ERGONOMIC & SAFETY DISCUSSION PAPER

MARINER SAFETY RESEARCH INITIATIVE

Vessel Motion Effects on Crew

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INTRODUCTION

The effects of motion on human performance are varied and can be challenging and debilitating. Crew members in a moving work environment must learn to overcome the effects of motion and develop strategies to cope with the changes in job performance that can occur as a result of motion. It is important for people working in the marine industry to understand how such things as motivation, thinking, making decisions, and perceptual and physical tasks are affected by vessel motion.

Standing or walking while underway can be difficult under some environmental conditions. The effect these conditions have on a vessel or offshore structure can cause crew members to lose balance, slip, and fall. Known as motion-induced interruptions (MII), postural disturbances require personnel to stop or alter their position or movement in order to regain or maintain balance.

Another concern related to vessel motion is the increased energy required to maintain balance above and beyond that which is normal in a stationary environment. Mariners may become fatigued sooner compared to when performing the same tasks on land or when the vessel is in calm or sheltered waters.

Motion sickness is suffered by people working in marine transportation and related professions. Working or traveling in moving environments can cause motion sickness symptoms plus fatigue and drowsiness due solely to a moving environment.

Terms/Definitions

Cognitive: The mental processes of perception, memory, judgment, and reasoning/thinking.

Psychomotor: Movement or muscular activity associated with mental processes.

Motion-Induced Interruption (MII): A postural disturbance that requires subjects to stop or alter their position or movement in order to regain balance (also known as Motion-Induced Instability).

Sopite Syndrome: Drowsiness, disinclination to perform physical or cognitive work, decreased motivation, and lack of participation in social/group activities attributable only to motion exposure.

Vessel: Any ship, boat, or offshore installation where people work, live, and are subjected to the marine environment.

DISCUSSION

Level of Concern

The levels of motion vessel crews are exposed to at sea in their working and living environments are often unique and unpredictable. Some significant human performance and safety aspects associated with varying levels of vessel motion include:

- Energy consumption
- Motion-induced interruption
- Motion sickness

- Sopite syndrome
- Cognitive/reasoning performance
- Motivation
- Sleep interruption

These challenges are discussed in the following sections.

Energy Consumption

At sea, the heave, pitch, roll, yaw, and slam motions of a vessel pose unique challenges to the crew. Maintaining balance requires increased energy expenditure or increased calorie consumption by muscles as a greater number of muscles are recruited to provide increased stability (Houdijk et al., 2009). Pitch and roll pose a greater demand on human energy than vertical heave motions. Up to a 30% increase in energy demand has been reported in tests evaluating the energy requirements of people maneuvering in moving environments (Wertheim, Heus, and Vrijkotte, 1994; Heus, Wertheim, and Havenith, G., 1998).

The extra energy cost of maintaining balance can decrease the time it takes for an individual to become fatigued when performing a task. Mariners must therefore cope with the added demands of vessel motion.

A series of studies (Wertheim et al., 2002; Wertheim et al., 1994) show that while human power output is not reduced in a moving environment, respiration efficiency is reduced by as much as 6-10%. As a result, people working in moving environments become fatigued faster. This is compounded by the approximate 30% increase in energy demand to overcome MIIs. The implications of these findings point toward reduced mariner efficiency as crew members often must work over a long duration while physically fatigued. This can affect other aspects of performance such as reaction time and mental tasks.

Motion Induced Interruptions

A motion-induced interruption is “an incident where the accelerations due to the vessel motions become sufficiently large to cause a person to slide or lose balance unless they temporarily abandon their allotted task to make a postural adjustment in order to remain upright” (Crossland and Rich, 1998). Balance and stability of the crew are consistently challenged even under relatively calm conditions at sea.

Performing a task easily undertaken in a stable, unmoving environment can be difficult on a rolling, pounding deck. The effects of an unstable environment can include increased task errors as well as decreased efficiency in tasks requiring balance and coordination. Increased risk of injury due to potential falls resulting from MIIs must also be considered. There is also a greater risk of crew injury or error if MIIs are encountered by fatigued crew members.

The incidence of MIIs in the virtual environment of simulators and seakeeping models and in literal environments (at sea) is measurable and predictable. Replicating rough seas or measuring MIIs at sea in variable conditions of wind and wave

allows us to predict the rate of incidence of postural instabilities and interruptions. These may be useful in influencing vessel design (Coldwell, 2005; Crossland et al., 2007) to encourage the strategic placement and sizing of handrails and handholds at workstations to help overcome MIIs.

Motion Sickness

Motion sickness manifests itself by a wide range of symptoms from feelings of general lethargy to extreme discomfort, dizziness, nausea, and vomiting as a result of exposure to motion (Graybiel et al., 1968). Motion sickness can reduce the desire to perform daily routine tasks and can result in an individual's likelihood to not perform tasks (Haward et al., 2009; Comperatore and Rivera, 1998).

Sopite Syndrome

Sopite syndrome is different from motion sickness, but the symptoms of drowsiness, reduction in performance, fatigue and loss of appetite are similar. Symptoms can be attributed to exposure to rigorous motions similar to those that cause motion sickness in susceptible individuals. Sopite syndrome can, however, be present in the absence of motion sickness and can be experienced by otherwise non-motion sickness susceptible individuals (Kiniorski et al., 2004). Mood effects are also symptoms of the syndrome (Lawson and Mead, 1998). Symptoms become apparent shortly after a person is exposed to motion and can persist after the person has been removed from exposure or the motion is no longer present. Sopite syndrome can also be an unrecognized source of low performance (Kiniorski et al., 2004). Finally, Sopite syndrome can intensify with basic fatigue and render the mariner or offshore worker more tired and sleepy.

Cognitive/Reasoning Performance

There is a noted trend toward increased quantity of mental work required on board vessels today versus in the past (Stevens and Parsons, 2002). Reasoning tasks require physical and reasoning task demands to work together effectively. For example, in rough seas when a mariner is directing much attention and thinking towards countering MIIs, the physical demands intrude on the mariner's cognitive resources.

Maintaining postural control and overcoming MIIs influence performance on cognitive tests such as the Stroop test (right). Quickly read the list from left to right ignoring the color in which it is printed. Next, go through the list naming the actual color used and not reading the word. In a stable environment it takes longer to name the color than to read the word, and naming the color is also more prone to errors. In a rolling sea, performance worsens; taking more time to name the colors, while also accompanied by more errors in naming the colors correctly. This suggests that in the presence of increasing ship roll, yaw, slam, etc., the demand for attention and cognitive resources is divided between maintaining stability and cognitive task performance. As a result, thinking ability suffers (Dault et al., 2001; Teasdale et al., 1993). In a maritime context, this means that less attention and cognitive resources are available to perform ship duties such as navigating.

The effect on thinking becomes less of a problem as mariners become accustomed to repetitive vessel motion ("sea legs"). The lack of a pattern in variable sea states (such as the presence of meeting waves or quartering variable seas) creates MIIs that are less predictable to the mariner. The instability under these motion conditions is likely to result in general interference with an individual's capacities of cognition (remembering, reasoning, comparing, extrapolating, deciding, etc.) while maintaining physical stability (Dault et al., 2001).

Motivation

It has been observed that most people who become motion sick can exert themselves to a level of adequate performance in the face of urgency (Birren, 1949). This is referred to as "peak efficiency" and is distinct from the level of performance

needed for routine tasks that Birren termed “maintenance efficiency,” a point where motivation may be influenced by motion sickness so that important tasks are likely to be performed but those deemed less important by the motion sickness sufferer are not performed.

It is uncommon for motion sickness to lead to the abandonment of critical tasks. The more common outcome is that a motion sick person rallies and performs when the need is great enough, such as in an emergency (Stevens and Parsons, 2002). The distinction between peak efficiency and maintenance efficiency is that while peak efficiency is likely to be unaffected by seasickness, maintenance efficiency (performing routine, daily tasks) may suffer during rough weather.

Signs of declining maintenance efficiency may include the crew losing interest in doing anything except what is absolutely required, losing interest in leisure activities and spending most free time in their bunks. Participants in a long-term experiment (over a week in length) in a rotating room used to simulate sensory conflict similar to that experienced in moving environments spent most of their free time in bed, reported being prone to daydreaming, and experiencing increased irritability (Graybiel and Knepton, 1976). In a shorter, 3-day rotating room experiment, participants spent most of their free time in bed and the onboard observer noted that even after their relatively minor initial disturbances subsided, the participants sought every opportunity to rest and were notably lethargic, often sleeping 12 hours or more (Reason and Graybiel, 1969).

Sleep Interruption

The inability to perform work because of fatigue is an issue for personnel working at sea. Having a suitable period of rest and quality sleep is highly important to combat fatigue.

It is often observed by mariners and offshore workers that the ability to obtain adequate sleep is confounded by the motion conditions on a vessel. Reports by those unable to get adequate sleep indicate several reasons why sleep is unattainable: vessel motion, high noise and vibration, falling/rolling items, and rolling in or falling from their bunks (Haward et al., 2009). While nothing can be done to control the seas, making sleep areas more habitable can influence the quality and quantity of sleep. Control and management of environmental variables (noise, temperature, humidity, and vibration) in sleep/rest areas and bunk designs that help overcome issues with vessel motion can facilitate sleep.

SUMMARY

Mariners work in an environment like no other. Working on a moving and unstable surface presents a series of concerns to the maritime industry. These concerns can compound other difficulties: isolation from family, long and irregular work hours, working around the clock, limited duration and periods of sleep, and the resultant fatigue. Vessel motion makes the marine workplace unique and intensifies the magnitude of the other difficulties. Aside from vessel motion, other industries share related concerns such as sleep deprivation, shift work, and long work hours. While there is significant behavioral research in those other industries, the presence of vessel motion makes application of those data to the marine environment tenuous. Vessel motion can:

- Rapidly advance the onset, magnitude, and duration of human fatigue
- Induce Sopite syndrome, making mariners sleepy when not fatigued
- Present special safety and health hazards
- Introduce postural instabilities
- Interrupt task performance in order to physically and mentally address instabilities

Vessel motion clearly distinguishes the working life of maritime personnel from that of personnel in other industries.

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