EFFECTS OF MODERATE MOTION SICKNESS ON ESTIMATION OF TASK DURATION AND PERFORMANCE ON COGNITIVE TASKS

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Effects of Moderate Motion Sickness on Estimation of Task Duration and Performance on Cognitive Tasks

By

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ABSTRACT

While motion sickness (MS) is a well known concern, the effects of moderate levels of MS are still not understood. Marine workers are responsible for ensuring the safe and effective functioning of a ship, regardless of their reactions to an adverse environment. In effort to gain more insight into potential effects of moderate MS on operators, this thesis observed task performance and subject estimated task duration in two movement conditions, motion and no motion.

Seventeen subjects performed various cognitive and psychometric task batteries in both 'Motion' and 'No Motion' conditions. Moderate levels of MS were contained throughout the two hour 'Motion' session. Estimation of time on task was recorded while performance of tasks was dependent upon response time and errors. Subjective task load data were also collected. An α of 0.05 was used to determine statistical significance and although there was no evidence found at that level, statistical evidence suggests that there may an effect of moderate MS on estimation of time on task at the $p<0.10$ level. Cognitive task batteries gave little evidence of effect, however subjective task load was perceived as greater when the subject was experiencing moderate MS. Future research is needed to gain a complete understanding of how moderate MS effects task performance.

Key Terms: motion sickness (MS), estimation of time on task (ETT), cognitive tasks, response time (RT), error percentage (EP).

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LIST OF ABBREVIATIONS

ABCD	American, British, Canadian, and Dutch
ADD	Addition Test (a component of SusOps test battery)
ANOVA	Analysis of Variance
ANS	Autonomic Nervous System
AT	Actual Time of a task serial
C2	Command and Control
CMP	Line Comparison Test (a component of SusOps test battery)
CMS	Centre for Maritime Simulation, Marine Institute
ConOps	Continuous Operations
DRDC	Defence Research and Development Canada
ETT	Estimated Time on Task
HIC	Human Investigation Committee
HREC	Human Research Ethics Committee
ISO	International Standards Organization
LRT	Logical Reasoning Test (a component of SusOps test battery)
MATB	Multi-Attribute Task Battery
MIF	Motion Induced Fatigue
MII	Motion Induced Interruptions
MISC	Misery Scale (for rating the severity of sea sickness)
MS	Motion Sickness
MSSQ-Short	Motion Sickness Susceptibility Questionnaire - Short
MUN	Memorial University of Newfoundland

NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
OCS	Observer Checklist Score (experimenter's assessment of MS severity)
PAQ	Performance Assessment Questionnaire
PAR-Q	Physical Activity Readiness Questionnaire
PNS	Parasympathetic Nervous System
RMS	Root Mean Squared
RT	Response Time (of subject on a subtask)
SMS	Ship Motion Simulator
SNS	Sympathetic Nervous System
SRT	Serial Reaction Time (a component of SusOps test battery)
STM	Short Term Memory (a component of SusOps test battery)
SusOps	Sustained Operations - DRDC
TLX	Task Load Index
WBV	Whole Body Vibration

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CHAPTER 1 INTRODUCTION

Previous research on human performance in moving environments has shown that platform motions can have both a direct or indirect effect upon an individual's ability to perform a task (Crossland, Colwell, Baitis, Holcombe, & Strong, 1994). Task performance can be affected by many factors such as loss of balance, sleep disruptions or poor quality of sleep and motion sickness. The term motion induced interruptions (MII) describes events when an individual loses balance due to platform motions, thus removing or distracting a worker from the task at hand as they attempt to regain their stability (Crossland & Rich, 2000). MII events may also put persons at risk for work-related musculoskeletal injuries (Matthews, MacKinnon, Albert, Holmes, & Patterson, 2007; Holmes, MacKinnon, Matthews, Albert, & Mills, 2008). Motion induced fatigue (MIF) has been attributed to loss of sleep due to motion or by increased energy expenditure due to the maintenance of postural stability due to moving platforms (Stevens & Parsons, 2002). Motion induced sickness (MS) can also affect the cognitive or physical performance of a person on a moving platform. While vomiting, as an outcome of MS, will likely render a person incapacitated and require the abandoning of one's duties. However, the problems associated with moderate symptom severity of MS are not well understood.

Members of the American, British, Canadian and Dutch (ABCD) Working Group on Human Performance at Sea have contributed to a body of research that examines the influences of motion on physical and cognitive tasks. Their model (see Figure 1-1) suggests that tasks performed in a moving environment can have both a direct and indirect effect on physical and cognitive tasks performed as part of regular command and control operations (Colwell, 2005).

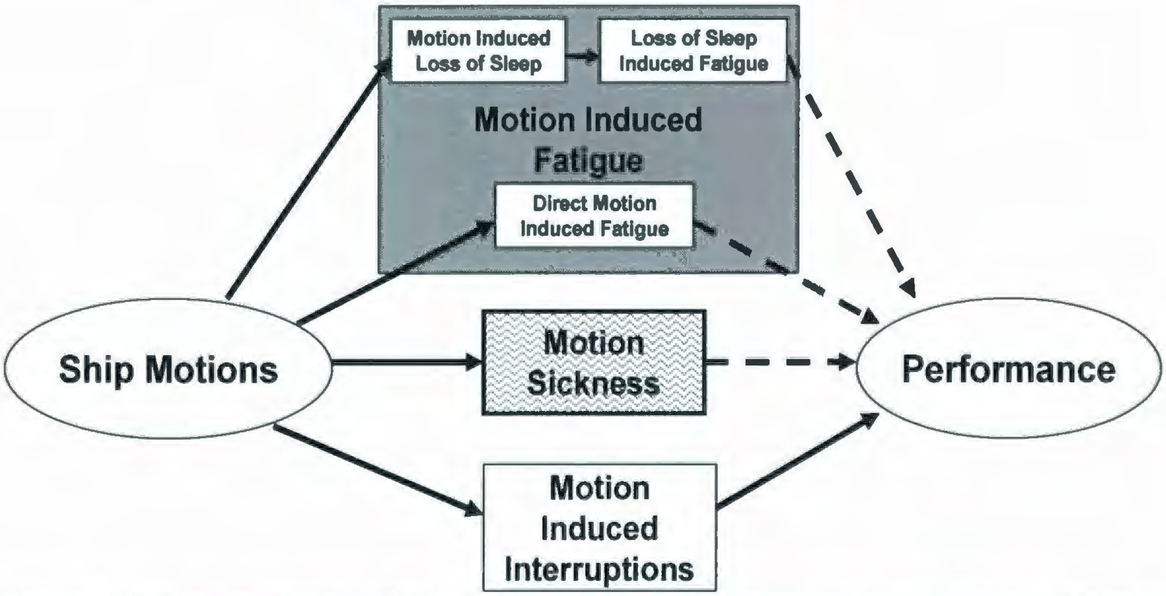


Figure 1-1: A representation of how ship motions can affect operator performance. Adapted from the ABCD Working Group

As a vessel responds to the environmental conditions (i.e. wind, waves, and current) tasks can become increasingly challenging. Sea states are an uncontrollable variable in seakeeping. Recognition of how human performance is affected by the changes in sea state is required for ship design, for evaluating of crew performance and for crew habitability (Dobie, 2000, 2003).

A 1997 North Atlantic Treaty Organization (NATO) exercise collected data employing the NATO Performance Assessment Questionnaire (PAQ) from 1026 personnel from seven (NATO) ships and assessed the effects of motion sickness on several performance factors (Colwell, 2000). During the exercise, one-half of the reporting subjects claimed mild to moderate MS symptoms during rough seas (Colwell, 2000). These same subjects who experienced MS symptoms also reported substantially higher levels of difficulty with completing both cognitive and physical tasks.

The NATO PAQ brought attention to many concerns that MS symptoms can affect tasks and ultimately increase the time needed to perform operational tasks. It examined correlations between ship motions, fatigue, motion sickness and task performance for the development of new human performance models. Findings concluded that the onset and escalation of motion sickness symptoms were related to self-reported decrements in performance.

Experimental studies that examined MS have induced symptoms in multiple ways; visually-induced via optokinetic drums (Webb & Griffin, 2003), rotational chairs (Gretsy, Golding, Le, & Nightingale, 2008), single direction simulators (Hawthorne & Griffin, 2003) and multiple direction simulators (Bos, MacKinnon & Patterson, 2005; Colwell & MacKinnon, 2007). However, most of these studies have either focused on how (or if) motion affects cognitive performance or what exactly it is about motion that causes MS symptoms. There has been little research that has focused primarily on how MS symptoms, not just the motion itself, may influence tasks of a cognitive nature.

Earlier studies have considered vomiting or abandonment of task(s) as evidence that MS limits performance. However, a person can experience many MS symptoms prior to these termination points (Colwell & MacKinnon, 2007). The question remains whether moderate symptoms of MS, such as lethargy or stomach awareness may affect an individual's performance long before the task is abandoned due to more severe symptoms of MS. Moderate MS symptoms such as stomach awareness, sweating, nausea, disorientation, increased salivation, and headache are common physiological symptoms linked to moderate stress (Money, Lackner, & Cheung, 1996). The impact of such MS symptoms on cognitive performance has yet to be elucidated, however, the effect of time estimation while under duress has been examined with the majority of research agreeing that duration judgment increases (subject overestimates time) when in a stressful situation (Hancock & Weaver, 2005; Angrelli, Cherubini, Pavese, & Manfredini, 1997). Thus, a methodology that controls for symptoms of MS (Colwell & MacKinnon, 2007) in order to understand the relationship between MS symptoms and time on task, whether actual or perceived, is required.

Colwell (2004) developed a protocol to keep subjects moderately seasick over a period of time in a ship motion simulator. Colwell and MacKinnon (2007) reported that utilizing tools such as the Misery Index Scale (MISC) (Wertheim, Ooms, De Regt, & Wienjes, 1992) and the Observer Checklist Score (OCS) (Colwell, 2004) that it was possible to maintain a subject at a specific level of moderate MS by adjusting simulator motions based on both the reported subjective MS symptoms and the observed MS signs. This protocol stemmed from Reason and Diaz's (1971) approach that both observed signs of MS and reported MS are necessary in the assessment of level of MS. MS symptoms were also 'graded' in severity by using diagnostic criteria introduced by Graybiel, Wood, Miller and Cramer (1968). By using the protocol from Colwell and MacKinnon (2007) and an appropriate compilation of cognitive task batteries, the data collected in a moving environment can be used to measure the cognitive performance of those undergoing moderate levels of MS.

The purpose of this study is to examine the effects of moderate levels of motion sickness on cognitive performance and time estimation of task duration in a simulated maritime environment. This will provide the needed insight into how moderate MS symptom severity may affect upon operator performance in time critical operations.

1.1 STATEMENT OF THE PROBLEM

Marine workers (military and civilian) are responsible for ensuring the safe and effective functioning of a ship and this becomes particularly challenging in adverse environmental conditions. Challenges that marine workers face while at sea include MII, MIF and MS. It is desirable that, despite different environments (e.g., calm versus stormy seas), that there be minimal deviation from task completion time.

With continuous advances and reliance upon technology, tasks are becoming more cognitively challenging (Endsley, 2000). This becomes a command and control (C2) issue as crew size diminishes and fewer workers are assigned for a given task (Colwell, 2005). Attaining a level of situation awareness within and between individuals is paramount to the successful operation of marine vessels. It is crucial to examine and understand the potential loss in crew performance due to MS in order to maintain effective operations. A commander who has an appreciation for the probable consequences of declining performance due to MS will be enabled to instill proper courses of action such as improved scheduling and task assignment in order to help avoid or minimize effects on ship operations (Cheung, Brooks, Simoes-Re & Hofer, 2004).

1.2 HYPOTHESES

This study will address the following hypotheses:

1. Do moderate symptoms of motion sickness influence a person's estimate of time on task?

2. Do moderate symptoms of motion sickness influence a person's performance on a battery of cognitive tests?

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

As crew compliment continually gets replaced with technology the consequences of any single operator error also increases (Colwell, 2000; Grootjen, Neerincx & Veltman, 2006). While it would be easy to assume that technology would result in more efficient sea-keeping, it could result in increased time demands and psychological stress upon personnel (Grootjen et al., 2006; Stevens & Parsons, 2002). Unfortunately, while the new technology is developed to increase the processing rate of data these new systems do not account for operator functionality (NATO, 2004). A danger of making systems more autonomous or self-regulating is that it is easier for a skilled operator to become distracted or inattentive and thereby increase the possibility of missing critical cues. With the reduction in personnel the potential loss in crew performance aboard ship during operations is a concern. It becomes more crucial to understand and consider the factors that may influence performance and also the alertness of crew members and bridge resource management (Benaskeur, Bosse & Blodgett, 2007; Colwell, 2005). Crew performance is likely compromised when personnel demonstrate symptoms of motion sickness (Colwell, 2000). This review will examine the relevant literature relating to motion and Motion Sickness (MS) symptomology and the possible influence(s) on task performance.

2.2 MOTION SICKNESS

2.2.1 Theories of Motion Sickness

Motion sickness (MS) is a common, albeit discomforting, response to motion stimuli that nearly all of the population will experience, with a rare 5% hardly being affected and 5% being severely affected, at some point in their lives (McIntosh, 1998; Wertheim, 1998). MS can cause an array of symptoms such as stomach awareness, nausea, sweating, decreased motivation, dizziness, disorientation, increased salivation, increased respiration, drowsiness, and the most observable, vomiting (Benson, 2002). While to some, the symptoms may just border on discomfort, to others they can be debilitating (Nakashima & Cheung, 2006; Reason, 1969).

Why humans get MS is still not completely understood; however there are a few generally accepted theories. Treisman (as cited in Golding, 2006a, p. 67) stated that symptoms such as nausea, dizziness, disorientation, are similar to the body's reaction of ingested poison and that the act of vomiting is a defense mechanism or a "Toxin-Detector". Cheung (2000) describes MS as an atypical response to both real and apparent motion stimulus. This response to motion can be elicited through several field and laboratory methods. Experimental studies have induced MS symptoms in multiple ways; visually-induced via optokinetic drums (Webb & Griffin, 2003), rotational chairs (Gretsy, at al., 2008; Reason & Graybiel, 1969), single direction simulators (Hawthorne & Griffin, 2003) and multiple direction simulators (Colwell & MacKinnon, 2007). The role of motion varied in previous experiments; either acting to induce symptoms of MS or to assess how the motion itself affected task performance. Motion sickness symptoms were gathered by either the subject's nausea ratings or by the indication of emesis (O'Hanlon &

McCauley, 1974) while other studies used motion sickness questionnaires to gather subjective symptom information (Golding 2006a, 2006b; Colwell, 2000). It is generally accepted that MS is attributed to an overstimulation of the vestibular system, either by the introduction or removal of sensed body position information (Reason, 1969). To understand how the vestibular system factors into MS there must first be an explanation of the anatomy.

2.2.2 Vestibular System

The labyrinth system (see Figure 2-1) consists of a series of fluid passages located in the inner ear that comprises both the cochlea (required for hearing) and the vestibular system (required for balance). The two components that make up the vestibular system are the otolith organs and the semi-circular canals and their functions are to detect position and changes of location of the head. The otolith organs consist of the saccule and the utricle, both of which have the function of tracking both the linear movement and acceleration, and also orientate the location of the head and body to gravity. The saccule interprets information gained from vertical acceleration while the utricle focuses on horizontal movement. The three semi-circular canals; the horizontal, superior, and posterior canal of the labyrinth measure the angular or rotational movements of the head and/or body. Together the otoliths and the semi-circular canals act to maintain a person's equilibrium. If the vestibular system is not functioning correctly then the individual's balance will be affected and they may also experience dizziness or vertigo. If the vestibular system is acted upon by unusual or unnatural forces such as those motions felt on marine vessels then the disturbance of the vestibular system can cause MS symptoms (Graybiel, 1968).

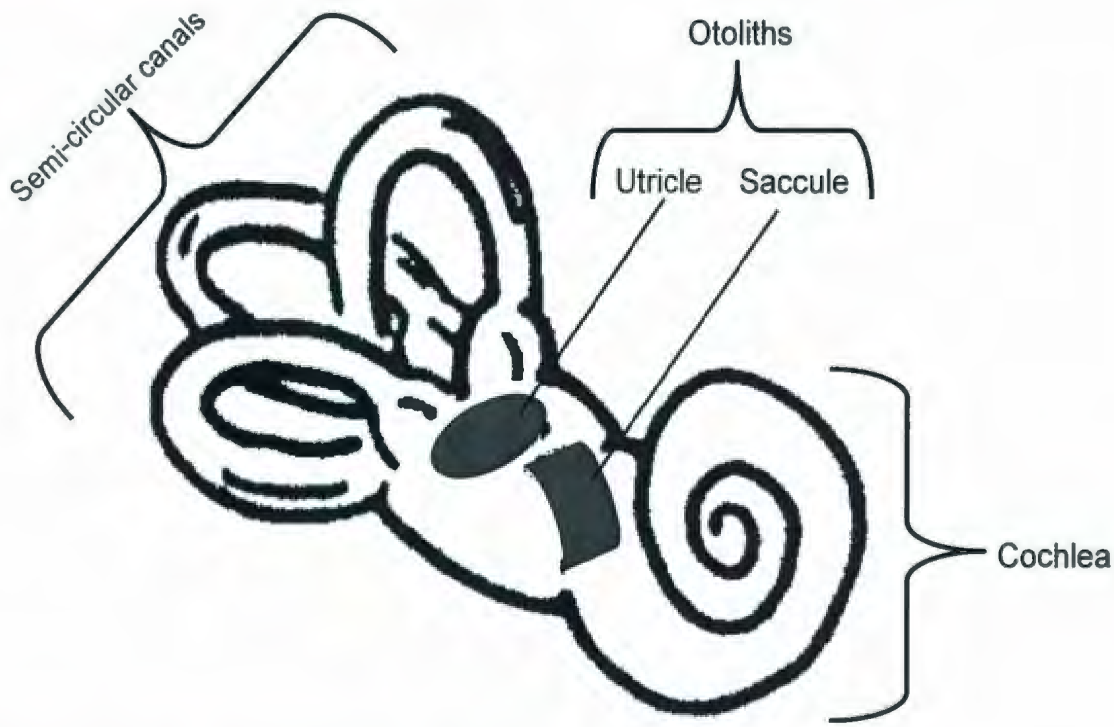


Figure 2-1: The labyrinth system of the inner ear

2.2.3 Sensory Conflict

Reason (1969) proposed a theory called "Neural Mismatch Hypothesis" that suggested that MS symptoms were invoked by the sensory systems receiving different input from external cues, specifically conflicting information is received by the visual system and the vestibular system. Reason and Brand (1975) built on this theory and introduced their now widely accepted "Sensory-Conflict theory".

The Sensory-Conflict theory claims that if there is a perceived difference between the actual motion and the expected motion then an individual will begin to experience MS symptoms. Other influencing factors such as individual susceptibility and specific types of provocative motion will be discussed later in this review. This theory suggests that a divergence *between* the sensory systems (proprioceptive, visual, and vestibular) as well as the variance *within* these sensory systems, particularly within the vestibular system, will cause problems for the individual. Two of the conflicts, the Visual-Vestibular conflict and the Canal-Otolith conflict are described.

2.2.3.1 Visual-Vestibular Conflict

While motions of the head and body are detected by the vestibular system, the eye transfers information by visually tracking motion of the environment and sending the information to the brain. MS symptoms can be induced when there is a variance between what the person sees and what that individual's vestibular system senses. Those with a dysfunctional vestibular system do not get MS even when introduced to provocative visual stimuli, supporting that the vestibular system has an affect on visually induced motion sickness (Bos, Bles, & Groen, 2008) and those with a working vestibular system can develop MS symptoms if exposed to visual stimulus without the actual motion itself. Reason and Graybiel (1969) found that when visual input was incompatible with vestibular input that the subject would report an increase in the magnitude of the motion compared to when visual input was absent.

2.2.3.2 Canal-Otolith Conflict

There are two key organs necessary to maintain an individual's state of equilibrium: the otoliths organs (tracking linear movement) and the semi-circular canals (tracking angular movement). If there is a sensed conflict between these two components (*within* the vestibular system) then there is a likelihood of motion induced MS.

2.2.3.3 Inducing Sensory Conflict

There are two categories of sensory conflict that provoke MS symptoms; conflicting signals are received by sensory systems, or one signal is received and the other expected signal is absent. Conflicting signals occurs when signals that are received from the Visual-Vestibular oppose one another (between what is seen and what is sensed) or it occurs when the signals that are received from the Canal-Otolith (angular versus linear motion) are opposing.

Another conflict is a signal received by one sensory system but the other expected signal is absent. A Visual-Vestibular conflict can occur within this system when the signals are received visually by the individual but there is a lack of motion (e.g., motion is seen but not physically experienced). Consequently the vestibular system does not receive an indication of motion. The conflict can also occur when there is observed real motion sensed by the vestibular system, however, the individual fails to have visual stimulus (e.g., within a moving closed cabin with no outside visual). Bos, MacKinnon, and Patterson (2005) found difference in MS severity between when a subject had no outside visual cues and when they were able to see the horizon.

Motion sickness symptoms can also be invoked when a canal-otolith conflict occurs. This is when signals for rotational motions are received by the semi-circular canals but the otoliths have not received any linear motion signals, or vice versa.

Stemming from the sensory conflict theory, the "Subjective-Vertical (SV) Conflict" motion sickness model was proposed (Bles, Bos, de Graaf, Groen, & Wertheim, 1998). This simplified explanation proposed that MS is evoked when the sensed vertical (how the sensory system responds to where the body and head are located in respect to gravity) is in conflict with the subjective vertical (where the individual logically thinks he or she is in space). The SV-conflict model is limited, however, as it focuses on the subject experiencing only one source of conflict: the vertical component.

Roll motion stimuli were also examined via visual roll and lateral tilt motion, and found that although there was a conflict of motion there was little to no MS reported by the subjects (de Graaf, Bles & Bos, 1998). They reported that not only the direction (linear or rotational axes) matters but also frequency and acceleration and exposure time of that motion (O'Hanlon & McCauley, 1974; Wertheim et al., 1998; Hawthorne & Griffin, 2003).

2.3. PROVOCATIVE MOTION

Motion sickness symptoms can be provoked in a variety of situations; on land (e.g., while in a car or a train), in the air (e.g., while in a plane/helicopter), on water (e.g., while on a ship), or in virtual lab experiments (Benson, 2002). As theories on physiological explanations of MS symptoms are offered, what is it about certain types of motion that makes one more provocative than another?

O'Hanlon and McCauley (1974) investigated frequency and vertical acceleration (heave motion) in attempt to obtain how a type of motion(s) induced the most incidences of MS symptoms. For two hour durations the researchers induced nausea by testing several levels and combinations of frequency and vertical acceleration. They used an enclosed cabin, thereby eliminating visual cues to make the motion more provocative. They found that moderate vertical accelerations with frequencies between 0.05 Hz to 0.8 Hz were most nauseating with a peak at 0.2 Hz. MS, in this case, was limited to one symptom; vomiting. Nausea increased with longer exposure duration and elevated acceleration intensity; however, frequencies above 1 Hz become less nauseating.

Hawthorne and Griffin (2003) examined roll (r_x-axes) oscillation and its contribution to MS symptoms by placing subjects in a closed cabin with no outside visual stimulus. They exposed subject groups to several different frequencies of motion for thirty minutes. MS incidence was measured on a subjective scale of symptoms. Their results concluded that there was little difference in frequencies in regards to roll oscillation causing illness. However, 0.2 Hz and 0.4 Hz caused greater MS issues.

Wertheim, Bos, and Bles (1998) examined how different combinations of motion would be most provocative. They also found that vertical acceleration (heave) alone caused MS symptoms. MS incidences increased dramatically when small heave motions were paired with pitch and roll amplitudes. Thus, concluding that the required intensity of single nauseating motions, such as frequency and/or magnitude, are greatly reduced when paired with other motions.

2.3.1 Vessel Motions

Platform motions on water mediums seem to be the most studied and most provocative of MS symptoms (Shupak & Gordon, 2006; Dobie, 2003; Wertheim et al., 1998). Vessel motions (see Figure 2-2) are described by six degrees-of-freedom: three linear axes; x - surge, y - sway, and z - heave, and three rotational axes; r_x, - roll, r_y, - pitch, and r_z - yaw.

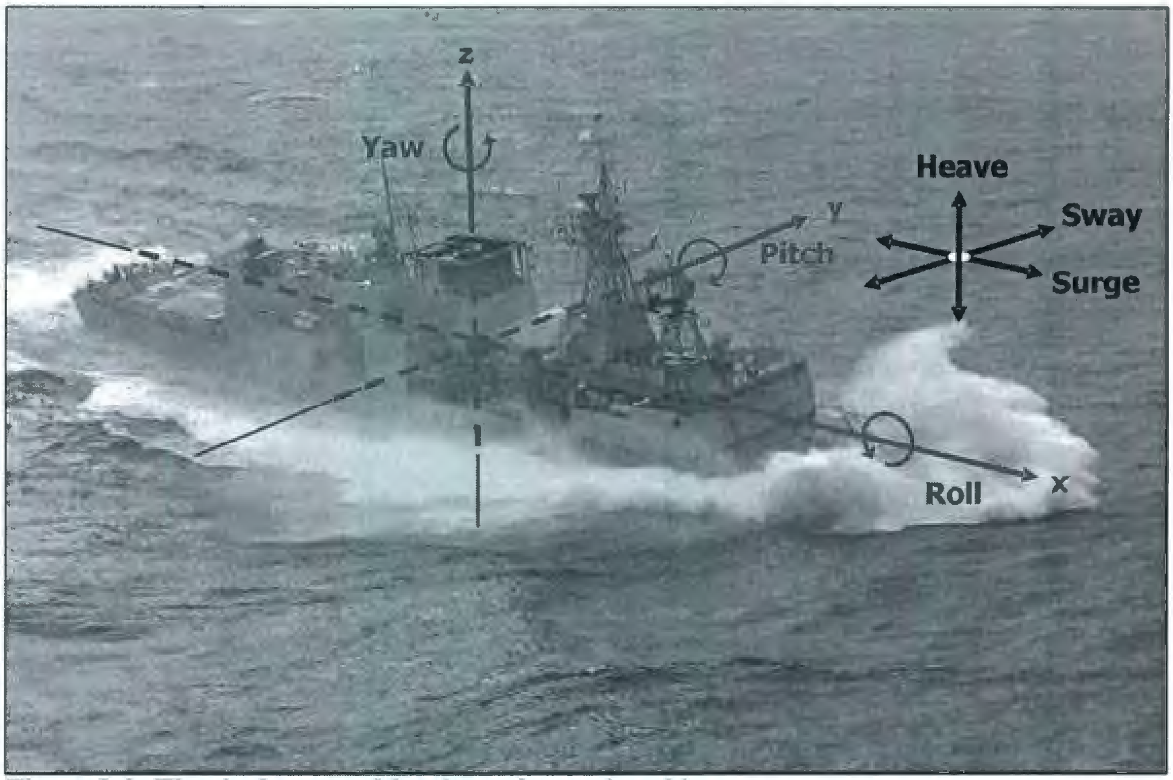


Figure 2-2: The six degrees of freedom of a moving ship

2.3.2 Motion Sickness as a Stress Response

While the vestibular portion of the labyrinth system functions to keep the body's balance, the introduction of unusual stimulation disturbs its equilibrium (Graybiel, 1968). Certain motions are noted as being more provocative than others (Hawthorne & Griffin, 2003; Wertheim et al., 1998), however, the MS symptom response to such motions is viewed as an abnormal one as the motion stimuli itself is not perceived by the individual as an immediate stressor (Money et al., 1996; Cheung, 2000). Repetitive patterns of significant stimuli have been noted to stimulate the Autonomic Nervous System (ANS) to respond in certain ways (Money et al., 1996). Since the most nauseating single motion to individuals is at 0.2Hz (O'Hanlon & McCauley, 1974) and incidents of nausea increases still with the addition of pitch and roll motions (Wertheim et al, 1998) then it stands to reason that the experienced MS symptoms due to the repetitive motions can indirectly provoke an ANS response within the Sympathetic Nervous System (SNS) and the Parasympathetic Nervous System (PNS). The resulting stress response produces conscious awareness of MS which consequently produces anxiety and distress thus provoking increased endocrine response, specifically epinephrine and norepinephrine, through activation of the SNS. It is these symptoms that trigger a stress response such as an endocrine response, a conscious awareness (anxiety, dread), and an ANS response (pallor, cold sweats).

2.3.3 Habituation

Reason and Brand proposed (as cited in Benson, 2002; Golding, 2006a) that MS susceptibility to provocative motion, not including individual differences such as gender and ethnicity, is due to three primary factors; initial sensitivity, adaptability to motion, and retention of that adaptation. If adaptation to certain motion stimuli is able to be preserved then habituation to that stimulus can be established. Cheung (2000) reiterates the differences between the terms adaptation and habituation; where adaptation weakens MS response to a single exposure and habituation is a desensitized response to a repeated similar exposure over time. However, changing motions at sea may disrupt the habituation process and must also be considered. Colwell (2005) stated that three phases need to be addressed: initial MS peak response, habituation to that response, and habituation retention or loss as sea states change.

As sea states change the individual's response to changing motion can be unpredictable. If a loss of adaptation or habituation can occur due to changes in sea states then a worker who has already been through an initial adaptation period may find that they are vulnerable to experiencing MS symptoms. Adaptation to one sea state does not guarantee that the worker will not experience MS symptoms in another.

2.3.4 Susceptibility

Susceptibility of MS varies between individuals (Golding, 2006a, 2006b). However, a general trend is seen as one ages: children and infants under the age of two seem to be the least affected, there is a peak between the ages of 2 and 12 years, and sensitivity to motion tapers off after the age of 12 years. Sex and ethnicity have also been investigated as a root of vulnerability to motion but with conflicting reports (Lucertini, Lugli, Casagrande, & Trivelloni, 2008; Klosterhalfen, Kellermann, Pan, Stockhorst, Hall, & Enck, 2005).

There have been numerous versions of MS susceptibility questionnaires used to measure individual differences. The most commonly used susceptibility questionnaire was developed by Reason and Brand (1975). Their version of the Motion Sickness Susceptibility Questionnaire (MSSQ) was quite lengthy and Golding (2006b) adapted it to the Short- MSSQ that allowed for a quick and valid calculation of individual susceptibility. While strong evidence that motion characteristics has an impact upon incidence of MS, individual differences in susceptibility and habituation create issues when attempting to study MS from an experimental perspective.

2.4 MOTION AND PERFORMANCE

There have been several studies examining how motion can affect task performance. They included studies on how nauseated subjects performed on tasks (Dahlman, Sjörs, Lindström, Ledin, & Falkmer, 2009; O'Hanlon & McCauley, 1974), how motion affected cognitive task performance (Crossland, Evans, Grist, Lowten, Jones, & Bridger, 2007) and how manual materials handling tasks were affected while performed on a motion platform (Matthews et al., 2007). Previous research also reported associations with task performance decrements and visual disturbances caused by motion (Cheung & Hofer, 2003; Feng & Tseng, 2008) giving support to the concept of the Visual-Vestibular Conflict theory.

The American, British, Canadian, and Dutch (ABCD) Working Group on Human Performance is "an ad hoc partnership of government agencies, universities and private firms" who have a shared interest in human factors and performance at sea and have led or co-sponsored experiments in this area (www.abcd-wg.org). In a review of MS and biodynamic problems, Colwell (1989) categorized ship motion effects into three groups;

1. Motion Induced Interruptions (MII)
2. Motion Induced Fatigue (MIF) and
3. Motion Sickness (MS).

Motion Induced Interruptions (MII) occur when the individual's task performance is directly influenced by motion (e.g., loss of balance due to stumbling, falling or sliding).

In a study to examine how MII influences task performance, ten Royal Navy personnel completed several familiar duties in stormy weather (Crossland et al., 2007). Common tasks, such as a firefighting drill, took an extra 22.5 seconds to complete due to the roll motion of the ship. Feng & Tseng (2008) also found that roll motion had a negative effect on visual tracking and identification with regards to reaction time and accuracy. In a similar context, Schlick, Winkelholz, Motz, MacKinnon, & Patterson (2004) suggest that MII will influence how an operator executes a computer-based search task. More recent studies have also identified how MII may put an operator at risk for over-exertion injuries (Matthews et al., 2007; Holmes et al., 2008).

Motion Induced Fatigue (MIF) occurs when an individual either suffers sleep loss because of motion-induced decrement in quality of sleep or becomes physically tired due to an increased caloric expenditure by counterbalancing ship motion. However, little is known about how MIF either directly or indirectly influences performance. Extended time at sea may increase incidences of MIF (Pérez Arribas & López Pinerio, 2007) and likely a better understanding of the accumulative effects of fatigue is required.

Research is also limited on how MS symptoms affect performance as an individual copes with uncomfortable symptoms. How the human operator continues to perform at a cognitive level is still under speculation. Wertheim (1998) noted that some key outcomes of MS that may affect cognitive tasks are decreases in motivation that may cause a reduction in work rate and/or abandonment of a task.

A study on uncoupled motions reported a decrement in performance as MS symptoms increased (Muth, Walker, & Fiorello, 2006). Cheung, Nakashima, Hofer and Coyle (2007) attempted to examine how land transport vehicle motions could affect performance if the vehicle motions caused MS symptoms. The study conducted on the Light Armoured Vehicle (LAV) did not find that MS symptoms affected crew performance. It was noted that the collection of MS severity was compromised by the operational tempo of the environment in which the data were gathered. Because motion could not be controlled or repeated systematically, motion becomes a co-variant factor making it difficult to confirm if performance was affected directly by MS symptoms.

Haward, Lewis, & Griffin (2009) conducted a study that divided job descriptions into two categories, physical and cognitive; cognitive tasks included bridge and control room activities. They found significant correlations between motion and self-ratings of MS. The most severe incidences of MS nausea and stomach awareness were noted from the bridge and control room areas, where they stated that tasks are more cognitive than physical.

In 1997, during a NATO training exercise, Colwell (2000) deployed the NATO Performance Assessment Questionnaire (PAQ) and collected 1,026 responses (over 60% of the personnel on the exercise). The NATO PAQ included four sections: Personal Information, Symptoms, Performance, and General Comments and was developed to obtain information on MIF, MS, and how ship motion affects crew performance (Colwell, 2000). The PAQ contained questions pertaining to experienced symptoms (e.g., mental and physical fatigue), and also for problems associated with task completion, such as "made more mistakes than usual," and "tasks took longer than usual." More than 50% of the respondents reported mild to moderate levels of MS during the exercise and those who reported experiencing MS symptoms also reported problems with task performance and/or task completion. Answers were subjective and there was no way to collect the actual time on task or errors made. However, this research has served as a reference point for several follow-on studies.

The Misery Index Scale (MISC) was developed so that individuals could rate their MS symptoms against an ordinate scale (see Figure 2-3). It uses the many symptoms of MS such as sweating, headache, dizziness, and nausea by placing them in the order that they generally appear to an operator. The symptoms are rated along an eleven point scale (0-10) with "5" being the start of moderate sickness symptoms (Wertheim et al., 1992). A possible limiting factor in the previous studies on MS may have been the lack of control over the MS symptoms that the subject experienced. While it has been shown that certain motions are highly provocative, the susceptibility and adaptation of individual's to these motions are different (Cheung, 2000).

Misery Index Scale		
Symptoms		Score
No problems		0
Uneasiness (no typical symptoms)		1
Dizziness, warmth, headache, stomach awareness, sweating	Vague	2
	Slight	3
	Fairly	4
	Severe	5
Nausea	Slight	6
	Fairly	7
	Severe	8
	(near) retching	9
Vomiting		10

Figure 2-3: The Misery Index Scale - MISC

A protocol was developed to keep subjects moderately seasick for a substantial amount of time in a ship motion simulator (Colwell, 2004). A study validating the protocol was executed by Colwell and MacKinnon (2007). They approached the assessment of MS severity by taking two independent measures: subjective estimation of MS severity and the observed evaluation of MS severity. They found that utilizing Reason and Diaz's (1971) approach of using both subjective assessment and objective assessment measures of a subject's MS symptoms, that they were able to keep the subject at a moderate level of MS. Colwell and MacKinnon (2007) did this by incorporating both the MISC for subjective data on MS severity and the Observer Checklist Score (OCS) shown later in Section 3.6.2, for objective data. By combining these scores and using them as a guide, they were able to manipulate motion levels of the Ship Motion Simulator (SMS) and maintain a subject at a level of moderate seasickness (e.g., subject reported "5" on the MISC). The OCS allows the researcher to monitor signs of MS such as pallor, excessive swallowing, yawning, and belching, to help ensure the subject does not escalate to a higher rating on the MISC which would place the subject at an elevated risk of vomiting. Levels of MS symptoms can be categorized by using diagnostic criteria introduced by Graybiel et al., (1968) thus allowing the researcher to recognize when MS symptoms were increasing in severity. This protocol potentially removes limitations for future research by allowing experimenters control for motion sickness and thus more systematically evaluate outcome performance.

2.4.2 Cognitive Performance

Before delving deeper into cognitive performance, one must understand what factors are involved prior to and during task execution. Situation awareness (SA) is described as not only how an operator perceives stimulus within the current environment but also how the operator understands, reacts and projects what these factors may mean in the future (Endsley, 1995). Therefore, an operator's current SA acts as the basis for decision making and cognitive processing. If an environment changes, or is perceived to have changed, it could affect an operator's performance. Since perception of time is a critical aspect of SA (Endsley, 2000), a skewed perception of time may affect decision making. Further research is required to assess what factors influences an operator's perception of time.

Attention and working memory are influenced by current SA (Colwell, 2005). If motion stimulus causes MS symptoms such as disorientation, decreased motivation, and dizziness, then SA may be altered. Thus, MS symptoms may have an indirect effect on cognitive performance (see Figure 2-4). Problems with cognitive performance can be measured in aspects of attention such as increased time response, increased number of errors and missed visual cues. Dahlman et al. (2009) suggests MS symptoms have an effect on an aspect of the working memory by affecting short term memory. Computer based tests such as the Multi-Attribute Task Battery (MATB) (Comstock & Arnegard, 1992) and the subtasks of the Sustained Operations (SusOps) (DRDC Toronto) task battery allow researchers to systematically test cognitive performance.

The data collected during the NATO exercise (Colwell, 2000) raised some interesting questions for those who experienced MIF and MS symptoms and also expressed concerns completing the tasks. Common complaints from those experiencing MS symptoms were that participants thought they made more errors than usual and that the task took longer to complete. Situations that are perceived as negative tend to seem longer (Angrelli et al., 1997) which can have a detrimental effect on SA.

Haward at al. (2009) reaffirmed that there is a need for a deeper understanding of what types of problems may arise due to motion and to what scale they affect the operator(s). After a five month study of crew performance on a floating production and storage offshore (FPSO) vessel they found that subjective performance ratings on cognitive tasks significantly correlated with ship motion magnitude. Although these findings agree that tasks are seemingly longer and that performance subjectively declines with increasing MS symptoms, the question is whether there is an actual degradation in performance or if it is only perceived as such. Figure 2-4 represents these associations.

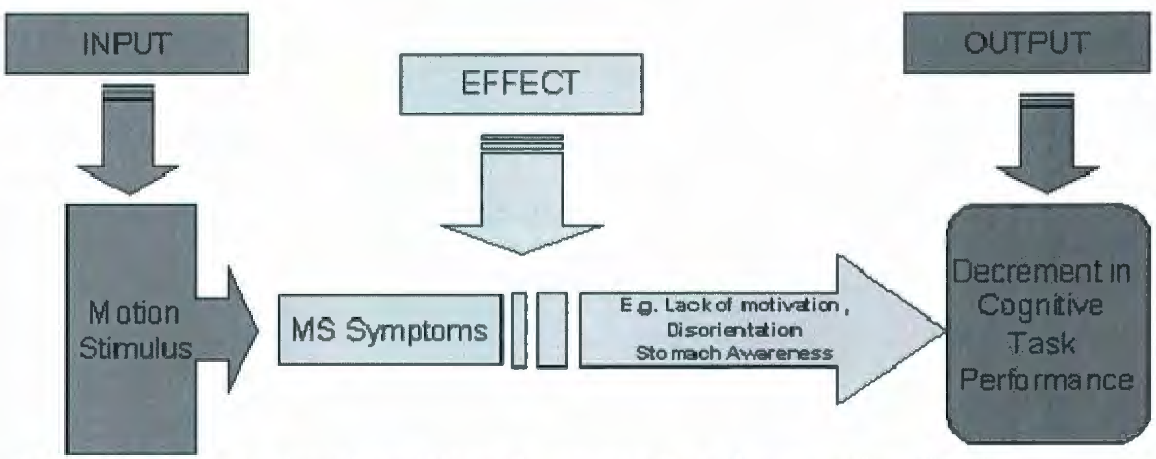


Figure 2-4: A description of possible performance effects due to motion stimulus

2.4.3 Tasks and Time Estimation

Brown (1995) noted that tasks that are identical in the level of difficulty and duration should be perceived as such, meaning that an individual should estimate the same time for the same task(s) regardless of the environment. However, when focus is drawn away from the task at hand or when a current situation is perceived as a negative experience there is a subjective perception that events are longer in duration (Angrelli et al., 1997). Colwell (2000) found that those reporting increased MS symptoms also reported that tasks seemed longer to complete while experiencing these symptoms. If an individual experiences subjective time to be longer than the actual time then it is theorized that less focused attention is given to the required task. This presents a problem with autonomous tasks as attention can be diverted with little conscious awareness and with vigilant tasks an operator can assume "tunnel vision" and miss necessary peripheral cues. Tasks that are considered autonomic in nature are theorized to be at the most risk while under the influence of MS symptoms as the operator may not be able to sustain proper attention to these types of tasks (Money at al., 1996).

2.5 SUMMARY

Performance of cognitive tasks requires considerable higher order mental resources from the human operator and studies have attempted to investigate how MS affects performance on such tasks. Because of the large variability in human response to provocative motion, the relationship between MS and performance is not well understood. Ideally, situational awareness, time on task, and task performance should remain consistent throughout changing sea states. However, further research is still required to fully grasp the influence of moderate MS on task performance. A more detailed understanding of MS and the effects of MS on task batteries can increase operation efficiency by the improving of crew scheduling and task assignments (Cheung et al., 2004).

CHAPTER 3 METHODS

3.1 INTRODUCTION

There has been limited research examining the effects of moderate levels of motion sickness on cognitive performance. Colwell and MacKinnon's (2007) study was a proof of concept study that demonstrated that a ship motion simulator (SMS) protocol could maintain a subject at a moderate level of motion sickness (MS) for extended periods of time. This protocol allows for an empirical research approach on the effects of moderate symptoms of motion sickness on the performance of cognitive tasks. In this protocol, the simulator motions are adjusted in real time, according to the reported and observed motion sickness symptoms of a participant.

3.2 PARTICIPANTS

Fifty-three volunteers were recruited through posters, email, and word of mouth and were initially screened using the Short Motion Sickness Susceptibility Questionnaire-MSSQ (Golding, 2006b) (see 0). Females who were or might have been pregnant, individuals with heart or respiratory illness, and individuals with vestibular system (or balance organ) problems were screened out from participating in the experiment (see Appendix B). Of the 53 volunteers, 17 subjects were deemed to be susceptible for motion sickness (Table 3-1). These seventeen healthy participants had a mean age of 33.06 ± 9.76 years. Seven males (*n* = 7, 32.57 ± 11.28 years) and ten females (*n* = 10, 33.40 ± 8.71 years) were included in the experimental sample. All participants completed the Physical Activity Readiness Questionnaire (PAR-Q) (see Appendix C). Subjects signed consent to participate forms (see Appendix D and Appendix E). Subjects were remunerated for participating. The experimental protocol was approved by Memorial University's Human Investigation Committee and the Defence Research and Development Canada's Human Research Ethics Committee.

Table 3-1: Subject demographics and MSSQ- Short Score

	Mean Age (yrs)	Min. Age (yrs)	Max. Age (yrs)	Mean MSSQ	Min. MSSQ	Max. MSSQ
Male	32.57	21	48	29.55	18.5	41.63
Female	33.4	23	47	33.26	22	54
Combined	32.99	21	48	31.41	18.50	54

3.3 EXPERIMENTAL VARIABLES

3.3.1 Independent Variables

The independent variable was motion condition: 'No Motion' (static platform) and 'Motion' (dynamic controlled platform). The motion profile of the SMS was quasi-controlled using protocol from Colwell and MacKinnon (2007). Motion experienced by each subject was controlled by considering the subjective sickness ratings obtained reported from the Misery Index Scale (MISC) and a researcher appraisal using the Observer Checklist Score (OCS) (see Table 3-2). The protocol for assessing subject sickness and simulator motions is described further in Section 3.4.2. The 'No Motion' segment of the experiment was situated in a stable environment, simulating the lighting and workspace characteristics of the SMS.

3.3.2 Dependent Variables

The dependant variables evaluated in this research were:

Estimate of time on task(s), test battery scores from the Multi Attribute Task Battery (MATB), test battery scores from Sustained Operations (SusOps), and results from psychometric test batteries.

3.4 TASK BATTERIES

3.4.1 Estimation of Time on Task

The estimation of time on task (ETT) was collected eight times within a two hour protocol (see Appendix F and Appendix G). Actual times (AT) of specific intervals ranged from four to eleven minutes in length. The tasks within these time blocks consisted of differing durations of the Multi-Attribute Task Battery (MATB) and Sustained Operations (SusOps) subtasks, both of which are described below in detail. The time blocks could consist of one of the task batteries, either the MATB or a SusOps subtask, or combinations of both. The researcher instructed the subject prior to the beginning of a task(s) that they would be required to provide an ETT. The reported judged duration for each interval was provided by the subject and recorded by the researcher. The ETT was then calculated as: Estimation of Time on Task = Actual Time-Time Reported/Actual Time*100% or ETT = AT - TR/AT*100%). This was done to standardize the ETT to the actual time of the interval.

3.4.2 Multi-Attribute Task Battery

The Multi-Attribute Task battery (MATB) (Comstock & Arnegard, 1992) developed by National Aeronautics and Space Administration (NASA)/Langley Research Centre, simulated multi-tasking events to which pilots would typically be exposed. It allowed for data collection of response time, tracking, missed cues and errors. This multi-tasking portion required the subject to perform three subtasks simultaneously on the same screen (as seen in Figure 3-1.). The 'Scheduling' and 'Communication' portions of the MATB were not used in this experiment.

Within the two hour MATB specific script, task times varied from three minutes to eleven minutes with the MATB being attempted by the subject a total of seven times throughout. The three MATB subtasks were; tracking, resource management, and monitoring. Figure 3-1 illustrates the computer interface.

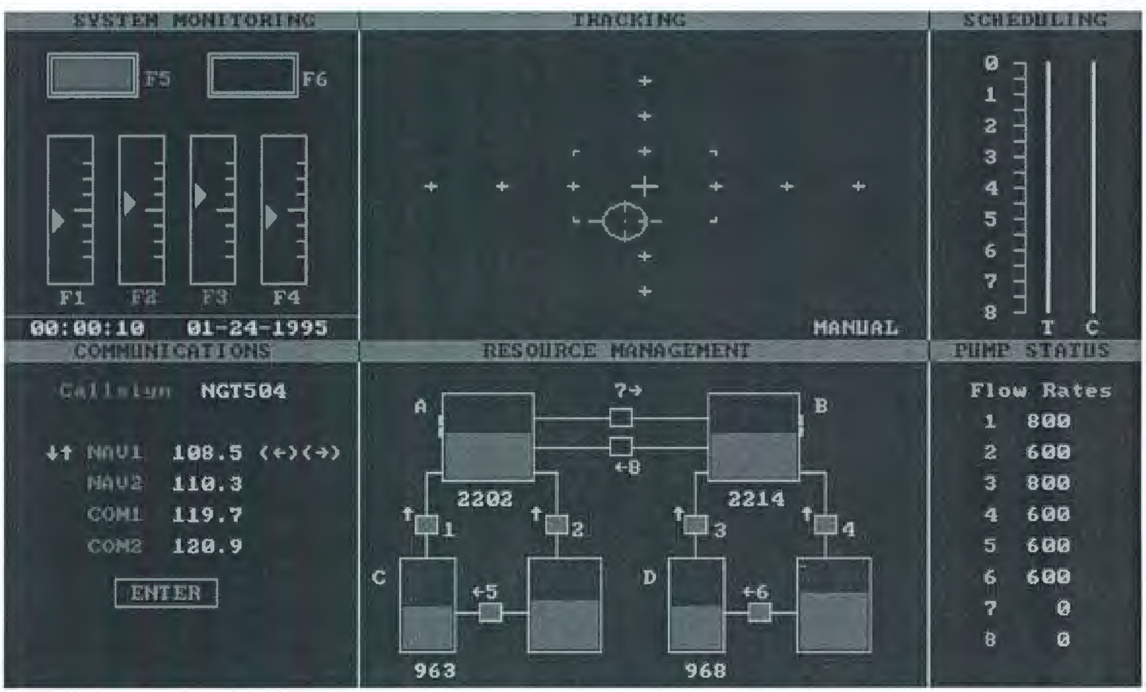


Figure 3-1: Screenshot of the Multi-Attribute Task Battery (MATB)

3.4.2.1 Tracking

This portion of the MATB required the subject to use the computer mouse to keep the cursor within a defined square area on the screen. Performance was calculated as the root mean square (RMS) tracking error. RMS was calculated as the square root (SQRT) of the sum of squares (SS) divided by the number of data points (N). Further calculation was conducted for each of the seven MATB "segments" performed over the two hours. The Mean RMS was averaged according to the number of times the MATB saved each five second position.

3.4.2.2 Resource Management

This portion of the MATB required the subject to keep two fuel tanks (A and B) at 2500 units. Each tank was allowed a buffer zone of 250 units above or below the desired level. The subject was required to toggle eight pumps in on and off positions as necessary to maintain the desired level which could be complicated by pumps programmed to fail.

A mean Resource Management level for each MATB segment was calculated by averaging the total deviations for each segment. For each of the seven MATB segments Resource Management was averaged by the amount of deviations (above 2750 or below 2250) and by the number of segments automatically saved by the MATB.

3.4.2.3 Monitoring

The monitoring task required the subject to react to fluctuations of four dials in each gauge that were moving above and below a midline demarcation. The subject was instructed to correct deviations of more than one mark above or below the median, by pressing a corresponding function key. For example, if the dial in Gauge One moved above or below the allowed distance then the subject was to press the F1 key. If the dial in Gauge Two moved, then the F2 key was pressed and so on. If the subject did not properly react the dial would correct itself and it was logged as a miss. An incorrect response (e.g., hitting F2 when F3 should have been pressed) was logged as an error.

Two indicator lights above the four dials were also subject monitored. If the green light went out in the left window then the subject would have to turn it back on by pressing the correct key (in this case F5) and if the light turned red in the right window then the subject would have to turn it off (in this case F6). Mean response times were calculated for each event and the missed signals and errors were recorded.

3.4.3 Sustained Operations

The Sustained Operations (SusOps) task battery was developed by NTT Systems Incorporated for Canadian Department of National Defence use at their Defence Research and Development Canada (DRDC) research facilities. SusOps experiments were designed to test how various aspects of cognitive ability are affected by stresses such as sleep deprivation (Pen-Based Sustained Operations, no date). It includes mental arithmetic, reaction skill tests, and simple logical reasoning. By utilizing a "scheduling program", the researcher can control which subtasks are presented, the order in which they are presented, and the duration of the subtask. For this study there were five SusOps subtasks employed during the sessions: Addition (ADD), Line Comparison (CMP), Short Term Memory (STM), Logical Reasoning (LRT), and Serial Reaction Test (SRT).

3.4.3.1 Addition (ADD)

The ADD subtask presented eight consecutive numbers, one after the other, which the subject had to summate. The subject was asked to enter the sum (see Figure 3-2) and then indicate how confident they were on a scale from 0-100% that the answer was correct (see Figure 3-3). The subject was required to provide a response before the task timed out. Performance on the ADD subtask was calculated by the error percentage (EP) and also the mean response time (RT) within a timed segment. Error percentage (EP) was calculated as $E = Tot_{Error}/Tot_{Presented}*100\%$. The ADD subtask was conducted four times over the two hours in both conditions (see Appendix F and Appendix G).

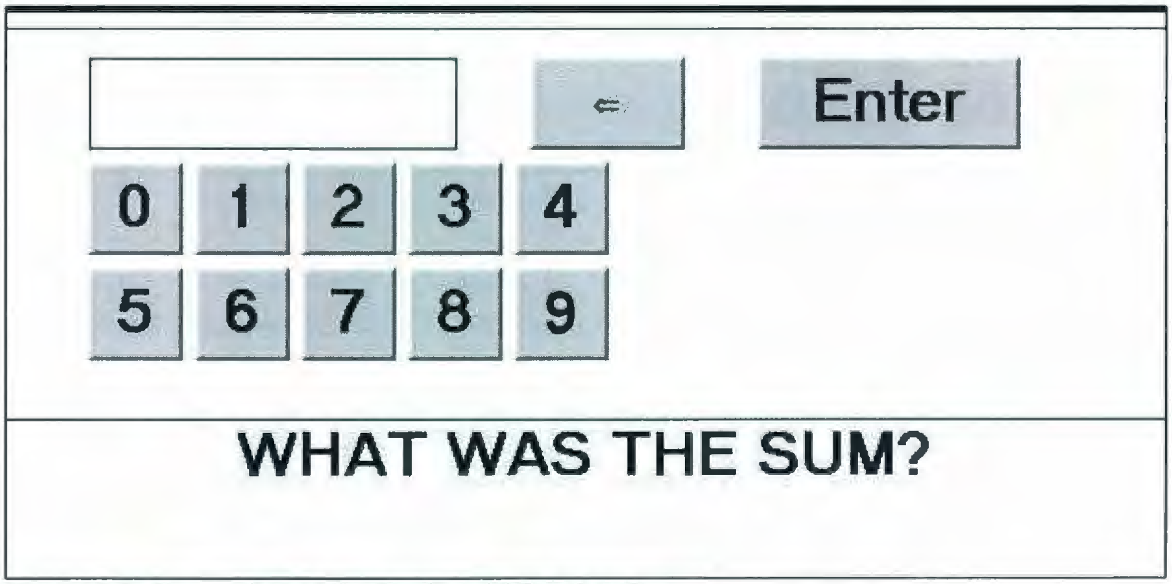


Figure 3-2: Screenshot of the SusOps ADD subtask

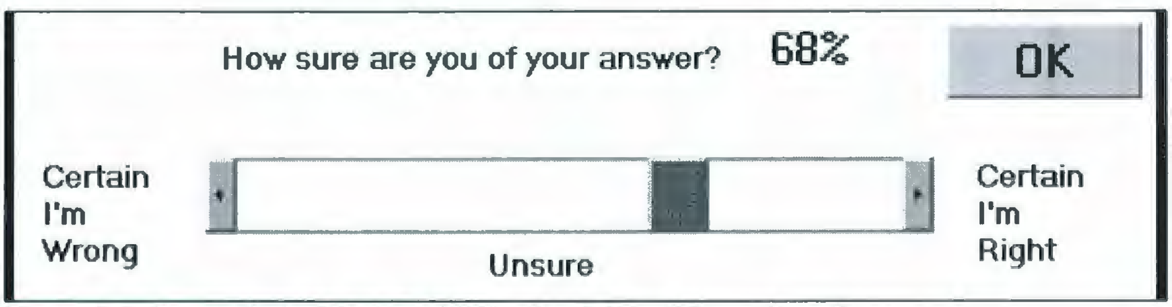


Figure 3-3: Screenshot of SusOps ADD subtask 'Confidence Score'

3.4.3.2 Line Comparison (CMP)

The CMP subtask presented a horizontal line that is bisected by another vertical line. The horizontal line was longer on one side of the vertical line and shorter on the other. Above the bisected lines the word "Longer" or "Shorter" was presented (see Figure 3-4). The subject then indicated if the left or right line was longer (or shorter) by clicking on the correct answer, 'L' for left or 'R' for right. The subjects were then asked to rate their confidence from 50% to 100%. Performance on the CMP subtask was calculated by the error percentage (EP) and also the mean response time (RT) within a timed segment. Error percentage (EP) was calculated as $E= Tot_{Error}/Tot_{Presented}*100\%$. The CMP subtask was conducted four times over the two hours in both conditions (see Appendix F and Appendix G).

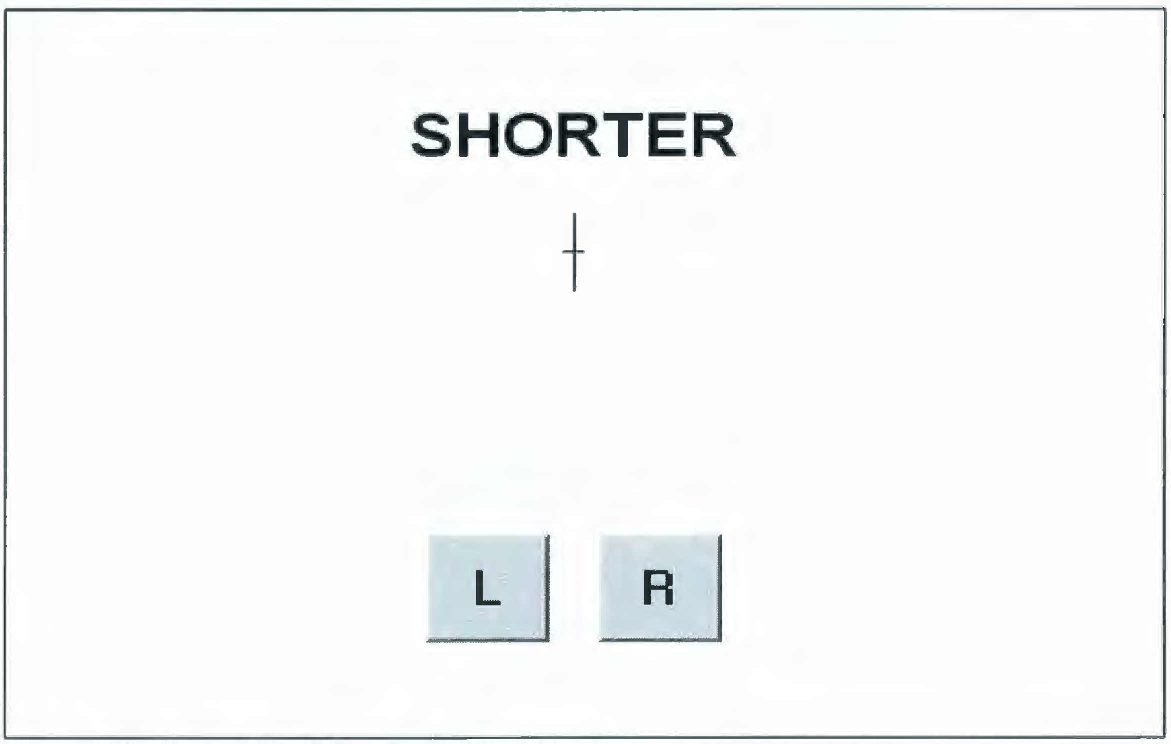


Figure 3-4: Screenshot of SusOps CMP subtask

3.4.3.3 Short Term Memory (STM)

STM subtask presented a series of digit strings to the subject along with a direction indicator. If the indicator is "FORWARD" the subjects must enter the digits in the order they were presented (see Figure 3-5). If it is "REVERSE", they must enter the digits in the reverse order. The digit string length and direction of recall vary according to a set of programmed rules. Performance on the STM subtask was calculated by the error percentage (EP) and also the mean response time (RT) within a timed segment. Error percentage (EP) was calculated as $E = Tot_{Error}/Tot_{Presented}*100\%$. The STM subtask was conducted two times over the two hours in both conditions (see Appendix F and Appendix G).

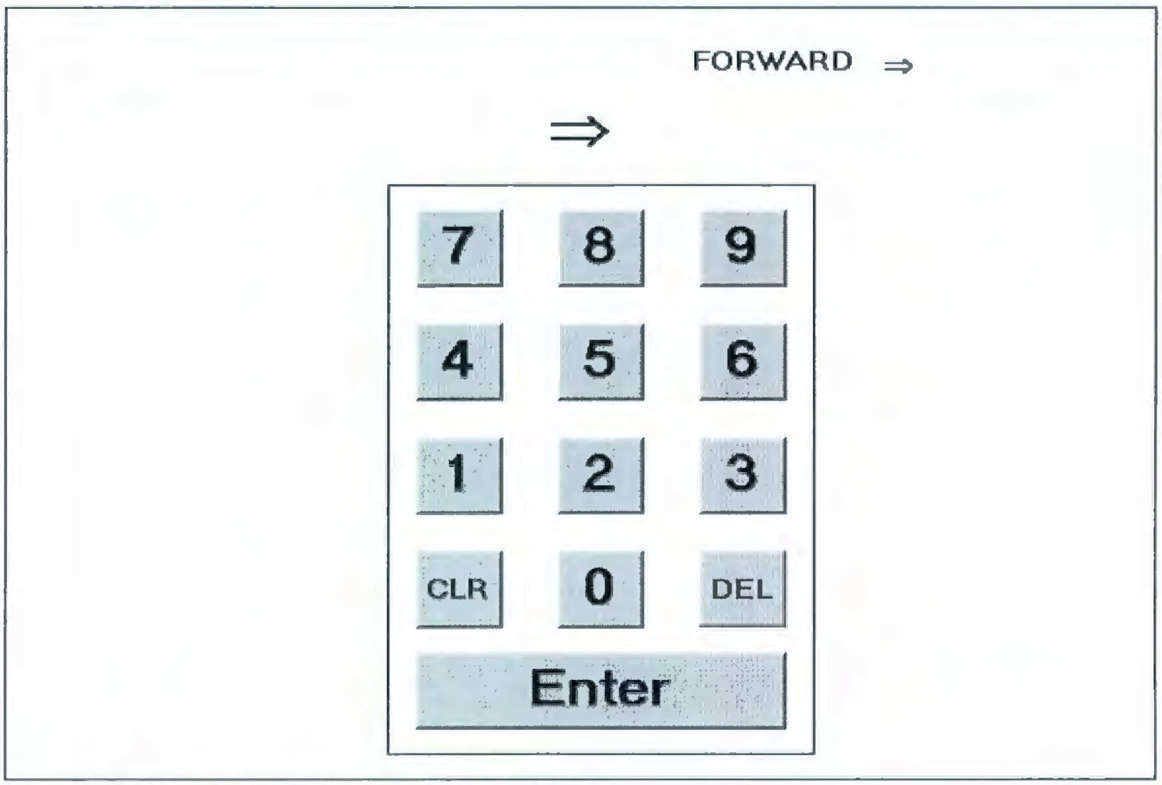


Figure 3-5: Screenshot of SusOps STM subtask

3.4.3.4 Logical Reasoning (LRT)

The LRT sub task presented a series of problems concerning the relationship between two entities: A and B. They are presented in the form "AB" or "BA" along with a statement regarding the relationship between the two. The subject responded by clicking either the TRUE or FALSE button (see Figure 3-6). For example, "A" is preceded by "B". Performance on the LRT subtask was calculated by the error percentage (EP) and also the mean response time (RT) within a timed segment. Error percentage (EP) was calculated as $E = Tot_{Error}/Tot_{Presented}*100\%$. The LRT subtask was conducted four times over the two hours in both conditions (see Appendix F and Appendix G).

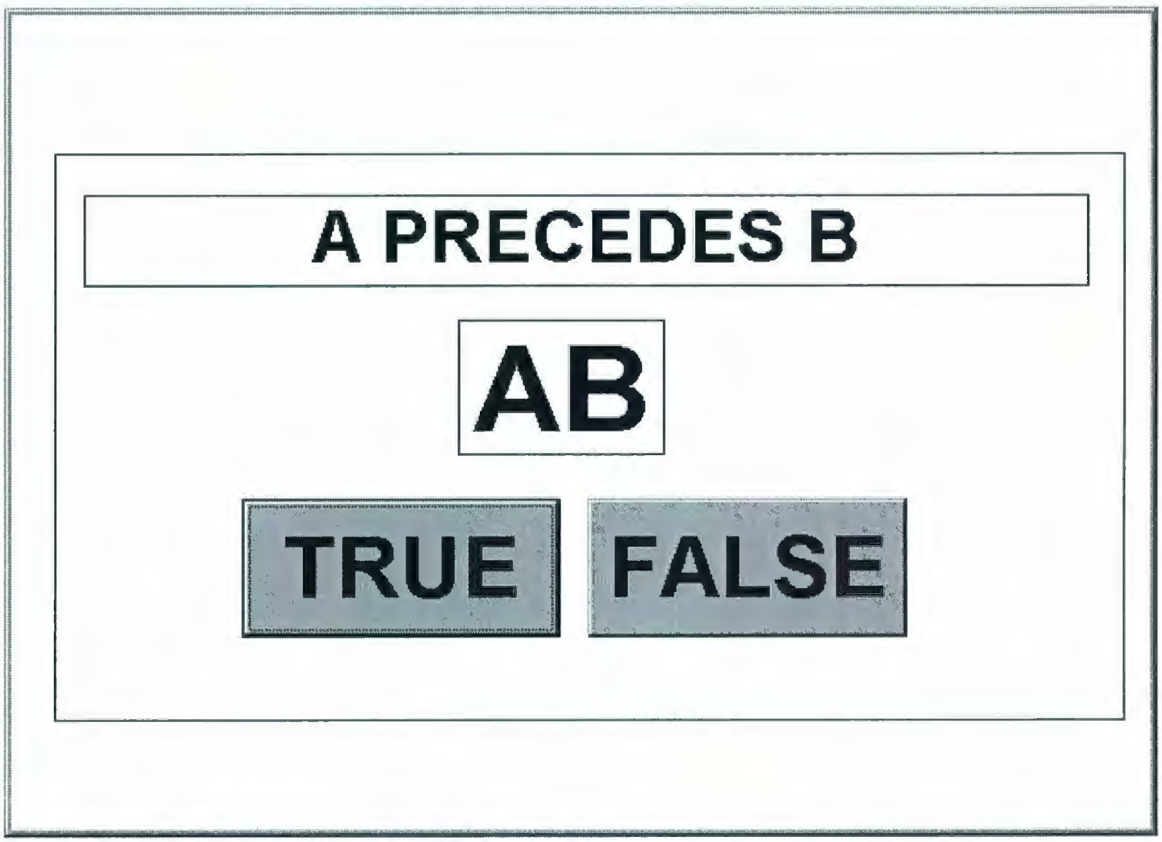


Figure 3-6: Screenshot of SusOps LRT subtask

3.4.3.5 Serial Reaction Time (SRT)

The SRT subtask displayed a four digit keypad with a different character or symbol on each key (see Figure 3-7). One of the four graphics was shown in a display area and the subjects clicked on the corresponding key as quickly as possible. Since sequential repetition of a character is possible due to random selection, the display black and white contrast was reversed from presentation to presentation so that the subject detected the onset of a new stimulus. Performance on the SRT subtask was calculated by the error percentage (EP) and also the mean response time (RT) within a timed segment. Error percentage (EP) was calculated as $E = Tot_{Error}/Tot_{Presented}*100\%$. The SRT subtask was conducted four times over the two hours in both conditions (see Appendix F and Appendix G).

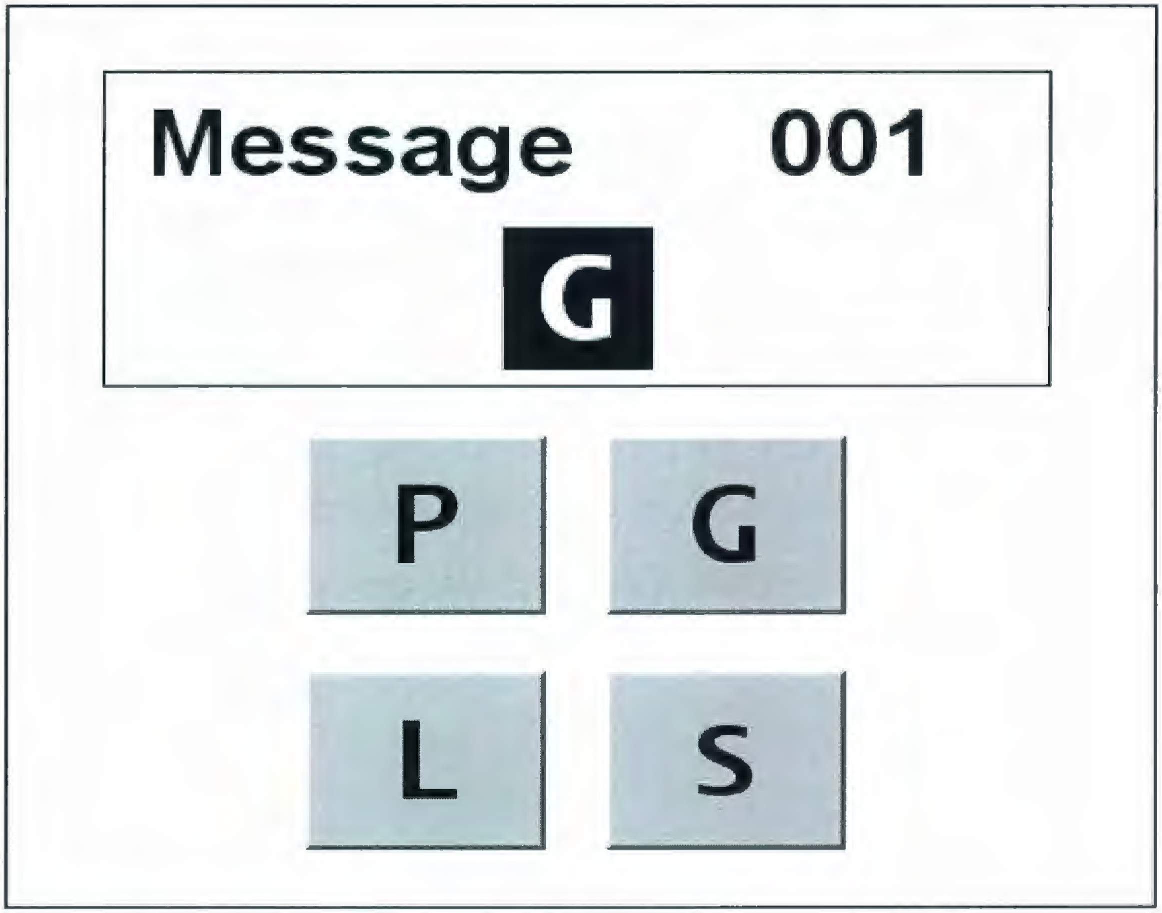


Figure 3-7: Screenshot of SusOps SRT subtask

One computer was dedicated to MATB and another was used for SusOps subtasks, and so each computer was required to run two scripts simultaneously. To ensure that each would run concurrently without interfering with each other both MATB and SusOps were programmed with complimenting two hour scripts, meaning one would 'pause' while the other would 'start'.

3.4.4 Psychometric Test Battery

Subjects were required to fill out questionnaires 'Pre' (before), 'Mid' (halfway) and 'Post' (after) each of the session. The test battery included the MISC (Appendix H), an amended NATO Performance Assessment Questionnaire (Appendix I), the NASA Task Load Index (TLX) (see Appendix J), and the Stanford Sleepiness Scale (see Appendix K). The time allocated for completing the battery of psychometric tests was four minutes in duration.

3.4.4.1 Misery Index Scale (MISC)

Although the researcher requested a verbal MISC as per Colwell and MacKinnon's protocol (2007), the subject was also required to report MISC on paper for psychometric test battery (see Appendix H).

3.4.4.2 North Atlantic Treaty Organization (NATO) Performance Assessment Questionnaire (PAQ) – Amended

The NATO PAQ (Colwell, 2000) contains four sections: Personal Information, Symptoms, Performance, and General Comments. An Amended NATO PAQ of two sections, Symptoms and Performance, were used for this experiment (see Appendix G). The PAQ was used to collect subjective assessment of MS incidence and personal performance.

3.4.4.3 NASA TLX

The NASA Task Load Index (Hart & Staveland, 1988) assesses workload on six subscales: Mental demand, Physical demand, Temporal demand, Effort, Performance, and Frustration (see Appendix J). Workload for each subscale was based on a 1-20 scale with a '1' denoting low task workload and a '20' representing extreme high task workload. An explanation of each was provided to the subject. Each subscale is described as:

i. 'Mental Demand' - How much mental and perceptual activity was required to complete the subtasks?

ii. 'Physical Demand' - How much physical activity was required?

iii. 'Temporal Demand' - How much time pressure was felt due to the rate or pace at which subtasks occurred?

iv. ‘Effort’ – How hard did the subject have to work to accomplish the level of performance required?

v. 'Performance' - How successful the subject felt they were at accomplishing the desired goals of the subtasks?

vi. 'Frustration' - How discouraged, insecure, stressed versus relaxed and gratified in completing the subtask?

3.4.4.4 Stanford Sleepiness Scale

The Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Philips & Dement, 1973) allowed the subject to rate how tired s/he was. The scale is based on a seven increment levels, with "1" as being active and alert, and "7" as struggling to remain awake (see Appendix K).

3.5 INSTRUMENTS

3.5.1 Ship Motion Simulator

The experiment was performed in the Full Mission Ship Bridge Simulator (SMS of the Centre for Marine Simulation, Marine Institute, Memorial University of Newfoundland (see Figure 3-8). This facility is a large ship bridge (5m x 7m), mounted on a six degrees of freedom motion base, and surrounded by 360° azimuth coverage visual projection screens.

The key variables that relate to the simulated motions were the size and shape of the hull, the ship speed and course, the significant wave height, wave period or wave length, and wave direction. All of these variables were used as input to the mathematical model which produced the simulator motions. The motions for the experiment were developed for a relative wave direction of approximately 45° off the bow, and with a frequency of vertical motion of approximately 0.2 Hz, which corresponded to the peak in human sensitivity to motion sickness for vertical sinusoidal motion. The amplitude of the simulated ship motions were changed by adjusting the simulated wave height, which provided control over how 'provocative' the motions were for motion sickness.

Figure 3-8: Ship Motion Simulator (SMS) at the Centre for Marine Studies

3.5.2 Experiment Script

A standard two hour script was developed for the 'Motion' and 'No Motion' conditions (see Appendix F and Appendix G).

3.6 PROCEDURE

This study was divided into three experimental sessions. Session one was the initial interview and introduction to and familiarization of the test batteries. Sessions 2 and 3 were data collection sessions and occurred with a minimum of one week between each session.

3.6.1 Session One

During the initial meeting the subject received a detailed explanation of the procedure. The subject signed consent to participate forms and was provided with the opportunity to ask questions about the experiment. This information session was also used to provide instruction on operation of the computer tasks that would be employed during the two data collection sessions. The subject was instructed on the five sub-tasks from the DRDC Toronto Sustained Operations (SusOps) package and the three sub-tasks of the Multi-Attribute Task Battery (MATB). The task batteries, SusOps and MATB, were located on two separate laptops that were placed side by side and in front of the subject. The subject sat in a chair facing forward and was instructed to keep their eyes fixed on the computer screen in front of them. Each of the subjects was given the same task in the same order (see Figure 3-9). The task batteries were explained and demonstrated individually and then practiced by the subject. Once the subject received instructions on all of the tasks, had practiced all independently, and was confident that s/he knew what was expected for each task, the subject underwent a 20 minute practice period that simulated the testing conditions. Instructions included telling the subject that periodically they would be prospectively instructed to estimate the duration of a proceeding interval during the data collection. After the 20 minute practice session the first data collection session was booked.

Figure 3-9: Experiment setup in SMS

3.6.2 Session Two

Subjects were assigned randomly to either the 'Motion' or 'No Motion" for the first data collection trial. Nine subjects completed 'No Motion' as their first data collection, and eight subjects completed 'Motion' as their first data collection.

Following arrival at the test site, the subject completed the same 20 minute orientation session to refresh what had been practiced during Session One. Watches were removed, clocks were removed from sight and the time display on the laptops were covered with tape, eliminating all time cues.

The subject sat on a chair facing a desk that held the two laptops (see Figure 3-9). The laptop on the left presented and collected data from SusOps sub-tasks and the laptop on the right presented and collected data from the MATB. To ensure that each would run concurrently without interfering with each other both MATB and SusOps were programmed with complimenting two hour scripts, meaning one would 'pause' while the other would 'start'.

During the two hour data collection each subject was required to complete the psychometric questionnaires, as previously described in Section 3.4.4.

Once the data collection began the researcher executed a pre-determined two hour script that followed a timeline of specific tasks (see Appendix F and Appendix G). This script dictated what the type and duration of task(s) were and which predetermined intervals a subject was to estimate the elapsed time.

At the start of each timed test interval, using a prospective method, the experiment observer told the subject that the interval was about to start, by saying "I will ask you how long it took to complete the tasks once you are completed". The subject then proceeded to perform a sequence of scheduled computer-based test batteries (as described in the next section) until advised by the researcher that the time interval had finished. The subject was then required to judge the duration of the completed interval, to the nearest integer or "full" minute, which the researcher then recorded. All time intervals in this experiment were devised to have durations of an integer number of minutes. The participant did not receive feedback on the accuracy of their time estimation at any time during the experiment. The only direction given to the subject was to which computer they were to use for the cognitive tests. The script was identical for both the 'Motion' and 'No Motion' cases except for one feature: the 'Motion' script was in reverse order compared to the 'No Motion' script.

Several times during the two-hour protocol, regardless of whether it was 'Motion' or 'No Motion' condition, the researcher asked the subject to rate their motion sickness symptoms according to the MISC. The scale and its description were taped to the desk in front of the subject for easy reference. Although the researcher requested MISC feedback at certain times throughout the session, the subject was also instructed to notify the researcher if they felt themselves progressing quickly on the scale of greater than '6'. It was also noted on this sheet that if the MISC symptoms escalated above a "5" at any time the subject was to notify the researcher. The researcher also used the OCS (see Figure 3-10) and compared them against the subject-reported MISC scores.

Observer Checklist Score				
0 = None, 3 = Severe:	0	1	2	3
Pallor	☐	☐	☐	☐
Cold	☐	☐	☐	☐
Salivation	☐	☐	☐	☐
Swallowing	☐	☐	☐	☐
Increased Breathing	☐	☐	☐	☐
Yawning	☐	☐	☐	☐
Belching	☐	☐	☐	☐

Figure 3-10: Observer Checklist Score (OCS)

Together these scores were considered by the investigator in attempts to keep the subject at a MISC level of 4 or 5 (see Table 3-2). If the MISC was too high or too low the researcher was able to communicate to the SMS controller to decrease or increase the motion. The SMS had a starting sea state of 6, when the researcher gave the indication to increase the motion the SMS controller increased it by one sea state; when the researcher gave the indication to decrease motion it went down by 2. Verbal MISC and OCS were recorded for each subject.

Table 3-2: Criteria for controlling motion of full motion bridge (Colwell & MacKinnon, 2007)

Increase SMS Motion if	Decrease SMS Motion if
a. MISC < 3, or	a. MISC > 5, or
b. MISC < 4 and OCS < 2 for ALL parameters	b. MISC > 4 and OCS > 2 for any single parameter

3.6.3 Session Three

The protocol for Session Three was the same as the Session Two protocol except that it was in the condition the subject had not completed yet. For example of they completed 'No Motion' in Session Two then they were to complete 'Motion' in Session Three.

3.7 STATISTICAL ANALYSIS

A repeated measures within-subject ANOVA was used to compare task battery scores and time estimations between the 'Motion' and 'No Motion' conditions. Specific analysis will be explained in the Chapter 4.

CHAPTER 4 RESULTS

Data were collected in the conditions, 'Motion' and 'No Motion', according to the script (see Appendix F and Appendix G) as described in Methods. Two types of data were collected during the series of time intervals - estimation of time on task (ETT) and test battery scores (SusOps and MATB). A repeated measure ANOVA was used to assess these data and homogeneity of variance was scrutinized for each test. Where Mauchly's test indicted that the assumption of sphericity had been violated the degrees of freedom and *p*-values were adjusted.

A third set of data were also collected in both the 'Motion' and 'No Motion' conditions. During the two hour sessions psychometric questionnaires were collected 'Pre' (before), 'Mid' (halfway), and 'Post' (after). A 2 (movement condition: Motion and No Motion) X 3 (collection time: pre, mid and post) repeated measures ANOVA were used to assess these data. In all cases, if a post hoc analysis was performed a Bonferroni correction was considered in the paired t-tests.

4.1 ESTIMATION OF TIME ON TASK

Estimation of time on task (ETT) was analyzed to examine if there were differences between 'Motion' and 'No Motion' conditions. During the two hour sessions the subjects were asked, at eight different intervals according to the script (see Appendix F and Appendix G), to estimate how long it had taken to complete prescribed tasks. Actual time of specific serials ranged from four minutes to eleven minutes in duration and consisted of differing ratios of task batteries. In order to compare ETT in the 'Motion' condition to the 'No Motion' condition the relative difference of reported time from actual time was calculated. The percentage ratio of the Time Reported (TR) and Actual Time (AT) were compared (e.g., Estimation of Time on Task = Actual Time-Time Reported/Actual Time*100% or ETT = AT - TR/AT*100%). A negative number indicated if the subject judged task(s) duration less than the AT of the task(s) and a positive number represented an overestimation of the AT.

A 2 (movement condition: Motion and No Motion) X 8 (collection time: time interval) repeated measures ANOVA was conducted. When Mauchly's test indicated that the assumption of sphericity had been violated the degrees of freedom and *p*-values were adjusted. There was some statistical evidence that time on tasks was perceived to take longer in the 'Motion' condition when compared to 'No Motion' (see Table 4-1). Table 4-2 contains the results of the post hoc analysis employing the Fisher LSD approach. Although p=0.065 (and thus >0.05) a post hoc was also conducted to assess the differences in ETT.

Table 4-1: Tests of Within Subject Effects - Relative difference 'No Motion' and 'Motion'

Time	Movement Condition		Collection Time		Interaction	
Sub Task	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value
Time Estimation	3.934	0.065	7.542	0.000	2.527	0.053

Table 4-2: Post hoc results between relative group mean 'No Motion' and 'Motion'

Time	Mean No Motion	Mean Motion	SD	SE	t	*p* value (2 tail)
TNM1-TM1	-22.22%	-4.28%	49.04	11.89	-1.509	0.151
TNM2-TM2	2.35%	6.62%	53.34	12.94	-0.330	0.746
TNM3-TM3	27.94%	34.12%	93.82	22.75	-0.271	0.790
TNM4-TM4	-8.82%	0.53%	42.48	10.30	-0.908	0.377
TNM5-TM5	-19.79%	25.88%	56.32	13.66	-3.343	0.004
TNM6-TM6	0.00%	39.71%	40.91	9.92	-4.002	0.001
TNM7-TM7	-10.29%	20.00%	53.05	12.87	-2.354	0.032
TNM8-TM8	-9.09%	-3.92%	55.16	13.38	-0.386	0.704

In the experimental design, the time scripts (see Appendix F and Appendix G) simply were a reversed but identical replication of each other. Thus, the first of the time series (Time 1) of the 'Motion' condition was of identical duration and task as the last (Time 8) of the 'No Motion' condition. Therefore, the data was also analyzed in “reverse” order so that comparable time and tasks could be examined. As seen in Table 4-3 when comparing blocks of the time series that contained the same amount of time and the same tasks then p=0.057. Again, a post hoc (see Table 4-4) was conducted to assess differences.

Table 4-3: Tests of Within Subject Effects - Difference in minutes 'No Motion' and 'Motion'

Time	Movement Condition		Collection		Interaction	
Sub Task	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value
Time Estimation	4.196	0.057	4.207	0.005	2.004	0.120

Table 4-4: Post hoc results between group mean 'No Motion' and 'Motion'

Time	Mean No Motion	Mean Motion	SD	SE	t	*p* value (2 tail)
TNM8-TM1	-1.00	-0.47	4.836	1.173	-0.451	0.658
TNM7-TM2	-0.82	0.53	3.840	0.931	-1.453	0.166
TNM6-TM3	0.00	1.71	3.531	0.856	-1.992	0.064
TNM5-TM4	-2.18	0.06	3.993	0.968	-2.308	0.035
TNM4-TM5	-0.88	2.59	5.713	1.386	-2.505	0.023
TNM3-TM6	1.12	1.59	2.672	0.648	-0.726	0.478
TNM2-TM7	0.12	1.00	2.619	0.635	-1.389	0.184
TNM1-TM8	-2.00	-0.35	4.663	1.131	-1.456	0.165

The group’s mean of the total reported time from the actual total time was investigated in both conditions. Throughout each condition the subject was requested to provide ETT in eight serials. The combined time of the eight serials summed to 63 minutes. There was slight evidence of significant effects between conditions ($F(1, 16)$ =

4.196, p=0.057), with 'Motion' overestimating the time (M=6.647, SD=2.75) to 'No Motion' underestimating the time (M= -5.547, SD=1.99).

4.2 TASK BATTERIES

Cognitive task batteries were divided into two subsets, SusOps and MATB. As explained in Section 3.4.2 in Methods the MATB was performed by the subject a total of seven times in each of the 'No Motion' and 'Motion' conditions. Section 3.4.3 in Methods explained how SusOps subtasks were performed.

4.2.1 MATB

The MATB subtasks measured were 'Monitoring', 'Tracking', and 'Resource Management' (see Section 3.4.2). 'Monitoring' was further divided into three performance measurements: RT, EP, and percentage of missed cues. The performance measures for 'Tracking' were the deviations from the center square (RMS) and performance measures for Resource Management was mean deviation in units. A 2 (movement condition: Motion and No Motion) X 7 (score: collection 1....collection 7) repeated measure ANOVA was used for each subtask and no significant differences were found between 'Motion' and 'No Motion' (Table 4-5). When Mauchly's test indicated that the assumption of sphericity had been violated the degrees of freedom and p-values were adjusted.

Table 4-5: Results from MATB subtasks

Subtask	Measurement	p - value	Group Mean	
			No Motion	Motion
Monitoring	Response Time (RT)	0.315	4.33	4.14
	Error Percentage (EP)	0.695	6.51	7.06
	Percentage of Missed Cues	0.804	9.11	8.70
Tracking	Root Mean Square (RMS)	0.202	36.75	45.37
Resource Management	Mean Deviation	0.145	34.92	56.33

4.2.2 SusOps

SusOps subtasks were examined to determine if there was significant difference between the 'No Motion' and 'Motion' condition (Table 4-6). Performance measures were subtask mean response time (RT) and error percentage (EP). The Addition (ADD), Line Comparison Test (CMP), Serial Reaction Test (SRT), and Logical Reasoning (LRT) subtasks were each presented four separate times during the sessions according to the session script (see Appendix F and Appendix G). The Short Term Memory (STM) was presented twice. The mean RT was calculated by summing the response times for each task presented within that segment by the number of tasks presented within that segment.

A 2 (movement condition: Motion and No Motion) X 4 (SusOps attempt: 1, 2, 3 and 4) repeated measures ANOVA was used to compare these data for ADD, CMP, LRT and SRT. A repeated measures ANOVA was used to compare these data. When Mauchly's test indicated that the assumption of sphericity had been violated the degrees of freedom and *p*-values were adjusted. Although not deemed as significant the CMP RT showed slight evidence ($p<0.10$) that there was a difference between the two conditions (see Table 4-6). The group mean of CMP RT showed an increase in response time during 'Motion' as compared to 'No Motion' (see Table 4-6). There was evidence of a significant difference in EP between conditions with CMP EP (see Table 4-6). The group mean of CMP EP was higher in 'Motion' than CMP EP in 'No Motion' (see Table 4-6).

The SRT displayed a significant difference in RT between the 'No Motion' and 'Motion' conditions (see Table 4-6). The group mean of SRT RT showed an increase in response time during 'Motion' when compared to 'No Motion' (see Table 4-6). There were no significant differences in SRT EP.

A 2 (movement condition: Motion and No Motion) X 2 (SusOps STM score: 1 and 2) repeated measures ANOVA was used. STM RT did not show evidence of a significant effect between conditions, however, strong evidence of a significant effect of the condition and STM EP was observed (see Table 4-6). The 'Motion' condition displayed a higher group mean in STM EP than in STM EP in 'No Motion' (see Table 4-6).

Table 4-6: Results from SusOps subtasks - Response Time (RT), Error Percentage (EP)

Response Time (RT)	*p*-value	Group Mean			Error Percentage (EP)	*p*-value	Group Mean	
		NM	M				NM	M
ADD	0.203	3.07	3.23		ADD	0.896	47.46	48.09
CMP	0.084	1.55	1.69		CMP*	*0.007	3.94	6.22
LRT	0.112	3.72	4.00		LRT	0.120	14.70	18.69
SRT*	*0.012	0.75	0.80		SRT	0.820	0.76	0.72
STM	0.307	4.63	4.72		STM*	*0.008	37.11	43.55

A further examination into SusOps subtasks was conducted to determine if there was a significant difference in the number of attempted tasks within these subtasks between the two conditions. A 2 (movement condition: Motion and No Motion) X 4 (SusOps attempt: 1, 2, 3 and 4) repeated measures ANOVA was used to compare these data for ADD, CMP, LRT and SRT. A 2 (movement condition: Motion and No Motion) X 2 (SusOps attempt: 1 and 2) repeated measures ANOVA was used to compare these data for STM. When Mauchly's test indicated that the assumption of sphericity had been violated the degrees of freedom and *p*-values were adjusted. There was a significant difference in the number of completed tasks completed in CMP as there were more tasks attempted in the 'No Motion' session than the 'Motion' session (see Table 4-7).

Table 4-7: Total number of tasks completed in SusOps subtasks

# Tasks Completed	*p*-value	Complete Time (mins)	Group Mean	
			NM	M
ADD	0.672	9	5.65	5.59
CMP*	0.007	10	42.87	40.28
LRT	0.707	9	36.54	35.60
SRT	0.106	8	137.66	132.56
STM	1.000	6	13.59	13.59

4.2.3 Psychometric Test Battery

Psychometric tests were performed at three separate times during the sessions; 'Pre' -before any tasks began, 'Mid' - half way into the session and, 'Post' - after the last task had been completed (see Section 3.6.3). The tests were:

i. Misery Index Scale (MISC)

ii. Amended NATO Performance Questionnaire (PAQ)

iii. NASA Task Load Index (TLX)

iv. Stanford Sleepiness Scale

A 2 (movement condition: Motion and No Motion) X 3 (collection time: pre, mid and post) repeated measures ANOVA was completed for each test to examine if there was a significant difference between conditions and also to examine if there was a difference in subjective answers as time progressed.

4.2.3.1 Misery Index Scale - MISC

Significant effects between conditions were found with reported MISC symptoms ($F(1, 16) = 401.264$, $p<0.000$), with 'Motion' displaying a higher group mean (M=3.227, SD=0.988) to 'No Motion' (M=0.000, SD =0.000). Significant effects were also found in the 'Motion' condition between 'Pre', 'Mid', and 'Post, (($F(1.231, 19.691) = 93.239$, $p<0.000$) (Figure 4-1). It can be generally reported that during the 'No Motion' condition subjects reported a MISC score of 0.

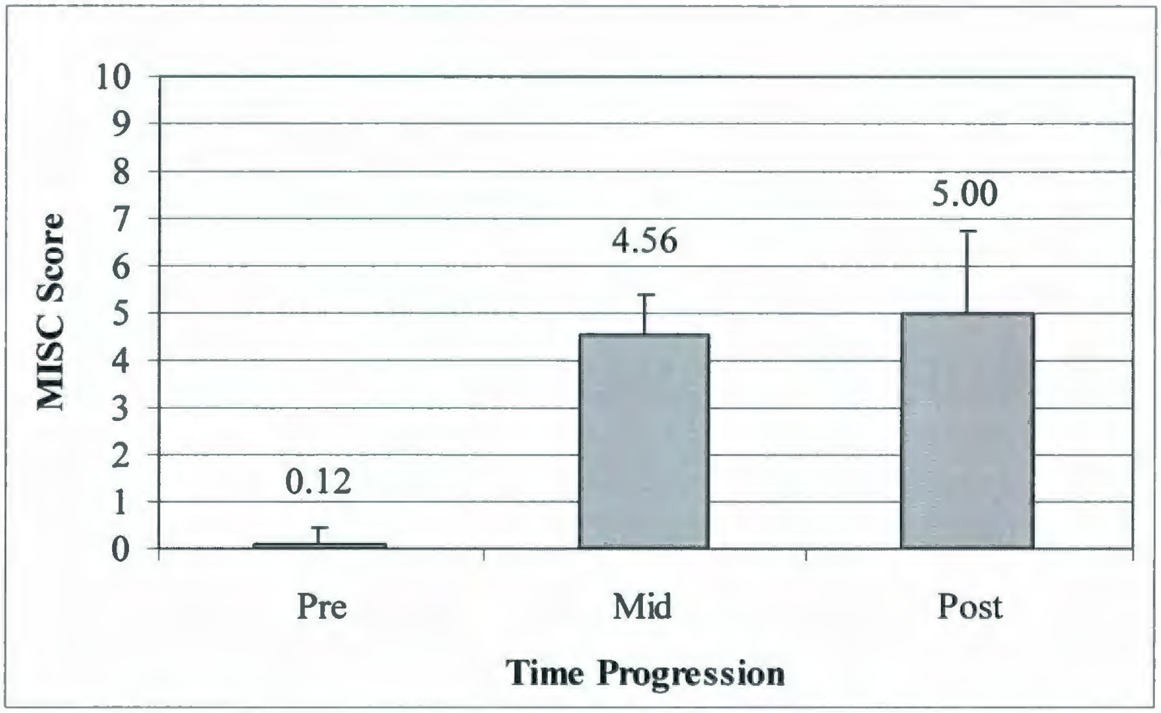


Figure 4-1 : Reported mean MISC 'Pre', 'Mid', and 'Post' during the 'Motion' session

4.2.3.2 Amended NATO PAQ

Significant effects between conditions were found with NATO PAQ symptoms with the exception of 'Apathy' (see Table 4-8). Subjects reported increasing symptoms and performance difficulties on the 0-3 scale (with the exception of 'Motion Sickness' which was on a 0-10 scale) in 'Motion' when compared to 'No Motion'. Significant effects were also found in the 'Motion' condition between 'Pre', 'Mid', and 'Post' collections (see Table 4-9, Table 4-10, and Table 4-11).

Table 4-8: Results from the Amended NATO PAQ comparing 'Motion' to 'No Motion'

Amended NATO PAQ	Movement Condition		Collection		Interaction		Group Mean	
Symptoms	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value	No Motion	Motion
Mental Fatigue	12.72	*0.003	26.743	0.000	18.557	0.000	0.333	0.961
Physical Fatigue	11.132	*0.005	21.255	0.000	10.783	0.000	0.133	0.756
Sleepy	10.232	*0.006	16.175	0.000	14.037	0.000	0.313	1.083
Headache	7.273	*0.017	12.842	0.000	4.639	0.018	0.156	0.600
Apathy	2.901	0.111	6.920	0.009	6.096	0.006	0.178	0.422
Tension/Anxiety	22.278	*0.000	10.280	0.002	4.285	0.022	0.118	0.686
Nausea	79.405	*0.000	31.179	0.000	16.374	0.000	0.044	1.000
Stomach Awareness	120.664	*0.000	49.347	0.000	50.541	0.000	0.022	1.400
Motion Sick?	273.133	*0.000	100.098	0.000	89.969	0.000	0.078	3.510
Performance	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value	No Motion	Motion
Making Decisions	24.648	*0.000	33.780	0.000	24.365	0.000	0.292	1.146
Concentration/attention	21.867	*0.000	59.425	0.000	20.589	0.000	0.417	1.333
Memory	15.306	*0.001	50.868	0.000	13.647	0.000	0.417	1.250
Simple Tasks	15.252	*0.001	33.473	0.000	16.304	0.000	0.250	0.937
Hand Coordination	10.863	*0.005	42.465	0.000	17.432	0.000	0.271	0.917
Vision	5.561	*0.035	19.547	0.000	13.461	0.000	0.286	0.881
Completion Problems	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value	No Motion	Motion
Made more mistakes?	5.660	*0.035	5.063	0.015	1.371	0.271	0.487	0.744
Take longer for tasks?	5.149	*0.043	2.526	0.101	23.579	0.000	0.308	0.590

Table 4-9: Results from the 'Symptoms' section of the Amended NATO PAQ comparing 'Pre', 'Mid', and 'Post' answers while in the 'Motion' condition

Symptoms	As Time Progressed			*p* value		Mean		
PAQ Question	Condition	*F ratio*	*p* value	Pre-Mid	Mid-Post	Pre	Mid	Post
Mental Fatigue	Motion	29.664	0.000	0.000	0.006	0.176	1.000	1.706
	No Motion	7.398	0.002	0.579	0.009	0.176	0.235	0.558
Physical Fatigue	Motion	18.705	0.000	0.000	0.189	0.200	0.933	1.133
	No Motion	1.548	0.228	0.332	0.332	0.059	0.118	0.176
Sleepy	Motion	18.261	0.000	0.002	0.027	0.250	1.250	1.750
	No Motion	0.585	0.563	0.579	0.579	0.235	0.294	0.353
Headache	Motion	9.614	0.001	0.033	0.054	0.067	0.667	1.067
	No Motion	1.836	0.176	0.332	0.163	0.059	0.118	0.235
Apathy	Motion	7.990	0.002	0.029	0.055	0.000	0.467	0.800
	No Motion	0.320	0.728	0.579	1.000	0.118	0.176	0.176
Tension/Anxiety	Motion	7.491	0.006	0.024	0.332	0.294	0.824	0.941
	No Motion	1.548	0.228	0.163	0.332	0.059	0.176	0.118
Nausea	Motion	24.182	0.000	0.000	0.531	0.000	1.400	1.600
	No Motion	0.485	0.620	0.332	1.000	0.000	0.059	0.000
Stomach Awareness	Motion	53.083	0.000	0.000	0.384	0.133	2.133	1.933
	No Motion	1.000	0.379	0.332	0.332	0.000	0.059	0.000
Motion Sickness	Motion	95.941	0.000	0.000	0.238	0.000	4.940	5.590
	No Motion	1.000	0.379	1.000	0.332	0.059	0.059	0.118

Table 4-10: Results from the 'Performance' section of the Amended NATO PAQ comparing 'Pre', 'Mid', and 'Post' answers while in the 'Motion' condition

Performance	As Time Progressed			*p* value		Mean		
PAQ Question	Condition	*F ratio*	*p* value	Pre-Mid	Mid-Post	Pre	Mid	Post
Making Decisions	Motion	73.889	0.000	0.000	0.164	0.188	1.563	1.688
	No Motion	4.042	0.027	0.163	0.104	0.059	0.294	0.529
Concentration/attention	Motion	80.625	0.000	0.000	0.104	0.250	1.750	2.000
	No Motion	7.362	0.002	0.056	0.056	0.118	0.412	0.706
Memory	Motion	51.597	0.000	0.000	0.270	0.188	1.688	1.875
	No Motion	5.760	0.007	0.029	0.269	0.118	0.471	0.647
Simple Tasks	Motion	35.803	0.000	0.000	0.432	0.188	1.250	1.375
	No Motion	2.630	0.114	0.163	0.163	0.118	0.235	0.353
Hand Coordination	Motion	43.039	0.000	0.000	0.055	0.063	1.188	1.500
	No Motion	2.337	0.136	0.188	0.332	0.118	0.294	0.353
Vision	Motion	18.195	0.000	0.000	0.301	0.067	1.200	1.467
	No Motion	1.552	0.228	0.333	0.333	0.188	0.250	0.313

Table 4-11: Results from the 'Completion Problems' section of the Amended NATO PAQ comparing 'Pre', 'Mid', and 'Post' answers while in the 'Motion' condition

Task Completion Problems	As Time Progressed			*p* value		Mean		
PAQ Question	Condition	*F ratio*	*p* value	Pre-Mid	Mid-Post	Pre	Mid	Post
Made more mistakes?	Motion	8.111	0.002	0.015	0.333	0.375	0.875	0.938
	No Motion	4.409	0.022	0.500	0.019	0.286	0.429	0.786
Take longer for tasks?	Motion	12.769	0.000	0.000	0.333	0.125	0.813	0.688
	No Motion	1.988	0.157	0.189	0.040	0.357	0.143	0.429

4.2.3.3 NASA TLX

The NASA TLX subscales were each analyzed to determine if there were significant differences between the 'Motion' and 'No Motion' conditions. The NASA TLX assesses workload on six subscales: Mental Demand, Physical Demand, Temporal Demand, Effort, Performance, and Frustration. Workload for each subscale was based on a 1-20 scale with a '1' denoting low task workload and a '20' representing extreme high task workload. A repeated measure ANOVA revealed significant differences for Mental Demand, Effort and Performance (see Table 4-12). A repeated measures ANOVA was also conducted on the data from each condition to see if significant differences were found between 'Pre', 'Mid' and 'Post' collections (see Table 4-13).

Table 4-12: Results from the NASA TLX comparing 'Motion' to 'No Motion'

NASA TLX	Movement Condition		Collection		Interaction		Group Mean		t-Tests Sig. (2-tailed)		
Sub Task	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value	**No Motion**	**Motion**	**Pre**	**Mid**	**Post**
Mental Demand	4.499	*0.050	39.687	0.000	10.220	0.002	6.33	8.25	0.131	*0.026	*0.011
Physical Demand	2.603	0.126	11.748	0.000	3.143	0.057	2.67	4.14	0.533	0.072	0.213
Temporal Demand	1.646	0.218	29.709	0.000	4.503	0.019	5.76	7.00	0.214	0.069	0.218
Effort	5.412	*0.033	26.654	0.000	8.736	0.004	5.94	8.08	0.188	*0.031	*0.009
Performance	5.124	*0.038	33.460	0.000	10.806	0.000	6.00	8.20	0.250	0.138	*0.000
Frustration	3.998	0.063	17.416	0.000	10.391	0.000	3.53	6.24	*0.045	0.170	*0.000

Table 4-13: NASA TLX

Subscale	As Time Progressed			p value		Mean		
	Condition	*F ratio*	*p* value	Pre-Mid	Mid-Post	Pre	Mid	Post
Mental Demand	Motion	76.197	0.000	0.000	0.219	1.82	11.00	11.94
	No Motion	10.240	0.002	0.007	0.487	2.94	7.76	8.29
Physical Demand	Motion	9.565	0.001	0.007	0.889	1.35	5.47	5.59
	No Motion	4.487	0.040	0.118	0.053	1.59	2.47	3.94
Temporal Demand	Motion	28.374	0.000	0.000	0.319	2.00	9.06	9.94
	No Motion	14.342	0.000	0.004	0.006	2.76	6.35	8.18
Effort	Motion	57.637	0.000	0.000	0.026	2.06	10.35	11.82
	No Motion	6.245	0.014	0.013	0.639	2.94	7.24	7.65
Performance	Motion	71.325	0.000	0.000	0.015	2.59	9.76	12.24
	No Motion	4.242	0.023	0.024	0.746	3.82	7.29	6.88
Frustration	Motion	23.504	0.000	0.000	0.195	1.59	7.94	9.18
	No Motion	3.565	0.040	0.016	0.316	3.29	6.00	5.00

4.2.3.4 Stanford Sleepiness Scale

As seen in Table 4-14 significant effects between conditions were found between the two conditions with subjects reporting increasing sleepiness in 'Motion'. It was also found as time progressed in that subjects got increasingly sleepier in the 'Motion' condition (see Table 4-15) than in the 'No Motion' condition.

Table 4-14: Results from theStanford Sleepiness comparing 'Motion' to 'No Motion'

Psychometric Task	Movement Condition		Collection		Interaction		Group Mean		T-Tests Sig. (2-tailed)		
Subtask	*F ratio*	*p* value	*F ratio*	*p* value	*F ratio*	*p* value	No Motion	Motion	Pre	Mid	Post
Stanford Sleepiness	17.249	*0.001	20.520	0.000	20.544	0.000	1.882	2.961	0.718	*0.000	*0.001

Table 4-15: Results from the Stanford Sleepiness questionnaire comparing 'Pre', 'Mid', and 'Post' answers while in the 'Motion' condition

Stanford Sleepiness	As Time Progressed		*p* value		Mean		
Movement Condition	***F ratio***	***p* value**	**Pre-Mid**	**Mid-Post**	**Pre**	**Mid**	**Post**
Motion	23.831	0.000	0.000	0.455	1.650	3.530	3.710
No Motion	3.021	0.080	0.083	0.269	1.710	1.880	2.060

CHAPTER 5 DISCUSSION

The hypotheses for this study investigated whether moderate levels of MS influenced individual's ETT. It also investigated if moderate levels of MS symptoms influenced performance on a battery of cognitive tests. Although ETT was not found to be statistically significant at the 0.05 level, as seen in Table 4-1, there was evidence at the 0.10 level. Cognitive task batteries were not conclusive in explaining if there was a relationship between moderate MS and task performance.

Previous studies in this area have shown that a moving environment can have both direct and indirect affects on human performance (Crossland et al., 1994). Colwell and MacKinnon's (2007) protocol to employ a ship motion simulator (SMS) to initiate and maintain perceived MISC between 4 and 5 was employed in this study. This protocol minimized subject attrition due to abandonment of task due to incapacitating symptoms of MS. All subjects in this study were kept at a moderate level of MS throughout the 'Motion' sessions (see Figure 5-1). Only one subject abandoned the 'Motion' session during the final minutes.

A repeated measures ANOVA was used to examine if there were significant differences between the reported MISC score in the 'Motion' condition. This was conducted to reaffirm that the subject remained at a consistent level of moderate MS throughout the session. Verbal MISC scores were recorded at the same instance as the subject reported ETT. From Time 2 (T2) to Time 8 (T8) there were no significant differences in reported MISC score. Time 1 (T1) was not included as the requested MISC was collected only 13 minutes into the session and was used as a base line to increase or decrease the motion platform wave profiles.

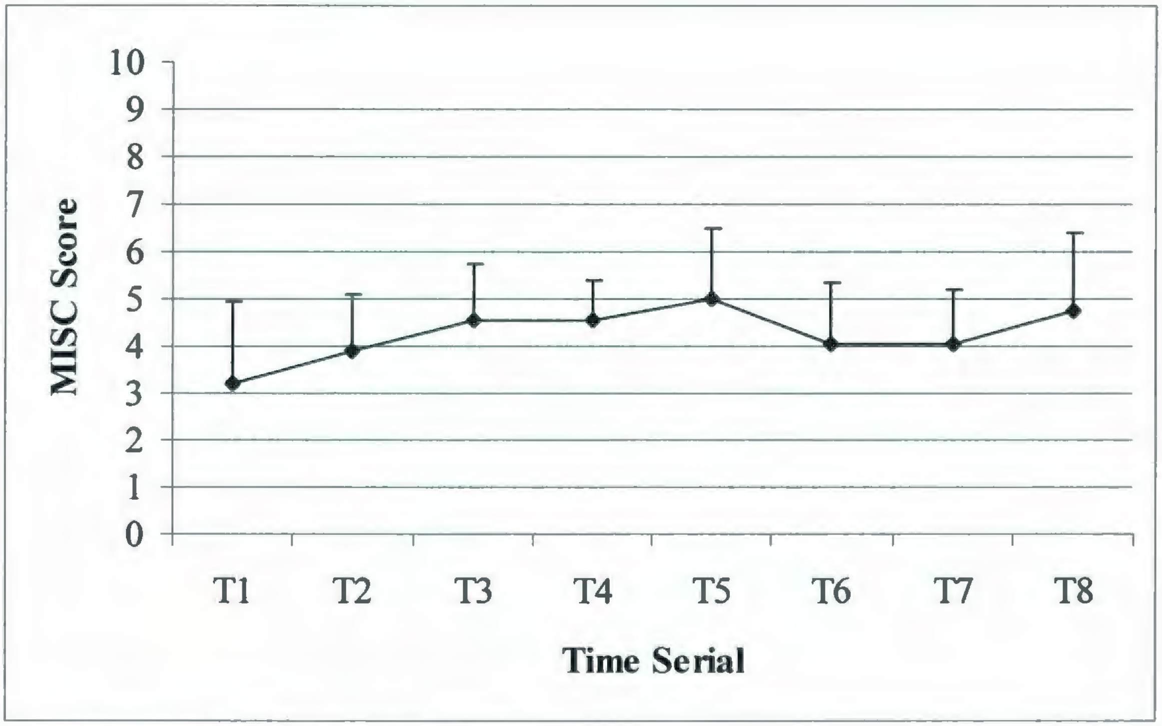


Figure 5-1: Verbal MISC Score in 'Motion' condition

The study in 1997 (Colwell, 2000) reported that those who experienced MS symptoms also reported that tasks seemed to take longer to complete. Data collected from the NATO PAQ during this thesis also concluded the same findings. The hypotheses that MS symptoms have an effect on ETT were not supported as it was not found to be significantly different at the 0.05 level. However, due to the near significance of p=0.057 it would be erroneous to assume that Motion does not affect time estimation. As seen in Figure 5-2 and, Table 4-3, the grouped 'Motion' scores overestimated the time an average of 6.65 minutes from the original 63 minutes while 'No Motion' underestimated an average of 5.65 minutes below the original time; $F(1, 16) = 4.196, p=0.057$. Individually, subject's generally overestimated time when compared to the real time in 'Motion' and underestimated in 'No Motion' (see Figure 5-3 and Table 4-1 and Table 4-2).

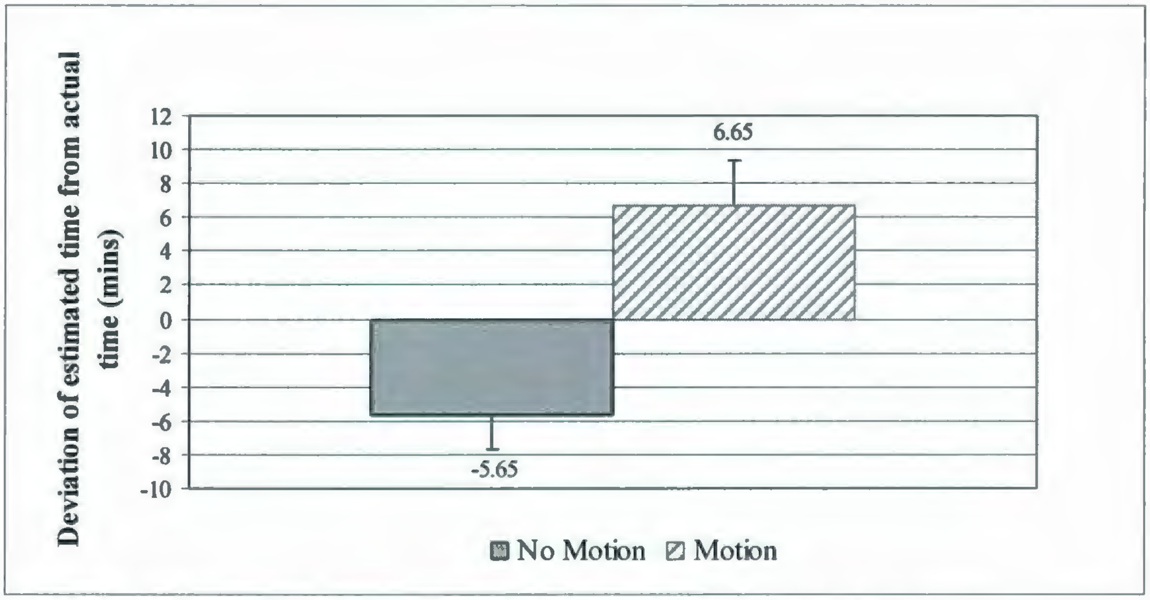
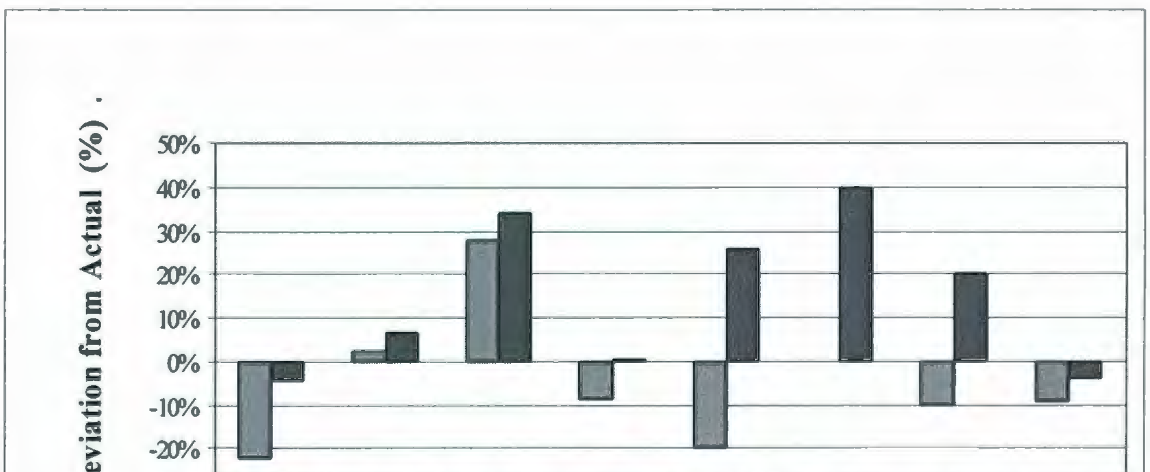


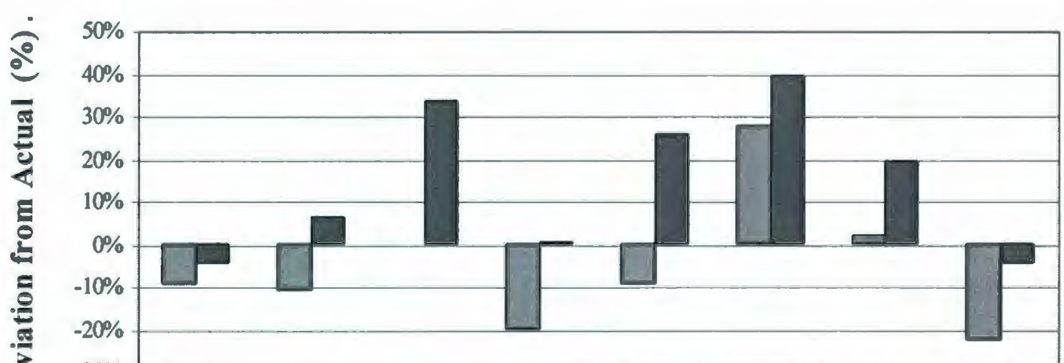
Figure 5-2: Group mean deviation from the total actual time of 63 minutes



	T1		T2		T3		T4		T5		T6		T7		T8	
	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Actual	9	11	5	8	4	5	10	11	11	10	5	4	8	5	11	9
Mean Reported	7.0	10.5	5.1	8.5	5.1	6.7	9.1	11.1	8.8	12.6	5.0	5.6	7.2	6.0	10.0	8.6
SD	1.8	5.9	1.8	5.1	1.8	3.9	2.6	5.5	2.9	6.1	1.7	2.3	2.8	3.4	4.0	4.7

Figure 5-3: Relative deviation from actual time while the x-axis shows the actual mean time reported in minutes

The session scripts (see Appendix F and Appendix G) were in opposite order of each other, meaning that the tasks and time sequence that began in 'Motion' would be the last task and time sequence in 'No Motion' (e.g., The time and subtasks in T1 of 'Motion' contains the same time and subtasks as T8 of 'No Motion'). The ETT calculation was used to normalize the length of the reported time. The data were also analyzed in "reverse" order so that comparable time and tasks could be examined (see Table 4-3 and Table 4-4). When comparing the identical task and time blocks the subject overestimated duration of task(s) in the 'Motion' condition (see Figure 5-4).



	T8	T1	T7	T2	T6	T3	T5	T4	T4	T5	T3	T6	T2	T7	T1	T8
	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M	NM	M
Actual Time	11		8		5		11		10		4		5		9	
Mean Reported	8.7	10.5	7.2	8.5	5.0	6.7	8.8	11.1	9.1	12.6	5.1	5.6	5.1	6.0	7.0	8.6
SD	4.7	5.9	2.8	5.1	1.7	3.9	2.9	5.5	2.6	6.1	1.8	2.3	1.8	3.4	1.8	4.7

■ NM Mean ■ M Mean

Figure 5-4: Deviation in time comparing identical time blocks of 'Motion' to 'No Motion'. 'No Motion' time is reversed

Brown (1995) suggested that if tasks consisted of the same time and subtasks, at the same level of difficulty, then individuals should report them as the same duration of time as these tasks should require the same attention processing to complete. However, in this study there were differences with ETT when identical tasks were compared to each other. Although significant differences at the $p<0.05$ level were only seen between 'Motion' Time 4 (T4) and 'No Motion' Time 5 (T5) and between the 'Motion' T5 and 'No Motion' T4 segments (see Table 4-3 and Table 4-4), these differences were associated with subject reported MISC scores (see Figure 5-1) as the subject was experiencing moderate levels of MS. It is important to note that a significant difference at the $p<0.10$ level between 'Motion' Time 3 (T3) and 'No Motion' Time 6 (T6) (see Table 4-4) was observed and is relevant as it associated with the increasing reported MISC (see Figure 5-1). The reporting of ETT was asked prospectively, and since the researcher told the subjects prior to the beginning of tasks that they would be asked to judge the duration, it might allow for smaller variability in the reported answers (Block, Hancock & Zakay, 2000; Glicksohn, 2001).

The reported overestimation of time during this experiment agrees with the previous work on how influential factors, such as MS symptoms, can affect perceived time. Situations that are interpreted by an individual as uncomfortable or undesirable tend to seem longer to that individual (Angrelli at al., 1997). MS symptoms such as stomach awareness, nausea, sweating, decreased motivation, dizziness, disorientation, increased salivation, increased respiration, drowsiness, and the most observable, vomiting (Benson, 2002) can certainly be viewed as negative experiences. It has been stated in previous studies that a 'trade-off' occurs between the processing of time and cognitive tasks (Glickshom, 2001) and if the person is positively engaged in the task at hand then the time will seem shorter (Fink & Neubauer, 2005). Given this understanding, it can be assumed that if a subject overestimates time duration then less attention is focused on the task at hand as more attention is diverted towards the processing of time (Glickshom, 2001). Diverting cognitive resources for sake of time estimations can prove detrimental, especially in vigilant automated tasks, as signals may not be as easily recognized and thus not receiving the appropriate response from the operator. Operators are required to remain vigilant for extended periods of time during a work shift on tasks that may be monotonous and repetitious in nature. The task batteries used for this experiment were of a nature in that the subject was required to perform as an active controller and keep consistent attention on a constantly changing task(s). The amount of time that was required to concentrate was also of a short nature (four to eleven minutes in duration) and possibly did not allow the subject to become fully affected by the MS symptoms. While real life situations provide long duration shifts which can contain unpredictable signals to which the worker must respond (Warm, Dember, & Hancock, 1996), the tasks for this thesis were short in length and could be deemed as predictable due to the lab setting. Interestingly enough, however, there was still evidence that time perception of the events in this study was skewed. Time perceptions are a critical portion of operator SA (Endlsey, 2000) and while the overestimation of time in this study is not statistically significant it should be acknowledged. Essential factors that influence decision making include time processing by the operator which enables them to ensure safe, efficient, and proper task execution.

Is there a relationship between MISC scores and reported ETT? While Figure 5-3 displays the actual time in minutes of each segment in both 'Motion' and 'No Motion' as well as the deviation in minutes and relative percentage, Figure 5-5 and Figure 5-6 better illustrate that subjects generally over estimated time as MS symptoms increased. While not at the 0.05 level the resultant p=0.057gives reason to believe that moderate levels of

MS have an effect on ETT. Both figures show the deviation of estimated time from actual time for the 'Motion' sessions. The left side y-axis in Figure 5-5 represents a scale of minutes while the y-axis in Figure 5-6 represents a percentage scale of relative difference. A positive number on each axis signifies increased ETT. The right side y-axis in both figures represents the reported MISC. The x-axis depicts the chronological time scale at which the subjects were to report the time it took to complete tasks. For example, the first time subjects were asked to estimate time in 'Motion' T1 was 13 minutes into the 'Motion' script, 'Motion' T2 was at 23 minutes and so on (see Appendix G).

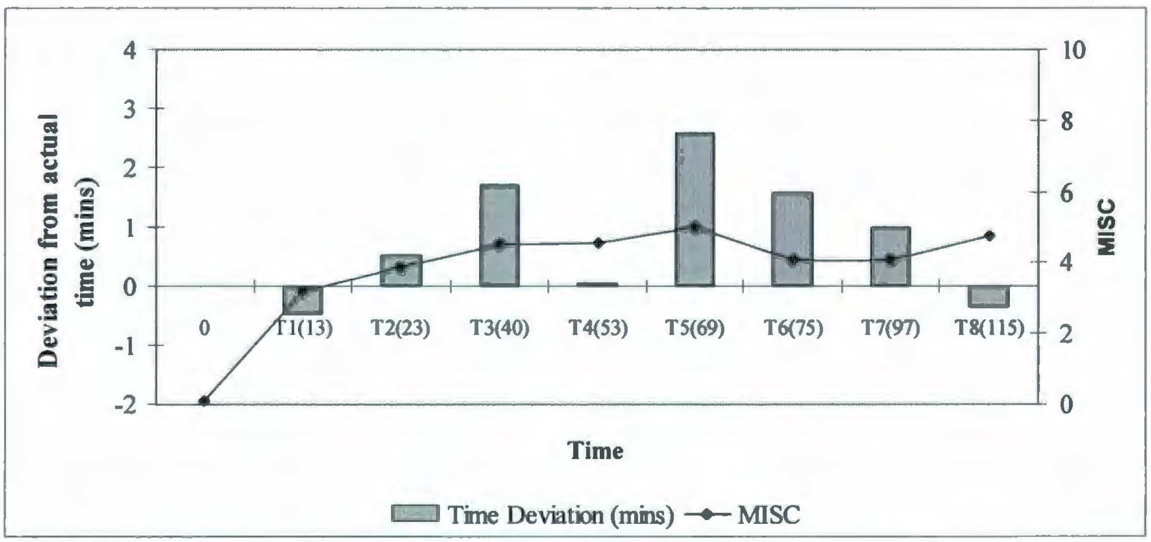


Figure 5-5: Deviation in minutes in the 'Motion' condition from actual time and MISC

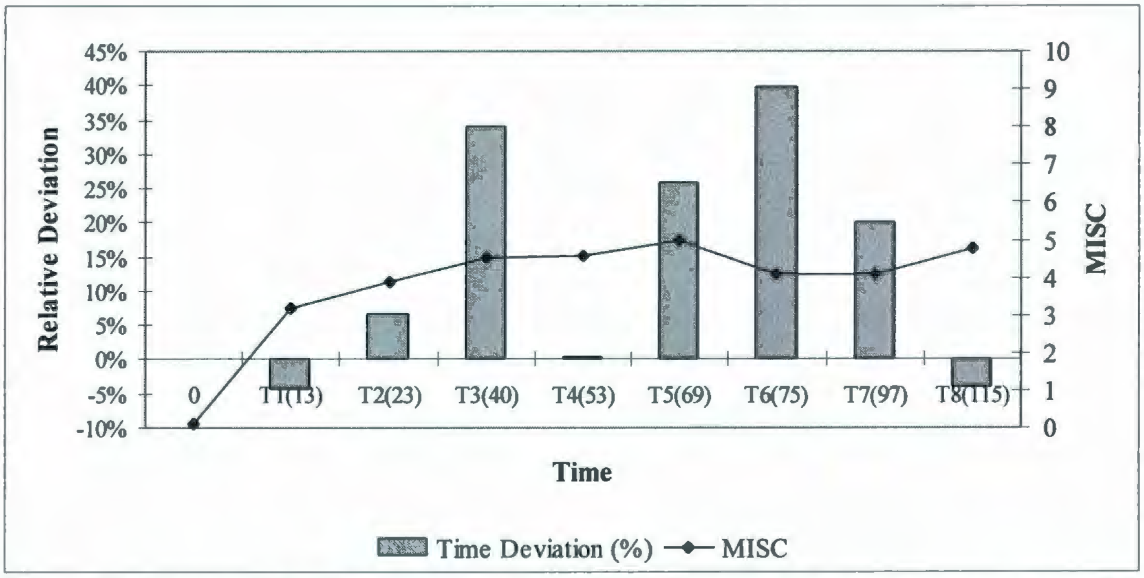


Figure 5-6: Deviation in relative difference of ETT from real time in the 'Motion' condition and MISC

Verbally reported MISC scores showed differences between T1 and T2 (p=0.027), and between T5 and T6 (p=0.011). Figure 5-5 displays the differences in time as well as the MISC scores. As stated earlier the increase between T1 and T2 makes sense as it was the first subject reported MISC and was used as a base line to increase or decrease the motion platform. The difference between T5 and T6 may be explained due to the researcher decreasing the motion of the SMS due to an increase in reported MISC from T4 to T5. The greatest deviation from ETT and actual time in the 'Motion' condition was at the T5 interval which consisted of ten minutes (see Figure 5-3). It was also at this time that the verbal MISC score peaked (see Figure 5-1). Prior to the requested ETT for T5 in the 'Motion' condition the subjects were required to complete the collection of the 'Mid' battery of psychometric tests as described in Section 3.6.3 in Methods. During this time they had their head bent down and fixated on the paper based questions. An increase in reported MISC after the questionnaires were completed was noted. As discussed in

Chapter 2 – Literature Review, an intra-sensory conflict of the vestibular system can be an instigator of MS symptoms. The addition of the forward head tilt required to read the questions caused a deviation from the normal head position in respect to the body and this could have provoked a stronger nauseating response. Making head movements while rotating has also shown to be provocative in inducing strong MS responses (Graybiel, 1968; Bles, 1998; Stevens & Parsons, 2002).

The ETT in 'Motion' T4 was almost at 0% and may have been because the task at that time consisted of the MATB and subjects were required to complete three tasks at once, thereby not allowing time segments to be collected as the subject was completing a task. However, the ETT in 'Motion' T5 increased to almost 26% above AT. The tasks that were completed during this time serial consisted of a two minute break that required the subject to do nothing while waiting for the next task to begin. This 'break' would allow the subject to shift attention resources to the time and allow more time to be processed.

The decreasing MISC scores from T5 to T6 could have been due to the adjusting of the motion profiles to keep the subject at the desired MISC. As the MISC had increased at T5 the motion profile may have been decreased too much which resulted in a lower MISC reported at T6. Out of the 17 subjects, seven required a decrease in motion as their reported MISC and observed OCS combined were high. Six of the 17 subjects did not have a change in motion, however, two subjects were already at a low motion profile. Also, one subject of the six whom did not have a change in motion had recently had a decrease in motion prior to T5 and was still experiencing a high combined score of MISC and OCS. Four subjects required an increase in motion at T5.

Colwell (2000) reported that as MS severity increased task performance confidence decreased. In this study, as seen in Table 4-11, confidence in task performance significantly decreased in the 'Motion' condition. Although not statistically relevant, subjects verbally reported to the researcher that they "just didn't care anymore". When asked to estimate the time it was often reported as "It seems like forever but couldn't have been more than 'x minutes". So although the time was perceived longer due to the fact that it was in a laboratory setting some subjects used logic to report ETT as they knew it was a 2 hour session. As seen in Table 4-7 in Results, the number of tasks attempted was reduced in the 'Motion' condition.

5.1 INFLUENCES ON RESPONSE TIME AND ERROR PERCENTAGE

This study also investigated how moderate levels of MS affected performance on a battery of cognitive tests. Although response times (RT) demonstrated trends of being slower for all the SusOps subtasks in the 'Motion' condition (see Figure 5-7) there were only significant results seen in RT in the CMP and SRT subtasks (see Table 4-6). As CMP and SRT were not dictated by a computer 'time out', the subject was able to take however long they wanted to respond. Error Percentage (EP) increased in the 'Motion' condition and significant differences were seen in CMP and STM (see Figure 5-8 and Table 4-6).

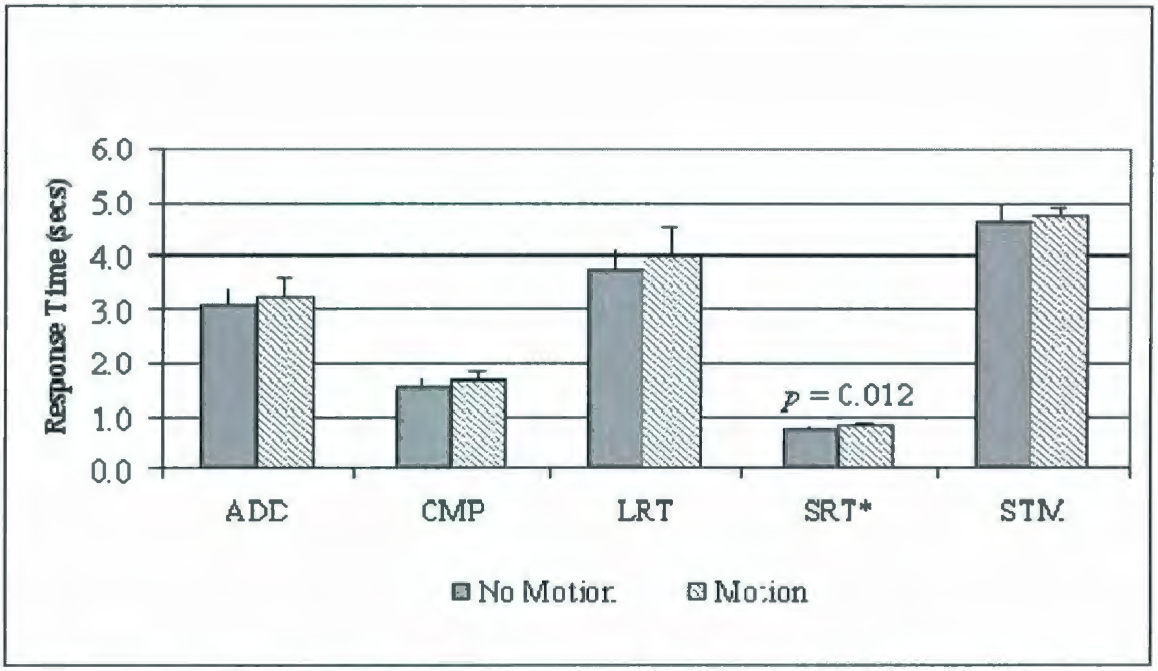


Figure 5-7: SusOps subtask Response Time (RT) in both 'Motion' and 'No Motion' condition

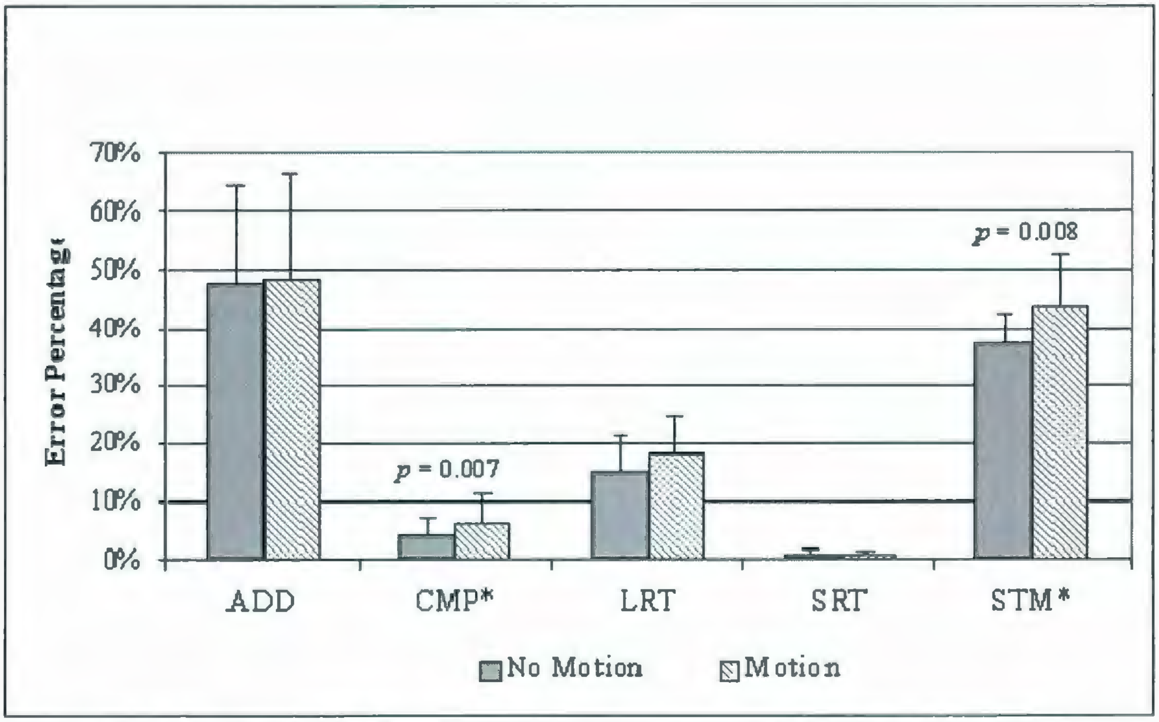


Figure 5-8: SusOps subtask Error Percentage (EP) in both 'Motion' and 'No Motion' condition

A possible reason that the SusOps subtask ADD did not show any significant differences in RT or EP may be that the ADD subtask 'timed out' when the subject did not respond within a certain amount of time. The number of tasks attempted did not differ as the same number of tasks was exposed to the subject (see Table 4-7). This possibly influenced the subject to rush an attempt to input their answers with little care for correct answers as can be seen with the very high error rate in ADD (see Table 4-6).

'Motion' T8 had the greatest underestimation ETT and consisted of SRT4, LRT4, CMP4, and ADD4 with no breaks during that timed task. 'No Motion' T1, which consisted of the same tasks also had the greatest underestimation in relative time. As there was a continuous changing of tasks the operator did not have time to lose interest. The underestimation of the first set of tasks T1 for 'Motion' could be explained as motivation (as reported by verbal MISC) was not yet interrupted by MS symptoms and there was still interest in the tasks.

Table 5-1 shows each SusOps subtask and result throughout the 2 hour session. As scripts for the 'Motion' and 'No Motion' are reversed of each other, the 'No Motion' in Table 5-1 is listed in reverse so that the actual subtasks are comparable. CMP showed consistent problems in the 'Motion' condition, having a significant difference in EP and the number of tasks completed.

Table 5-1: Number of tasks completed by serial in SusOps subtasks

Subtask	Actual Time of Task (mins)	Tasks Completed		Error Percentage		Response Time	
		NM	M	NM	M	NM	M
ADD	2	4.94	5.00	49.71%	53.82%	3.12	3.11
	2	5.06	5.00	46.57%	50.29%	3.16	3.16
	2	4.82	4.94	49.41%	42.16%	2.91	3.28
	3	7.76	7.41	44.15%	47.22%	3.11	3.34
CMP	3	52.53	47.18	4.49%	4.51%	1.48	1.73
	3	51.24	49.71	4.09%	6.08%	1.60	1.63
	2	33.47	31.71	3.81%	6.29%	1.61	1.70
	2	34.24	32.53	3.35%	7.99%	1.50	1.68
LRT	2	32.94	29.24	15.50%	18.65%	3.60	4.20
	2	32.53	32.76	12.43%	17.07%	3.79	4.20
	3	48.47	47.06	15.18%	20.20%	3.74	3.90
	2	32.24	33.35	15.71%	18.85%	3.74	3.69
SRT	2	141.41	136.06	0.90%	0.66%	0.74	0.78
	2	139.59	129.82	0.88%	0.85%	0.75	0.83
	2	135.41	133.12	0.59%	0.47%	0.77	0.79
	2	134.24	131.24	0.67%	0.92%	0.76	0.80
STM	4	18.24	17.94	38.17%	44.23%	4.68	4.74
	2	8.94	9.24	36.05%	42.87%	4.58	4.70

5.2 INFLUENCE OF MOTION ON PSYCHOMETRIC TEST BATTERIES

The SMS motion profiles were adjusted throughout the two hour session based on the subject-reported MISC scores and researcher-reported OCS (see Table 3-2). The amended NATO PAQ showed that subjects perceived tasks taking longer in 'Motion' than in 'No Motion' (see Table 4-8) and subjects reported problems in both the symptoms and the performance portion of the NATO PAQ at higher group means in 'Motion' (see Table 4-8). The results from the amended NATO PAQ are consistent with the reported subject MISC as MS symptoms increased the subject perceived increasing difficulty with the tasks.

5.2.1 NASA TLX

The NASA TLX showed significant differences between four out of the six subtasks (see Table 4-12). , 'Mental Demand' displayed a significant difference between 'Motion' and 'No Motion' supporting evidence that MS symptoms caused an increasing mental strain on the subject (see Table 4-12). A paired sample t-test was conducted (see Table 4-12) and significant differences were found between 'No Motion' and 'Motion' in both 'Mid' and 'Post' collections. Even though an increasing mental demand was found in 'No Motion' it was significantly worse in the 'Motion' condition. As seen in Table 4-13, there was a significant difference between 'Pre' and 'Mid' in the 'Motion' condition as well as between 'Pre' and 'Mid' in the 'No Motion' condition.

'Effort' also showed a significant difference between 'Motion' and 'No Motion' (see Table 4-12). As the motion platform had not yet started when the 'Pre' data was collected the statistical analysis showed that no significant differences were found between the conditions, suggesting that the subject started each condition with no foreseen issues or problems. However, significant differences were found between the conditions in 'Mid' and also in 'Post' collections suggesting that MS symptoms affected perceived exertion. Table 4-13 shows that in the 'Motion' condition perceived effort significantly increased from 'Mid' to 'Post, however, it did not in the 'No Motion' condition.

The TLX showed that subjective 'Performance' assessment was significantly affected by the condition of the session (see Table 4-12). Table 4-12 also displays results from a paired t-test that reveal significant difference between conditions in 'Post' collections. Within the 'Motion' condition significant differences were found from 'Pre' to

'Mid' and from 'Mid' to 'Post' showing that as the session progressed and as MS symptoms increased, perceived performance difficulty increased (see Table 4-12). However, in the 'No Motion' condition there was an increased in perceived performance difficulty from 'Pre' to 'Mid' but no significant change from 'Mid' to 'Post'. In fact, in the 'No Motion' condition perceived performance difficulty actually decreased from 'Mid' to 'Post'. This may have been due to the subject becoming more familiar with the task performance.

Subjects showed more 'Frustration' in 'Motion' as there was slight evidence (p=0.063) that there was a significant difference between Motion (M=6.24, SD=4.13) and No Motion (M=3.53, SD=4.69).

5.2.2 Stanford Sleepiness

Paired t-tests revealed significant differences between conditions in both 'Mid' and 'Post' collections (see Table 4-8 and Table 4-14). Within each specific condition the repeated measures ANOVA revealed a significant difference within the 'Motion' condition only from 'Pre' to 'Mid'. The 'No Motion' condition displayed no significant change as time progressed. Increased sleepiness due to MS would pose a major concern for the safe operations of a ship.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

Moderate symptoms of MS showed slight effects on ETT. Subjects were consistent in over estimating duration of tasks and perceived tasks as taking longer to complete. There was little evidence to support effects on cognitive task performance. While statistical significance for ETT was not at the $p<0.05$ level the resultant $p=0.065$ reaffirms the requirement that further research in required in this area.

The results from the psychometric test batteries consistently display a perceived increase in difficulty as MS symptoms increase. While MS symptoms cause obvious discomfort and distraction from tasks and in turn decrease confidence in performance, the resultant RT and EP from the task batteries did not consistently show a significant decrease in performance. A possible reason that the outcome of the SusOps and MATB subtasks may not have corresponded with the subjective assessment of decreased performance may have been due to the types of tasks (and their associated levels of difficulty) chosen for the study. The SusOps subtasks were short in duration with a maximum singular subtask running four minutes in length and the shortest being two minutes before changing to another subtask. The ever changing situation did not allow the subject to become uninterested to a subtask. In a real life situation an operator who is required to be vigilant on longer continuous operations (ConOps) will be more at risk than those required to conduct shorter duration tasks. It was also realized once the study began that the ADD 'time out' (the amount of time given to the subject to answer) was probably programmed for too short a period thus not collecting a true RT from the subject. Sustained tasks that are monotonous allow for easy diversion. The distraction from the tasks will allocate more cognitive resources towards the MS symptoms and the accumulating time of task.

The psychometric tests demonstrated a significant difference between the conditions revealing that a subject perceived worsening performance as MS symptoms increase. The subtasks from SusOps and MATB should be critically examined as whether they are the proper tool to use on the general population for data collection. For example, common tasks for examining short term memory could be simplified into reading text or looking at pictures and having to reconstruct or identify later in a session.

During this study the subject was requested to deliberately focus on the time prior to the tasks in order to gather a more true representation. While this prospective approach allows for the subject to specifically bring his or her attention to the time and thus allowing fewer deviations from the real time, future research should employ a mixed methods approach. This combined prospective and retrospective duration requests, may clearly point to where the subject's attention is actually directed while experiencing MS symptoms. Subjects commonly remarked "that seemed forever but couldn't have been more than 'x' minutes" showing that the time seemed longer but they logically knew, due to a lab scenario, that a longer time couldn't have passed.

Identical scripts for both conditions, 'Motion' and 'No motion', should be used so that equal time durations can be compared and in the same time sequence as relative comparisons leave room for statistical error. Identical scripts for both conditions will also allow subtasks to be compared in the same time sequence.

In order to get true response times the subject should be given no time restriction during that subtask to supply an answer. The duration of the sessions should also be slightly longer in order to get the subject at the proper MISC before gathering subtask data. The data collection would then begin at the ten minute mark of the session. This would ensure that the subject was indeed experiencing some MS symptoms and that they were performing tasks while under the influence of MS. The 'Motion' condition experimenter script shows that MATB was performed at the beginning of the session, perhaps before any MS symptoms were obvious. The MATB should run a minimum of ten minutes to twenty minutes in length in order to get a measurable data collection. Varying levels of difficulty throughout the MATB would also be important to see if monotonous tasks differ from high attentive tasks. It would also be of benefit to run situations where tasks, and combinations of tasks, are performed for various times, i.e. short duration tasks would be less than 10 minute durations, medium length tasks would be attempted between 10 and 20 minutes, and long duration tasks would last longer than 20 minutes. With less interference from the researcher the operator would have to rely on their own vigilant skills in order to identify and respond to cues and signals. Vigilant tasks or watch keep are long in duration and the study should replicate where possible.

Limitations of this study included both the types and length of the subtasks. In order to obtain adequate information to see if there was a decrement in performance then there needs to be a standard set of performance criteria that enables the researcher to compare true values.

Moderate levels of MS will have an effect on workers. The extent to which those effects reach into their performance is still not well understood. Further research in this area should be conducted in order to acquire insight into whether MS affects performance, as well as on what type of tasks are most vulnerable to decrements.

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APPENDICES

APPENDIX A : SHORT MOTION SICKNESS SUSCEPTIBILITY QUESTIONNAIRE

Please give your answers in words on the dotted lines, or encircle one of the printed options.

Date: .... (dd/mm/yyyy)

Name: ....

Age: .... year

Gender: male / female

Have you ever had any complaints regarding your ears? no / yes
If yes, what, ...
and at what age(s)? .... year

Do you suffer from headaches? never / seldom / sometimes / often
If yes, did your physician characterize this as migraine? no / yes

The next questions refer to your sensitivity to motion sickness in the past, and to the kind of motions that you dislike most. Here, motion sickness refers to a clear feeling of discomfort, nausea, or vomiting due to motion.

How often did you feel sick ***as a child*** (below the age of 12 years) in

	t 0 1 2 3 .
cars	n.a. / never / seldom / sometimes / often
busses	n.a. / never / seldom / sometimes / often
trains	n.a. / never / seldom / sometimes / often
aircraft	n.a. / never / seldom / sometimes / often
small boats	n.a. / never / seldom / sometimes / often
large ships	n.a. / never / seldom / sometimes / often
swings	n.a. / never / seldom / sometimes / often
merry-go-rounds	n.a. / never / seldom / sometimes / often
leisure park attractions	n.a. / never / seldom / sometimes / often

Did you ever have to throw up with this ***as a child***? no / yes

How often did you feel sick ***in the past 12 years*** in

	t 0 1 2 3 .
cars	n.a. / never / seldom / sometimes / often
busses	n.a. / never / seldom / sometimes / often
trains	n.a. / never / seldom / sometimes / often
aircraft	n.a. / never / seldom / sometimes / often
small boats	n.a. / never / seldom / sometimes / often
large ships	n.a. / never / seldom / sometimes / often
swings	n.a. / never / seldom / sometimes / often
merry-go-rounds	n.a. / never / seldom / sometimes / often
leisure park attractions	n.a. / never / seldom / sometimes / often

Did you ever have to throw up with this ***in the past 12 years***? no / yes

Thank you for your cooperation.

APPENDIX B : QUESTIONNAIRE ON PREGNANCY AND VESTIBULAR PROBLEMS

Protocol Number: L-XXX
Research Project Title: Effects of Moderate Sea Sickness on Estimating Task Duration

Principal Investigator: Dr. Scott N. MacKinnon, MUN, (709) 737-7249

Co-investigator: Mr. James L. Colwell, DRDC Atlantic, (902) 426-3100 ext. 125

Females who are currently pregnant and individuals with vestibular system (or balance organ) problems may not participate in the experiment.

FOR FEMALES ONLY: PREGNANCY

1. Are you pregnant? Yes No
2. Is there a possibility that you are now pregnant? Yes No

Acceptable reasons for answering NO to the second question are: contraception by birth control pills, sexual abstinence, and menstruation within 1-2 weeks of experiment.

ALL SUBJECTS: VESTIBULAR PROBLEMS

1. Have you ever been diagnosed with or taken medications for labyrinthitis, vertigo, dizziness, Meniere's disease or any other disease of the hearing or balance system? Yes No
2. Have you ever suffered a serious head injury? double vision? etc. Yes No

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ALL SUBJECTS:
To the best of my knowledge, I have answered these questions truthfully.

Volunteer's Name ______________________________

Signature: ___________________________________ Date: ____________________

Name of Witness to Signature: ________________________

Signature: ___________________________________ Date: ____________________

Principal Investigator: Dr. Scott N. MacKinnon

Signature: ___________________________________ Date: ____________________

APPENDIX C : PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ____________________

SIGNATURE OF PARENT ____
or GUARDIAN (for participants under the age of majority) WITNESS ____________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

...continued from other side

PAR-Q & YOU

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf

FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

References:

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For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (revisé 2002)».

APPENDIX D : VOLUNTARY CONSENT FORM FOR HUMAN SUBJECT PARTICIPATION

Research Project Title: Effects of Moderate Sea Sickness on Estimating Task Duration

Principal Investigator: Dr. Scott N. MacKinnon, MUN, (709) 737-7249

Co-investigator: Mr. James L. Colwell, DRDC Atlantic, (902) 426-3100 ext. 125

I, ____ (name)

of ____ (address and phone number)

hereby volunteer to participate as a subject in the study, "Effects of Moderate Sea Sickness on Estimating Task Duration". I have read the information package on the research protocol, and have had the opportunity to ask questions of the Investigator. All of my questions concerning this study have been fully answered to my satisfaction. However, I may obtain additional information about the research project and have any questions about this study answered by contacting Dr. Scott N. MacKinnon at (709) 737-7249, or Mr. James L. Colwell at (902) 426-3100 ext. 125.

I have been told that I will be asked to participate in two sessions each of approximately two hours duration and that I must not take any alcohol or medication, including cold medication with antihistamines, within 24 hours of the experiment. To the best of my knowledge I am not aware that I have any abnormal vestibular (balance organ) problems.

I have been told that the principal risks of the research protocol are experiencing a range of MS symptoms from stomach awareness to nausea and possibly vomiting.

I have been given examples of potential minor and remote risks associated with the experiment and consider these risks acceptable as well. Also, I acknowledge that my participation in this study, or indeed any research, may involve risks that are currently unforeseen by DRDC Toronto.

I have been advised that the following medical support will apply during the experiment: on site first aid.

I hereby consent to the medical screening assessment outlined in the protocol and agree to provide responses to questions that are to the best of my knowledge, truthful and complete. Furthermore, I agree to advise the Investigator of any health status changes since my initial assessment (including, but not limited to, viral illnesses, new prescription or 'over-the-counter' medications, and new risk of pregnancy). I have been advised that the medical information I reveal and the experimental data concerning me will be treated as confidential, and not revealed to anyone other than the Investigator without my consent except as data unidentified as to source. Moreover, should it be required, I agree to allow the experimental data to be reviewed by an internal or external audit committee with the understanding that any summary information resulting from such a review will not identify me personally. In the highly unlikely event that I become incapacitated during my participation, I understand that every necessary medical treatment will be instituted even though I am unable to give my consent at that time. I will go with the Investigator to seek immediate medical attention if either the Investigator or I consider that it is required. Every effort will be made to contact a family member or the designated person indicated below should that be necessary.

For female subjects: To the best of my knowledge, I am not pregnant. Furthermore, I have no reason to suspect I might be pregnant. I understand that this information and all discussion pertaining to this matter will be treated as confidential. If I have any concern regarding a possible pregnancy, I will consult a physician before undertaking or resuming any phase of the experiment. Furthermore, I will take appropriate precautions to prevent pregnancy for the duration of the entire experiment. Moreover, I understand that the only absolute method of preventing pregnancy is abstinence of sexual intercourse.

I understand that I am free to refuse to participate and may withdraw my consent without prejudice or hard feelings at any time. Should I withdraw my consent, my participation as a subject will cease immediately, unless the Investigator determines that such action would be dangerous or impossible (in which case my participation will cease as soon as it is safe to do so). I also understand that the Investigator or their designate may terminate my participation at any time, regardless of my wishes.

I understand that by signing this consent form I have not waived any legal rights I may have as a result of any harm to me occasioned by my participation in this research project beyond all risks I have assumed.

Volunteer's Name: ______________________________

Signature: ______________________________ Date: ________________

Name of Witness to Signature: ______________________

Signature: ______________________________ Date: ________________

Certified fit to participate in this experiment as outlined in the research project.

Family Member or Contact Person (name, address, daytime phone number & relationship)

____

Principal Investigator: Dr. Scott N. MacKinnon

Signature: ______________________________ Date: ____________________

FOR SUBJECT ENQUIRY IF REQUIRED:

Should I have any questions or concern regarding this project before, during, or after participation, I understand that I am encouraged to contact any of the people listed below:

Principle Investigator:

Dr. Scott N. MacKinnon, (709) 737-7249smackinn@mun.ca

Co-Investigator:

Mr. James L. Colwell, (902) 426-3100 ext 125 jim.colwell@drdc-rddc.gc.ca

Chair, DRDC Toronto Human Research Ethics Committee (HREC):

Dr. J.P. Landolt (416) 635-2104 jack.landolt@drdc-rddc.gc.ca

I understand that I will be given a copy of this consent form so that I may contact any of the above-mentioned individuals at some time in the future should that be required.

APPENDIX E : CONSENT TO TAKE PART IN HEALTH RESEARCH

School of Human Kinetics and Recreation
Memorial University of Newfoundland

TITLE: Effects of Moderate Sea Sickness on Estimating Task Duration

INVESTIGATOR(S):

You have been asked to take part in a research study. It is up to you to decide whether to be in the study or not. Before you decide, you need to understand what the study is for, what risks you might take and what benefits you might receive. This consent form explains the study.

The researchers will:

- discuss the study with you
- answer your questions
- keep confidential any information which could identify you personally
- be available during the study to deal with problems and answer questions

If you decide not to take part or to leave the study this will not affect your student status.

1. **Introduction/Background:**
   Marine workers are responsible for ensuring the safe and effective functioning of a ship, regardless of their reactions to an adverse environment. It is critical that the time taken to complete tasks has the least amount of deviation between different environments, i.e. calm seas versus stormy weather. Everyday operations must continue and time taken on cognitive tasks should be similar regardless of type of weather/environment. Challenges that marine workers face while at sea include motion induced sickness that can cause diminished concentration causing while completing tasks.

2. **Purpose of study:**
   The purpose of this study is to determine how motion induced sickness can affect how a worker estimates time taken to perform tasks.

3. **Description of the study procedures and tests:**
   You will be required to meet on two separate occasions at the Centre for Marine Simulation of the Memorial University of Newfoundland during this study. The first meeting will be for 3 hours and the second meeting, held a minimum of one week later, will be for 2 hours.

At the first meeting we will explain what is expected of you as a participant in the study. You will fill out a questionnaire at this time for your susceptibility towards motion induced sickness. It will be during this initial meeting that you will be required to "learn" the cognitive tasks that you will be required to complete during the study. The Learning Stage will take approximately 1 hour.

After a short break you will be required for the first part of the study. You will be required to perform a series of cognitive tasks on a computer screen, which you have previously learned, in either a moving (dynamic) or non-moving (static) environment. This will take place in the Ship Motion Simulator located at Marine Institute. Data will be collected on how you perform the tasks that you have learned. This portion of the study will take 2 hours which will be broken down into segments of tasks. You also will be required to complete another questionnaire to assess your level of motion sickness during the session.

The second meeting will be the opposite of your first visit. For example, if you completed tasks while in a dynamic (moving) environment during the first data collection this meeting will be held in a static (non-moving) environment. You will be given time, approx 20 minutes, to get refreshed of the tasks you had learned a minimum of 1 week prior. The second portion of the study will then begin. As with the first meeting this will also take two hours. You also will be required to complete another questionnaire to assess your level of motion sickness.

The tasks that you will have to learn and complete during the study will all be computer based.

4. **Length of time:**

   You will be required to attend two experimental conditions. Each visit will last approximately 3 hours. The first meeting will be considerably longer with an hour to learn the tasks and to prepare you for the data collection session and two hours for the data collection session. There will be a minimum of 1 weeks rest in between experimental sessions.

5. **Possible risks and discomforts:**

   There will be some discomfort during the moving (dynamic) portion of this study. During the two hours of data collection the Ship Motion Simulator (SMS) will be controlled to keep you at a constant state of motion sickness. You will not be brought to the point of vomiting. If you feel at any time the level of motion sickness is too great than the SMS will be adjusted to ensure the discomfort level is reduced. There will be always a Researcher with you in the SMS. As a precautionary measure there will be transportation available post test if you feel any adverse affects from the session.

6. **Benefits:**

   It is not known whether this study will benefit you.

7. **Liability statement:**
Signing this form gives us your consent to be in this study. It tells us that you understand the information about the research study. When you sign this form, you do not give up your legal rights. Researchers or agencies involved in this research study still have their legal and professional responsibilities.

8. **Compensation:**
In the event that you suffer injury as a direct result of taking part in this study, necessary medical treatment will be available at no additional cost to you.

9. **Questions:**
If you have any questions about taking part in this study, you can meet with the investigator who is in charge of the study at this institution.

   Or you can talk to someone who is not involved with the study at all, but can advise you on your rights as a participant in a research study. This person can be reached through:

   Office of the Human Investigation Committee (HIC) at 709-777-6974
   Email : hic@mun.ca

Signature Page

Study title: Effects of Motion Induced Sickness on Performance of Cognitive Tasks.

Name of principal investigator:

To be filled out and signed by the participant:

Please check as appropriate:

I have read the consent [and information sheet]. Yes { } No { }

I have had the opportunity to ask questions/to discuss this study. Yes { } No { }

I have received satisfactory answers to all of my questions. Yes { } No { }

I have received enough information about the study. Yes { } No { }

I have spoken to ___________(or designate) and he/she has answered my questions. Yes { } No { }

I understand that I am free to withdraw from the study Yes { } No { }

- at any time
- without having to give a reason
- without affecting my student status or reputation in the community

I understand that it is my choice to be in the study and that I may not benefit.
Yes{ } No { }

I agree to take part in this study. Yes { } No { }

________________________________ ________________________

Signature of participant Date

________________________________ ________________________

Signature of witness Date

To be signed by the investigator:

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

________________________________ ________________________

Signature of investigator Date

Telephone number:

APPENDIX F : RESEARCHER SCRIPT – NO MOTION

Date: ____________ **Subject #**

NO MOTION

Time		Time Reported	Start Time	End Time	Abandoned			Observed: 0= None, 3 = Severe.							Motion	Time
(min)	Task				Task	Psych	MISC	Pallor	Sweat	Salvation	Swallowing	Breathing	Yawning	Belching	Change	(min)
T-3 (T-10)																T-3 (T-10)
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35																35

Date: ____________ Subject #

NO MOTION

Time		Time Reported	Start Time	End Time	Abandoned			Observed: 0= None, 3 = Severe.							Motion	Time
(min)	Task				Task	Psych	MISC	Pallor	Sweat	Salvation	Swallowing	Breathing	Yawning	Belching	Change	(min)
36																36
37																37
38																38
39																39
40																40
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42			42													42
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Date: ______________ Subject #

NO MOTION

Time		Time Reported	Start Time	End Time	Abandoned			Observed: 0= None, 3 = Severe.							Motion	Time
(min)	Task				Task	Psych	MISC	Pallor	Sweat	Salvation	Swallowing	Breathing	Yawning	Belching	Change	(min)
76																76
77			77													77
78																78
79																79
80																80
81																81
82		5		82												82
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119																119
120	STOP															120

APPENDIX G : RESEARCHER SCRIPT – MOTION

Date:												Subject #					
									MOTION								
Time		Time Reported	Start Time	End Time	Abandoned			Observed: 0 = None, 3 = Severe							Motion	Time	
(min)	Task				Task	Psych	MISC	Pallor	Sweat	Salvation	Swallowing	Breathing	Yawning	Belching	Change	(min)	Task
T-3 (T-10)																T-3 (T-10)	
0																0	
1																1	
2			2													2	
3																3	
4																4	
5																5	
6																6	
7																7	
8																8	
9																9	
10																10	
11																11	
12																12	
13		11		13												13	
14																14	
15			15													15	
16																16	
17																17	
18																18	
19																19	
20																20	
21																21	
22																22	
23		8		23												23	
24																24	
25																25	
26																26	
27																27	
28																28	
29																29	
30																30	
31																31	
32																32	
33																33	
34																34	
35			35													35	
36																36	
37																37	
38																38	
39																39	
40		5		40												40	

MOTION																	
Time		Time Reported	Start Time	End Time	Abandoned			Observed 0 = None, 3 = Severe							Motion	Time	
(min)	Task				Task	Psych	MISC	Pallor	Sweat	Salvation	Swallowing	Breathing	Yawning	Belching	Change	(min)	Task
41																41	
42			42													42	
43																43	
44																44	
45																45	
46																46	
47																47	
48																48	
49																49	
50																50	
51																51	
52																52	
53		11		53												53	
54																54	
55																55	
56																56	
57																57	
58																58	
59			59													59	
60																60	
61																61	
62																62	
63																63	
64																64	
65																65	
66																66	
67																67	
68																68	
69		10		69												69	
70																70	
71			71													71	
72																72	
73																73	
74																74	
75		4		75												75	
76																76	
77																77	
78																78	
79																79	
80																80	
81																81	

Date: ____________ **Subject #** **Date:**

MOTION

Time (min)	Task	Time Reported	Start Time	End Time	Abandoned Task	Psych	MISC	Observed: 0 = None, 3 = Severe Pallor	Sweat	Salvation	Swallowing	Breathing	Yawning	Belching	Motion Change	Time (min)	Task
82																82	
83																83	
84																84	
85																85	
86																86	
87																87	
88																88	
89																89	
90																90	
91																91	
92			92													92	
93																93	
94																94	
95																95	
96																96	
97		5		97												97	
98																98	
99																99	
100																100	
101																101	
102																102	
103																103	
104																104	
105																105	
106			106													106	
107																107	
108																108	
109																109	
110																110	
111																111	
112																112	
113																113	
114																114	
115		9		115												115	
116																116	
117																117	
118																118	
119																119	
120	STOP															120	STOP

APPENDIX H : MISERY INDEX SCALE

Misery Index Scale		
Symptoms		**Score**
No problems		**0**
Uneasiness (no typical symptoms)		**1**
Dizziness, warmth, headache, stomach awareness, sweating	**Vague**	**2**
	Slight	**3**
	Fairly	**4**
	Severe	**5**
Nausea	**Slight**	**6**
	Fairly	**7**
	Severe	**8**
	(near) retching	**9**
Vomiting		**10**

APPENDIX I : NATO PERFORMANCE ASSESSMENT QUESTIONNAIRE

NATO PERFORMANCE ASSESSMENT QUESTIONNAIRE
amended

Date ______________________ Time ________________
Location ______________________________________
Tasks ____

Symptoms

Sleeping problems before this session

0 = none, 3 = severe:	0	1	2	3
Quality of sleep was poor	☐	☐	☐	☐
Amount of time sleeping was short	☐	☐	☐	☐
Other: ________________________	☐	☐	☐	☐

Symptoms experienced during this session

0 = none, 3 = severe:	0	1	2	3
Mental fatigue	☐	☐	☐	☐
Physical fatigue	☐	☐	☐	☐
Sleepy	☐	☐	☐	☐
Headache................................	☐	☐	☐	☐
Apathy (just don't care)	☐	☐	☐	☐
Tension/anxiety	☐	☐	☐	☐
Vomiting or retching	☐	☐	☐	☐
Nausea	☐	☐	☐	☐
Stomach awareness	☐	☐	☐	☐
Other: ________________________	☐	☐	☐	☐

How Motion Sick are you? 0 = feel fine, 10 = feel awful

☺ ☹ ☹

0	1	2	3	4	5	6	7	8	9	10

Did you vomit before/during this session? Yes ☐ No ☐
If yes, at about what time? ________________
How did you feel after? Better ☐ Same ☐ Worse ☐

Performance

Task Performance problems during this session

0 = none, 3 = severe:	0	1	2	3
Making decisions	☐	☐	☐	☐
Concentration/attention	☐	☐	☐	☐
Memory	☐	☐	☐	☐
Simple tasks	☐	☐	☐	☐
Hand coordination	☐	☐	☐	☐
Vision	☐	☐	☐	☐
Other: ____________	☐	☐	☐	☐

Task Completion problems during this session

Do you think that you made more mistakes than you had anticipated?	Yes	☐	No	☐	
Did tasks take longer than you had anticipated?	Yes	☐	No	☐	
Tasks not completed in time available	Yes	☐	No	☐	
Had to abandon tasks	Yes	☐	No	☐	
Not allowed to attempt tasks	Yes	☐	No	☐	N/A I
Other: ____________	Yes	☐	No	☐	

Others problem during this session

0 = none, 3 = severe:	0	1	2	3
Cold, flu or other illness	☐	☐	☐	☐
Air quality (bad smells)	☐	☐	☐	☐
Noise	☐	☐	☐	☐
Vibration	☐	☐	☐	☐
Lighting (bright ☐, dark ☐)	☐	☐	☐	☐
Temperature (hot ☐, cold ☐)	☐	☐	☐	☐
Other: ____________	☐	☐	☐	☐

Comments ____

____

APPENDIX J : NASA TASK LOAD INDEX (TLX) SCALE

MENTAL DEMAND

Low High

PHYSICAL DEMAND

Low High

TEMPORAL DEMAND

Low High

EFFORT

Low High

PERFORMANCE

Good Poor

FRUSTRATION

Low High

APPENDIX K : STANFORD SLEEPINESS SCALE

Please circle the number that best describes your sleepiness now:

1. Feeling active and vital; alert; wide awake;
2. Functioning at a high level, but not at peak; able to concentrate;
3. Relaxed; awake; not at full alertness; responsive;
4. A little foggy; not at peak; let down;
5. Fogginess; beginning to lose interest in remaining awake; slowed down;
6. Sleepiness; prefer to be lying down; fighting sleep; woozy;
7. Almost in reverie; sleep onset soon; lost struggle to remain awake.