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THESIS

A FIELD STUDY OF PERFORMANCE AMONG EMBARKED INFANTRY PERSONNEL EXPOSED TO WATERBORNE MOTION

by

Byron M. Lee

September 2012

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With the cancellation of the Expeditionary Fighting Vehicle program by the Secretary of Defense in January 2011, the Marine Corps Combat Development and Integration Command started a revision of the core capabilities for future amphibious assault vehicles. With limited information on the aftereffects of waterborne motion on embarked infantry, the Habitability Assessment Test was conducted to investigate and characterize these effects on infantrymen's combat effectiveness. The level of degradation due to exposure to waterborne motion on agility, coordination, and cognitive function was measured utilizing two types of amphibious assault vehicle. Sixty-one Marines were exposed to varying lengths of waterborne motion. They completed a test battery before and after waterborne motion exposure including an obstacle course, marksmanship assessment and cognitive performance test.

Analysis reveals no degradation in either marksmanship or obstacle course performance. Cognitive performance, on the other hand, was degraded. Participants' performance on the cognitive test was 9.34 percent lower after exposure to three hours of waterborne motion. Additionally, cognitive performance for participants not reporting to be suffering from motion sickness had a greater deficit. After a one-hour resting period, the participants' performance on the cognitive test was still degraded for the participants exposed to three hours of waterborne motion.

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A FIELD STUDY OF PERFORMANCE AMONG EMBARKED INFANTRY PERSONNEL EXPOSED TO WATERBORNE MOTION

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

A2/AD   Anti-Access Area-Denial

AAV   Amphibious Assault Vehicle

ANOVA   Analysis of Variance

AVTB   Amphibious Vehicle Test Branch

CD&I   Combat Development and Integration

EFV   Expeditionary Fighting Vehicle

HAT   Habitability Assessment Test

HSD   Honestly Significant Difference

LMTS   Laser Marksmanship Training System

LVTP   Landing Vehicle, Tracked Personnel Carrier

MSAQ   Motion Sickness Assessment Questionnaire

MSSQ   Motion Sickness Susceptibility Questionnaire

NATO PAQ   North Atlantic Treaty Organization Performance Assessment Questionnaire

NASA TLX   National Aeronautics and Space Administration Task Load Index

RAM/RS   Reliability Availability Maintainability Rebuild to Standard

RFID   Radio Frequency Identification

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EXECUTIVE SUMMARY

With the cancellation of the Expeditionary Fighting Vehicle program by the Secretary of Defense in January 2011, the Marine Corps Combat Development and Integration Command started a revision of the core capabilities for future amphibious assault vehicles. With limited information on the aftereffects of waterborne motion on embarked infantry, the Habitability Assessment Test was conducted to investigate and characterize these effects on infantrymen's combat effectiveness. The level of degradation due to exposure to waterborne motion on agility, coordination, and cognitive function was measured utilizing two types of amphibious assault vehicle. Sixty-one Marines were exposed to varying lengths of waterborne motion. They completed a test battery before and after waterborne motion exposure including an obstacle course, marksmanship assessment and cognitive performance test.

The Habitability Assessment Test was conducted at the Marine Corps Base, Camp Pendleton, in southern California from August 9 to August 24, 2011. The test consisted of a weeklong training period, conducted at Pelican Point, followed by two weeks of testing. The test site was relocated to Red Beach after the first week of testing to facilitate a special test event. The training period included morning and afternoon test events which allowed for the attainment of reliable and repeatable performance by the sixty-one Marines. The test of record followed the training week with participants completing one of four exposure levels per test day.

Analysis of the data collected reveals no degradation in either marksmanship or obstacle course performance. Cognitive performance, on the other hand, was degraded. Participants' performance on the cognitive test was 9.34 percent lower after exposure to three hours of waterborne motion than their performance for no motion exposure. Additionally, cognitive performance for participants not reporting to be suffering from motion sickness had a greater deficit. After a one-hour resting period, the participants' performance on the cognitive test was still degraded for the participants exposed to three hours of waterborne motion.

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I.   INTRODUCTION

There are three kinds of people…the living, the dead, and the seasick.

Archimedes, 250 B.C.

Seasickness, airsickness, and carsickness, all variants of motion sickness, have been studied throughout history. Yet, due to the variability in an individual's response to motion, little is known about motion sickness' overall impact on human performance (Bos & Bles, 2000). Of particular concern is the performance of military personnel after transportation in a moving vehicle to an operational area. Hal Baumgarten, an Omaha Beach D-Day survivor from the 116th Infantry Regiment, commenting on his fellow infantrymen's abilities during the amphibious assault, says, "Seasickness affected sixty percent of their ability to fight" (Gale, 2011). Early experiences in training exercises and in amphibious operations have shown "how disabling sea-sickness can be to troops taking part in such landings" (Hill & Guest, 1945). In today's fiscally constrained military environment that requires higher levels of performance from a shrinking population of military personnel, degradations in a military member's performance could have a resounding impact on mission completion and, in turn, power projection from the sea.

The United States Navy and Marine Corps are an expeditionary sea-based force. Simultaneously, the military faces new challenges associated with power projection (Conway, Roughhead, & Allen, 2010). Military personnel not only contend with the performance limiting factors of battle stress, but also face challenges created by deployments covering great geographical distances and forward presences aboard vessels at sea. The increasing number of disaster relief, humanitarian and crisis response operations faced by the uniformed services requires military forces to be rapidly deployable. Military operations other-than-war often occurs in distant lands and requires some form of transportation by U.S. armed forces. By land, by sea, by air or a combination thereof, military personnel are subjected to some level of motion exposure. While motion sickness may be a factor during ship, aircraft and land transport, the focus

of our efforts is on the terminal phase of amphibious operations – the ship-to-objective maneuver. The extent of this motion exposure and any impairment due to motion on the operational effectiveness of military personnel needs to be scrutinized by military planners and leaders. This thesis explores performance degradation due to mild motion sickness of embarked infantrymen during amphibious operations.

A.   OBJECTIVES

The objective of this research is to quantify the effects of waterborne motion on performance of embarked infantrymen using the data from the Habitability Assessment Test (HAT) study. The HAT study's aim was to define the level of degradation due to exposure to waterborne motion on combat effectiveness. Combat effectiveness was measured after exposure to motion in two types of amphibious assault vehicle (AAV), the AAVP7A1 and the system demonstration and design prototype of the expeditionary fighting vehicle (EFV), by a test battery that included an obstacle course, marksmanship accuracy assessment, a computerized cognitive performance test, and a motion sickness self-assessment. Participants were exposed to varying treatment conditions. They completed the test battery before and after each treatment condition. Data collected during the HAT study addressed the following areas:

- Is there degradation in obstacle course performance among embarked infantry personnel when exposed to varying lengths of waterborne motion?

- Is there degradation in marksmanship among embarked infantry personnel when exposed to varying lengths of waterborne motion?

- Is there degradation in cognitive performance among embarked infantry personnel when exposed to varying lengths of waterborne motion?

- Is there a difference in reported levels of motion sickness for embarked infantry personnel when exposed to varying lengths of waterborne motion?

- Is there a relationship between self-reported levels of motion sickness and performance for embarked infantry personnel exposed to varying lengths of waterborne motion?

- Does performance return to pre-treatment levels after a one hour recovery period?

B.   BACKGROUND

1.   Decision Making and Critical Thinking of Military Personnel

With the ever increasing demands of military operations, individual performance is paramount to mission success. General Charles C. Krulak eloquently detailed this necessity in his 1999 article *The Strategic Corporal: Leadership in the Three Block War*. In this fictional story set in the context of a military humanitarian security operation, Corporal Hernandez was faced with an escalating situation. The fate of the mission rested in his ability to make the 'right decision' at the 'right time' (Krulak, 1999). Soldiers, Sailors, Airmen and Marines operate in a technologically advanced battle space that requires various levels of critical thinking, problem solving and action. In addition to the stress of battle, an individual's performance on the battlefield on any given day is dependent on myriad factors that include physical conditioning, environmental stress and mental well-being. Mission success or failure will rest on the ability of military members "to confidently make well-reasoned and independent decisions under extreme stress" (Krulak, 1999).

2.   Anti-Access/Area Denial and Power Projection

As the Department of Defense transitions from the forward presence of the Cold War to an expeditionary era, forward basing of military forces on foreign lands has diminished. The Armed Services of the United States face new political, economic and geographic challenges to power projection. In addition to reduced forward basing, advances in ballistic missile technology have afforded would-be adversaries and non-state actors the ability to deny access to regions under their control (Krepinevich, Watts,

& Work, 2003). These Anti-Access and Area-Denial (A2/AD) challenges stand in stark contrast to the fundamental pillar of the Department of the Navy's *Naval Power 21* operational concept and the promise of "assured access" (England, Clark, & Jones, 2002). The ability of United States Navy and Marine Corps to project power, respond to global crises, and provide humanitarian relief all depend on access to foreign and possibly hostile shores. With most of U.S. naval forces stationed within the United States and deploying on a rotational basis to satisfy operational needs and A2/AD threats, the guarantee of assured access exposes the uniformed service members to the added stress associated with rapid global mobilization (Conway, Roughhead, & Allen, 2010).

### 3.	Forcible Entry and Amphibious Operations

Forcible entry is defined by *Joint Publication 3-18: Joint Forcible Entry Operations* as:

> joint military operation conducted against armed opposition to gain entry into the territory of an adversary by seizing a lodgment as rapidly as possible in order to enable the conduct of follow-on operations or conduct a singular operation. A lodgment is a designated area in a hostile or potentially hostile territory that, when seized and held, makes the continuous landing of troops and material possible and provides maneuver space for subsequent operations (a lodgment may be an airhead, a beachhead, or a combination thereof). (Joint Publication 3–18, 2008)

Forcible entry via amphibious operations has been a part of many modern military conflicts. From the ancient Greek Wars to the epic battles of World War II and Korea, amphibious operations have been used to gain access to hostile territory. Amphibious operations are integral to the ship-to-objective maneuver and the ability of United States to project power. Power projection from the sea is and has been the primary employment of the Navy and Marine Corps for over 200 years.

From their creation by the Second Continental Congress on November 10, 1775, the Marine Corps have been a force to fight for independence at sea and ashore. Only a few weeks after their organization, Captain Samuel Nicholas led his Marines on the first amphibious assault on hostile shores. On March 3, 1776, 236 Continental Marines seized

Fort Montague and marched on Fort Nassau the following day. "This unimpressive force of seagoing musketeers had executed one of the most difficult maneuvers in all military science—an amphibious assault launched from naval ships at sea against hostile shore" (Alexander J. H., 1997). This marked the beginning of a long history of forcible entry onto hostile shores undertaken by the United States Marine Corps.

4.   Future of the Amphibious Assault Vehicle

Like the row boats used by the Marines in 1776, today the Marine Corps employs amphibious assault vehicles (AAV), also known as amphibious tractors or AMTRACs, to get infantrymen ashore. The current AAV used for troop and cargo transport are the AAVP7A1 and the upgraded AAVP7A1 RAM/RS (Reliability, Availability and Maintainability: Rebuild to Standard) (MCWP 3–13, 2005). The AAV was originally designated as the LVT-7 (landing vehicle tracked) which replaced the aging LVT-5 and was placed in service in 1972. The LVT-7 saw performance upgrades starting in 1982 by the FMC Corporation and was re-designated as the AAVP7A1 (Global Security, 2011). The AAVs were rebuilt again in 1998 as part of the RAM/RS program.

The AAV has a maximum swim speed of 8.2 miles per hour and has the ability to swim for seven hours. The AAV can operate effectively in sea states one through three with reduced maneuverability in sea state four. On land, the AAV has a maximum speed of 45 miles per hour and a range of 300 miles. It is operated by a crew of three and can transport twenty-one combat loaded infantrymen or 10,000 pounds of cargo. AAVs are manufactured with welded ballistic aluminum, which provides protection for the passenger and crew (MCWP 3–13, 2005).

The aging and slow AAV was scheduled to be replaced by the expeditionary fighting vehicle (EFV). As cited by Lieutenant General George Flynn, Deputy Commandant of Combat Development and Integration (CD&I), appearing before the House of Representatives Armed Service Committee, the minimum safe launch distance for amphibious vehicles is twelve miles (Amphibious Operations, 2011). The transit time using the existing AAV from a distance of 12 miles will be well over an hour as the naval

delivery vessels are required to stay out of range of enemy combatant coastal defenses. The EFV was designed with a planning hull allowing it to swim at speeds as high as twenty-five miles per hour. The increased speed of the EFV would offer better over-the-horizon assault capabilities in an A2/AD environment, thus providing a safe distance from hostile shores for naval ship and minimizing the time spent embarked in the assault craft for the infantrymen. Unfortunately, the EFV program was plagued by performance and reliability issues, leading to program cost over-runs and ultimately program cancellation (Amphibious operations, 2011).

With the cancellation of the EFV program by the Secretary of Defense in January 2011, the Marine Corps Combat Development and Integration (CD&I) Command started a revision of the core capabilities for amphibious assault vehicles. With little information on the effects of waterborne motion on embarked infantry, the Commandant of CD&I and Program Manager Advanced Amphibious Assault (PM AAA) sought to characterize these effects (Amphibious Vehicle Test Branch, 2011). The Habitability Assessment Test (HAT) was completed in August 2011 as part of this process. The HAT study was conducted to investigate and characterize the aftereffects of waterborne motion on an infantrymen's combat effectiveness, specifically, the ability to move, shoot and communicate.

The Amphibious Vehicle Test Branch (AVTB) onboard Camp Pendleton in southern California was tasked to complete this study. The AVTB Lead Test Director consulted with the Naval Postgraduate School (NPS) Human Systems Integration (HSI) Program in the Operations Research Department, Naval Surface Warfare Center Panama City Division (NSWC PCD), and Expeditionary Systems Evaluation Division (ESED) to develop the methodology and measures for the HAT study. NPS completed two pilot studies to assess viable measures of performance and methods for conducting the experiment. In addition to identifying the required methods and measures of performance, these initial experiments highlighted the importance of overcoming the learning effect experienced by the initial test participants (Eonta et al., 2011).

C.   SCOPE, LIMITATIONS, AND ASSUMPTIONS

1.   Scope of Thesis

This thesis explores the relationship between the duration of waterborne motion exposure aboard an amphibious vehicle and the performance of embarked Marine infantrymen in the role of amphibious vehicle passengers. Additionally, this thesis develops a model for assessing the cognitive performance characteristics of embarked infantry personnel using duration of waterborne exposure, environmental variables, motion sickness susceptibility questionnaire (MSSQ) responses and motion sickness assessment questionnaire (MSAQ) responses as possible predictors of performance.

2.   Limitations on Research

Every field study has elements that are impossible to control. The HAT study was conducted under near-operational conditions meaning that the motion profile experienced by the participants was representative of conditions that would be encountered during regular amphibious operations. Parameters deemed important to the study objective but outside of the control of the field study were considered limitations. These limitations and a brief explanation are:

- Troop Movement Mode. Amphibious operations are generally conducted via a ship-to-shore movement versus shore-to-shore movement. Ship-to-shore operations would have required a significant increase in manpower and assets required to complete the study.

- Environmental Conditions. The environmental conditions in August in Southern California are mild, moderate temperatures and low sea states. Therefore, environmental extremes could not be evaluated during this field test .

- Test Participant Fatigue. The HAT study was designed with concerns about test participant fatigue. Tests involving repetitive test batteries

maybe affected by participant fatigue. Therefore, treatments were limited to a single treatment per day.

- Learning Effect. Participant learning occurs when individuals are exposed to repetitive tests. We trained the participants for one week prior to data collection in an attempt to address this issue. Following one week of training, the participant learning curve is nearly asymptotic although incremental performance increases still occur.

3. Assumptions

Assumptions made during the HAT study to address the above limitations are:

- Adaptation to Motion. Ship-to-shore operations involve some level of adaptation to the waterborne motion experienced by infantrymen while aboard the larger ship. Infantrymen undergo an additional adaptation to the motion of the smaller amphibious vehicle during an amphibious transit. It was assumed the additional adaptation during the amphibious transit is similar to the adaptation required during the shore-to-shore movement.

- Test Participants. It was assumed the recruited test participants are representative of the entire population of would-be amphibious vehicle passengers. Additionally, it was assumed that changes in participant's performance were the result of motion exposure.

- Test Design. It was assumed that the test design controlled test participant fatigue, participant learning effect and adaptation to motion aboard the amphibious vehicles and that there was no carryover effect from one test day to the next.

II.   LITERATURE REVIEW

A.   MOTION SICKNESS

1.   Defining Motion Sickness

Motion Sickness (*n*.): Nausea and sometimes vomiting caused by the effects of certain movements on the inner ear typically experience in a moving vehicle, ship, or airplane. (Webster Illustrated Contemporary Dictionary, 1999)

Nausea (*n*.): 1. A disagreeable sensation accompanied by an impulse to vomit. 2. A feeling of loathing. (Webster Illustrated Contemporary Dictionary, 1999)

Motion sickness in one form or another has been recognized throughout recorded history. The word nausea comes from the Greek word *nausia* meaning seasickness (Webster Illustrated Contemporary Dictionary, 1999). The recognition of seasickness by early civilizations is evidence of a connection between a mode of transportation and an illness. For instance, camel sickness, seasickness and airsickness all became a part of man's collective consciousness only after camels, boats and airplanes were used to transport human beings. As new forms of transportation and technology have appeared, a new word associated with that particular form of transportation or technology has appeared in the collective vocabulary of human kind to describe the feeling of sickness. Today, seasickness, train sickness, carsickness, airsickness, space sickness are all considered forms of motion sickness. However, the symptoms associated with these sicknesses may also arise in the absence of motion. Cinema sickness and simulator sickness both occur in the absence of real motion. Clearly, there exists a connection between motion, either real or perceived, and the display of a common symptomology.

Motion sickness, according to Benson (2002), is somewhat of a misnomer. Motion sickness is a natural response of a healthy individual to unusual motion, real or perceived, stimuli (Benson, 2002; Rolnick & Gordor, 1991; Mccauley, O'Hanlon, Royal, Nackie, & Wylie, 1976). Only individuals without a functioning balance organ of the

inner ear are immune to the effects of motion (James, 1882). Of the individuals that are not immune to motion sickness, 95 percent of them adapt to the motion stimuli in a matter of two to three days (Stevens & Parsons, 2002; Wertheim, 1998).

2. Physiological and Psychological Response to Motion Sickness

For many people, the term motion sickness conjures a vision of an individual, having fallen victim to the sensation of motion, vomiting. Vomiting or emesis is only a part of the symptomology that surrounds motion sickness. Motion sickness is typically characterized by stomach awareness, pallor, cold sweats, stomach discomfort, headache, nausea, and emesis (Benson, 2002; McCauley, O'Hanlon, Royal, Mackie, & Wylie, 1976). The progression of symptoms leading to emesis follows a common path, but the time necessary for emesis to occur, if it occurs, depends on the individual (Stevens & Parsons, 2002). Highly susceptible individuals may progress to emesis and be affected for days, while less susceptible individual will only show milder symptoms and never experience emesis.

Graybiel and Knepton (1976), while studying individuals in a slow rotating room, identified a mild form of motion sickness that they called sopite syndrome. Sopite syndrome is characterized by drowsiness, yawning, and a lack of interest in participating in work or physical activities in connection with motion. They discovered or in their words 'gleaned the evidence' of sopite syndrome through the analysis of journals entries kept by the test participants. Sopite syndrome was often the sole manifestation of motion sickness occurring either before other motion sickness symptoms or after other motion sickness symptoms had dissipated (Graybiel & Knepton, 1976). Sopite syndrome, they reported, followed a different time horizon independent of other motion sickness symptomology.

Other physiological phenomena associated with motion sickness have been measured in clinical settings. These are decreased gastric motility (movement of food through the stomach), increased heart rate, and increased blood flow in skeletal muscles (Money, 1996). Additionally, there are increased levels of the antidiuretic hormone,

cortisol, adrenalin, and growth hormone in plasma have been recorded (Everman et al., 1978; Benson, 2002). These objective measures are not specific to motion sickness, unfortunately, they are also associated with stress response and other physical ailments (Money, 1996).

3.   Mechanics of Motion Sickness

To understand the mechanics of motion sickness one, needs to understand how humans perceive motion through the balance organs. Balance is a complex process requiring input from the visual system, the proprioceptive system (network of pressure sensors throughout the body), and vestibular systems (part of the inner ear). These systems work in concert to allow an individual to control the position of his head relative to gravity and sense exogenous motion (Stevens & Parsons, 2002). Understanding the process of maintaining one's balance and self-motion underpin the widely accepted sensory conflict theory of motion sickness proposed by Reason and Brand (1975). A brief discussion of the visual, proprioceptive and vestibular systems is inherent to any discussion on the motion sickness.

The principle components of the visual system are the eyes, optic nerves, the neural pathways and the visual cortex (Seeley, Stephens, & Tate, 2003). The eye is a complex sensory receptor where images are processed by the eyes and passed to the visual cortex via the optic nerve and neural pathways. This process allows humans to ascertain information about the surroundings such as the horizon, fixed and moving objects, and the smiling faces of colleges. Within a visual reference, humans perceive, for example, the top of a written page and the movement of the second hand of the clock on the adjacent wall. Eyesight, alone, cannot identify a moving object or moving environment in the absence of a frame of reference.

The proprioceptive system, much like the visual system, requires a change in a frame of reference to identify motion. The proprioceptive system is composed of a network of corpuscles distributed throughout the body. Human skin, joints, tendons, and connective tissue all contain various types of corpuscles (Seeley, Stephens, & Tate,

2003). One type of corpuscles is the Pacinian corpuscle, which is an onion shaped nerve ending, that senses pressure and vibration (Gray, 1966). To gain an appreciation for the function of the proprioceptive system, one only has to close one's eyes while standing. Once the eyes are closed, an individual quickly becomes aware of pressure modulating between the feet in order to maintain one's balance.

The vestibular system, shown in Figure 1, works with the visual system and the proprioceptive system as the body's primary balance organ. It is located in the bony labyrinth of the inner ear. The vestibule and the semicircular canals detect the head's position relative to gravity and perceive linear acceleration and angular movement of the head (Seeley, Stephens, & Tate, 2003). Within the vestibule are maculae oriented parallel and perpendicular to the base of the skull. The maculae are small collections of hairs (cilia) that are embedded in a gelatinous mass containing otoliths. The otoliths move in response to gravitational force enabling the vestibule the ability to detect the position of the head relative to gravity and changes in linear acceleration. The semicircular canals are nearly orthogonal and have ampullae at their bases. The ampullae are similar to the maculae in function. The hairs of the ampullae are contained in a gelatinous mass (cupula) which respond to the movement of fluid (endolymph) in the canals. As the head moves, the fluid displaces the hairs indicating the direct of angular motion.
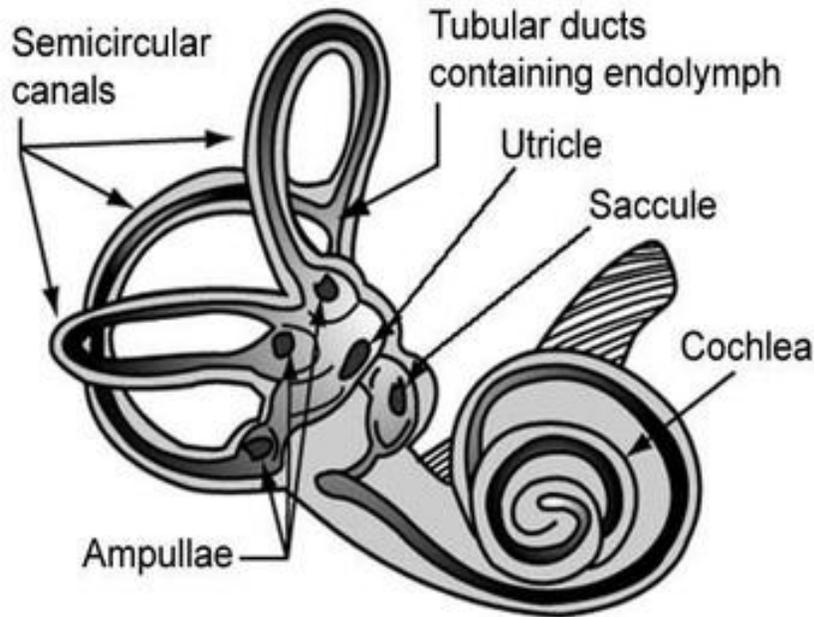
Figure 1.   Vestibular System. Diagram of the three semicircular canals, associated ampullae and the utricle and saccule of the vestibule that are responsible for sensing the motion of the head. Retrieved from http://kin450-neurophysiology.wikispaces.com/VOR on 16 June, 2012.

The inputs of these systems are interconnected and combine to facilitate balance by providing the brain with information about self-motion and the direction of gravity. Additionally, these systems rely on information from each other through reflexive pathways (Seeley, Stephens, & Tate, 2003). The proprioceptive system works in conjunction with the vestibular system to maintain balance. The vestibular system provides signals to the extrinsic muscles of the eye to accommodate visual fixation on an object while the head is moving. With a functional understanding of how humans perceive motion, a discussion on motion sickness theory is possible.

B.   PREVAILING THEORY ON MOTION SICKNESS

1.   Origination of Sensory Conflict Theory

One widely accepted theory of motion sickness is characterized by a conflict in the sensory information received by the brain. A review of the literature shows the evolution of thought on the subject. Sensory conflict was articulated by Irwin in 1881

who wrote: "In the visual vertigo of seasickness there appears to be a discord between the immediate or true visual impressions and a certain visual habit or visual sense of the fitness and order of things, which passes into consciousness as a distressing feeling of uncertainty, dizziness and nausea" (Reason, Motion sickness adaptation: A neural mismatch model, 1978). The basic premise of the sensory conflict theory is that signals from the sensory balance organs, which normally agree, become discrepant. For example, when below decks aboard a ship, the vestibular system senses the motion of the ship, but the visual system, lacking the necessary visual horizon frame of reference, does not. Numerous authors revised this sensory conflict theory, but the theory lacks a connection between the actual conflict and the output pathways of motion sickness, i.e., emesis (Oman, 1990; Money, 1996; Treisman, 1977).

2. Sensory Rearrangement Theory

In 1975, Reason and Brand expanded the sensory conflict theory in a way to account for the process of adaptation, which could result in the eventual disappearance of motion sickness symptoms during continued exposure to motion stimuli. Their sensory rearrangement theory was based on two premises: the conflict that induces motion sickness was between the signals from the balance organs being discrepant with each other and the expected signal on the basis of previous interactions with the perceived environment; and the motion stimuli must be changing over time to implicate the vestibular system either directly or indirectly. There are two categories of sensory rearrangement and three types of signal conflict used to explain the circumstances that evoke motion sickness (Reason, 1978). The two categories of sensory conflict are visual-vestibular and canal-otolith. The three types of sensory conflict are; receipt of simultaneous contradicting signals, receipt of the first signal in the absence of the expected second signal, and receipt of the second signal in the absence of the first. Table 1 illustrates the causal circumstances all associated with motion sickness.

Type of Sensory Conflict	Visual (**A**) – Vestibular (**B**) (intersensory)	Canal (**A**)- Otolith (**B**) (intrasensory)
Type 1: A and B signals simultaneously give contradicting information	Watching waves from a ship Use of binoculars in a moving vehicle Making head movements while wearing an optical device that distorts the visual field Vision is distorted by an optical device Reading hand held material in a moving vehicle Cross Coupled (Coriolis, Illusions) Stimulation Simulator sickness (moving base)	Making head movements while rotating about another axis (Coriolis, or cross coupled, stimulation) Making head movements in an abnormal acceleration environment, which may be constant (e.g., hyper or hypo-gravity) or fluctuating (e.g., linear oscillation) Space sickness (fast head movement) Vestibular disorders (acute labyrinthitis, trauma)
Type 2: A signals are received but expected B signals are absent	Simulator sickness (fixed base) Cinerama/IMAX sickness Hunted swing (stationary position with swinging visual surroundings) Circular linear vection	Space sickness (slow head movement) Pressure vertigo Caloric stimulation of semicircular canals Vestibular disorders (cupulalithiasis, round window fistula)
Type 3: B signals are received but expected A signals are absent	Looking inside a moving vehicle without external visual reference Reading in a moving vehicle	Low – frequency translational oscillation Rotating linear acceleration vector

Table 1.   Six categories of sensory rearrangement. Listed are some of the known circumstances leading to motion sickness within the three types of signal conflict and the two categories of sensory (Benson, 2002; Reason, 1978)

3. Neural Mismatch Model and Sensory Conflict Theory

Reason, in 1978, went on to explain specificity and transfer of protective adaptation with his neural mismatch model. The premise set forth by the neural mismatch model is this: the neural memories stored for a comparable environment containing motion signals of previously experienced sets of motion stimuli are compared to the incoming set of motion stimuli. For an example, the neural memories stored for motion stimuli resulting from playing on a swing would be compared to the motion stimuli resulting from the subtle sway of riding in an elevator in a tall building. The results of these comparisons, if it exceeds a certain threshold, produce a mismatched signal and symptoms of motion sickness. Sustained neural mismatched signals update the neural memory stores as in a feedback loop. The neural mismatch model explains not only the process of adaptation, but also explains the rapid process of re-adaptation and certain factors related to susceptibility (Benson, 2002; Reason, Motion sickness adaptation: A neural mismatch model, 1978). Figure 2 shows a flow chart of the processes controlling the neural mismatch model. Oman (1990), realizing the analogy between the neural stores and control engineering observer theory, further refined the theory of neural mismatch and sensory conflict with a mathematical model postulating the processes of the central nervous system while controlling orientation of the body. Although Oman's model adds additional insight, he cautions "the physiological mechanisms underlying motion sickness remain poorly defined" (Oman, 1990; Benson, 2002).
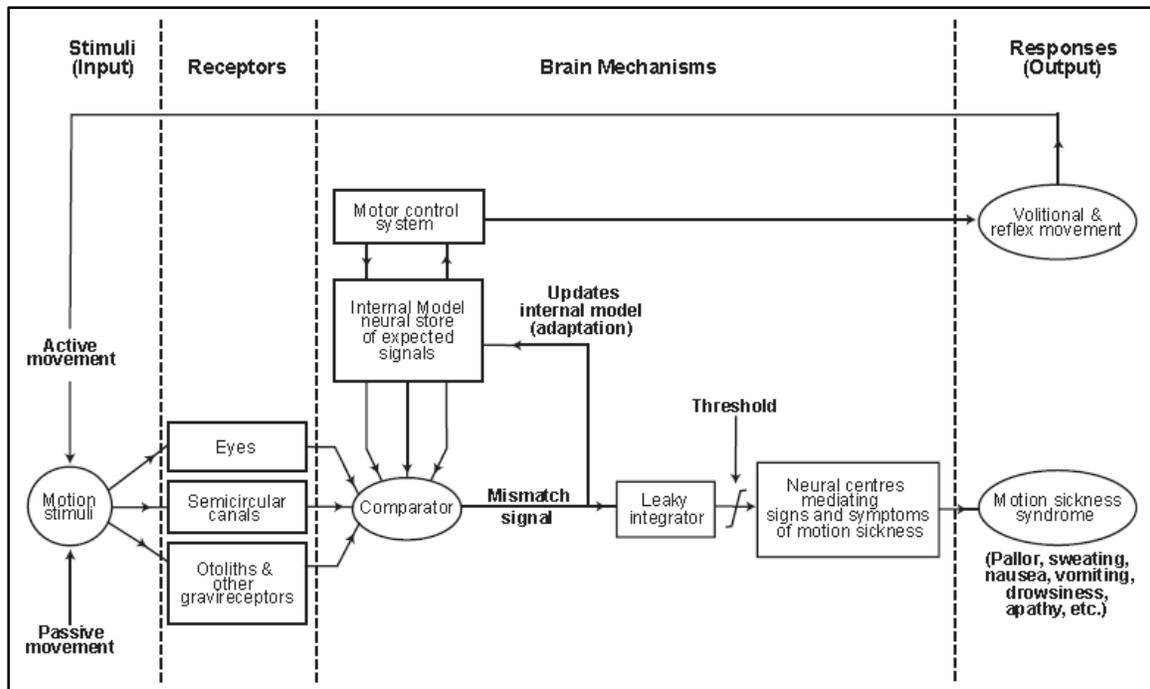
Figure 2.   Heuristic model of neural mismatch. As motion stimuli are perceived by the balance organs, they are compared to expected neural stores of the internal model for the motion environment. The excess signal induces motion sickness and the neural stores are updated (Benson, 2002).

C.   PERFORMANCE AND MOTION

1.   Performance in a Moving Environment

Measuring human performance in a moving environment is a difficult task because of the different effects that motion imposes on the human subject. Wertheim (1998) classified these effects into two types, general and specific. General effects, according to Wertheim, are motivational (caused by motion sickness), energetical (due to motion-induced fatigue), or biomechanical (due to motion-induced interruptions). The specific effects are defined as effects that interfere with specific human abilities such as cognition and perception. Through the examination of multiple studies carried out in a ship motion simulator, Wertheim concluded that the motion-induced performance degradation on complex tasks requiring cognitive skills, perceptual skills, and fine motor control are small but significant (Wertheim, 1998).

Bos and Bles (2000) state that, "Human performance at sea generally decreases with increasing severity of seasickness". The American, British, Canadian, and Dutch Working Group on Human Performance supported this claim. During a multi-national exercise in the North Atlantic in 1997, the North Atlantic Treaty Organization (NATO) Performance Assessment Questionnaire (PAQ) was administered to seven ships during the two-week exercise. This study produced 16,511 responses to the forty-one parameter questionnaire from 1,026 sailors (Colwell, 2000). The responses indicating problems with "carry/moving things", "had to abandon task", and "task took longer than usual" were all highly correlated with "stomach awareness" (Colwell, 2000). Additionally, three selected questions pertaining to task completion were further analyzed. The questions included responses pertaining to task that were either "not completed", "abandon", or "not allowed." All of the responses were then compiled into a task failure rate. This task failure rate increased as the reported misery rating increased (Bos, 2004). Colwell (2000) also concluded that crewmembers suffering from seasickness have more problems with performance of their tasks and that low or background levels of motion sickness are associated with serious performance problems on both cognitive and physical tasks.

With Archimedes' quote, there is little doubt that he was commenting on the feeling of remarkable dread experienced by those individuals who succumb to motion sickness. While active emesis precludes the performance of most tasks, performance decrements due to mild motion sickness are not clearly understood (Colwell, 1994). When it comes to performance implications of motion sickness, there are a number of inconsistent findings (Hettinger, Kennedy, & McCauley, 1989; Benson, 2002). Studies on motion exposure conducted in controlled environments often draw conflicting conclusions when compared to field studies (Hettinger, Kennedy, & McCauley, 1989; Rolnick & Gordor, 1991). Individual variability in susceptibility to motion sickness, adaptation to motion, and willingness to perform within the population are some possible reasons for the inconsistency (Benson, 2002; Reason, 1978). Another possible reason for the inconsistency is the lack of a standard and reliable human performance test (Rolnick & Gordor, 1991).

2. Cognitive Performance and Motion

Wertheim, in his 1998 article *"Working in a Moving Environment,"* cited numerous studies that measured cognitive performance in either a ships motion simulator or during trials at sea. He noted that most of the cognitive measures used in these studies were short in duration. The cognitive measures mentioned were; paper-and-pencil tasks, memory comparison test, digit addition test and visual-motor tasks. The general conclusion from these studies is that cognitive performance degradation was not observed (Wertheim, 1998).

An experiment to address soldiers' performance while riding in command and control vehicles was conducted by the U.S. Army Research Lab (Cowings, Toscano, DeRoshia, & Tauson, 1999). In this experiment, twenty-four soldiers were exposed to a four – five hour transit in three differently configured command and control vehicles. The primary objective of the study was to determine the differences in soldiers' performance under field conditions for three seat configurations. These configurations included forward, perpendicular and oblique, and between three vehicle conditions, parked, moving and during short halts. The participants completed the Delta Human Performance test battery: once upon entering the parked vehicle, twice while the vehicle was moving, and once during each of three the short halts. In addition to the cognitive test battery, participants reported their motion sickness symptoms and their current mood and alertness levels at specific times during the transit.

The soldiers completed two days of classroom training prior to the twelve days of field-testing. During the training period, each participant was required to complete the Delta Human Performance test eight times, four times a day. The performance scores from the last training session and the post-field testing session of the Delta Human Performance test were averaged together as a baseline. The baseline was then used to calculate decrements in participant performance. A decrement in performance was defined as a greater than five percent change in performance from the baseline in at least five of the seven subtasks (Cowings, Toscano, DeRoshia, & Tauson, 1999).

The study found that performance was degraded in eleven of the twenty-four participants when the vehicle was moving. Performance degradation in three of the seven subtasks was found for twenty of the participants. Furthermore, slight to severe motion sickness symptoms were reported by all participants. Drowsiness was the most commonly reported symptom during the study.

In this study, it is apparent that sopite syndrome affected the participants and may be the prime factor in the performance degradations recorded. This degradation could also be attributed to the effects of the vehicle's motion on the participants' psychomotor capacities. The study found significant change in the Delta Human Performance test for parked versus moving and parked versus short halts. Of particular interest, in this study, is the interaction between vehicle and condition. Cognitive performance was degraded for the perpendicular configuration for each vehicle condition (Cowings, Toscano, DeRoshia, & Tauson, 1999).

In a study by Coady (2010), seventeen participants performed various cognitive and psychometric task batteries in both motion and no motion conditions for a two hour period. The motion stimulus used in this study was a ship motion simulator using a protocol developed to maintain the subjects at moderate levels of motion sickness for extended periods. Three test sessions were conducted. During the introductory session, the participants received detailed instruction on the performance tests and the test procedures. Afterwards, the participants were allowed to practice the test battery. Once the participants felt comfortable with their performance, they underwent a twenty-minute practice session that simulated the testing conditions. Following the initial session, the participants were divided into two groups. They would complete the same twenty-minute practice session prior to the start of their first exposure. The second exposure followed the same process as the first with participants receiving the opposite treatment condition.

The test battery included three different types of tasks. The estimated time-on-task was given eight times during each two-hour session. The multi-attribute task battery, requiring participants to perform three subtasks simultaneously, was administered seven times. The amount of time for each multi-attribute task battery was varied three-to-eleven

minutes during the experiment. The cognitive test battery was given five times during each session. The psychometric test included the NATO PAQ and the National Aeronautics and Space Administration (NASA) Task Load Index (TLX). These tests were completed pre-, mid- and post-exposure (Coady, 2010).

The results of the psychometric test battery showed an increase in perceived difficulty as motion sickness symptoms increased. Performance on the cognitive test battery revealed minimal effects due to motion condition. The multi-attribute task battery showed no effects due to motion condition. The only dimensions of the NASA TLX effected by the motion condition were "Mental Demand," "Effort," and "Performance." The author concluded that the effects of motion condition on the estimation of time-on-task were nearly significant due to the p-value equal to 0.065 (Coady, 2010).

3.   After-effects of Motion Exposure and Cognitive Performance

Muth (2009) designed an experiment to study the duration of cognitive and physiological after-effects caused by exposure to uncoupled motion, which is the simultaneous exposure to two asynchronous motions. In this experiment, eleven participants, all pilots, flew a flight simulator stationed on an oscillating platform for one hour. Motion sickness assessments were taken every ten minutes during the trials. A cognitive battery consisting of math processing, two-handed tapping, grammatical reasoning, and code substitution was administered both before one-hour exposure and at given intervals after the exposure. Muth equated the decrement in cognitive test battery scores to the impairment caused by blood alcohol levels. The participants reported only mild motion sickness symptoms. Immediately and two hours after exposure to uncoupled motion the average blood alcohol levels were 0.053 and 0.051 respectively (Muth, 2009).

Ljungberg and Neely (2007) conducted an experiment to assess the after-effects of vibration and noise on cognitive performance. Thirty-two participants, sixteen with high and sixteen with low sensitivity to noise, were exposed to four conditions: no noise or vibration, noise only, vibration only, and both noise and vibration. Each exposure lasted forty-four minutes. The vibration stimulus was accomplished using a hydraulic

vibrator attached to a six degrees of freedom motion platform. Two loudspeakers at seventy-eight decibels provided the noise. A search and memory task was used to measure the participants' cognitive performance.

The Ljungberg and Neely concluded that the participants had lower performance on the cognitive test when vibration was present as compared to the other conditions. Furthermore, the participants completed the test faster with an increased error rate after exposure to vibration. Ljungberg and Neely conclude their study by identifying three areas for future study: how exposure time affects post-exposure performance, how other types of cognitive function are affected, and how long a recovery period is necessary before participants can perform normally again (Ljungberg & Neely, 2007).

4.   Marksmanship and Obstacle Course Performance and Motion

In a series of low frequency vibration experiments to assess the impact of vertical acceleration on human performance was conducted by Alexander, Cotzin, Hill, Ricciuti and Wendt in the 1945. The participants were exposed either to twenty minutes of vertical oscillations or until vomiting occurred. Four constant accelerations levels were used in the experiment that corresponded to wave frequencies of thirteen, sixteen, twenty-two and thirty-two cycles per minute. The corresponding wave heights were four foot, six foot eight inches, seven foot six inches, and nine feet. The participants' performance was measured before and after the exposure on an obstacle course, sixty yard dash, dart throwing, and the Mashburn Complex Coordination test. Alexander et. al., reported a four percent deficit for only the Mashburn Complex Coordination test for the participants who became sick. The authors concluded that brief motion exposure probably has no effect on laboratory motor performance test (Alexander, Cotzin, Hill, Ricciuti, & Wendt, 1945).

Stinson (1979) used obstacle course and marksmanship performance to gauge the effects of a high-speed landing vehicle on troop performance when compared to the current lower speed vehicle. The participants in the study were eighteen marine infantrymen. Performance measures were taken before and after either a thirty-minute open-ocean transit in an LVTP-7 amphibious assault vehicle or one hour open-ocean

transit aboard a high-speed planning hull vehicle. The study concluded that vehicle type had no significant effect on either marksmanship or obstacle course performance. The study did note large variations in marksmanship scores for some LVTP-7 trials when compared to concurrent trials for the high-speed landing vehicle. This study did not, however, compare pre-exposure to post-exposure performance, which is of interest.

More recently, studies involving marksmanship as a dependent variable have been conducted. The Swedish Defense Research Agency studied pre- and post-exposure marksmanship performance of twenty-two basic training conscripts to assess the influence of vehicle motion on performance (Dalhman, Nahlinder, & Falkmer, 2005). The participants' shooting accuracy, number of hits within the target frame, and spread, distance between the outermost hits in the target frame, were measured once after a thirty minutes and then after a forty minutes of vehicle motion exposure. This study found a significant correlation between subjective motion sickness ratings and decreased marksmanship performance, while, no differences were found in the number of target hits between the trials. The participants' perceived performance rating and measured performance was lower after the second motion exposure.

The U.S. Army Aeromedical Research Laboratory, in 2011, conducted a comparative study for a motion sickness prevention method using marksmanship as one of the dependent variables. This study exposed nineteen soldiers to eight hertz stroboscopic motion sickness countermeasure during transit in a helicopter. Marksmanship performance was compared for stroboscopic exposure and non-stroboscopic exposure. The authors stated that no effect for the stroboscopic exposure was found (Webb, Estrada, Athy, & King, 2011). Unfortunately, no comparison was made between the established baseline and post flight marksmanship performance.

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III. METHODOLOGY

A. APPROACH TO THE EXPERIMENTAL DESIGN

The Habitability Assessment Test (HAT) study was designed as a within-subjects, repeated measures quasi-experimental design with counterbalancing to control for order of exposure (Amphibious Vehicle Test Branch, 2012). Each participant's performance was compared to their own performance in each condition to control for individual variability. Participants were exposed to either one of three treatment conditions or a control condition. The treatments were either one, two, or three hours of waterborne motion aboard an amphibious vehicle. The control condition was defined as two hours inside a stationary amphibious vehicle. Additionally, each test vehicle used in the experiment was instrumented to record speed, motion data and cabin temperature. With a test design in place, the Amphibious Vehicle Test Branch (AVTB) and the other participating organizations applied for Institutional Review Board (IRB) approval. Following IRB approval, the participants were recruited for the study.

The participants were recruited via a request for participation message from various Marine Corps units onboard Camp Pendleton and Twenty-Nine Palms. From the pilot studies performed by students at NPS, the sample size necessary to maintain a confidence interval of 95 percent for a ten percent change in mean performance was calculated. From this calculation, it was determined that approximately 70 individuals would be needed. The HAT study was designed with four groups with 16 participants per group to accommodate the calculated sample size and the maximum seating capacity of the vehicles used in the study. Sixty-four volunteers were recruited for the study with 61 able to complete the necessary water egress training requirement. The 61 remaining volunteers then completed EFV and AAV safety training. Data was not collected on the amphibious vehicle crew members who were responsible for operating the amphibious vehicles.

Originally, the test design was blocked on length of exposure (0, 1, 2, or 3 hours), vehicle type (AAV or EFV) and ventilation (conditioned air or vented air). The number of trials for a full factorial experimental design was twelve since only one test vehicle type provided vented air. The number of trials was subsequently reduced from twelve to four trials due to time constraints and to minimize test participant fatigue. Noting differences between squads during the training week, the test design was modified to a full factorial design blocking on squad and length of exposure, with each squad completing all four exposures since length of exposure was the primary variable of interest. Due to vehicle and location availability, Squad C could not complete a three hour exposure and Squad D could not complete a two hour exposure, resulting in an incomplete randomized block design.

B.   VARIABLES

1.   Independent Variables

The independent variables in the study were the duration of waterborne motion, the vehicle type and the order of exposure. The HAT test was conducted under operational conditions which prevented any control of environmental variables. The uncontrollable environmental variables which were recorded included the test vehicle motion during water transit and the test vehicle internal cabin temperature. Each test vehicle was instrumented to record the motion and internal cabin temperature of the vehicle during waterborne exposure. Sea state varied over the duration of the test. Significant wave height, ambient temperature as well as water temperature were also recorded. The primary focus of the experimental design was the duration of waterborne motion and order of exposure to waterborne motion.

2.   Dependent Variables

The dependent or outcome variables for the HAT study addressed various aspects of an individual participant's performance. The performance measurements were selected to assess the participant's ability to move, shoot and communicate (Amphibious Vehicle

Test Branch, 2011). An additional measurement of motion sickness was also collected. These performance measures are as follows:

- Move: The length of time, measured in seconds, required for a participant to complete a physical coordination course (obstacle course).

- Shoot: The mean radius of impact (MRI), measured in millimeters, for five shots taken at a simulated distance of 300 yards from a standing position using the laser marksmanship trainer.

- Communicate: The participant's performance measured by a cognitive test battery.

- Motion Sickness: The participant's score on the self-reported Motion Sickness Assessment Questionnaire (MSAQ).

C.   PARTICIPANTS

The participants recruited for the HAT study were 61 enlisted Marines. The Marines came from various units and military occupational specialties. Participants were divided into four squads, A, B, C and D. All of the squads contained fifteen participants except Squad D, which contained sixteen. The participants' ages ranged from eighteen to twenty-eight years of age, with a median age of twenty-two years shown in Figure 3. The majority of the 61 Marines were Corporals (E-4) and Lance Corporals (E-3). The average number of years of service was 3.5 years shown in Figure 4.
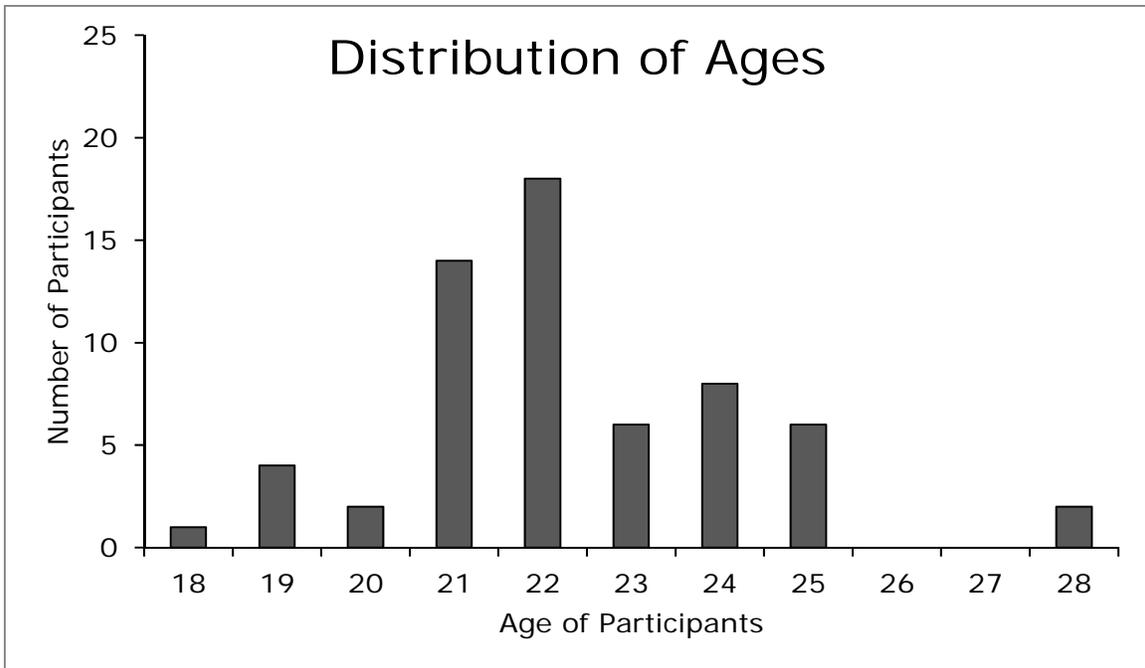
Figure 3.   Distribution of Ages–The median age of the participants was twenty-two.
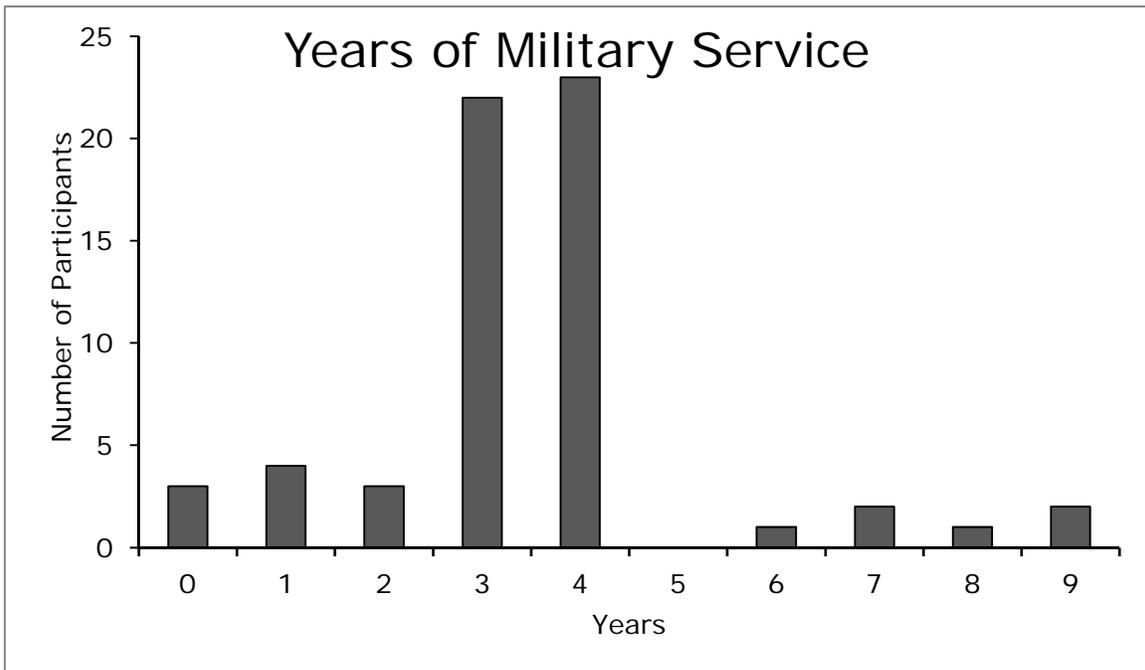
Figure 4.   Distribution of the number of years of Military Service–The average length of
service for the participants was 3.5 years.

Squad assignment was based on a stratified random assignment based on Motion Sickness Susceptibility Questionnaire (MSSQ) scores and amphibious assault vehicle landing experience. The distribution of MSSQ scores is shown in Figure 5. The median MSSQ score was 6.79. The mean MSSQ score was 17.70 with a standard deviation of 26.96. Landing experience in an amphibious assault vehicle was reported by fourteen of the participants (23%). First, individual participants with a MSSQ score greater than 45, one standard deviation above the mean, were randomly assigned to separate squads. Second, individual participants with amphibious landing experience were randomly assigned to separate squads. Additionally, one of the three Sergeants and the senior Corporal were assigned to each squad. Finally, participants were moved between squads to balance each squad's mean MSSQ score and amphibious vehicle experience. Furthermore, the participants were assigned identification numbers corresponding to each squad. Squad A was assigned participant numbers 1–15. Squad B was assigned participant numbers 21–35. Squad C was assigned participant numbers 41–55. Squad D was assigned participant numbers 61–76.
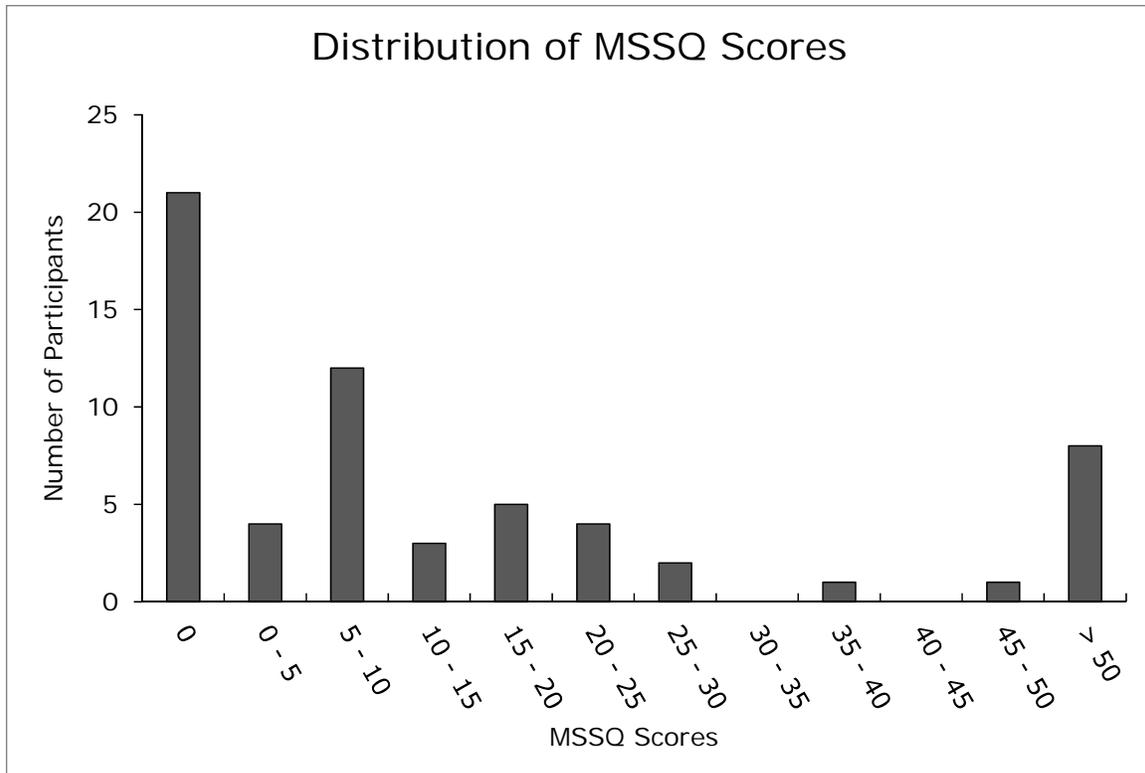
Figure 5.   Distribution of the participants' Motion Sickness Susceptibility Questionnaires Scores–The median MSSQ score was 6.79 and the mean MSSQ score was 17.70. Nine participants had a score above 45, one standard deviation above the mean.

D.   APPARATUS

1.   Motion Sickness Susceptibility Questionnaire

Motion Sickness Susceptibility Questionnaire (MSSQ) used during the HAT study was the revised questionnaire proposed by Gooding in 1998. The revised MSSQ is a variant of the MSSQ developed by Reason and Brand in 1975. The original MSSQ, as Golding points out, required "additional guidance and explanation" for participants to complete. The revised MSSQ simplified the completion and the scoring of the questionnaire while maintaining the integrity of the original MSSQ score (Golding, 1998). The linear relationship between the scores of the two questionnaires is shown in Figure 6. The questionnaire is completed in two parts. Part A of the questionnaire

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pertains to the participant's childhood experiences with motion sickness. Part B covers the experiences in regards to motion sickness the participant has had in past ten years. See Appendix for the MSSQ questionnaire.
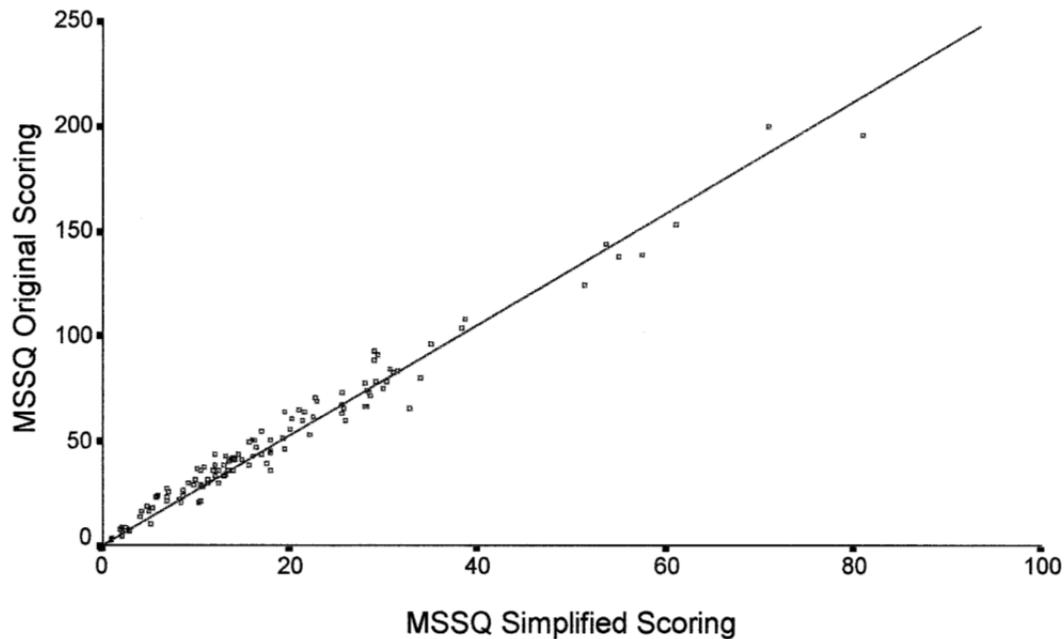
Figure 6.   MSSQ simplified scoring and Reason and Brand MSSQ. Plotted points are the MSSQ and MSSQ simplified scores taken from a study conducted by Golding. The performance of the MSSQ simplified closely follows the performance of the original MSSQ. The coefficient of correlation was $R^2 = 0.989$ and p-value (p = 0.0001) (Golding, 1998).

2.   Motion Sickness Assessment Questionnaire

The Motion Sickness Assessment Questionnaire (MSAQ) developed by Gianaros and colleagues (2001) was used to assess individual participant's self-reported level of motion sickness. The MSAQ provides a means of measuring the overall reported motion sickness (MSAQ Total) as well as scores for the four dimensions of motion sickness: gastrointestinal, central, peripheral, and sopite syndrome. The questionnaire consists of sixteen symptom statements; for example, after exposure to motion, participants were asked to respond "I felt drowsy" or "I felt queasy." (Gianaros, Muth, Mordkoff, Levine, & Stern, 2001). Each participant rated how accurately each of the symptom statements measured against their perceived symptoms on a scale from one (Not at all) to nine

(Severely). The maximum score on the MSAQ is 100 points and the minimum score is 11.11, Table 2. The MSAQ was completed immediately after exiting the test vehicle for each treatment condition and again one hour after the conclusion of the post-treatment test battery. The MSAQ Total score was used as the primary variable for motion sickness.

Instructions: Using the scale below, please rate how accurately the following statements describe your experience.

Not at all   Severely

1------2------3------4------5------6------7------8------9

1. I felt sick to my stomach (G)
2. I felt faint-like (C)
3. I felt annoyed/irritated (S)
4. I felt sweaty (P)
5. I felt queasy (G)
6. I felt lightheaded (C)
7. I felt drowsy (S)
8. I felt clammy/cold sweat (P)

9. I felt disoriented (C)
lo. I felt tired/fatigued (S)
11. I felt nauseated (G)
12. I felt hot/warm (P)
13. I felt dizzy (C)
14. I felt like I was spinning (C)
15. I felt as if I may vomit (G)
16. I felt uneasy (S)

Note. G: Gastrointestinal; C: Central; P: Peripheral; SR Sopite-related. The overall motion sickness score is obtained by calculating the percentage of total points scored: (sum of points from all items/144) X 100. Subscale scores are obtained by calculating the percent of points scored within each factor: (sum of gastrointestinal items/36) X 100; (sum of central items/45) x 100; (sum of peripheral items/27) X 100; (sum of sopite-related items/36) X 100

Table 2.   Motion Sickness Assessment Questionnaire. The questionnaire provides an overall assessment of participant's motion sickness symptoms and assessment of the participant's scores for the four dimensions of motion sickness, central, gastrointestinal, peripheral and sopite syndrome (Gianaros et al., 2001).

3.   Laser Marksmanship Training System

The Laser Marksmanship Training System (LMTS) employed during the HAT study was produced by BeamHit®. The BeamHit® system is a commercial-off-the-shelf (COTS) system used by the Army and Marine Corps. The system consisted of a muzzle-mounted visible light laser, a target capable of recording the visible light laser and a personnel computer for collecting the data. The muzzle-mounted laser was activated by dry-firing the weapon. The vibration caused by the weapon's firing mechanism triggered the muzzle-mounted visible light laser. With no recoil available to the weapon to recharge the firing mechanism, the weapon had to be manually charged by the shooter

between subsequent shots; therefore, to continue shooting, the participant had to lower the weapon and actuate the charging handle. The participants shot the target from a distance of fifteen meters. The target was an "E-type" silhouette scaled to simulate shooting distance of 300 yards. A depiction of the LMTS equipment and its utilization by the HAT study participants is shown in Figure 7.

Figure 7.   Laser Marksmanship Training System. BeamHit® equipment (left) and two participants shooting during the HAT study (right). The same BeamHit® equipped weapons were used by all participants. (Photo courtesy of AVTB)

During the HAT study, the participants shot two at a time in their respective squad's numerical order. Each participant was to shoot five shots within 30 seconds. There was no penalty assessed for not completing the five shots. The mean radius of impact was used to measure their performance. The mean radius of impact, measured in millimeters (mm), is the radius the circle that encloses the majority of the shots recorded. Mean radius of impact is calculated by finding the centroid of the recorded shots (average of x and y coordinates); then, computing the Euclidian distance from the centroid of the group and each recorded shot; and finally, taking the average of all the computed distances (Amphibious Vehicle Test Branch, 2011).

4.   Physical Coordination Course

The physical coordination course used during the HAT study was modeled after the Marine Corps Loading Effects Assessment Program (MCLEAP) used by the Marine Corps. Participants' completion time, measured in seconds, was used as the measure of performance. The course consisted of obstacles designed to challenge the participants' balance and agility. The physical coordination course required participants to navigate the following obstacles:

- balance log

- five bounding rushes

- wall

- window

- staggered cone agility run with obstacles

- inclined balance beam

During the HAT study, the participants ran the course twice each day. The first run of each day was completed prior to the participant's scheduled treatment. The second run of the course was completed after the scheduled treatment. Figure 8 shows the details of the physical coordination course setup. At the start of the course, participants ran fifteen yards to a balance log that was ten yards in length. Immediately following the balance log, the participants completed four staggered bounding rushes, each seven yards apart. For each bounding rush, they dropped to a prone firing position marked by a small stack of sandbags. Following the bounding rushes, the participants climbed over the wall obstacle, ran five yards, and climbed through a window obstacle. After the window obstacle, the participants completed a twenty-yard agility run requiring the participants to zigzag through six cones with sandbags placed in between them. The last obstacle encountered on the physical coordination course before the fifteen yard run to the finish was a staggered inclined balance beam. If a participant fell off either the balance log or the inclined balance beam, they were required to return to the start of that obstacle before continuing. Two identical courses were constructed to facilitate the timely completion of

the physical coordination course. Participants with an odd identification number ran on the first course and participants with an even identification number ran on the second.

Figure 8. Schematic of the Physical Coordination Course. The course was approximately 100 yards long and consisted of six types of obstacles. Participants completed the course as part of the test battery pre- and post-treatment (Amphibious Vehicle Test Branch, 2011).

Data collection for the physical coordination course was done with a radio frequency identification (RFID) station. The RFID receiver was placed at the start/finish line of each course. The participants wore colored vests indicating their squad and their individual identification number. Each vest contained RFID tags. The RFID system recorded the date and time when each participant crossed the start/finish line. The course completion time was calculated by subtracting the two times. The start/finish lines were also captured by video. In the event that the RFID did not record a start or finish time, the

video recorders were utilized as a means of completion time verification. The course completion time calculated from the video footage was used when the RFID system failed.

The physical coordination course was set up at Pelican Point beach adjacent to the Amphibious Vehicle Test Branch (AVTB) at Camp Pendleton, California. In the first week, testing was completed at Pelican Point. To facilitate a special test event that was completed in conjunction with the HAT study, the course was moved to Red Beach prior to the completion of the HAT test evolutions. The two locations were similar in terrain and the course layout at Red Beach was nearly identical to the layout at Pelican Point. Figure 9 shows the detailed course layout superimposed over an aerial view of Red Beach.
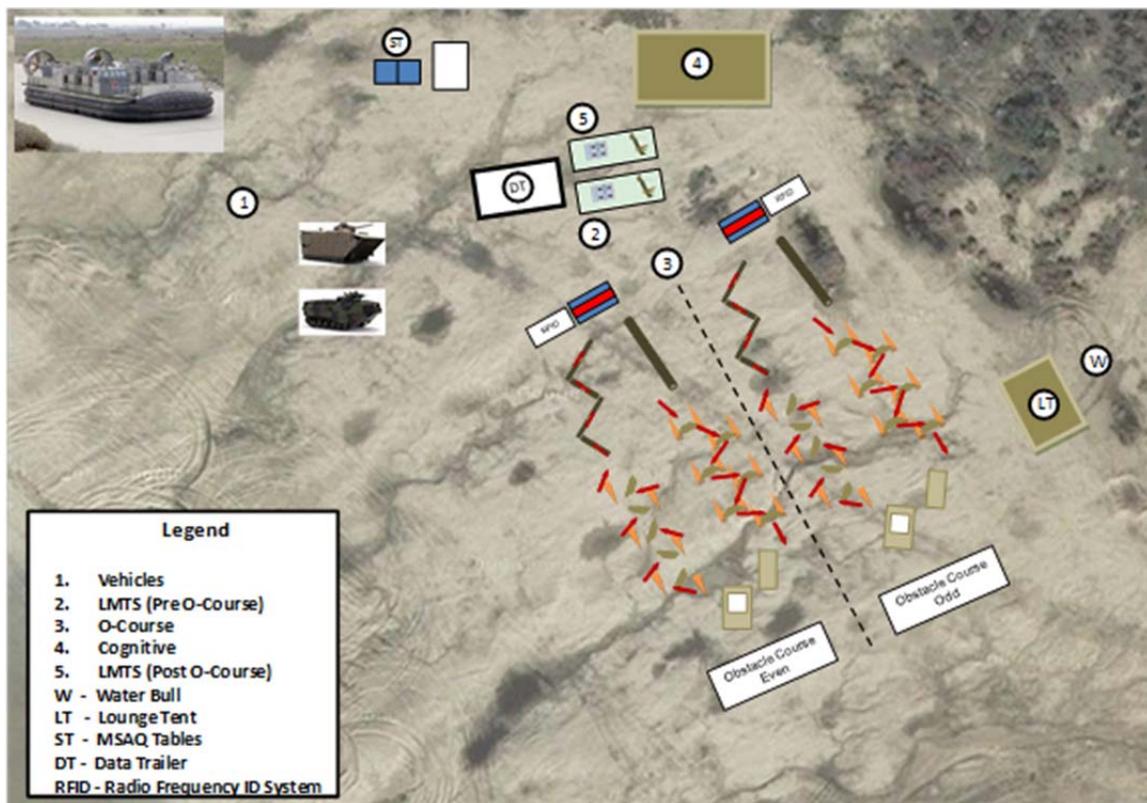
Figure 9.   Red Beach Obstacle Course. Aerial view of Red beach with both physical coordination courses superimposed. Participants with an odd identification number completed the course on the right while even numbered participants completed the course on left. (Courtesy of AVTB)

5.   Automated Neuropsychological Assessment Metric Switching Test

The Automated Neuropsychological Assessment Metric, Version Four (ANAM4®) software was used to assess differences in participant's cognitive performance during the HAT study. The ANAM4® Switching Test was chosen for its ability to assess multiple dimensions of cognitive performance while minimizing participant fatigue (Reeves, Winter, Bleiberg, & Kane, 2007). The Switching Test consists of 64 questions presented randomly. The ANAM4® software records the date and time of completion for each test. Additionally, the software records the participant's mean reaction time, number of correct responses, standard deviation of mean reaction time, and cognitive throughput (i.e., number of correct responses per minute) for each portion of the test. HAT study participants completed the test three times each day: pre-treatment, post-treatment, and one hour after the conclusion of the post-treatment test battery. Throughput was used as the performance measure for the Switching Test.

The Switching Test (Figure 10) is comprised of three parts: a visual-spatial test (Manikin Test), a mathematical test, and a red arrow indicating the test to be processed. All three portions of the Switching Test are displayed on the screen at the same time. The Manikin test requires the participant to identify the hand in which a manikin is holding an object that is identical to the object that appears below the manikin. The Manikin test assesses an individual's ability to discern three-dimensional spatial rotation, left-right orientation, problem solving and attention. The mathematical test requires the participant to solve a basic three step mathematical equation (e.g., $5 + 3 - 4 =$) and determine if the result is greater or less than five. The mathematical test assesses an individual's basic computational skills, concentration and working memory. Of the 64 questions completed during the Switching Test, there are 32 Manikin and 32 math questions. The red arrow centered at the bottom of the screen is the switch for the Switching Test. The switch indicates the test that the participant is to complete. The switch assesses the test participant's executive function and directed attention (ANAM4 User Manual, 2007). The switch occurs approximately 16 times during the test.

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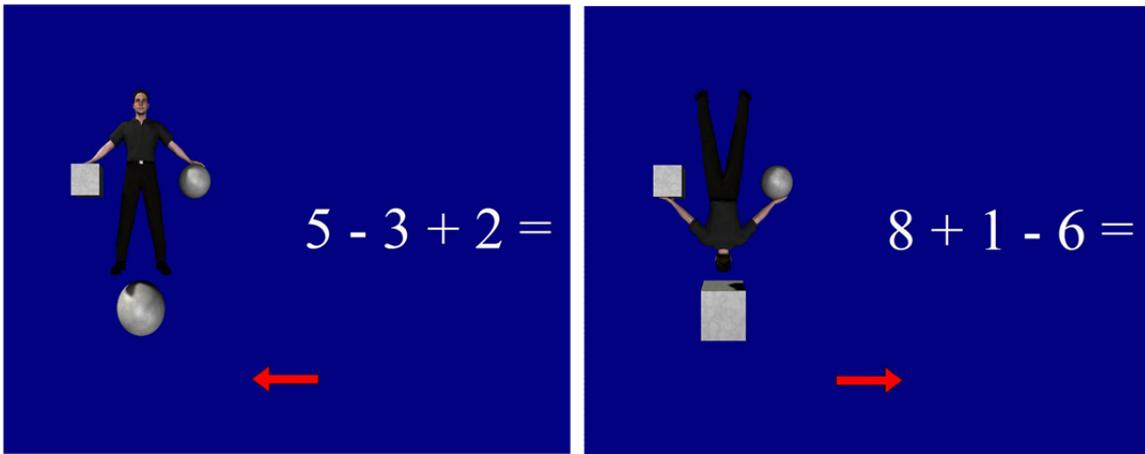
Figure 10.   Switching Test. For the test on left hand side, the participant would answer the spatial relations problem (left hand) while for the example on the right the participant would answer the math problem (solution is less than 5) (ANAM4 User Manual, 2007).

6.   Amphibious Assault Vehicles

Two types of amphibious vehicle were used during the HAT study, the Expeditionary Fighting Vehicle (EFV) and the Amphibious Assault Vehicle (AAV). The EFVs (PV3 and PV4) were both prototypes in the late stages of developmental test and evaluation. The AAVs (RAM1 and GATOR1) were both AAVP7A1 RAM/RS currently fielded by the Marine Corps (Figure 11). As shown, RAM1 is fitted with the Enhanced Appliqué Armor Kit. RAM1 was utilized for almost all of the AAV waterborne treatments since it is a more realistic portrayal of the AAVs currently used by the Marine Corps.

Figure 11. Vehicles utilized during HAT study. EFVs are both system demonstration and design prototypes. AAVs are both AAVP7A1 RAM/RS. RAM1 is equipped with Enhanced Appliqué Armor Kit. (Photos courtesy of AVTB)

Each amphibious test vehicle was equipped with instrumentation to record a number of environmental parameters to include internal and external temperatures were recorded. Vehicle speed and position were recorded via global positioning satellite data. The acceleration in the vertical plane encountered by each amphibious vehicle during the waterborne motion was recorded. Additionally, selected seating positions were equipped with accelerometers to measure the vertical acceleration experienced by the participants during the waterborne motion treatments.

E. PROCEDURES

1. Design of the Training Period

The HAT study consisted of a weeklong training period prior to the test of record. This training period was necessary to allow the test participants to reach asymptotic performance for the computerized cognitive test, the obstacle course, and the marksmanship test. For the training period, an abbreviated test battery was employed. In

the training phase, participants were not required to complete the MSAQ or participant surveys. The participants completed the training test battery twice a day, morning and afternoon. Amphibious vehicle familiarization events preceded the training test battery. The participants completed the same events onboard both types of amphibious vehicle used in the study each day. These familiarization events were periods of time inside an amphibious vehicle while stationary or moving on land. Additionally, during the training week, the participants were instructed on amphibious vehicle egress and safety procedures.

2. Training Period

The training week served two purposes. First and foremost, it afforded the participants time to acclimate to the test battery and the different amphibious vehicles used during the study. Secondly, the training week allowed the data collection team an opportunity to refine data collection procedures, test data collection equipment and address any issues or safety concerns prior to the completion of the test of record.

The agenda for the training week followed the crawl-walk-run philosophy. The first day was spent with equipment set up and test explanation as well as data collection team introductions. The second day was filled with detailed explanation of the test events and test battery walk through. The following days, participants spent one hour inside the vehicles on land, either static or moving, followed by the participants completing the test battery. The test battery was completed once in the morning with one type of vehicle and in the afternoon with the other type. With the data collection team satisfied with the progress, the final day of the training week involved a complete wet run of the experiment. The participants ran the test battery before and after a 30 minute amphibious evolution. The data collected during the training week consisted of LMTS, physical coordination course and the Switching Test.

3. Design of Test of Record

After the test participants achieved relative asymptotic performance during the training week, the test of record commenced. The participants were required to perform a

pre-treatment, post-treatment and a one-hour recovery test battery. The pre- and post-treatment test battery consisted of a laser marksmanship trainer system (LMTS), an obstacle course, a standardized computer-based cognitive test, and participant surveys. The one-hour recovery test only required the participants to complete the computerized cognitive test and a motion sickness assessment questionnaire (MSAQ). The pre- and post-treatment test batteries were identical in execution. The pre-treatment test battery contained a pre-treatment survey and the post-treatment test battery contained a post-treatment survey. The only notable difference between the test batteries was the completion of the MSAQ prior to the post-treatment test. The recovery test battery occurred one hour after the conclusion of the post-treatment test battery (Figure 12).
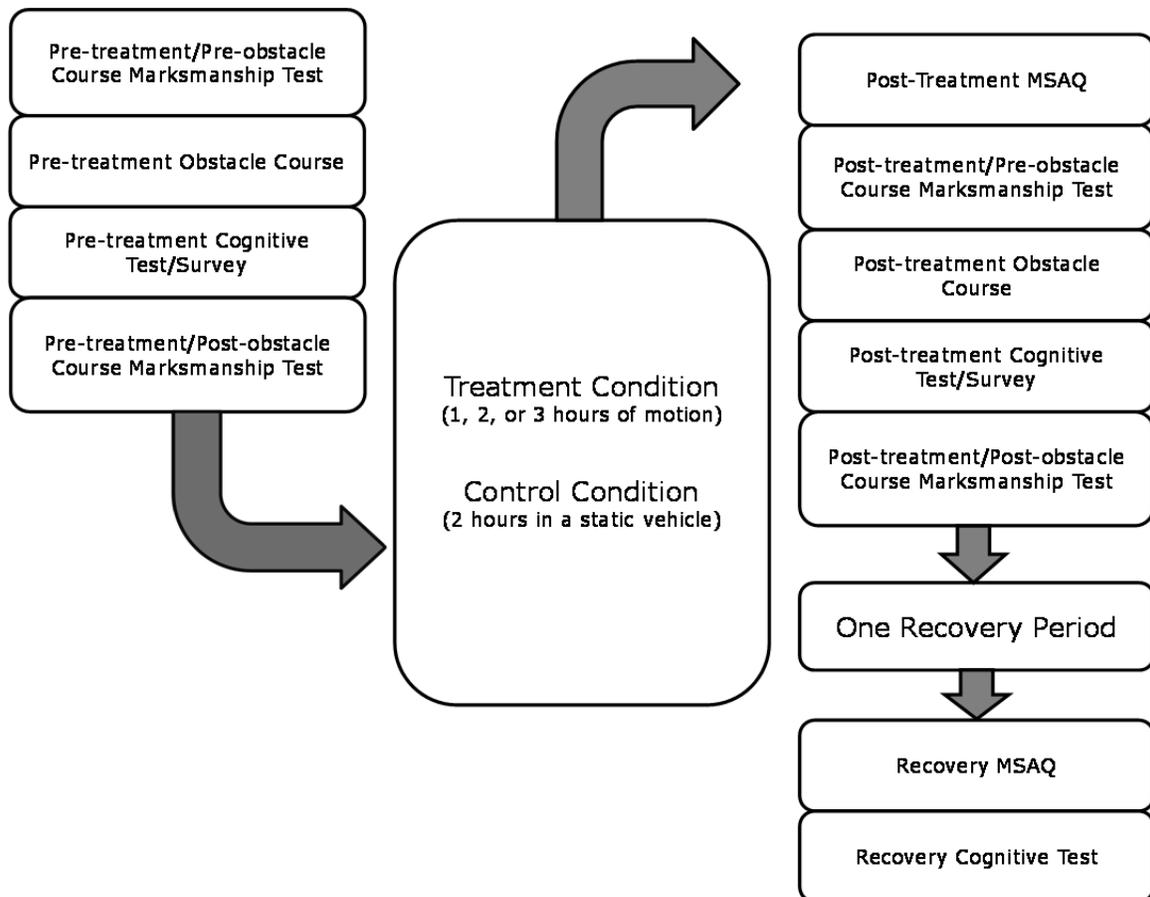
Figure 12.   Flow chart of the daily schedule for the HAT study.

4. Test of Record

The test of record was conducted on 15–24 August 2011. The HAT study events were completed 15 to 17 and 23 August. The special test events were completed on 22 and 24 August. The test site changed from Pelican Point to Red Beach on 21 August.

Each day of testing, the participants mustered at 0600. The squad leaders gathered their squads and the daily schedules were disseminated. Pre-treatment test battery commenced at 0700 at Pelican Point for the first two squads of the day. Only two test vehicles were in the water at any given time for safety reasons. The first test of the day took place at 0900 at Red Beach due to delays while transporting the participants to the test site. The remaining squads completed their pre-treatment test battery prior to the test vehicles return. On return from waterborne motion exposure, the squads would disembark the test vehicle and start the post-treatment battery. After completion of the post-treatment test battery, participants were observed for one hour. The participants then completed a recovery test battery consisting of the MSAQ and the Switching test. The participants completed this cycle only once per day.

The pre- and post-treatment test battery was identical with the exception of the MSAQ which was given only during the post-treatment battery. The participants shot prior to the physical coordination course, ran the physical coordination course, and then completed the Switching test and a pre-/post-treatment survey. Finally, they returned to the LMTS station to complete their post physical coordination course marksmanship test. Then, they were allowed to rest for one hour before repeating the Switching Test and MSAQ.

F. DATA SETS

1. Training Week

Data collection for the training week was limited to the measures of performance for the participants. The data collected included the following: LMTS mean radius of impact, physical coordination course completion times and the data collected by the

ANAM4 software for the Switching test. There were two collection points for each day for the participants. Due to scheduling of the water egress training for some of the participants, a small number of missing entries were recorded during the training period.

2. Test of Record

The data collected during the test of record included the LMTS, physical coordination test, Switching Test, and a post-exposure MSAQ. Additionally, the data for the test of record included environmental variables. Significant wave height, water temperature and wind velocity were recorded by AVTB for each day of testing. The motion experienced by each test vehicle while underway, the internal temperatures of the test vehicle, and the test vehicle direction and speed were recorded. Pre- and post-treatment surveys were completed by each participant. One hour after the conclusion of the post-treatment test battery, participants completed the Switching test and the MSAQ prior to concluding the days testing.

Table 3 shows the date and start time of each treatment for the squads and test vehicle used for the data collection. Squad A and Squad C received two one-hour exposures. Squad C did not receive a two-hour exposure. Squad D did not receive a three-hour exposure. There was no zero-hour exposure for the EFV with vented air.

The data was compiled into an Excel spreadsheet. Each row of the spreadsheet contained a participant's data for that day's test. The columns were the independent and dependent variables recorded.

| Squad | Exposure | | | | | | | | | | | |
| | 0 (Stationary for 2 Hours) | | | 1 Hour | | | 2 Hours | | | 3 Hours | | |
	AAV	EFV (AC)	EFV (V)	AAV	EFV (AC)	EFV (V)	AAV	EFV (AC)	EFV (V)	AAV	EFV (AC)	EFV (V)
A	8/17 0900				8/22 1100	8/15 0900			8/23 1000		8/16 0830	
B	8/23 1100			8/16 0830				8/15 0900				8/17 0830
C	8/23 1030			8/23 1130	8/17 0830					8/15 0900		
D		8/15 1030				8/23 1000	8/17 0830		8/16 0830			

Table 3.   Event Schedule for Data Collection.

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IV.   ANALYSIS OF DATA

Data analysis was performed on the training period and the test of record data sets. Each section of the data analysis includes a separate analysis for the performance measures within each data set. Regression models were constructed on the test of record data set. All of the analysis was performed using the JMP® Pro 10 statistical software package.

A.   EFFECTIVENESS OF TRAINING

The training period was conducted during the week of 9 - 12 August, 2011 at Pelican Point. Data for the 61 participants was collected in morning and afternoon test events. The purpose of the training period was to assure stable performance and test – re-test reliability prior to the commencement of the test of record.

1.   Marksmanship Performance

The Marine Corps prides itself on marksmanship ability, for every Marine is a rifleman first, and the participants of the HAT study were no exception. The majority of the participants, 53%, qualified as expert marksmen. As one would expect, the participants quickly achieved reliable performance on the Laser Marksmanship Training System (LMTS). Figure 13 is a graphical representation of the marksmanship scores for the training period and the pre-treatment scores recorded during the test of record.

In Figure 13, the dashed horizontal line is the median of the performance measure across all of the collected observations during the training week and the pre-treatment performance during the test of record. The vertical line indicates the separation of the training week from the pre-treatment observations taken during the test of record. To highlight the change in the performance measures from test event to test event, a trend-line of the mean of each test event is plotted. Additionally, boxplots for each test event are provided to facilitate an understanding of the magnitude of the variation within the participants of the performance measures. The boxplots depict a vertical rectangle with a

horizontal line segment for the median of the observations and whiskers at the top and bottom. The bottom of the rectangle represents the 25th percentile or lower fourth and the top of the rectangle represents the 75th percentile or upper fourth of the observations. The whickers encompass data points that fall outside of the rectangle and are less than one and a half times the difference of the upper and lower fourth. Data points outside of the whisker are outliers.
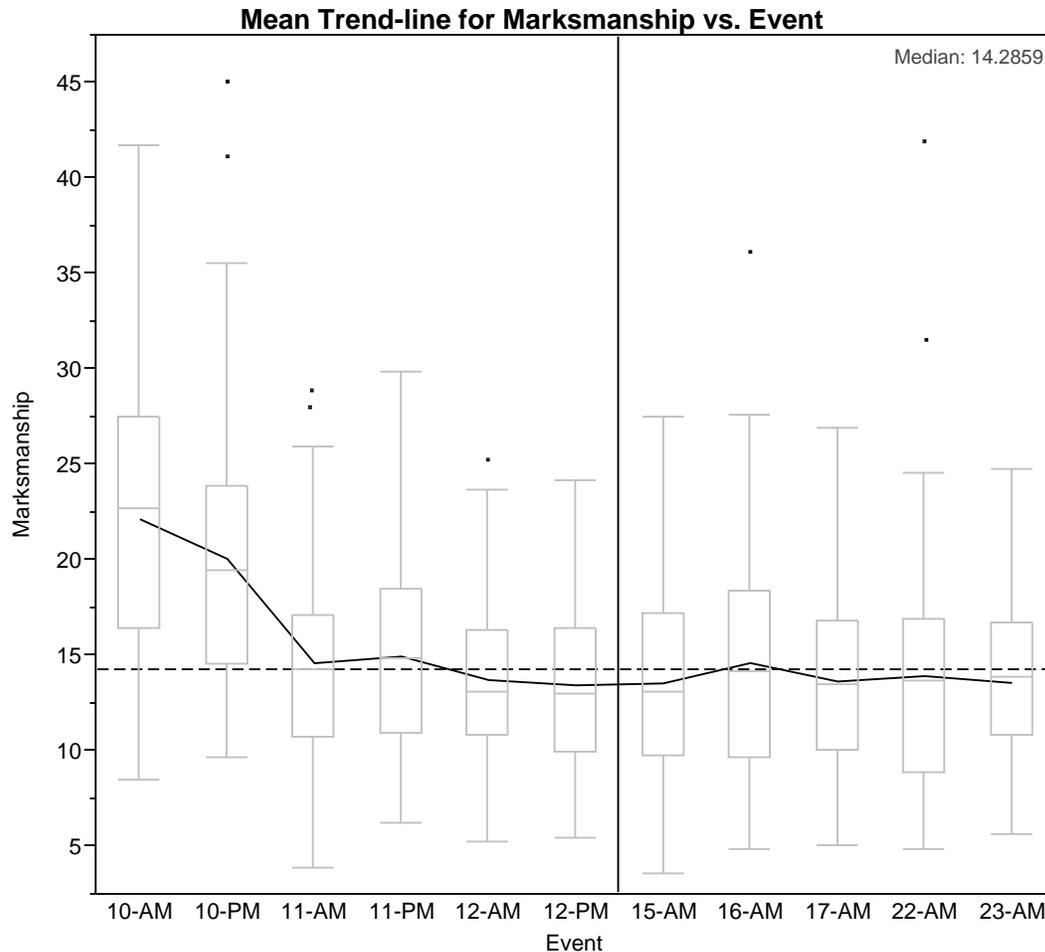
Figure 13.   Marksmanship vs. Date. After the first day of training, participants' marksmanship scores rapidly stabilize during the training week. Differences from day-to-day pre-treatment marksmanship scores are not statistically significant. The vertical line divides training week from the test of record.

As shown in Figure 13, after the first day of training, the participants quickly reached stable performance as seen by the convergence of the means trend-line and the

dashed median line. Excluding the marksmanship scores for the first day, a one-way ANOVA test revealed no significant differences in marksmanship performance ($F_{(8,526)}$ = 0.6552, p = 0.7310). Table 4 shows the day-to-day differences for the pre-treatment scores during the test of record with associated confidence intervals, t-tests and p-values. The day-to-day differences in marksmanship scores are small and have relatively large p-values indicating no significant differences in performance day-to-day. Thus, asymptotic performance was achieved.

Date	Date	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
15-AM	16-AM	-1.07	0.99	-0.88	3.01	0.2804
16-AM	17-AM	0.97	0.99	-0.98	2.91	0.3298
17-AM	22-AM	-0.28	0.99	-1.67	2.23	0.7774
22-AM	23-AM	0.36	1.00	-1.60	2.32	0.7183

Table 4.   Day-to-day differences in pre-treatment marksmanship scores. Note the overlapping confidence intervals and the p-values>0.05, indications of reliable performance from day-to-day.

2.   Obstacle Course

The participants' performance on the physical coordination course (O-Course) followed the same trend as their performance in marksmanship. After the first day of training, the participants' performance stabilized as shown the graphical representation of the data (Figure 14). The means trend-line converges to the dashed median line after the first day of the training period. The dotted vertical line marks the relocation of the test site to Red Beach. One-way ANOVA test reveals significant differences in performance for the 12-AM and the 15-AM test events when compared to that of the 22-AM and 23-AM ($F_{(8,516)}$ = 2.1146, p = 0.0329). The day-to-day performance for the pre-treatment O-Course scores recorded during the test of record, shown in Table 5, indicates no significant differences. Performance on the O-Course marginally improved on the last two days of testing. This improvement in participant performance is attributed to moving the test site to Red Beach to facilitate the special test event that coincided with the HAT study. With no test event to test event differences found, asymptotic performance was achieved.

Mean Trend-line for O-Course vs. Event
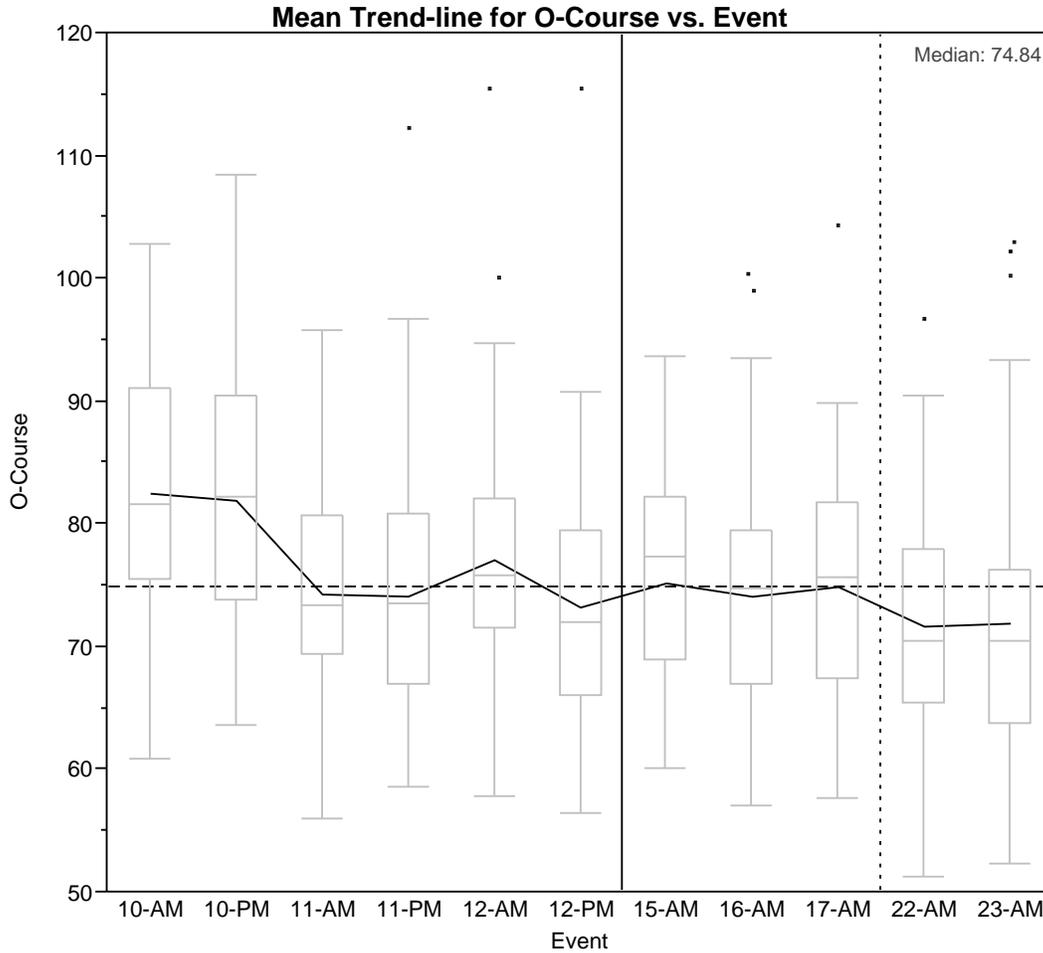
Figure 14.   O-Course vs. Event. After the first day of the training week, the participants'
performance on the obstacle course quickly stabilized as did with their
marksmanship scores. The vertical line divides the training week from the test of
record. The vertical dotted line marks the relocation of the test site to Red Beach.

Date	Date	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
15-AM	16-AM	2.36	1.69	-0.96	5.69	0.1628
16-AM	17-AM	-0.79	1.69	-2.54	4.11	0.6423
17-AM	22-AM	3.23	1.70	-0.11	6.57	0.0577
22-AM	23-AM	-0.25	1.70	-3.10	3.60	0.8838

Table 5.   Day to day comparison of pre-treatment obstacle course scores. No
significant differences were revealed, implying the attainment of asymptotic
performance.

3. Cognitive Performance

Learning effects associated with repeated practice impacted participants' performance on the Switching Test. Figure 15 is a graphical depiction of the data collected during the training period and the pre-treatment scores for the test of record. The mean trend-line does not converge with the dashed median line as it did for marksmanship and obstacle course performance. This failure to converge is indicative of the continued learning on the Switching Test.

Even with the exclusion of the first two days of training, a one-way ANOVA test on the training and pre-treatment Switching Tests shows significant differences among the test events ($F(8,527) = 5.2298$, $p < 0.001$). The 12-AM test event is different from the 16-AM, 17-AM, 22-AM and the 23-AM events. Additionally, the 15-AM test event is different from the 17-AM, 22-AM and the 23-AM events.

Although learning is still occurring, the day-to-day differences on the pre-treatment Switching Test during the test of record are not significantly different. Table 6 shows the results for the day-to-day comparison of the pre-treatment Switching Test scores recorded during the test of record. The small day-to-day differences and p-values greater than 0.05 allow for the conclusion that performance on the Switching Test had stabilized. These results are similar those found by Eonta et al., (2011) for ANAM4® test—re-test reliability and repeated performance. A satisfactory level of reliable and repeatable performance on the Switching Test was assumed to be attained.
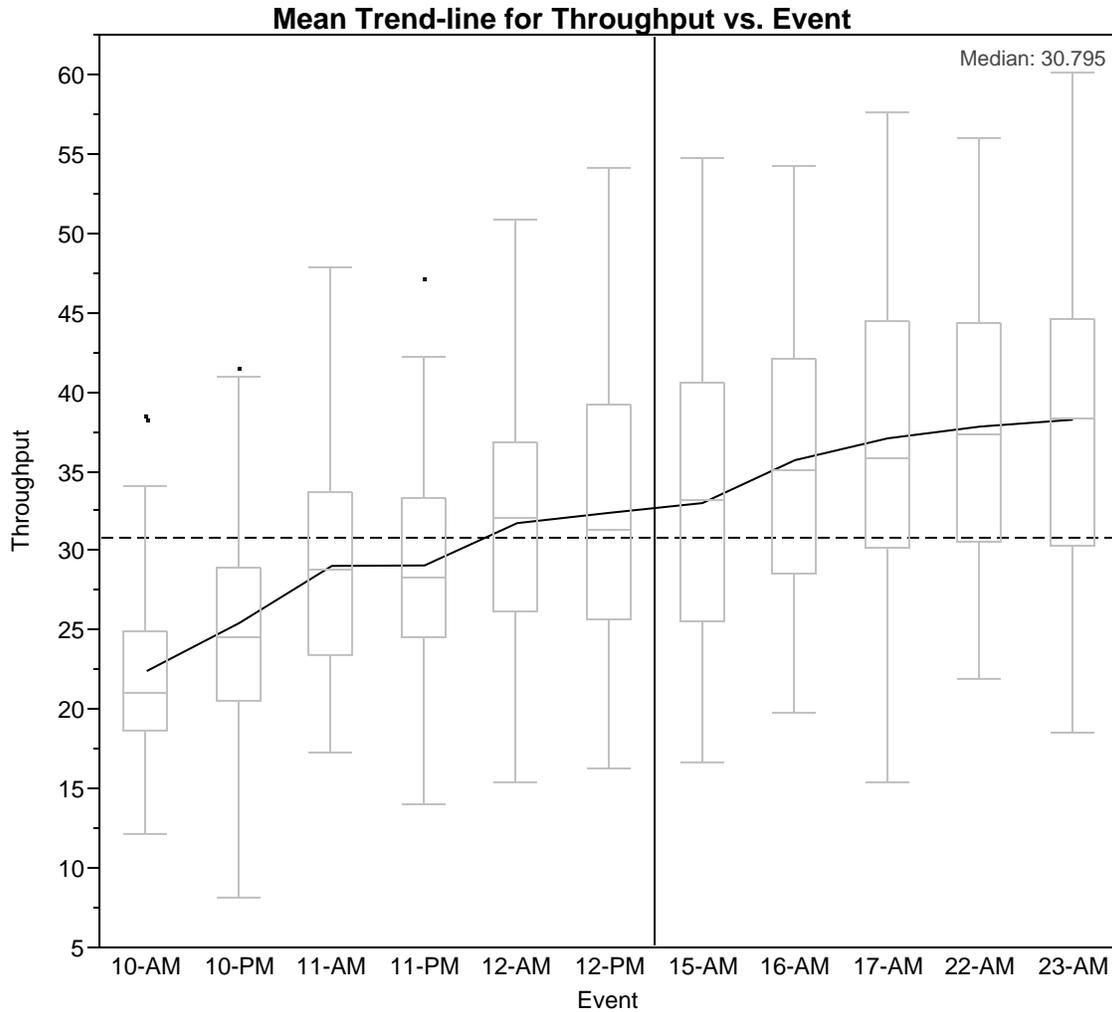
Figure 15.   Throughput vs. Event. From this graph, the incremental increases from test event to test event are apparent. Learning is affecting Switching Test performance.

Date	Date	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
15-AM	16-AM	-2.70	1.69	-0.62	6.03	0.1102
16-AM	17-AM	-1.37	1.69	-1.95	4.70	0.4164
17-AM	22-AM	-0.74	1.70	-2.60	4.07	0.6639
22-AM	23-AM	-0.44	1.70	-2.91	3.79	0.7959

Table 6.   Day-to-day differences in pre-treatment throughput. No significant differences were revealed by the day-to-day comparisons.

4.   Squad Effect during Training Week

As stated in chapter three, the data collection team noted differences in squad performance during the training period. Repeated measures ANOVA by squad and test event on the performance measures during the training week revealed significant differences in both test event and squad for the obstacle course and the Switching Test. The test events were found to have significant differences for obstacle course performance ($F(5,321.2) = 9.6098$, $p < 0.001$) and the Switching Test scores ($F(5,338) = 16.2743$, $p < 0.001$). Note: the denominator degrees of freedom are constructed using Satterthwaite's method (JMP, Version 10, 1987–2012). Student's t-test of squad across the test events shows Squad B's performance on the obstacle course to be different from Squad D ($p = 0.0213$). On the Switching Test, Squad A was found to be different from both Squads C and D ($p < 0.05$).

The differences in performance among the squads continued into the test week additionally affecting the marksmanship scores. Squad A's performance in marksmanship was found to be different from that of the other squads when tested across the training period and the pre-treatment test events during the test of record. The performance on the three performance measures by squad and testing week are plotted in Figure 16. The differences among the squads as shown by the bar graph are small but significant.
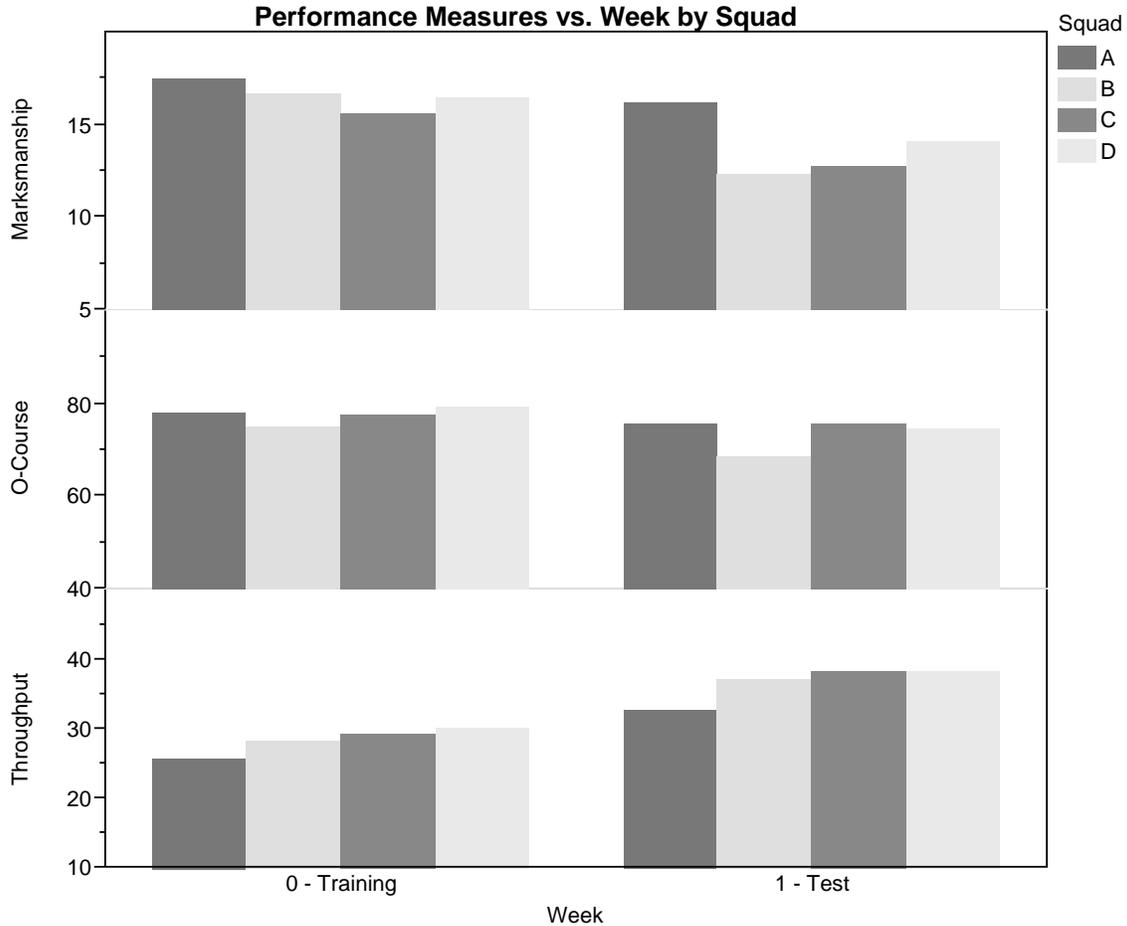
Figure 16.   Performance Measures by Squad. Squad A's performance for marksmanship and Switching Test where different from the other squads. Squad B's performance on the O-Course was different from the other squads.

B.   TEST OF RECORD

The test of record was conducted 15–17 August 2011 at Pelican Point and 22–23 August 2011 at Red Beach. To evaluate the participants' performance during the test of record, graphical representations of the participants' post-treatment performance, summary statistics, univariate repeated measures ANOVA test, and Tukey Honestly Significant Difference (HSD) tests by treatment level, exposure to waterborne motion, were performed for each performance measurement. The graphical representations of the data are plotted for the participants' performance by treatment level. Also included in the graphical representation are a mean trend-line with a 95 percent confidence interval and

boxplots, as in the previous section, to facilitate an understanding of the magnitude of the variation within the participants' performance at each level.

Additionally, participants who reported motion sickness symptoms (sick = 1) and those that did not report motion sickness symptoms (sick = 0) on the post-treatment MSAQ were separated. Participants with a MSAQ score higher than that experienced by the 90th percentile of the participants during the two-hour static treatment were considered to be suffering from motion sickness (MSAQ > 20.0694).

Table 7 is a table of the percentage of participant for each exposure reporting to be sick and not sick. There were 187 observations recorded for participants that did not report motion sickness symptoms. There were 68 observations for participants that reported to be suffering from motion sickness symptoms. Thirty-one of the participants reported to be sick for at least two of the treatments levels during the test of record.

Percentage of Participants Sick and Not Sick by Exposure							
Not Sick				Sick			
0	1	2	3	0	1	2	3
90.00%	75.56%	60.66%	63.64%	10.00%	24.44%	39.34%	36.36%

Table 7.   Percentage of Participant Not Sick and Sick by Exposure.

Analysis of the effects of the exposure, treatment levels, on the sick and not sick is done in the same manner as the analysis of the all of the observations. The same style of graphical representations are presented with not sick and sick plotted together. Additionally, summary statistics for both not sick and sick, univariate repeated measures analysis, and Tukey HSD tests by treatment level were conducted for each performance measurement.

1.   Marksmanship Performance

Post-exposure performance on the LMTS is graphically represented in Figure 17. The means trend-line for the mean radius of impact rises from the zero-hour treatment of 12.83 mm to the two-hour treatment level of 16.62 mm. The line falls from the two-hour level to the three-hour level of 14.07 mm. Table 8 contains the summary statistics for the observations collected for the sixty-one participants for each treatment level. It is

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important to note that there are repeated observations at the one-hour level for Squads A and C and repeated observations for Squad C at the two-hour treatment level. The mean radius of impact for the 246 recorded observations was 14.72 mm with a standard deviation of 10.8020 mm. Repeated measures analysis by treatment level revealed no significant differences between treatment levels (F(3,200.8) = 1.3230, p = 0.2680, R^2 = 0.1875).

There were ten missing observations for Squad C on 17 August 2011 due to an equipment failure. The scale for the y-axis on Figure 17 was truncated for better viewing. Three participants' scores were greater than a forty millimeter mean radius of impact on the LMTS and these scores fall considerably outside the whisker on the boxplots. Participant 1 scored a 91.47 mm after a three-hour exposure on 15 August. Participants 61 and 73 scored 89.06 mm and 109.88 mm, respectively, after the two-hour exposure on 16 August. The large variation for the two-hour exposure is partially attributed to participants 61 and 73 scoring quite high and participant 69 scoring a low 0.48 mm during the same trial.
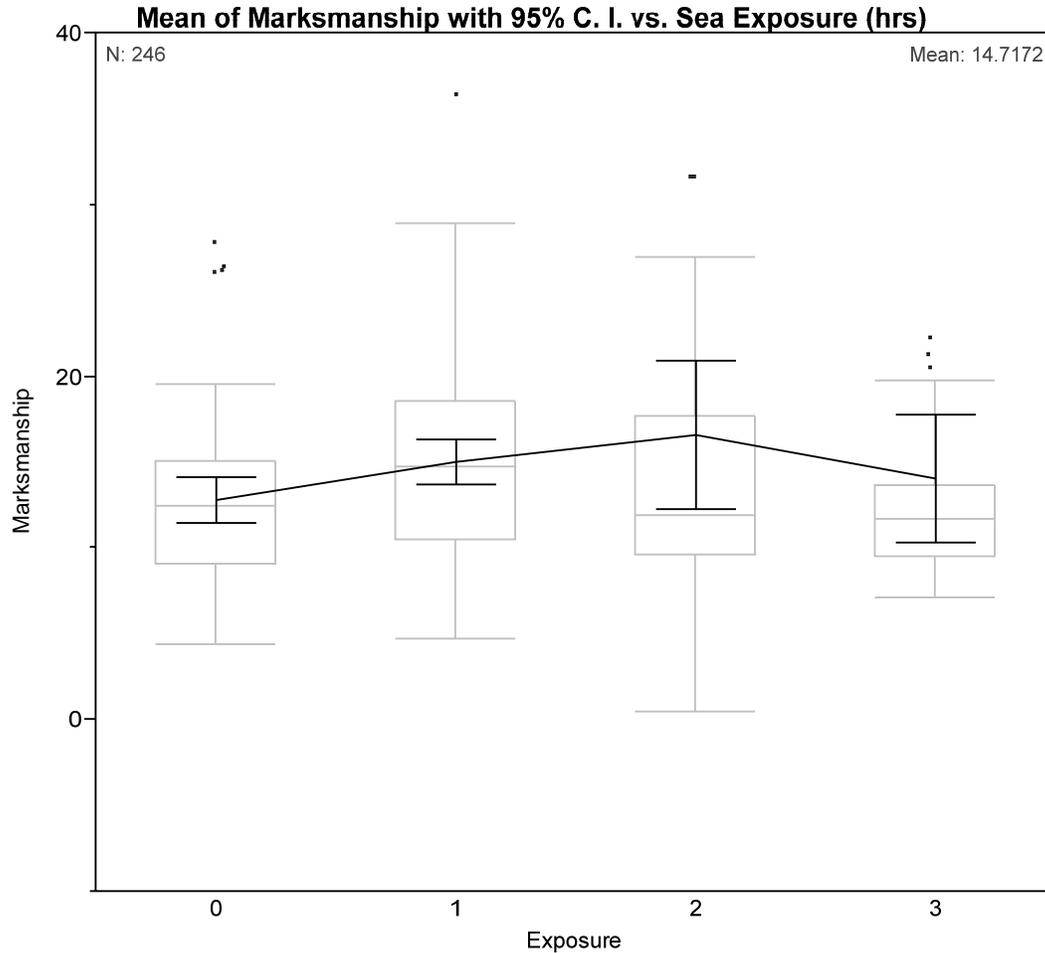
Figure 17.   Marksmanship scores vs. exposure to motion. Three participants' marksmanship scores are omitted to facilitate better viewing of the data.

Summary Statistics for Marksmanship Post Exposure							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	60	12.83	5.15	4.41	27.82	14.16	11.49
1	80	15.05	5.90	4.76	36.37	16.36	13.73
2	61	16.62	16.86	0.48	109.89	20.94	12.30
3	45	14.07	12.39	7.11	91.47	17.80	10.35

Table 8.   Summary Statistics for Marksmanship.

When the data are separated by sick and not sick as depicted in Figure 18, a repeated measures ANOVA test does not show significant differences between sick and not sick ($F(1,213.9) = 2.0686$, p = 0.1518, $R^2 = 0.1683$). Repeated measures ANOVA tests for sick and not sick by treatment levels also do not show any significant differences. The summary statistics for the observations recorded of the participants that

reported to be sick and not sick are shown in Table 9. Participant 9 was missing a MSAQ score for on 16 August and was therefore omitted from the analysis of sick and not sick. The participants that are not reporting to be suffering from motion sickness symptoms scores for the zero-hour, 12.88 mm, and three-hour, 12.35 mm, treatments are nearly equivalent. Repeated measures analysis by treatment level for participants, which are not reporting to be sick, approached significance (F(3,134.9) = 2.5810, p = 0.0561, R^2 = 0.5449).
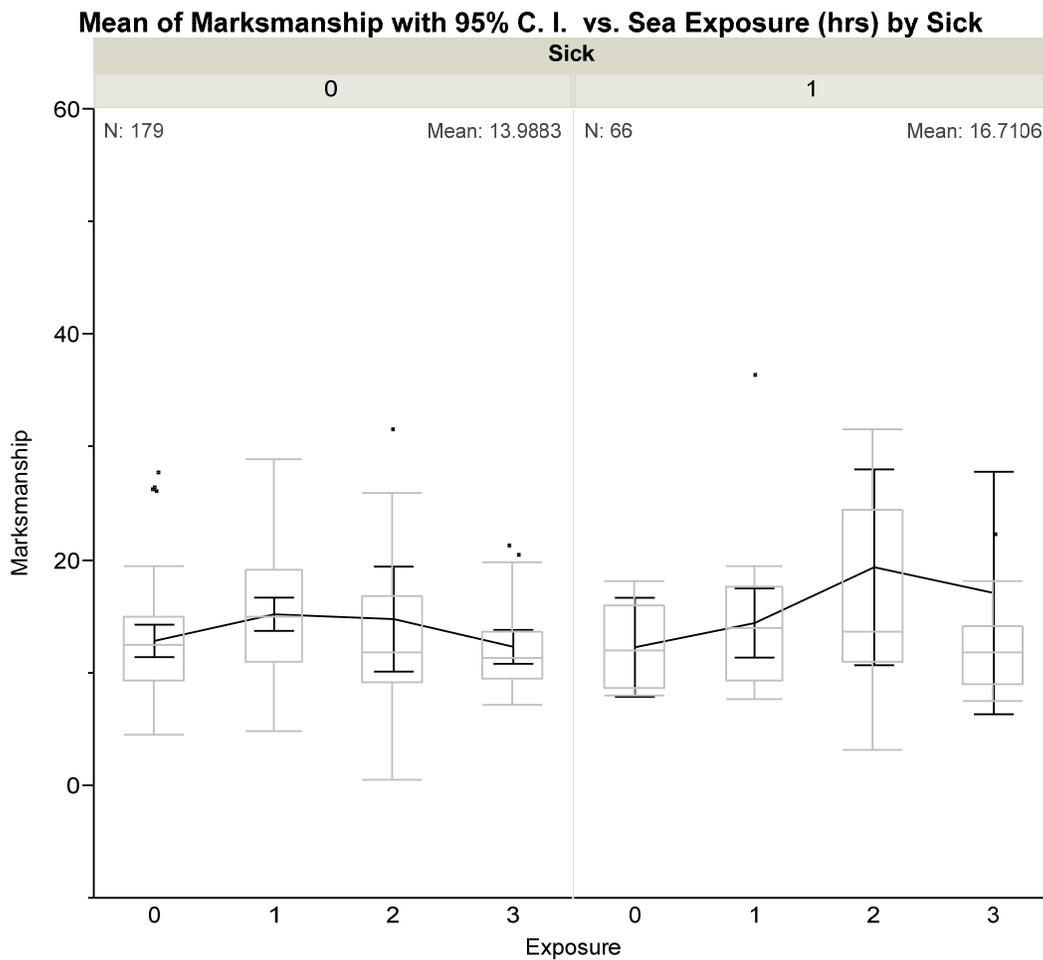
Figure 18.   Marksmanship vs. Sea Exposure by Sick/Not Sick.

Summary Statistics for Marksmanship Post Exposure (Not Sick)							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	54	12.88	5.28	4.41	27.82	14.32	11.44
1	60	15.24	5.70	4.76	28.84	16.71	13.77
2	37	14.81	13.97	0.48	89.08	19.47	10.15
3	28	12.35	3.89	7.11	21.29	13.86	10.84
Summary Statistics for Marksmanship Post Exposure (Sick)							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	6	12.31	4.19	7.88	18.16	16.71	7.92
1	20	14.47	6.57	7.57	36.37	17.54	11.39
2	24	19.41	20.57	3.08	109.89	28.09	10.72
3	16	17.12	20.18	7.48	91.47	27.88	6.37

Table 9.   Summary Statistics for Marksmanship for Not Sick and Sick by Exposure.

2.   Obstacle Course Performance

Post-treatment obstacle course performance is graphically depicted in Figure 19. The means trend-line for obstacle course to a certain degree is flat. Additionally, the confidence intervals and whisker on the boxplots are fairly equivalent in height. Table 10 contains the summary statistics for the observations collected for the 61 participants for each treatment level. It is important to note that there are repeated observations at the one-hour level for Squads A and C and repeated observations for Squad C at the two-hour treatment level. The mean for the 256 observations was 72.27 seconds with a standard deviation of 9.81 seconds.   Repeated measures analysis by treatment level revealed no significant differences $(F(3,196.7) = 1.9143, p = 0.1285, R^2 = 0.7028)$.
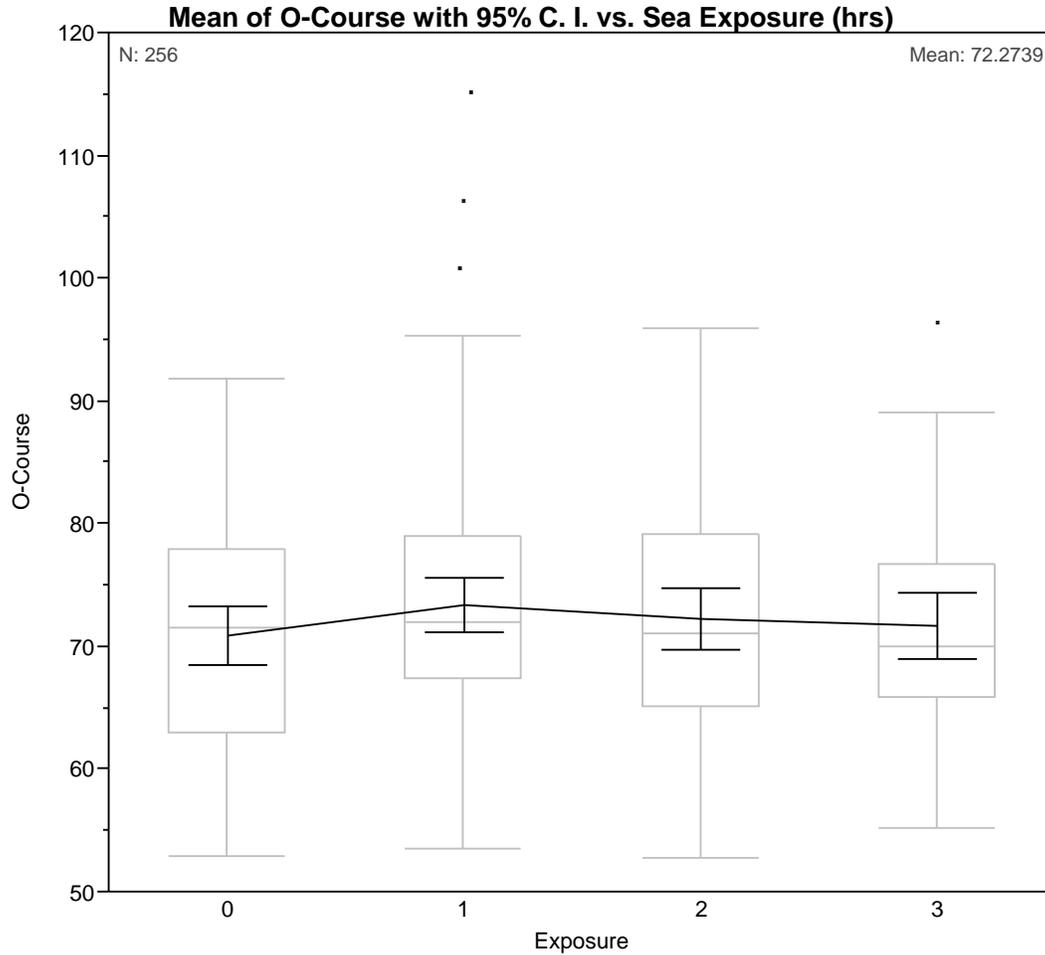
Figure 19.   Obstacle Course vs. Sea Exposure. The means trend-line is nearly horizontal, indicating no differences in performance across the exposures.

Summary Statistics for Obstacle Course Post Exposure							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	60	70.93	9.26	52.88	91.75	73.32	68.54
1	90	73.43	10.58	53.52	115.19	75.65	71.21
2	61	72.29	9.80	52.79	95.87	74.80	69.78
3	45	71.73	8.96	55.15	96.29	74.42	69.04

Table 10.   Summary Statistics for Obstacle Course.

When the data are separated by sick and not sick as depicted in Figure 20, a repeated measures ANOVA test does not show significant differences between sick and not sick (F(1,234.2) = 0.5498, p = 0.4592, R^2 = 0.6958). The summary statistics for observations recorded of the participants that reported to be sick and not sick are shown in Table 11. Participant 9 was missing a MSAQ score for 16 August and was omitted

from the analysis of sick and not sick. Repeated measures analysis by treatment level for participants, which are not reporting to be sick, was significant ($F_{(3,137.3)} = 3.0992$, p = 0.0289, $R^2 = 0.7293$). Tukey HSD test reveals a difference in the zero-hour treatment level, 70.12 seconds, from the one-hour treatment level, 73.61 seconds (p = 0.0223). Repeated measures analysis by treatment levels for participants, which are reporting to be sick, was not significant ($F_{(3,44.7)} = 1.0915$, p = 0.3625, $R^2 = 0.7588$).
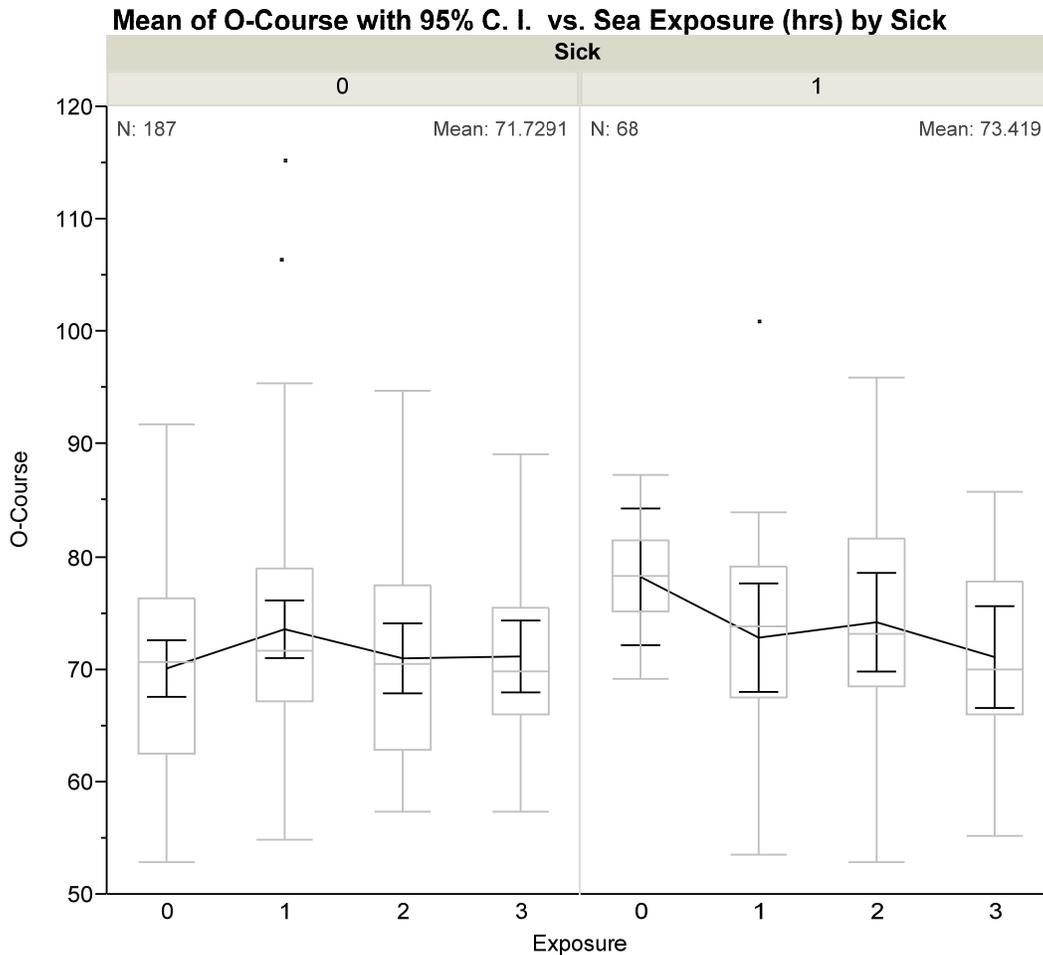
Figure 20. Obstacle Course Performance vs. Sea Exposure by Sick. The one-hour exposure is different from the zero-hour exposure for participants that did not report to be suffering from motion sickness symptoms.

Summary Statistics for Obstacle Course Post Exposure (Not Sick)							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	54	70.12	9.25	52.88	91.75	72.64	67.59
1	68	73.61	10.56	54.80	115.19	76.17	71.06
2	37	71.03	9.33	57.39	94.72	74.14	67.92
3	28	71.19	8.25	57.35	89.06	74.39	67.99
Summary Statistics for Obstacle Course Post Exposure (Sick)							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	6	78.27	5.78	69.20	87.31	84.34	72.20
1	22	72.87	10.88	53.52	100.80	77.69	68.04
2	24	74.24	10.38	52.79	95.87	78.62	69.85
3	16	71.14	8.49	55.15	85.73	75.66	66.61

Table 11.   Summary Statistics for Obstacle Course for Not Sick and Sick.

3.   Cognitive Performance

Post-treatment Switching Test performance is graphically depicted in Figure 21. The trend-line of the means has a noticeably negative slope. The means fall from 38.12 correct responses per minute for the zero-hour exposure to 34.56 correct responses per minute for the three-hour exposure. Table 12 contains the summary statistics for the observations collected for the 61 participants at each treatment level. It is important to note that there are repeated observations at the one-hour level for Squads A and C and repeated observations for Squad C at the two-hour treatment level. The mean for the 256 observations was 36.80 correct responses per minute with a standard deviation of 9.7928 correct responses per minute. Repeated measures analysis by treatment levels reveals a significant difference ($F(3,194.2) = 5.2909$, $p = 0.0016$, $R^2 = 0.8437$). Tukey HSD test reveals a significant difference in performance between the three-hour treatment level and both the zero- and one-hour treatment levels ($p = 0.0068$ and $p = 0.0056$ respectively).

Mean of Throughput with 95% C. I. vs. Sea Exposure (hrs)
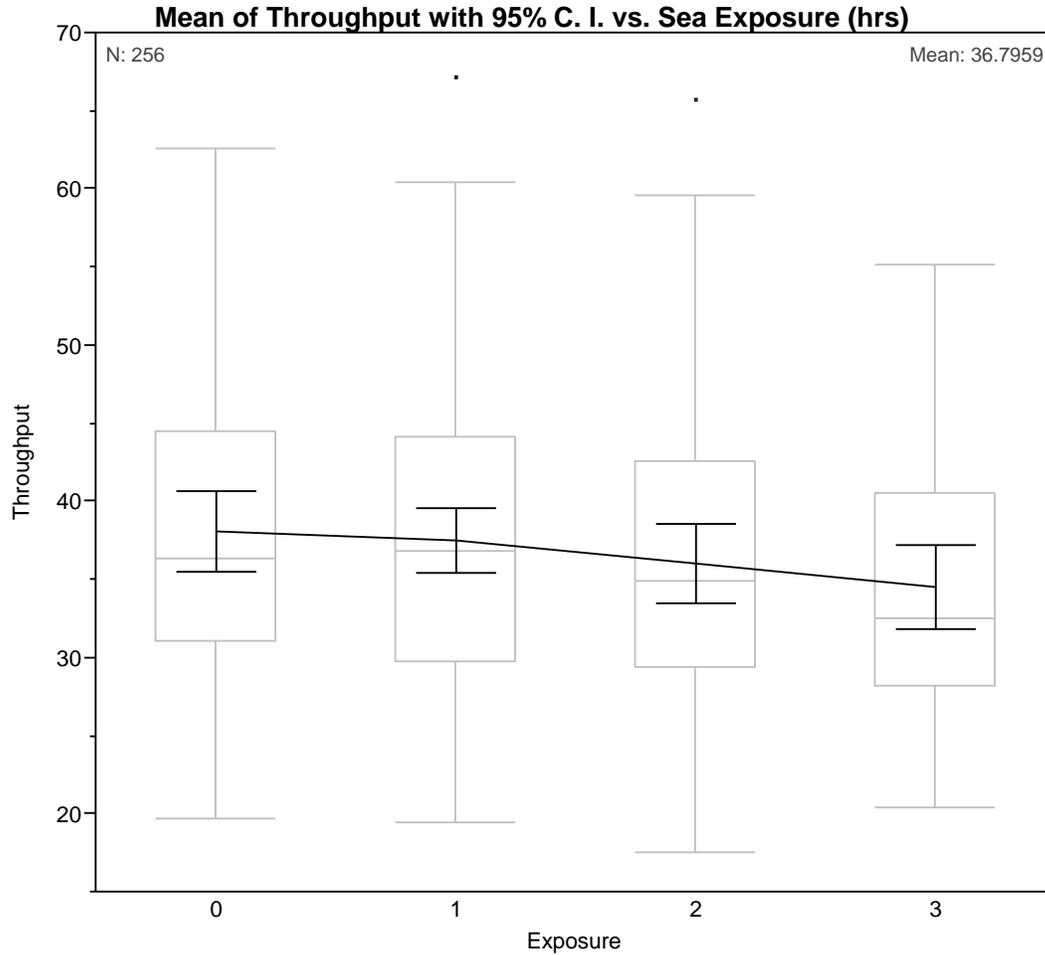
Figure 21.   Throughput vs. Sea Exposure. The slope of the means trend-line is negative, indicating a decrease in performance across the exposure levels.

Summary Statistics for Throughput Post Exposure							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	60	38.12	9.99	19.73	62.54	40.70	35.53
1	90	37.54	9.89	19.47	67.09	39.61	35.47
2	61	36.06	9.94	17.57	65.72	38.60	33.51
3	45	34.56	8.95	20.37	55.17	37.25	31.87

Table 12.   Summary Statistics for Throughput.

When the data are separated by sick and not sick as depicted in Figure 22, there is a noticeable decrease in the slope of the means trend-line as the line progresses from the two-hour to three-hour treatment level. However, the repeated measures ANOVA test does not show a significant difference between sick and not sick ($F(1,214.8) = 2.2651$, $p = 0.1338$, $R^2 = 0.8330$). The summary statistics for observations recorded of the

participants that reported to be sick and not sick are shown in Table 13. Participant 9 was missing a MSAQ score for 16 August and was omitted from the analysis of sick and not sick. Repeated measures analysis by treatment level for participants, which are not reporting to be sick, was significant ($F(3,130.4) = 4.2630$, $p = 0.0066$, $R^2 = 0.8676$). Tukey HSD test reveals differences in both the two- and three-hour treatment levels, 36.49 and 33.87 correct responses per minute respectively, from the zero-hour treatment level of 38.09 correct responses per minute ($p = 0.0263$ and $p = 0.0279$ respectively). Repeated measures analysis by treatment levels for participants, which are not reporting to be sick, was also significant ($F(3,42.04) = 3.3546$, $p = 0.0277$, $R^2 = 0.8683$), but the Tukey HSD test did not reveal a difference among the treatment levels. The confidence interval ranges for comparisons among treatments on the Tukey HSD tests included zero.

Mean of Throughput with 95% C. I. vs. Sea Exposure (hrs) by Sick
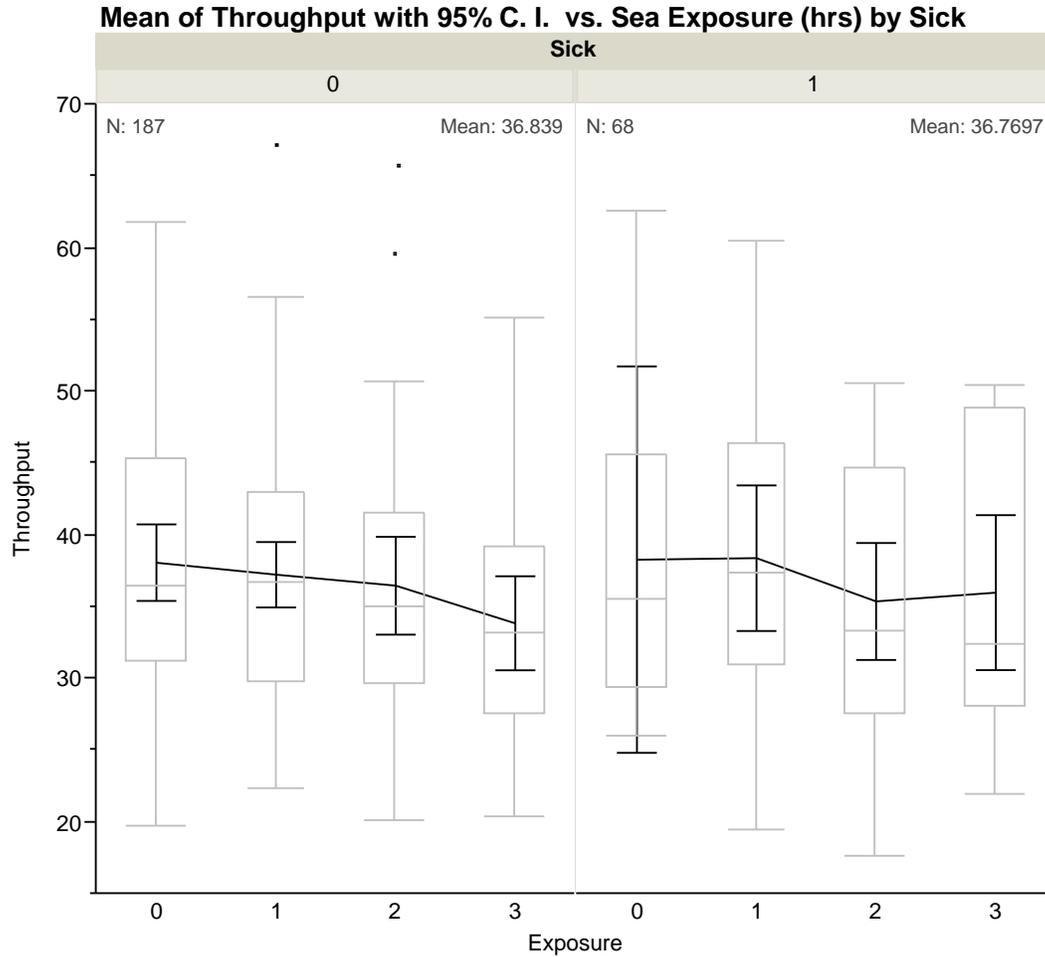
Figure 22.   Throughput vs. Exposure by Sick. The two- and three-hour exposure is different from the zero-hour exposure for the participants that are not reporting to be suffering from motion sickness symptoms.

Summary Statistics for Throughput Post Exposure (Not Sick)							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	54	38.09	9.78	19.73	61.73	40.76	35.42
1	68	37.25	9.41	22.27	67.09	39.53	34.98
2	37	36.49	10.22	20.08	65.72	39.90	33.08
3	28	33.87	8.44	20.37	55.17	37.14	30.60
Summary Statistics for Throughput Post Exposure (Sick)							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	6	38.31	12.82	25.91	62.54	51.76	24.85
1	22	38.41	11.43	19.47	60.45	43.48	33.34
2	24	35.39	9.65	17.57	50.47	39.47	31.32
3	16	36.01	10.13	21.90	50.34	41.41	30.61

Table 13.   Summary Statistics for Throughput Not Sick and Sick.

4.   MSAQ Scores

Post-treatment MSAQ Total scores are graphically depicted in Figure 23. The trend-line of the means for MSAQ gradually increases from the zero-hour exposure to the two-hour exposure. Table 14 contains the summary statistics for the observations collected for the 61 participants for each treatment level. It is important to note that there are repeated observations at the one-hour level for Squads A and C and repeated observations for Squad C at the two-hour treatment level. The mean for the 255 observations was 18.11 with a standard deviation of 9.4248. The MSAQ, by the nature of the scoring mechanism, has a minimum score of 11.11 as seen in the summary statistics. The maximum possible score on the MSAQ is 100. Given this scale, it is safe to state that the self-reported motion sickness levels for the participants overall was low. Participant 9 was missing a MSAQ score for 16 August and was omitted from the analysis. Repeated measures analysis by treatment level revealed a significant difference ($F(3,200.2) = 11.4049$, $p < 0.0001$, $R^2 = 0.5304$). Tukey HSD test reveals significant differences in MSAQ Total between both the two- and three-hour treatment levels, 21.39 and 20.44 respectively, from both the zero- and one-hour treatment levels, 14.33 and 17.27 respectively ($p < 0.0001$ and $p < 0.0001$ respectively for the zero-hour treatment and $p = 0.0228$ and $p = 0.0232$ respectively for the one-hour treatment).

Mean of MSAQ Total with 95% C. I. vs. Sea Exposure (hrs)
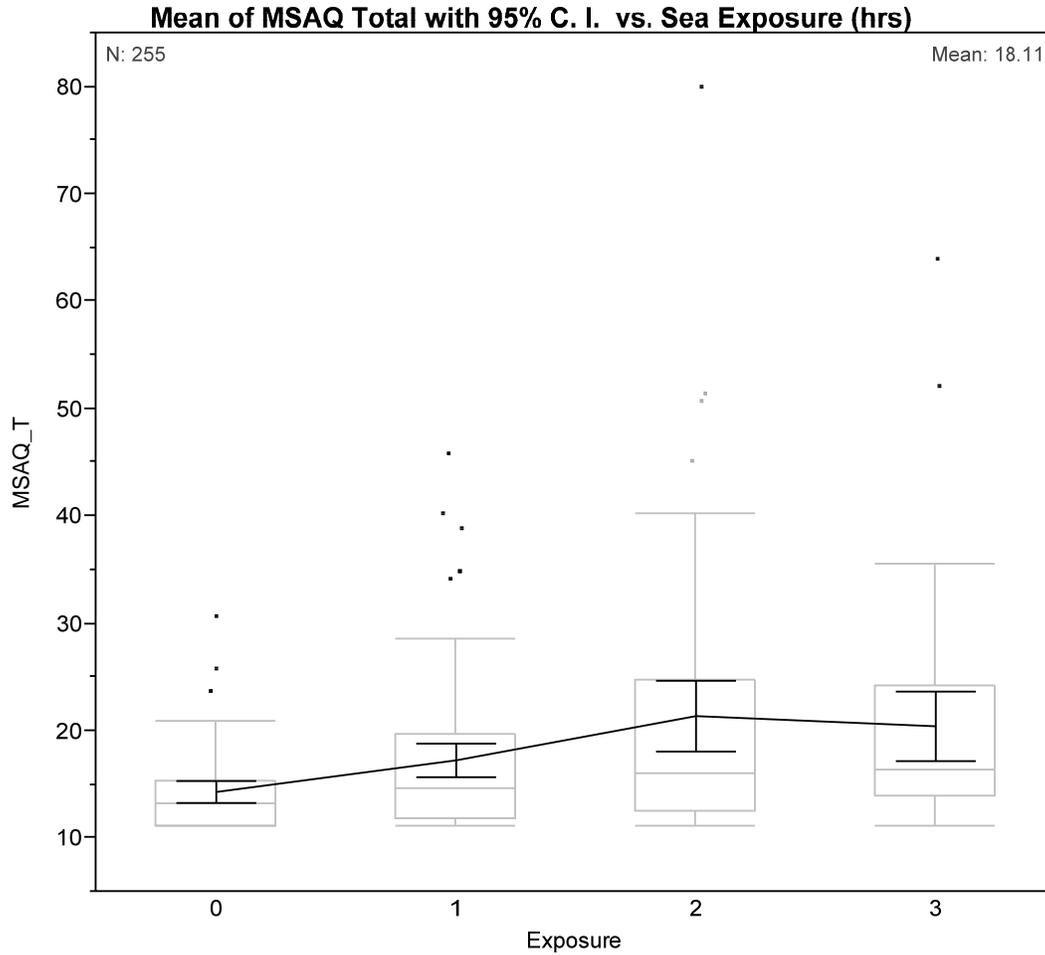
Figure 23.   MSAQ Total vs. Sea Exposure. MSAQ scores for the two- and three-hour
exposures are different from both the zero- and one-hour exposures.

Summary Statistics for MSAQ Total Post Exposure							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	60	14.33	3.97	11.11	30.56	15.35	13.30
1	90	17.27	7.49	11.11	45.83	18.84	15.70
2	61	21.39	12.89	11.11	79.86	24.69	18.09
3	44	20.44	10.63	11.11	63.89	23.67	17.21

Table 14.   Summary Statistics for MSAQ Total.

C. RECOVERY PERIOD EFFECTIVENESS

To assess the effectiveness of the one-hour recovery period, multivariate analysis of variance using a repeated measures design was used to compare post-treatment performance and the performance after the one-hour recovery period for the Switching Test and the MSAQ. Also provided are graphical depictions of the means of the performance measures, post-treatment and after the one-hour recovery period. Each graphical representation contains a solid trend-line for the post-treatment performance and a dashed trend-line for the performance measured after the one-hour recovery period. Each of the trend-lines of the means are plotted with 95 percent confidence intervals at each exposure level. Summary statistics for the performance measures after the one-hour recovery period are also provided.

1. Cognitive Performance after One-hour Recovery Period

Switching Test performance and Switching Test performance after a one-hour recovery are graphically depicted in Figure 24. The trend-lines have a similar values at the zero-, two-, and three-hour exposure. Table 15 contains the summary statistics for Switching Test correct responses per minute for each treatment level. The mean for the 256 observations for the Switching Test after the one-hour recovery period was 36.11 correct responses per minute with a standard deviation of 10.1730 correct responses per minute. Repeated measures analysis for the Switching Test after the one-hour recovery period by treatment levels reveals significant differences ($F(3,194.6) = 3.6242$, $p = 0.0141$, $R^2 = 0.8147$). Tukey HSD test reveals a significant difference in performance between the three-hour treatment, 34.54 correct responses per minute, and the zero-hour treatment level, 38.07 correct responses per minute ($p = 0.0105$). Multivariate analysis of variance test of pre-treatment throughput and throughput after the one-hour recovery period finds no differences among the treatment levels ($F(3,252) = 0.4466$, $p = 0.7199$).
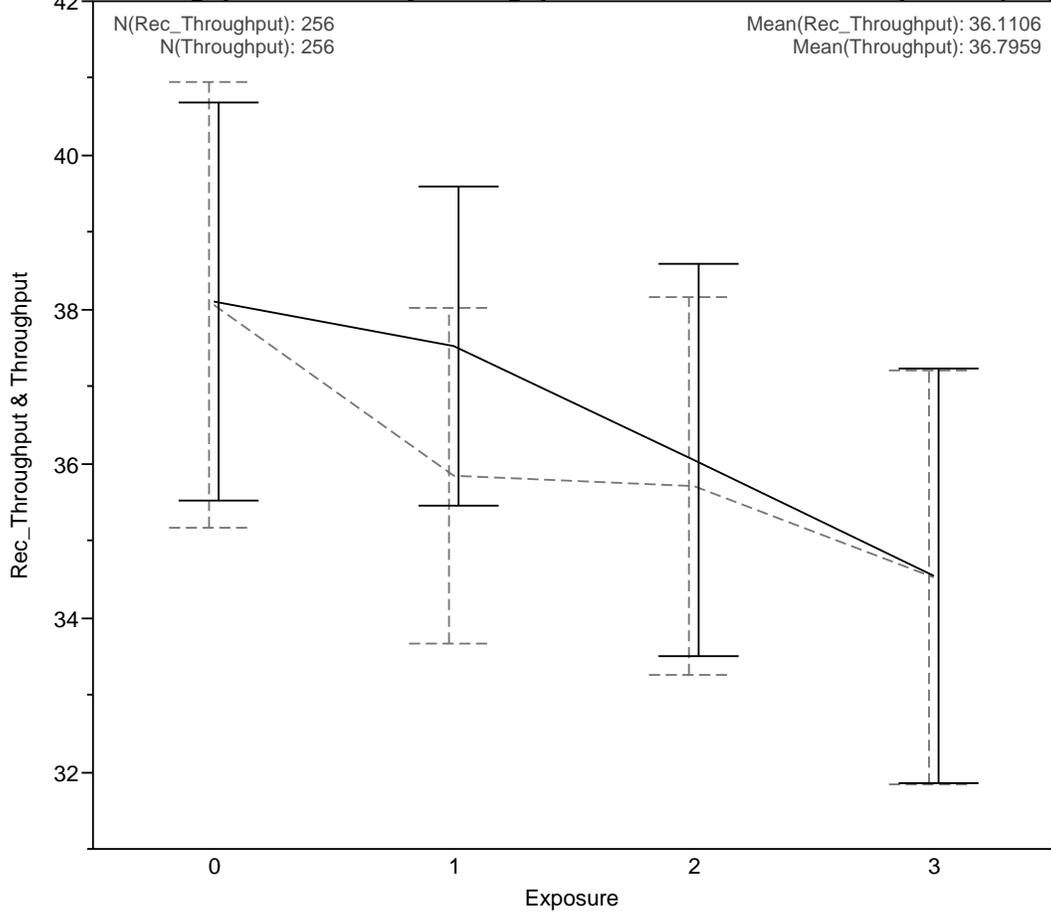
Figure 24.   Throughput and Throughput after a One-hour Recovery Period vs. Sea Exposure.
Throughput is represented by the solid line and throughput after a one-hour
recovery period is represented by the dashed line.

Summary Statistics for Throughput after One Hour Recovery							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	60	38.07	11.20	16.63	67.78	40.96	35.18
1	90	35.85	10.40	19.72	63.97	38.03	33.68
2	61	35.72	9.57	15.25	61.74	38.17	33.27
3	45	34.54	8.94	18.95	56.02	37.22	31.85

Table 15.   Summary Statistics for Throughput after a One-hour Recovery Period.

2.   MSAQ Scores after One Hour Recovery Period

Post-treatment MSAQ Total and MSAQ Total scores after the one-hour recovery period are graphically depicted in Figure 25. The trend-line for the means of the MSAQ scores makes a drastic departure from one another after the zero-hour exposure. The MSAQ scores after the one-hour recovery period have a linear appearance. Table 16 contains the summary statistics for MSAQ Total after the one-hour recovery period for each treatment. The mean for the 254 observations of the MSAQ Total after the one-hour recovery period was 18.11 with a standard deviation of 4.7060. Repeated measures analysis of MSAQ Total after the one-hour recovery period by treatment revealed significant differences ($F(3,197.2) = 3.9666$, $p = 0.0090$, $R^2 = 0.5911$). Tukey HSD test reveals a significant difference in MSAQ Total after the one-hour recovery period between the three-hours treatment and the zero-hours treatment ($p = 0.0056$). Multivariate analysis of variance between MSAQ Total and MSAQ Total after the one-hour recovery period show a significant difference among the treatment levels ($F = 5.9440$, $p = 0.0006$).

Mean of MSAQ Total & Mean of Recovery MSAQ Total with 95% C.I. vs. Sea Exposure (hrs)
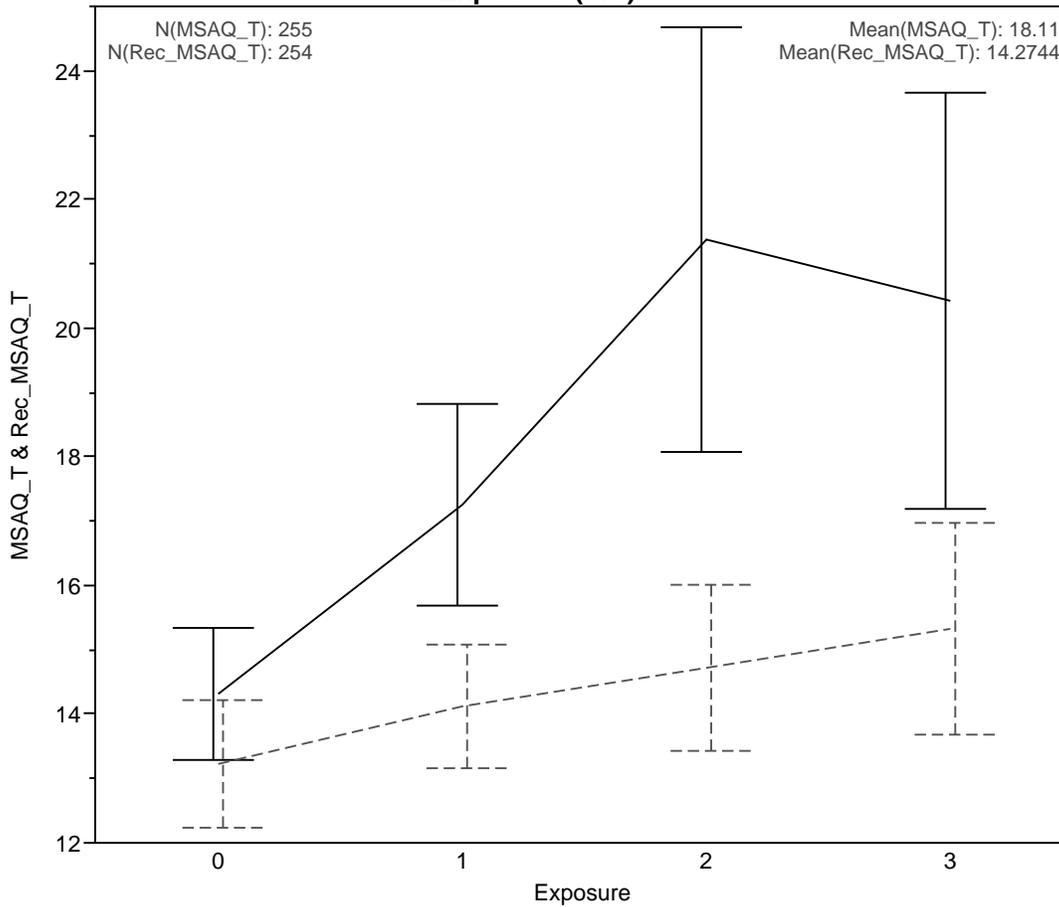
Figure 25.   MSAQ Total and MSAQ Total after One-hour Recovery Period. MSAQ Total is represented by the solid line and MSAQ Total after the one-hour recovery period is represented by the dotted line.

Summary Statistics for MSAQ Total after One Hour Recovery							
Exposure	N	Mean	Std Dev	Minimum	Maximum	Upper 95% Mean	Lower 95% Mean
0	60	13.24	3.84	11.11	36.11	14.23	12.25
1	90	14.14	4.59	11.11	37.50	15.10	13.18
2	60	14.73	4.99	11.11	33.33	16.02	13.44
3	44	15.34	5.41	11.11	33.33	16.99	13.69

Table 16.   MSAQ Total after a One-hour Recovery Period.

D.   PERFORMANCE MEASURE MODELING

The participants' performance was modeled using a univariate repeated measures model. The participants' identification numbers were included as a random effect to control for variation within subjects. Fixed effects were added to control for environmental variables, squad, time of day, test day, MSSQ scores, MSAQ scores, and test vehicle. This approach identifies the influence of possible confounding factors for each treatment level. A stepwise approach, forward and backwards, was used to identify significant factor effects. That is, a univariate repeated measures model with all possible covariates was fit. The covariates which were not significant were iteratively removed and added until the model with the best fit was found. The best fit was determined by the p-value for the model fit, the number of significant factors, and the coefficient of determination.

Model fitting for marksmanship and obstacle course performance did not reveal any significant factors for predicting the participants' performance. Model fitting for the Switching Test, on the other hand, revealed significant effects that influenced participant performance. Time of day, MSSQ, MSAQ, test day, and squad were not found to be significant factors for predicting participants' performance. The environmental conditions experienced by the participants, the test vehicle and sea exposure were all significant.

The best fitting model parameter estimates and associated p-values are in Table 17. The environmental factors for the best fitting model are: the median internal temperature of the test vehicle (Temp), the percentage of the exposure time spent above the median internal temperature of the test vehicle (Percent), the period of the waves during each exposure (Period), the wind speed during each exposure (Wind), and the wave height during each exposure (Wave). Although wave height is not a significant factor in this model, it is included in the model because it is a contributing factor in the determination of sea state. The coefficient of determination for this model is 0.887. The random effect, participants, accounted for 83.27 percent of the variation and the fixed effects accounted for the rest.

Post-hoc Tukey HSD tests were performed for test vehicle and sea exposure. Controlling for the environmental factors revealed a difference in Switching Test scores for the AAV and both the EFV with vented air and EFV with cooled air (p = 0.0180 and p = 0.0166 respectively). Additionally, differences in Switching Test scores were found between the zero-hour treatment and the one-, two-, and three-hour treatments (all p-values < 0.001). Differences between one-hour treatment and both the two- and three-hour treatments were also identified (p = 0.0129 and p = 0.0061 respectively).

Term	Estimate	p-value
Intercept	19.384	0.1484
Vehicle[AAV]	4.402	
Vehicle[EFV-C]	-0.646	0.0216
Vehicle[EFV-V]	-3.756	
Exposure[0]	-20.466	
Exposure[1]	9.876	<0.0001
Exposure[2]	5.788	
Exposure[3]	4.802	
Temp	0.451	0.0121
Percent	-0.199	0.003
Period	-5.837	<0.0001
Wind	4.813	<0.0001
Wave	0.084	0.9425

Table 17.   Parameters for Predicting Switching Test Performance.

To gain additional insight into the model for Switching Test performance, predicted values for cognitive throughput are calculated for each test vehicle at each treatment level. The values for the significant factors are held constant for the calculation of the throughput score for each vehicle. The internal temperature of the test vehicle was set at 88° Fahrenheit. The percent of the exposure time above the median temperature was set at 41.67 percent. The wind speed was set at one-half a mile per hour. For the exposures involving waterborne motion, the wave period was set at five seconds and the wave height was set at 1.2 meters. The factors were set to zero for the zero-hour exposure level. Table 18 contains the predicted values for cognitive throughput scores using this model.

The percentage differences for vehicle type and across the exposure levels were then calculated. The percentage difference across the exposure levels indicates a decrease in cognitive throughput scores from the zero-hour exposure of at least seven percent for the two-hour exposure and at least ten percent for the three-hour exposure. Additionally, the model predicts an increase in performance from the zero-hour exposure to the one-hour exposure of at least three percent.

Predicted Values for Vehicles and Treatments			
Treatment	AAV	EVF-C	EFV-V
0	37.15	32.1	28.99
1	38.41	33.35	30.25
2	34.32	29.27	26.16
3	33.33	28.28	25.17

Table 18.   Predicted Values for Switching Test Performance. The AAV is different from EFV across all exposure levels. Each exposure level is different from the zero-hour exposure.

V. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

A.   DISCUSSION

The objective of this study was to determine the effects of varying lengths of waterborne motion exposure on the combat effectiveness of embarked infantry personnel. Combat effectiveness, for the purpose of this study, was defined by three performance measures; move, shoot and communicate. An obstacle course was used to evaluate the participants' ability to move. The laser marksmanship training system was used to assess the participants' ability to shoot. A cognitive battery was used to test the participants' ability to process information and communicate. Motion sickness questionnaires were used to assess general level of comfort and well-being.

1.   Discussion of the Test Objectives

The participants completed a weeklong training period and two weeks of testing. The data collected was analyzed and the following research questions were answered:

- Is there degradation in obstacle course performance among embarked infantry personnel when exposed to varying lengths of waterborne motion? Analysis of the data collected suggests that there is not a difference in performance across all treatment levels. However, analysis of the data for participants not reporting to be suffering from motion sickness symptoms does suggest that there is a difference in obstacle course performance. A difference in performance from the zero-hours of exposure to the one-hour exposure of 3.49 seconds was observed.

- Is there degradation in marksmanship among embarked infantry personnel when exposed to varying lengths of waterborne motion? Analysis of the data collected suggests there is not a difference in marksmanship performance across all treatment levels. Additional analysis of the data for

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participants that did not report to be suffering from motion sickness was almost significant.

- Is there degradation in cognitive performance among embarked infantry personnel when exposed to varying lengths of waterborne motion? Analysis of the data collected does suggest there is a difference in cognitive performance across all treatment levels. The participants' scores after the three-hour treatment were on average 3.56 correct responses per minute lower than the scores after the zero-hour treatment (9.34 percent decrease). Additionally, the scores after the two-hour treatment was on average 2.98 correct responses per minute lower than the scores after the one-hour treatment (7.94 percent decrease). Analysis of the data collected for the participants that did not report to be suffering from motion sickness symptoms also found differences in performance. The two- and the three-hour post-treatment scores were on average 1.60 and 4.22 correct responses per minute, respectively, lower than the zero-hour treatment (4.20 and 11.08 percent difference, respectively)

- Is there a difference in reported levels of motion sickness for embarked infantry personnel when exposed to varying lengths of waterborne motion? Analysis of the data collected does suggest a difference in reported motion sickness symptoms across all treatment levels. MSAQ scores for the two- and three-hour treatment levels were found to be higher than from both the zero- and one-hour treatment levels. Post-treatment MSAQ scores for the two-hour treatment were on average 7.06 and 4.12 points higher than the zero- and one-hour treatment levels, respectively (33.01 and 19.26 percent higher, respectively) Post-treatment MSAQ scores for the three-hour treatment were on average 6.11 and 3.17 points higher than the zero- and one-hour treatment levels, respectively (29.89 and 15.51 percent higher, respectively).

- Is there a relationship between self-reported levels of motion sickness and performance for embarked infantry personnel exposed to varying lengths of waterborne motion? MSAQ and MSSQ scores were used as covariates in the model fitting for marksmanship, obstacle course, and cognitive performance. The self-reported levels of motion sickness and motion sickness susceptibility were not significant covariates in the regressions models. That is, after controlling for other effects, MSAQ scores were not predictive of performance across the treatment levels.

- Does performance return to pre-treatment levels after a one-hour recovery period? Only Switching Test data and MSAQ data were collected after the one-hour recovery period. Analysis of the data collected after the one-hour recovery period does suggest a difference in performance for the Switching Test across the treatment levels. The Switching Test scores for three-hour treatment were 3.53 correct responses per minute lower than the zero-hour treatment level (8.80 percent difference). This result suggests that the participants were still affected by the exposure to motion at the three-hour treatment. Pre-treatment MSAQ was not collected during this experiment; therefore, a comparison to pre-treatment levels is not possible. On the other hand, MSAQ scores were lower after the one-hour recovery period than the post-treatment scores.

2. Discussion of Cognitive Performance Model Results

The Switching Test model results show differences across treatment levels. From the predicted values of cognitive performance, a decrease in performance can be expected for the participants exposed to two and three hours of waterborne motion when compared to the participants that were not exposed to motion. These predicted values also suggest a difference in vehicle type. The difference in vehicle type is confounded by the demonstrated differences in squads and possibly an artifact of the test design not being balanced on vehicle type.

B. CONCLUSIONS

Exposure to waterborne motion can be expected to degrade the cognitive performance of embarked infantry personnel. This study found an average degradation following the three-hour exposure of 9.3 percent compared to participants' scores when not exposed to waterborne motion. This decrease in performance is similar to the findings of Cowings, Toscano, DeRoshia, & Tauson (1999); Ljungberg & Neely (2007); and Muth (2009). The practical implications of these findings to military operations is not known, since there is not a Department of Defence standard for cognitive performance of embarked infantry personnel. Extrapolating these findings to another population should be tempered with the realization that approximately 80 percent of the variation in the data collected is explained by the differences between individual participants.

Marksmanship and obstacle course performance does not appear to be affected by waterborne motion. This finding is similar to that of Stinson (1979) in that no degradation in obstacle course or marksmanship performance was found across vehicle type. Additionally, Alexander et al., (1945) did not find a change in running times for participants after brief exposure to a motion platform.

The graphical representations for both marksmanship and obstacle course have a similar pattern. The participants' performance decreases for the one- and two-hour exposures. After the three hour exposure, performance trends upwards towards the no motion exposure values. This findings was not statistically significant. However, this pattern could possibly result from adaptation to motion exposure and is consistent with the findings of McCauley, O'Hanlon, Royal, Mackie, & Wylie (1976). This trend is not present for MSAQ scores and cognitive performance. Both MSAQ scores and cognitive performance have a linear trend towards decreasing performance and increasing reports of motion sickness.

C. RECOMMENDATIONS

Future studies involving vehicle habitability should follow the testing methodology used in this study. A training period that establishes a baseline for performance should be conducted at the same time of day as the anticipated post-treatment test battery. This process will be necessary to control for the potential confounds due to the time of day effects. Future test designs should be conducted as a within subject design to control for human performance variability. Additionally, a pre-treatment assessment of participant well-being should be collected for comparison with post-treatment assessments, if such information is warranted.

Contrary to the studies cited by Werthiem, cognitive performance degradation, albeit small, has been detected following exposure to motion. The time course of the cognitive degradation found in this study does not appear to follow the pattern of adaption to motion exposure prevalent in marksmanship and obstacle course performance. Questions remain concerning the cognitive degradation experienced: Does the cognitive degradation dissipate following a period of continued motion exposure such as that seen in habituation situations? If the effect of continuous motion exposure on cognitive performance does dissipate, at what point does cognitive performance return to pre-motion exposure levels? What is the necessary amount of time for complete recovery from motion exposure? Further research to determine the time course characteristics of the effects of motion exposure on cognitive performance during sustained motion exposure and following motion exposures greater than the three hours will increase our understanding of the impact that motion exposure has on cognitive ability. Therefore, future studies to determine the time course of the cognitive performance degradation are imperative.

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APPENDIX

MOTION SICKNESS SUSCEPTIBILITY QUESTIONNAIRE

This questionnaire is designed to find out how susceptible to motion sickness you are and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.

After some background questions, the questionnaire consists of two sections:

Section A is concerned with your **childhood** experiences of travel and motion sickness, that is, before the age of 12 years.

Section B is concerned with your experiences of travel and motion sickness **over the last 10 years**.

The correct way to answer each question is explained in the body of the questionnaire. It is important that you answer every question.

Thank you for your help.

Background Questions

1. Please State Your Age   _____ Years

2. Please State Your Sex (tick box)

	Male	Female
	[ ]	[ ]
	1	2

3. Please State Your Current Occupation   _____

4. Do you regard yourself as susceptible to motion sickness? (tick box)

Not at all	Slightly	Moderately	Very much so
[ ]	[ ]	[ ]	[ ]
0	1	2	3

Section A: **Your CHILDHOOD Experience Only** (before 12 years of age)

For each of the following types of transport or entertainment please indicate:

5. As a **Child (before age 12),** how often you **Travelled or Experienced** (tick boxes):

	Never	1 to 4 trips	5 to 10 trips	11 or more trips
Cars				
Buses or Coaches				
Trains				
Aircraft				
Small Boats				
Ships, e.g. Channel Ferries				
Swings				
Roundabouts: playgrounds				
Big Dippers, Funfair Rides				
	0	1	2	3

6. As a **Child (before age 12),** how often you **Felt Sick or Nauseated** (tick boxes):

	Never	Rarely	Sometimes	Frequently	Always
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings					
Roundabouts: playgrounds					
Big Dippers, Funfair Rides					
	0	1	2	3	4

7. As a **Child (before age 12),** how often you **Vomited** (tick boxes):

	Never	Rarely	Sometimes	Frequently	Always
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings					
Roundabouts: playgrounds					
Big Dippers, Funfair Rides					
	0	1	2	3	4

Section B: **Your Experience over the Last 10 Years (approximately).**

For each of the following types of transport or entertainment please indicate:

8. Over the **last 10 years,** how often you **Travelled** or **Experienced** (tick boxes):

	· Never	1 to 4 trips	5 to 10 trips	11 or more trips
Cars				
Buses or Coaches				
Trains				
Aircraft				
Small Boats				
Ships, e.g. Channel Ferries				
Swings				
Roundabouts: playgrounds				
Big Dippers, Funfair Rides				
	0	1	2	3

9. Over the **last 10 years,** how often you **Felt Sick** or **Nauseated** (tick boxes):

	Never	Rarely	Sometimes	Frequently	Always
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings					
Roundabouts: playgrounds					
Big Dippers, Funfair Rides					
	0	1	2	3	4

10. Over the **last 10 years,** how often you **Vomited** (tick boxes):

	Never	Rarely	Sometimes	Frequently	Always
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings					
Roundabouts: playgrounds					
Big Dippers, Funfair Rides					
	0	1	2	3	4

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