increasingly technologically sophisticated and of immense economic and environmental significance. More than 80% of world trade moves by sea, almost 90% of EU external freight trade is seaborne, and some 40%

of intra-EU freight is carried by shortsea shipping. Around 40% of the world fleet is beneficially controlled in the EEA and EU-registered tonnage accounts for more than 20% of the world total. An average of around four million passengers embarks and disembarks in 27EU ports every year – the vast majority being carried by ferries.

The increasingly intensive nature of shipping operations means that seafarers frequently work long and irregular hours. Under the International Labour organisation regulations (social provisions) it is permissible for seafarers to work up to 91 hours a week – and, under the International Maritime Organisation's STCW 2010 amendments (safety provisions), a 98-hour working week is allowed for up to two weeks in 'exceptional' circumstances. Noise, vibration, sailing patterns, port calls, cargo handling and other activities can all reduce the ability of the seafarer to gain quality sleep during rest periods. Fatigue is generally understood to be a state of acute mental and/or physical tiredness, in which there is a progressive decline in performance and alertness. The term is often used interchangeably with 'sleepiness', 'tiredness' and 'drowsiness'. Fatigue is often considered to be a generic term, of which sleepiness is one of the major sub-components. In this project, the emphasis has been placed upon 'sleepiness' as the most effective description of the physical and physiological conditions under examination. Seafarers are already usually covered by company, sector-specific, flag state or IMO rules banning or severely restricting alcohol use at sea. Studies have shown that around 22 hours of wakefulness will have a similar effect upon the impairment of an individual's performance as a blood-alcohol concentration of 0.10% – double the legal driving limit in most EU member states. Laboratory research and studies in other transport modes have demonstrated that severe sleepiness (and even sleep onset) and performance deterioration is common amongst workers undertaking night shifts. Fatigue is also an important health issue, with significant evidence to show the way in which long-term sleep loss can be a risk factor in such conditions as obesity, cardiovascular disease and diabetes.

The issue is also one of great relevance to the recruitment and retention of skilled and

experienced seafarers. Reducing excessive working hours is of critical importance in delivering working conditions for maritime professionals that reflect the increasingly high levels of training and qualifications required to safely operate modern-day merchant ships. Project Horizon was established in response to growing concern about such issues and the increased evidence of the role of fatigue in maritime accidents. The project is therefore closely aligned to the FP7 (Sustainable Surface Transport 2008 RTD-1 call) aims of increased safety and security, and reduced fatalities. Over the past 20 years, the shipping industry has become increasingly aware of the importance of the 'human factor' in safe shipping operations. Marine insurance statistics have shown 'human error' to be the key contributory factor in around 60% of watchkeeper had only had 5 or 6 hours of sleep. The following are some of the reported accidents due to tiredness/sleeping issues:

- the grounding of the feeder containership Cita in the Isles of Scilly in March 1997, after the mate fell asleep and the ship sailed for two and a half hours with no one in control
- the grounding of the general cargo ship Jambo in Scotland in June 2003, after the chief officer fell asleep and missed an intended change of course;
- the grounding of the bulk carrier Pasha Bulker near the port of Newcastle in Australia in June 2007, in which an investigation report stated that 'the master became increasingly overloaded, and affected by fatigue and anxiety';

- the death of a Filipino AB in a fall onboard the Danish-flagged general cargo ship Thor Gitta in May 2009. Investigators who used FAID fatigue assessment software found that the seafarer's 6-on/6-off work pattern was at a score of 111 on the morning before the accident – a level considered to be in the very high range;
- the grounding of the bulk carrier Shen Neng 1 on the Great Barrier Reef in April 2010. The Australian Transport Safety Bureau investigation found that the grounding occurred because the chief mate did not alter the ship's course at the designated position. His monitoring of the ship's position was ineffective and his actions were affected by fatigue. Investigations showed that he had only two and a half hours sleep in the 38.5 hours prior to the casualty. Concern about such incidents was also mirrored by a growing weight of evidence gathered from research among seafarers.

It is generally accepted that fatigue at sea has been subjected to considerably less research than in other modes of transport or safety-critical industries, but from the 1980s onwards increasing academic attention was paid to working hours in the maritime sector – with a 1989 Medical Research Council report on hours of work, fatigue and safety at sea, by Professor ID Brown, serving as something of a watershed. In 1990, a report on shipboard crew fatigue, safety and reduced manning, by JK Pollard, ED Sussman and M Sterns noted that work at sea is characterised by longer working weeks, more non-standard work days, extensive night operations, and periods of intense effort preceded by periods of relative inactivity.

In 1995, the UK National Union of Marine Aviation & Shipping Transport Officers (NUMAST) published the result of a survey of 1,000 officers. Just over three-quarters of those surveyed said they believed that fatigue had increased significantly in the previous three to 10 years. In a further survey of 563 members, NUMAST found 50% reporting that they worked more than 85 hours a week.

A 2006 report on one of the most extensive research projects, carried out by the Centre for Occupational and Health Psychology at Cardiff University, found evidence that as many as one in four watchkeepers reported having fallen asleep on watch. As many as 53% of respondents reported having no opportunity to have six hours of uninterrupted sleep. A Swedish survey carried out in 2008 and 2010 showed that about 70% of officers had nodded off on watch one or more times during their career.

Another significant research study was published by the UK Marine Accident Investigation Branch (MAIB) in 2004. This analysed the role of fatigue in 66 collisions, near-collisions, groundings and contacts investigated between 1989 and 1999. Fatigue was considered to be a contributory factor to 82% of the groundings in the study which occurred between 0000 and 0600 and was also a major causal factor in the majority of collisions. This latter point was also highlighted in research published by the Karolinska Institute in Sweden in 2004, which found levels of sleepiness to be highest during the 00:00- 06:00hrs watch period.

In 2005, a report published by TNO in the Netherlands, recommended the setting up of a framework for the development of a fatigue management programme or tool to help shipping companies to take measures to manage fatigue. Other seafarer fatigue studies have also highlighted such factors as:

- the long working hours experienced by many crew members;
- problems in gaining quality sleep;
- the impact of watchkeeping patterns: notably six hours-on/six hours-off;
- stress and workloads;
- frequent port calls and associated cargo work, and
- tour lengths.

Against this background, Project Horizon seeks to address the marked concerns over the increasing human, financial and environmental impact of maritime accidents which frequently cite fatigue as a contributory cause. This is an issue of critical importance at a time when the high demand for shipping capacity has led to national and international shortages of well-qualified and experienced seafarers.

Project Horizon research has been based on very rigorous scientific principles, involving unprecedented and cutting-edge use of deck, engine and cargo handling simulators to create realistic seven-day simulated voyage scenarios for the volunteer officers. The study was focussed upon two of the most common watch schedules used at sea: six hours on watch followed by six hours off (6-on/6-off) and four hours on followed by eight hours off (4-on/8-off). The 6-on/6-off pattern is most common on smaller ships, often operating in shortsea and coastal trades and often operating with just two officers onboard. The simulator voyage plans were designed to ensure a high degree of authenticity, including variable workloads, port visits, mandatory reporting points, and passing traffic. The studies were carried out using the simulators at Warsash Maritime Academy in the UK and Chalmers Technical University in Sweden. At Warsash, the effects of the 6-on/6-off schedule were observed for deck and engine watchkeepers, whilst at Chalmers the tests examined the effects of

4-on/8-off and 6-on/6-off watches on deck watchkeepers only. Before the simulator runs began at Chalmers and Warsash, extensive pilot tests were conducted to ensure the methodology was right and a Simulation Protocol Handbook was produced.

A total of 90 officers were recruited to undertake the simulated voyages. All those taking part were appropriately qualified and experienced deck and engineer officers from west and east Europe, Africa and Asia. The mix of nationalities and gender (87 males and three women) provided a representative cross-section from the industry and all participants were required to be in good health, with no sleep disorders.

The volunteers were recruited through advertisements and crewing agencies as if they were going to sea and during the tests they lived as close to a shipboard life as possible – in institutional-style cabin accommodation at WMA and onboard an accommodation vessel at Chalmers. During the runs, there were a number of imposed restrictions and participants were allowed up to four cups of coffee a day, and no alcohol was permitted. The total time spent 'working' during the week-long simulator runs was 64 hours for those on 4-on/8-off and 90 hours for 6-on/6-off participants (including at Chalmers an interrupted off-watch period). In that experiment, participants were randomly assigned to a watch system and a simulator and were told in advance that one of their free watches would be interrupted – although they were not told which one it would be. During the interrupted off-watch period, participants were supervised and had to undertake a mix of cargo operations simulator work and 'paperwork', including reading and watching the TV. They were not allowed to sleep during this period. This element of the programme was introduced to simulate real-world conditions, in which work patterns may be interrupted by such factors as port visits, inspections, cargo work, drills and emergencies. To balance the experiment design, one watch system had this disturbed off-watch period in the first part of the week, and the second session with the same watch system had it in the second part of the week.

The test methodology was rigorous. Cameras tracked and recorded participants' every movement on watch, producing an enormous database of activity, while supervisors were able to observe remotely on CCTV monitors. Instructors were able to oversee the 'voyages', not only monitoring performance but also acting as 'masters' and 'chiefs' during handovers and in cases where intervention has been required to prevent an accident. The policy was one of minimal intervention, but instructors could not allow a collision, grounding or other major incident to occur as this would have prevented the completion of the exercise under experimentally controlled conditions.

The following data were collected:

- Actigraphy – participants wore the Actiwatch, a device that measures acceleration and enables physical activity and sleep duration to be calculated
- Electroencephalogam (EEG), electrooculogram (EOG), and electrocardiogram (ECG) – recordings of brain activity, eye movements and heart rates
- Psychomotor Vigilance Test (PVT) performed, using standard hand-held equipment, before and after each watch. The test involved participants having to press a button to record when they see a target presented on a screen at random intervals. Each test lasted approximately five minutes and the reaction time, the number of lapses, and the mean reaction time were all recorded and stored on the device
- Karolinska Sleepiness Scale (KSS)
- Karolinska Drowsiness Test (KDT) – administers at the end of a watch, when participants' EEG measurements were taken as they were asked to stare at a black spot on a wall for five minutes and then to close their eyes for five minutes
- Stress scores - Data on participants' alertness and sleepiness was amassed using both subjective and objective research methods. The subjective information was drawn from the three diaries participants were asked to keep: a sleep diary filled in on waking up; a work diary they completed during the watch; and a wake diary completed during the off-watch period. Data collected covered:
  - Work diary
  - Food intake
  - Symptoms of fatigue during work shift
  - Work (difficult/easy)
  - Satisfaction with own performance
  - Workload
  - Nodding off - Wake diary
  - Food intake
  - Type of activity during free time
  - Symptoms of fatigue

- Wellbeing (health)
- Recuperation- Sleep diary
- Intake of coffee
- Intake of medications
- Awakenings
- Difficulty to fall asleep
- Sleep quality
- Waking up early
- Easiness to get up
- Disturbed sleep
- Time awake during sleep period
- Depth of sleep
- Anxiety
- Special occurrences
- Reason for waking up

Comments

In the watch diary, participants indicated how they felt at various points on duty using the Karolinska Sleepiness Scale. This ranges from 1 for 'extremely alert' to 9 for very sleepy, great effort to keep awake, fighting sleep'. This scale has been validated against road driving accidents and electroencephalogram (EEG) changes characterising sleep. For two 24-hour periods the participants wore 10 scalp electrodes and ambulatory recorders of the EEG, which is the gold standard for measuring sleep and thus the absence of watchkeeper performance if it appears. They also wore Actigraph activity measuring devices to record brain and physical activity throughout the week, as well as being subjected to psychomotor vigilance tests (PVT) to check their reaction times at the beginning and end of each watch. The latter is considered the gold standard for behavioural fatigue measurement. At two stages of the 'voyage', the participants wore 10 electrodes that measure their brain activity, over two watch periods and two sleep periods. Data obtained allows experts to analyse cognitive performance at key stages and can also show instances of 'microsleep'. Data recorded from the off-watch periods was especially valuable, as it enabled an objective picture to be obtained of exactly when participants fell asleep and the quality of the sleep they obtained. At Chalmers, navigation simulations were carried out using two different watch schedules: 30 seafarers were assessed over 4-on/8-off schedules, and 20 were monitored on 6-on/6-off patterns. The voyage pattern was based on a simulated voyage in a small coaster and cargo simulations replicating a 210,000dwt VLCC. The data gained from these different patterns were analysed separately. The two-watch runs also included a section involving the disturbance of a single free watch, in which no sleep was allowed to enable the investigation of the effect additional workloads arising from a port visit. At Warsash, bridge and engine room simulators were used to investigate the effects of 6-on/6-off work patterns. Cargo handling simulations were carried out at both locations. At Warsash, the simulators were linked up, so that the participants sailed a 17,071dwt product tanker from Fawley to Rotterdam and back again, twice, with a varied workload including cargo loading and discharge, and picking up pilots. The simulations included some 'distinctly boring' sections as well as a number of realistic events and incidents, including:

- keeping the ship's logbook
- marking positions on a chart
- exchanging information at the end of a watch
- radio communications
- close-quarters situations
- a 'man overboard' from another ship
- a gyro-compass error
- machinery alarms

Using simulators allowed the researchers to 're-set' the voyage at the end of each watch, so that the watchkeeper coming on duty repeated the section of the voyage just completed by the previous participant. As 'handovers' were conducted by staff members acting in the role of master or chief engineer, the participants were unaware that the voyage sections were being repeated in this manner. The standard test conditions and replicated situations enabled the researchers to make valid comparisons, under statistically robust conditions, monitoring the way in which the volunteer officers reacted and how their judgement and performance were affected at different times during the week. Volunteers' performance was also checked by a wide range of indicators – with lecturers monitoring such things as their behaviour, body language and ability to pass on 10 standard items of information at each watch handover. During each bridge watch, participants were observed and rated by the simulator operators. The scoring system covered the general performance over the whole watch, the watch handovers, 'special' events – such as certain close-quarters situations – and 'unplanned' events – such as unintentional 'near-misses' with other vessels. The evaluation of watchkeeping performance was based on both expert rating (for example, how well the collision prevention regulations were followed) and objective scores (for example, the number and timing of positions marked on the chart). The cargo work simulations enabled supervisors to monitor performance on arrange of standard task indicators, including:

- correct sequence of events
- avoidance of 'forbidden' operations
- control of bending moments, shear forces and list
- ballast handling
- stability control
- monitoring pressures and temperatures.

Similarly, engine-room performance was rated on a wide range of indicators, including:

- standard watchkeeping duties
- adherence to standing orders and chief engineer's orders
- logbook entries
- communications with bridge
- quality of information at handovers

Outcome of Horizon Project:

This report contains several annexes as listed below. A copy can be obtained if requested.

Annex 1: Stress Management Training Course for Education and Training Providers

Annex 2: Stress Management Programme for Cadets – Causes of Stress and Countering their Effects

Annex 3: Classification of Causes of Non-Vocational Stress and Methods to Develop Learning to Identify, Cope and/or Alleviate These Causes