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The Effects of Different Optokinetic Drum Rotation Speeds on Motion Sickness Symptoms, Cognitive Performance and Sleep Amount

By

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B.S., University of Puerto Rico, 2007

A Thesis Submitted to the
Department of Human Factors & Systems
in Partial Fulfillment of the Requirements for the Degree of
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Embry-Riddle Aeronautical University
Daytona Beach, Florida
Spring 2012

The Effects of Different Optokinetic Drum Rotation Speeds on Motion Sickness Symptoms, Cognitive Performance and Sleep Amount

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This thesis was prepared under the direction of the candidate's thesis committee chair, Jonathan French, Ph.D., Department of Human Factors & Systems, and has been approved by the members of the thesis committee. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.

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Abstract

Symptoms of motion sickness can be disruptive to human performance. If vection-induced motion sickness symptoms, sleep amount disruptions, and worsening of cognitive performance can be measured and characterized, there are practical implications for equipment design, especially for virtual reality devices and simulators. The researcher conducted three studies. The first study examined the effects of different rotation speeds (0 RPM, 5 RPM, and 10 RPM) of the optokinetic drum on motion sickness symptoms. Motion sickness symptoms were measured using the Simulator Sickness Questionnaire (SSQ). Before exposure to the optokinetic drum, participants were not significantly different from one another in terms of motion sickness symptoms. During exposure to the optokinetic drum, the 5 and 10 RPM conditions experienced significantly more motion sickness symptoms than the 0 RPM condition. Comparing the 5 and 10 RPM conditions during the time of exposure to the optokinetic drum, the 5 and 10 RPM conditions were not significantly different from each other most of the time, with minor exceptions, where the 10 RPM condition induced significantly more motion sickness symptoms than the 5 RPM condition. The second study examined the effects of different rotation speeds of the optokinetic drum and time on cognitive performance. Cognitive performance was measured using the Switching test of the Automated Neuropsychological Assessment Metrics. Cognitive performance, accuracy and mean reaction time were not affected by exposure to the optokinetic drum. The third study examined the effects of different rotation speeds of the optokinetic drum and time on sleep amount. Sleep amount was measured using actigraphs and sleep logs. Sleep amount was not affected by exposure to the optokinetic drum. This project shows that the optokinetic drum is an effective tool to induce and study motion sickness symptoms. Future studies may use the optokinetic drum as a tool to study preventive measures against motion sickness in various environments.

Introduction

Symptoms of motion sickness can be disruptive to human performance. A simple, reliable means to induce motion sickness would provide a source for investigating its causes and implications. This project involves evaluating the rotation speed settings of a vection device, the optokinetic drum, which can reliably inflict motion sickness symptoms (Kennedy, Stanney, Rolland, Ordy, & Mead, 2002). This study will describe the effects of different rotation speeds of the optokinetic drum on motion sickness symptoms. Additionally, sleep amount will be assessed, as well as cognitive performance to determine the impact of motion disturbance on these additional important psychophysiological dimensions. Future research can use the results of this study to determine the effects of other optokinetic drum parameters on important psychophysiological dimensions, and study and develop possible countermeasures.

If vection-induced motion sickness symptoms, sleep amount disruptions, and worsening of cognitive performance can be measured and characterized, there are practical implications for equipment design, especially for virtual reality devices and simulators. Results from this study could lead to the development of human performance models and system design principles for dynamic visual scene environments and simulators that could optimize user experience.

The next section will provide the reader with general information about the vestibular system and motion sickness. It will be followed by an overview of optokinetic drum literature.

Vestibular System

The vestibular system is a set of specialized sense organs located in the inner ear right next to the cochlea. These organs sense motion of the head, as well as the orientation of gravity, and make a predominant contribution to our sense of tilt and our sense of self-motion (Wolfe et al., 2009). The vestibular system provides orientation in three dimensional space, modification of muscle tone and

balance. It is essential for the coordination of motor responses, eye movement and posture (Tascioglu, 2005).

To maintain balance and body posture, there has to be a continuous flow of information about position and movement from every part of the body, including head and eyes. The vestibular system detects motion of the head and maintains stability of images on the fovea of the retina as well as postural control during movements of the head. Signals representing angular and translational motion of the head as well as the tilt of the head relative to gravity are translated by the peripheral vestibular organs in the inner ear. This sensory information is used in turn to control reflexes used for maintaining the stability of the images on the retina during movements of the head. Vestibular information is also important for posture and gait. When vestibular function is normal these reflexes operate with exquisite accuracy (Tascioglu, 2005).

The peripheral portion of the vestibular system (see Figure 1) is located in the labyrinth. The labyrinth is composed of three major structures embedded in the temporal bone: the semicircular ducts, the utricle, and the saccule. The bony labyrinth, or osseous labyrinth, is the network of passages with bony walls lined with periosteum. The membranous labyrinth runs inside of the bony labyrinth. Between the bony and membranous labyrinth circulates a fluid called perilymph which in composition is similar to the cerebrospinal fluid. The membranous labyrinth on the other hand is filled with a fluid called endolymph with a high concentration of potassium (K^+) and a low concentration of sodium (Na^+).

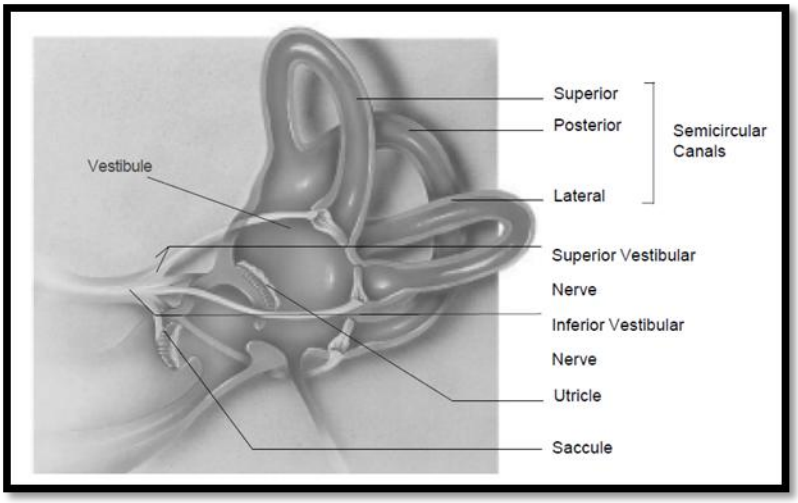

Figure 1. Anatomic organization of the peripheral vestibular system (Rutka, 2004).

The part of the membranous labyrinth related to vestibular function consists of three semicircular ducts or canals (superior, lateral or horizontal, posterior) and the utricle and saccule. Within these structures are areas containing neuroepithelial cells which form the peripheral receptors of the vestibular system.

The semicircular ducts

The semicircular ducts are also known as the semicircular canals. The semicircular ducts open into the utricle. The posterior limbs of the superior and posterior ducts unite before opening into the utricle, thus forming a common limb. One end of each duct is dilated and is called the ampulla and epithelial cells here thicken to form the ampullary crest. This zone contains neuroepithelial hair cells covered by a gelatinous substance, the cupula, which extends to the roof of the ampulla. These receptor cells are innervated by afferent peripheral processes from the vestibular ganglion. Hair cells contain a kinocilium arising from the cytoplasmic surface of the cell and stereocilia, their numbers varying between 40-70 (Tascioglu, 2005). The semicircular ducts respond to angular acceleration (rotation of the head). Figure 2 shows the angular acceleration receptor. When the head is rotated, movement of the endolymph causes displacement of the cupula resulting in deflection of the hair cells. Movement

towards the kinocilium depolarizes the hair cells causing stimulation, whereas movement away from the kinocilium hyperpolarizes the hair cell decreasing firing of the afferent fibers (Wolfe et al., 2009). The superior duct of one side lies approximately in the same plane as the posterior of the opposite side forming a functional pair. Similarly, the horizontal ducts of the two sides lie in the same plane again forming a functional pair. Movement of the endolymph on one side will cause excitation of hair cells on same side while inhibiting hair cells of its partner on the contralateral side.

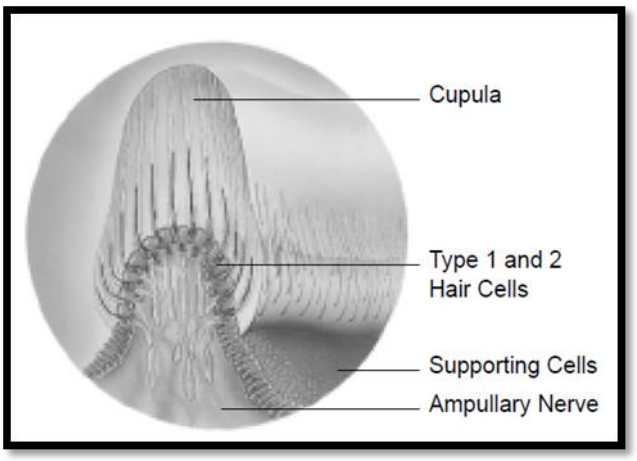

Figure 2. Stylized representation of the crista: angular acceleration receptor (Rutka, 2004).

The otolith organs: utricle and saccule

The utricle and saccule are related to static equilibrium (position of the head in space which is very important for the control of posture) and to changes in gravitational forces. They are also sensitive to linear acceleration. Figure 3 shows linear acceleration receptor. Saccular neurons appear to detect vertical acceleration while utricular neurons are sensitive to dorsoventral acceleration and sideways movement (Tascioglu, 2005). The utricle and saccule also contain an area of neuroepithelial cells, in this instance called the macula. Here, hair cells come into contact with a gelatinous substance containing particles of $CaCO_3$ (calcium carbonate). This structure is called the otolithic membrane. All hair cells have

their kinocilium at one end but they are not oriented in the same direction. Hair cells that come from all directions are oriented towards a curved border on the surface of the macula called the striola. When the head is bent in any direction a group of cells is stimulated while another group is inhibited, having no effect on yet a different group. This complicated pattern sends accurate messages to the brain related to the position of the head at any given time.

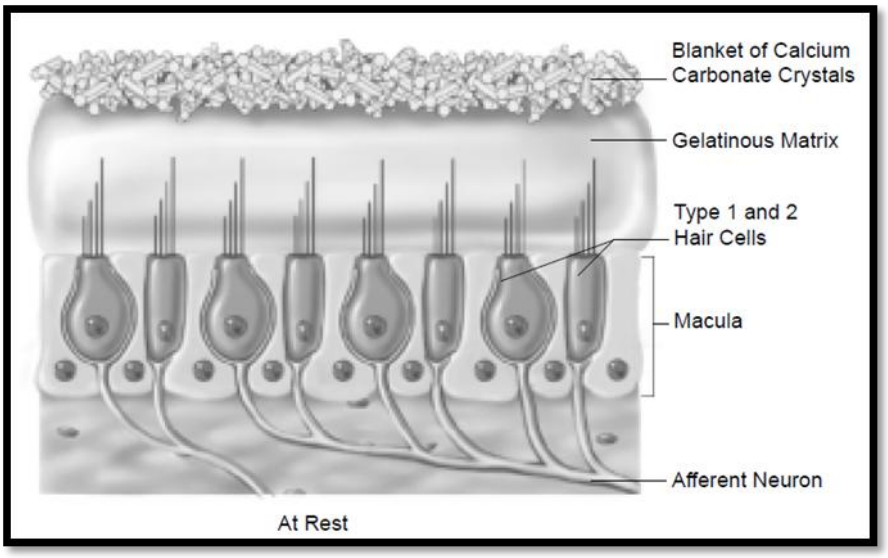

Figure 3. Stylized representation of macular end-organ: linear acceleration receptor (Rutka, 2004).

Diseases of the vestibular system can produce severe symptoms such as vertigo, nausea, vomiting, nystagmus, and other motion sickness symptoms (Rutka, 2004). In the following section motion sickness is explained.

Motion sickness

Historical chronicles of the human experience with motion sickness symptoms date back at least to Hippocrates and while Julius Caesar, Lawrence of Arabia, Charles Darwin, and Admiral Nelson all reported suffering bouts of sickness (Money, 1972), adaptation and repeated exposure can minimize these adverse effects (Trendel et al., 2010). Other human experiences with motion sickness symptoms

may be traced to the wide use of various means of passive conveyance (e.g., camels, carts, carriages, among others) (Kennedy, Drexler, & Kennedy, 2010). In the last hundred years, innovation of transport and industry have extended the range of provocative motion environments, to cars, tilting trains, funfair rides, aircraft, weightlessness, virtual reality, and simulators (Golding, 2006).

Motion sickness is a phrase used to refer to a wide range of unpleasant symptoms experienced during exposure to motion of the body or in response to motion of visual images without concurrent motion of the body (Webb, 2000). Motion sickness is a subjective experience characterized by dizziness, sweating, nausea and headache, sometimes for hours following the inducing event (Williamson, Thomas, & Stern, 2004). The pathognomonic sign of motion sickness is vomiting (and at times, retching), but other signs of the syndrome are many and disparate, including overt manifestations such as pallor, cold sweating and salivation (Stern, Koch, Stewart, & Lindblad, 1987), lassitude, reluctance to communicate, and a large increase of plasma levels of arginine vasopressin (Yates, Miller, & Lucot, 1998). The most commonly reported motion sickness symptoms (i.e., nausea, vomiting, sweating, salivation, apathy, fatigue, stomach awareness, disorientation, dizziness, and incapacitation) implicate the vagus nerve complex related to the autonomic nervous system (Kennedy & Frank, 1986). Other physiological signs of motion sickness include changes in cardiovascular, respiratory, gastrointestinal, biochemical, and temperature regulation functions (Kennedy, Drexler, & Kennedy, 2010).

The pathognomonic sign of motion sickness is medically known as emesis. Vomiting can occur due to a wide variety of conditions; it may present as a specific response to ailments like gastritis or poisoning, or as a non-specific manifestation of disorders ranging from brain tumors and elevated intracranial pressure to overexposure to ionizing radiation. The feeling that one is about to vomit is called nausea, which usually precedes, but does not always lead to, vomiting. Emesis is achieved by the coordinated activity of both smooth and somatic muscles to generate appropriate changes in intra-abdominal and intra-thoracic pressures, and opening of the esophageal sphincters. The presence of a

functioning vestibular system is not necessary for vomiting to be produced. Emesis can be evoked by activation of a variety of peripheral and central afferent mechanisms (Lackner, 2004). Earlier notions of a well-defined "vomiting center" in the brainstem have not been supported by neuroanatomical studies which point instead to a more broadly distributed neuronal representation in the medulla oblongata (Lackner, 2004). The input circuitry controlling emesis is plastic, allowing changes in the sensitivity of other pathways when one is interrupted (Lackner, 2004).

There are other symptoms not readily associated with motion sickness, like fatigue for example. It is common knowledge that motion can elicit drowsiness (e.g., rocking a baby), but it was not until 1976 that Graybiel and Knepton explicitly identified the “sopite syndrome” as a “sometimes sole manifestation of motion sickness.” Graybiel and Knepton characterized the sopite syndrome primarily by evidence of yawning, drowsiness, reluctance for physical or mental work, and lack of willingness to participate in group activities. Graybiel and Knepton also noticed a variety of other related symptoms: lethargy, apathy, decreased ability to concentrate, daydreaming, melancholy, sleep disturbances, performance errors, frequent daytime napping, irritability, and a desire to be left alone. Sopite syndrome symptoms can appear relatively quickly in response to a weak or brief stimulus, can appear in the absence of the classic gastrointestinal symptoms of motion sickness, and can persist even after the stimulation has ceased (Lawson & Mead, 1998). If sopite symptoms appear in the absence of the classic gastrointestinal symptoms of motion sickness, the affected individual may not recognize them as a response to the motion environment (Kiniorski et. al., 2004). It is important to study the sopite syndrome because it may be an unrecognized source of performance decrements in transportation (Kiniorski et al., 2004) or other occupational environments. Sopite syndrome can occur in people who have a very low susceptibility to motion-induced nausea (Lawson & Mead, 1998) and can persist in individuals fully adapted to nauseating stimuli. Many transportation jobs routinely involve long hours, sleep deprivation, or shift work. It is reasonable to expect that sleep deprivation and shift work would

exacerbate sopite syndrome symptoms. However, evidence suggests that the syndrome is caused by real or apparent motion and not merely isolation, confinement, or boredom (Lawson & Mead, 1998).

In 1965, Graybiel and his colleagues noted striking instances where participants exposed to rotating environments would rapidly go from fully alert or even moderately excited states to profound sleep (Graybiel et al., 1965, as cited in Lawson & Mead, 1998). The sleep would last hours, but it was not wholly refreshing. A vestibular etiology for the sopite syndrome was implied by the fact that participants tended to suffer their peak levels of drowsiness well before the end of the rotation period. They also tended to restrict their head movements (and hence the amount of vestibular stimulation) long after the cessation of nausea (Graybiel et al., 1965, as cited in Lawson & Mead, 1998).

One of the goals of this study is to determine if sopite syndrome symptoms like sleep disturbances and cognitive performance decrements occur after exposure to an optokinetic drum, and to determine the extent to which these symptoms are related to the motion stimuli in the drum.

When motion sickness occurs in response to real motion, it is often labeled with the related vehicle or situation to more specifically identify the ailment, e.g., car sickness, air sickness, sea sickness, space sickness, simulator sickness, and so on. Motion sickness can occur in response to real or apparent motion (Muth, 2006). Apparent motion refers to a situation in which the individual is stationary, but motion in the visual field causes the individual to experience an illusion of motion. Apparent motion can occur in rotating drums lined with variously contrasting scenes, in large field of view movies that display motion and in computer-generated simulations of real-world environments (Muth, 2006). When motion sickness occurs in response to computer-generated simulations, it is often referred to as simulator sickness or virtual environment sickness. All of these terms are somewhat misleading because motion sickness is not really a sickness, but rather a psychophysiological response of healthy individuals to real or apparent motion stimulation of significant intensity and/or duration (Stern & Koch, 1996).

The most critical signals required for the generation of motion sickness come from the vestibular system, as evidenced by the fact that individuals with bilateral vestibular dysfunction are not susceptible to motion sickness induced by stimuli that are typically provocative (Cheung, Howard, & Money, 1991; Reason, 1978).

It is important to study motion sickness because it is a common problem in people traveling by car (Albright, 1978), train (Förstberg, Andersson, & Ledin, 1998), airplanes (Harm & Schlegel, 2002), spacecraft (Reschke et al., 1998), boats (Fang & Chan, 2007; Wertheim, Bos, & Bles, 1998), and people interacting with high fidelity simulators (Brooks et al., 2010). For about 90 million Americans, equilibrium and dizziness disorders in general cause more than a passing problem. More than 8 million people visit their doctors each year because occasional or chronic feelings of dizziness, spinning, lack of balance, and fainting seriously interfere with their ability to work or enjoy their leisure (Cuthbert, 2006). Dizziness and other equilibrium disorders are some of the most common symptoms reported to physicians (Alexander, 1994).

Theories of motion sickness

Over the years, researchers have developed numerous theories explaining how motion sickness occurs. The most widely accepted (Brooks et al., 2010) by the motion sickness scientific community are the sensory conflict, subjective vertical conflict, postural instability, eye movement, and evolutionary theories.

Sensory conflict theory. The sensory conflict theory developed in 1975 by Reason and Brand is the most parsimonious (Reschke et al., 1998) and most widely accepted theory of motion sickness today (Bles, Bos, de Graff, Groen, & Wertheim, 1998). The basic idea is that all situations that provoke motion sickness are characterized by a condition of sensory rearrangement in which the motion signals transmitted by the eyes, the vestibular system and the nonvestibular proprioceptors are at variance either with one another or with what is expected from previous experience. In other words, conflict

between the motion one sees and the actual motion one is experiencing as well as conflicts between the structures within the vestibular system are the main contributors to motion sickness. This theory assumes that human orientation in three-dimensional space, under normal gravitational conditions, is based on at least four sensory inputs to the central nervous system: (1) the otolith organs, (2) the semicircular ducts, (3) the visual system, and (4) the kinesthetic system. When the environment is altered in such a way that information from the sensory systems is not compatible and does not match previously stored neural patterns, motion sickness results. As a final point, the sensory conflict theory proposed that for motion sickness to occur, sensory information must also be in conflict with one's own experiences of a motion environment. Based on this model, sickness is most likely when sensory information is repeatedly contradictory, greatly disparate, or does not match one's expectations.

Subjective vertical conflict theory. The popular theory of Reason and Brand has been refined by Bles et al. (1998) as follows: "All situations which provoke motion sickness are characterized by a condition in which the sensed vertical as determined on the basis of integrated information from the eyes, the vestibular system and the non-vestibular proprioceptors is at variance with the subjective (expected) vertical as predicted on the basis of previous experience." The sensed vertical is Earth's gravity as perceived by human sense modalities; the subjective (expected) vertical is also Earth's gravity, but in accordance with the expectations of the central nervous system, based on past interaction with the spatial environment. This subjective vertical conflict theory" can be regarded as a specific refinement of Reason and Brand's theory (Bos & Bles, 2004).

Postural instability theory. Riccio and Stoffregen (1991) opposed the sensory conflict theory by noting that congruent information from sensory systems is unusual even in normal, everyday tasks. Instead, they point out that maintaining postural stability is a natural inclination in most animals. According to this theory, motion sickness occurs when one is placed in a novel environment in which effective ways to maintain balance have not been learned (Duh et al., 2004; as cited in Brooks et al.,

2010). For example, travelers at sea must learn ways to adjust to a ship's motion, often referred to as getting one's "sea legs." Once they return to land, their sea legs come with them, sometimes causing them to sway when standing or walking until they adapt to being back on land.

Eye movement theory. According to the eye movement theory of motion sickness, certain stimuli can cause eye movements which create such tension in the eye muscles that they stimulate the vagus nerve resulting in motion sickness (Ebenholtz, 1992). Ebenholtz (2001) has proposed that two specific eye movements, optokinetic nystagmus and vestibular ocular response, lead to motion sickness. In optokinetic nystagmus the eye pursues a target object from one end of a visual scene to the other. When the eye can pursue the object no further, it snaps back to the far side of the visual field where it begins to pursue again. Similarly, the vestibular ocular reflex is responsible for keeping a target object on the fovea when the head is turning. Thus, if one rotates one's head to the right 3° while fixating an object straight ahead, the vestibular ocular reflex causes the eye to rotate to the left 3°. Errors in these eye movements can result in headache, eye strain, and difficulty concentrating (Brooks et al., 2010).

Evolutionary theory. Treisman's (1977) evolutionary theory of motion sickness differs from the four aforementioned theories in that it attempts to explain why motion sickness occur rather than how they occur physiologically. Specifically, Treisman suggests that the human species has not had sufficient time to adapt to the relatively new modes of transportation we use today and that the body responds to conflicts in sensory information as if it had ingested poison, the effective reaction being vomiting, a common motion sickness symptom (Brooks et al., 2010). In other words, Treisman's theory holds that modern circumstances such as space and air travel that result in conflicting sensory information regarding body position in the three-dimensional space can trigger mechanisms that evolved to prevent poisoning.

Provocative conflicts that induce motion sickness

The following section explores specific scenarios in which the sensed vertical as determined on the basis of integrated information from the eyes, the vestibular system and the nonvestibular proprioceptors is at variance with the subjective vertical as predicted on the basis of previous experience.

Coriolis effect. The nausea provoked by making head movements during yaw motion is known as the Coriolis effect, and the nausea as a consequence of head movements during optokinetic surround motion is known as the pseudo-Coriolis effect. The Coriolis effect is the consequence of the conflict between the head tilt indicated by the otoliths and neck receptors and the direction of the angular velocity vector as sensed by the semicircular ducts.

Sea sickness. Seasickness is a form of motion sickness characterized by a feeling of nausea and, in extreme cases, vertigo, experienced after spending time on a craft on water. Head movements play an important role in the enhancement of sea sickness can also be derived from the advice to minimize head movements as much as possible to prevent sea sickness. The common experience that sight of the horizon minimizes sea sickness is most probably due to the fact that seeing the horizon helps to keep the sensed and subjective vertical aligned.

Motion sickness in microgravity and hypergravity. A microgravity or hypergravity load per se does not provoke motion sickness symptoms (Bles, Bos, de Graff, Groen, & Wertheim, 1998). Continuously changing the G-load level as in parabolic flight may be provocative, but head movements during the different G-levels are the most provocative (Lackner & DiZio, 2006). Even during and after a centrifuge run at 3G's for 1.5 hours, subjects are asymptomatic as long as they remain motionless (Bles et al., 1998). The provocativeness of different types of head movements was investigated after such long-duration centrifuge runs. It was found by Bles, de Graff, and Krol (1995) that yaw head motion was not provocative at all, whereas pitch and roll head motion provoked motion sickness symptoms when

participants were sitting upright. Pitch motion was found to be the most provocative. However, when the subject subsequently took a supine posture, roll movements were not experienced as provocative any longer, whereas pitch head movements and now also yaw motion provoked sickness symptoms (Bles et al., 1998). Although it is not clear how the adaptation process has influenced the different parameter settings during the G-load, it is clear that only those head movements were provocative, which changed the orientation of the head relative to the gravitational vertical (Bles, de Graff, & Krol, 1995).

Space adaptation syndrome and space motion sickness. In the absence of gravity, signals from the central vestibular system, peripheral pressure receptors, and visual sense become inappropriate and thus misleading, to such point that immediate disorientation usually occurs (Souvestre, Blaber, & Landrock, 2008). Many astronauts suddenly feel as if they are upside-down or may even have difficulty sensing the location of their own arms and legs. This disorientation is described as space adaptation syndrome and is the main cause of space motion sickness (Legner, 2003). About 70% of astronauts will suffer from symptoms of space adaptation syndrome during the first few days of orbital flight (Lackner & DiZio, 2006).

The most incapacitating effects of space adaptation syndrome last from the first to fifth day of weightlessness, and reoccur within the first 10 days after landing (Legner, 2003). Commonly reported symptoms include dizziness, vertigo, headaches, cold sweating, fatigue, nausea and vomiting (Legner, 2003). Consequences may range from simple discomfort to incapacitation that may create potential problems during re-entry and emergency exits from a spacecraft. It is for this reason that no extravehicular activities are scheduled during the first few days of a mission.

Sensory conflict theory is favored by current research as the primary cause of space adaptation syndrome observed in astronauts, which can lead to space motion sickness (Lackner & DiZio, 2006). However, the precise mechanisms where the conflicts are occurring are not well understood and

effective therapies or preventive measures for space adaptation syndrome have yet to be developed. Interestingly, all symptoms of space adaptation syndrome have not been shown be reduced on veteran astronauts during subsequent spaceflights (Legner, 2003).

Air and car sickness. Although there are many movements of an aircraft that may cause motion sickness, aerobatics is well known as being provocative among student pilots. For passengers in civil transport aircraft, bumpy weather is known to provoke air sickness (Bles et al., 1998). Varying G-loads are the important vestibular stimuli in an otherwise stable visual surrounding. It is understandable that these stimuli easily lead to discrepancies between the sensed and the expected vertical.

Driving uphill at night along a winding road may provoke car sickness in the passengers in the back seat (Bles et al., 1998). The continuously changing gravitoinertial force vector, together with the inability of the semicircular ducts to appropriately signal the angular motion because of the stable visual interior of the car, will affect both the sensed vertical and the subjective vertical and subsequently provoke motion sickness (Bles et al., 1998). Linear acceleration and deceleration without appropriate view of the road ahead causes car sickness as well. Passengers who are susceptible to motion sickness benefit from sitting next to the driver and look at the road ahead. They anticipate on what maneuvers will come next. This explains as well why drivers are never motion sick (Bles et al., 1998).

Simulator sickness. Motion sickness is also encountered in simulators. It is called simulator sickness if an individual is motion sick in a simulated environment but the real-world environment does not provoke motion sickness. Simulator sickness might be due to insufficient motion capabilities of the simulator to mimic the amplitudes of the real motion (Bles et al., 1998). The motion characteristics of transport aircraft are such that the moving bases of transport aircraft simulators can move sufficiently to convince the human equilibrium system that the visually suggested motion is complemented by the appropriate physical motion stimuli. Simulator sickness is therefore not a common observation in these simulators. For highly maneuverable military aircraft (as well as for off-terrain vehicles), the motion

characteristics of a moving base are often insufficient to stimulate the vestibular system convincingly, which may result in simulator sickness. It is a common observation that experienced fighter pilots suffer more from simulator sickness than student pilots (Bles et al., 1998). This may be due to the fact that the experienced pilots have a fully developed expectation about the incoming sensory signals, which are not matched on the sensory side. In flight simulators and in driving simulators, fast maneuvering is one of the provocative factors in inducing simulator sickness. Differences between the sensed vertical and the subjective vertical may also arise when there is insufficient temporal concordance between the visual displays and the physical motion of the simulator. Such temporal problems may also add to the motion sickness encountered in virtual reality applications.

Motion sickness in amusement park rides. Amusement park rides are designed to be sensory experiences. Playground and amusement park rides are designed, in large part, to stimulate the vestibular system. In fact, much of the enjoyment from a good amusement park ride derives from tricking the vestibular system in some way; typically, the designer of a good amusement park ride is playing with one or more of the fundamental characteristics of the vestibular system (Wolfe et al., 2009).

Let's consider the simple child-powered merry-go-round found in playgrounds. These devices typically have a great deal of mass, especially compared to the mass of the children. The large device mass means that it takes a substantial amount of time for it to speed up or slow down. Such gradual changes have low-frequency components that trick the semicircular ducts into incorrectly sensing angular velocity. At the same time, the combination of the radius from the rotation axis at the center of the ride and the angular velocity at the edge yield a centripetal acceleration with low-frequency components that is sensed by the otolith organs. Low-frequency accelerations trick the brain into perceiving self-tilt even in the absence of actual tilt (Wolfe et al., 2009). This divergence of perception

from reality is the definition of an illusion. Such illusions seem to yield at least some of the fun experienced when riding amusement park rides but can also lead to motion sickness.

Now let's consider the roller coaster. Although part of the fun of a roller coaster comes from the thrill of moving at a high speed, the twists and turns of a roller coaster minimally change the speed of the carriage. These twists and turns are there primarily to yield vestibular stimulation well beyond that typically experienced by most people. Usually, the turns are located where the carriage travels with near-maximal speeds—thereby yielding high angular velocities transduced by semicircular ducts and high linear accelerations transduced by the otolith organs. These extreme vestibular stimuli add to the thrill experienced during roller coaster rides but can also lead to motion sickness.

Vection. When we are exposed to a visual motion field that simulates the retinal optical flow generated by our movement, we often perceive subjective movement of our own bodies. This phenomenon is called vection. Vection refers to the perception of self-motion induced by visual stimuli. Several stimulus attributes are known to affect the subjective strength or direction of vection, i.e. stimulus size, eccentricity, depth order, spatial frequency and attention (Seno, Ito, & Sunaga, 2009). For example, the magnitude of vection increases with an increase in stimulus size. Eccentricity has also been investigated as a determinant of vection. The depth-order effect on vection is well known. The farther away the perceived motion stimuli are, the stronger the vection that is induced. The furthest away motion stimulus also determines the direction of vection.

In daily life, vection may be experienced when waiting in a car at a stop light and observing another car in close proximity starting to move. Another example of naturally occurring vection is experienced while seated in a train and watching another train moving on an adjacent track. The stationary observer in these cases experiences a very compelling sensation of self-motion based solely on visual information.

The simplest types of vection are circular (illusion of rotation) and linear (illusion of traveling in a straight path). Vection occurs in the opposite direction to the stimulus direction and occurs either in addition to the perceived object motion or instead of the object motion. On occasions when the perception of self-motion dominates to the extent that the object appears stationary the vection is said to be saturated. To induce circular vection, participants may be seated in a chair surrounded by a cylinder (e.g., optokinetic drum) which rotates around the participant. Linear vection is typically induced by a display in which objects seem to be approaching or receding. Even when there is no physical motion, visually perceived motion can result in many of the same symptoms as motion sickness (Kennedy, Drexler, & Kennedy, 2010).

The conditions which produce the greatest vection also produce the greatest motion sickness (Webb & Griffin, 2003). However, evidence of a causal relationship has not been shown.

From a practical perspective, motion simulators would benefit from understanding how to improve the experience of vection. From a psychological perspective, vection has been investigated as a means to understand how the brain processes both visual and vestibular information. Mainly circular vection has been used for this purpose so far (Trutoiu, Mohler, Schulte-Pelkum, & Bülthoff, 2009).

Vection studies have been performed in a variety of conditions and setups. The first experiments on vection in a laboratory setting were performed by Mach in 1875 using an optokinetic drum consisting of a rotating cylinder with black and white stripes (Trutoiu, Mohler, Schulte-Pelkum, & Bülthoff, 2009). An optokinetic drum is a device used to induce circular vection and motion sickness symptoms (Stern, Hu, Vasey, & Koch, 1989). In an optokinetic drum participants either sit or stand at the center of the surrounding rotating apparatus and they usually experience a very compelling illusion of rotation. The experimental setups have since diversified and extended to include television screens, projectors, and fully immersive virtual environments. The stimuli used to induce vection also ranges

from the classical black and white stripes of the optokinetic drum to random dot fields, bar gratings, clouds, wood patterns and realistic computer graphics.

As a method for eliciting a range of motion sickness symptoms, illusory self-motion generated in the optokinetic drum is particularly useful because as with flight simulators, the participant determines the precise time at which the nauseogenic stimulus is stopped, thus alleviating the problem of uncontrolled nausea and vomiting often found with sea sickness. Thus, vection is a non-invasive neurovisual stimulus which may be safely used for the investigation of motion sickness symptoms ranging from the sopite syndrome to nausea, vomiting, and concomitant profiles of such neurohormones as cortisol. In 2003, Kennedy, French, Ordy, and Clarke, used optokinetic drum induced vection to produce symptoms of motion sickness that increased in a graded, stepwise manner. This study seeks to confirm that stepwise increase of motion sickness symptoms.

Overview of optokinetic drum research

Motion sickness is not only elicited by certain kinds of self-motion, but also by motion of a visual scene (Bos & Bles, 2004). An optokinetic drum is a useful device for studying motion sickness and the compelling visual illusion of self-motion experienced in virtual environments by stationary individuals when viewing moving visual surroundings, vection. Under optokinetic drum conditions, a stationary participant sits or stands inside a large rotating cylinder and simply views the pattern that comprises the drum's interior surface. Vection is usually experienced within 20 to 30 seconds. Also, it has been reported that up to 60% of healthy human participants experience motion sickness symptoms when placed in a rotating optokinetic drum (Stern, Koch, Stewart, & Lindblad, 1987). The simulator/optokinetic drum connection can be made because conditions produced by both share an important feature: the optic flow pattern results in vection. Vestibular input under optokinetic drum conditions indicates that the participant is stationary. Vestibular input in a simulator indicates the same,

or in the case of motion-based simulators, that the participant is moving, but in a manner that is not entirely consistent with the optic flow pattern.

The disagreement between vestibular and visual inputs may be at the root of simulator sickness (Kennedy & Frank, 1986) and motion sickness in general (Reason & Brand, 1975). According to these sensory conflict theories, input from two sensory modalities (visual and vestibular) send afferent signals to the central nervous system that do not correlate. In the case of viewing the interior of an optokinetic drum, the visual system indicates that the observer is moving, whereas the vestibular system indicates that the observer is stationary. Such conflicts may result in motion sickness-like symptoms. In true motion sickness, the vestibular system indicates motion while visual input often indicates that the individual is stationary. In simulators (fixed-base) and optokinetic drums the opposite sensory arrangement results: visual input indicates movement while the vestibular input indicates the individual is stationary. It should be noted here that although they are similar, the constellation of symptoms that constitute true motion sickness and simulator sickness differ slightly (Kennedy & Frank, 1986) in that vomiting and retching are rare occurrences in the latter.

The optokinetic drum has been useful for studying motion sickness and vection. Several optokinetic drum parameters can be manipulated to understand their effect on motion sickness symptoms and vection. The following lines show what happens when some optokinetic drum parameters like rotation speed, rotation direction, tilt and visual stimuli are manipulated.

Optokinetic drum speed

It has been well documented that motion sickness often occurs in optokinetic drums. In a 2006 study, Bubka, Bonato, Urmey, and Mycewicz tested if increasing visual-vestibular conflict would lead to more motion sickness. Given that the vestibular system responds to changes in tilt and velocity, an attempt was made to isolate the effects of changing velocity by holding the effects of tilt constant across conditions. In two conditions of the study, the drum rotated at a constant velocity, 5 rpm and 10 rpm,

respectively. In the third condition of the study the drum rotation velocity was changed between 5 rpm and 10 rpm every 30 seconds. In this condition, half of the participants first viewed the drum rotating at 5 rpm and the other half first viewed the drum rotating at 10 rpm. In the 5 rpm and 10 rpm conditions, drum velocity remained constant throughout the trial. Each participant served in all three conditions. There were six possible orders of participation. Participation was counterbalanced to control for any possible order effects, including adaptation. Motion sickness symptoms were evaluated using the Simulator Sickness Questionnaire (SSQ). The mean total SSQ score in the 5 RPM condition was significantly lower than the mean total SSQ score obtained in the 5/10 RPM condition. The means obtained in the 10 RPM condition were not significantly different from the means obtained in the 5 RPM and 5/10 RPM conditions. The results of this study indicate that intermittently changing optokinetic drum rotation velocity results in significantly more motion sickness compared with a steadily rotating drum. The mean total SSQ score obtained in the 5/10 RPM condition was 50% higher than the mean score obtained in the 10 RPM condition and 71% higher than the mean score obtained in the 5 RPM condition.

Optokinetic drum rotation direction

In 2005, an experiment by Bonato, Bubka, and Story, was conducted to investigate the effects of rotation direction change on motion sickness onset and severity. There were three conditions: (1) same direction, (2) different direction, and (3) control (steady rotation). The participant was instructed to close his/her eyes and the OKD motor was tuned on until the drum steadily rotated at a speed of 5 RPM. For the first 30 seconds of each trial the participant viewed the drum as it rotated clockwise. In the first and second conditions the participant was then instructed to close his/her eyes and the motor was turned off, subsequently stopping drum rotation. The motor was then turned on again causing the drum to rotate either in the same direction (first condition) or the opposite direction (second condition). After a second viewing interval of 30 seconds the participant was again instructed to close his/her eyes for a 5

second period. This cycle was repeated in the same direction condition and the different direction conditions until the end of each trial, resulting in a sequence of 30 seconds periods of drum viewing separated by 5 seconds of eyes closed. The only difference was whether drum rotation alternately changed or remained the same throughout a trial. In the control condition, the participant was instructed to simply view the interior of a steadily rotating drum. Overall well-being and subjective symptoms of motion sickness (SSMS) ratings were obtained after every 2 minutes of drum viewing throughout the trial. Each subject served in all three conditions and participation was counterbalanced to control for any possible order effects such as motion sickness adaptation. Bonato and colleagues found that motion sickness in the control and same direction condition were significantly lower than the motion sickness obtained in the different direction condition. Collectively, these results indicate that intermittently changing optokinetic drum rotation direction significantly speed up the onset of motion sickness symptoms.

Optokinetic drum tilt

Optokinetic drums typically rotate at a constant velocity and their axis of rotation is usually perpendicular to the ground. Tilt and direction, two variables to which the vestibular system responds, are not varied under typical optokinetic drum conditions, but in 2003, Bubka and Bonato manipulated the degree of sensory conflict by tilting an optokinetic drum so that it rotated in a wobble-like fashion. Each participant served in three tilt conditions in counterbalanced order on three separate days. In one condition, the drum was perpendicular to the floor (0° condition). In another condition, the drum was tilted 5°, and in a third condition the drum was tilted 10°. The rotation speed in this experiment was 10 RPM. They measured well-being with the well-being scale and motion sickness with the subjective symptoms of motion sickness (SSMS) ratings. Bubka and Bonato found that the well-being scores were significantly different between conditions. Participants felt worse when the drum was tilted 10°, followed by the 5° tilt, and then the 0° tilt. In terms of motion sickness, they found that participants

experienced more symptoms of motion sickness when the drum was tilted as when it was not. The difference between a tilt of 10° and 5° was not significantly different. These results support the hypothesis that as sensory conflict between the visual and vestibular systems is increased, the onset latency of symptoms decreases. In the control condition (0°) the onset of symptoms was the slowest. As the degree of tilt was increased, the onset of symptoms was accelerated.

Visual stimuli (wallpaper patterns) in the optokinetic drum

Vection is typically produced via alternating black and white vertical stripes with specific dimensions. However, in 2002 Kennedy and colleagues elected to use "naturalistic" patterned scenes found on wallpaper to study vection and record any sickness produced. They used four patterns: (1) green "wood," (2) "random dots," (3) "waves," and (4) "clouds." They found that the random dots scene produced the most sickness, while horizontal patterns (i.e., clouds and waves) produced moderate sickness, and vertical paneling (i.e., green wood) produced the least sickness.

Summary of optokinetic drum research

Vection, an illusory perception of self-motion, is often experienced when a large portion of the visual field moves. Specifically, an observer may perceive self-movement in the direction opposite to that of the optic flow pattern, even if the observer is in fact stationary. An optokinetic drum is a useful device for studying vection and simulator sickness. Several parameters of the optokinetic drum can be altered to study their effects. Changing rotation velocity increases sensory conflict that in turn leads to more motion sickness symptoms. Motion sickness symptoms onset is accelerated when the drum rotation direction is changed. In tilted optokinetic drums, as tilt is increased, the quicker is the onset of motion sickness symptoms. Some researchers have used different colors, textures and scene content in the investigation of motion sickness. Random scenes produce the most symptoms of motion sickness, while regular horizontal patterns produce only moderate sickness.

Hypotheses & Aims

Reported vection-induced motion sickness symptoms may exhibit different characteristics (timing, duration and severity) specific to each experimental condition. The same may apply to the measurements of cognitive performance and sleep amount. More information will be provided about the experimental conditions and the methods of this study later on, but for now please notice that there were three rotation speed settings for the optokinetic drum: (1) no rotation, (2) slow rotation, and (3) fast rotation. Hence, the researcher hypothesizes:

Hypothesis 1

The severity of motion sickness symptoms will be different during and after exposure to the rotating optokinetic drum. In other words, the severity of motion sickness symptoms will be worst after exposure to the fast rotation, intermediate after slow rotation, and minimal or asymptomatic after being inside a non-rotating optokinetic drum at particular periods of time.

Specific Aim 1

Conduct a psychophysiological study to describe and quantify the effects of different optokinetic drum rotation speeds on motion sickness symptoms.

Hypothesis 2

A decline in cognitive performance will take place after exposure to the rotating optokinetic drum. In other words, the decline in cognitive performance will be most striking after exposure to the fast rotation, intermediate after slow rotation, and minimal or without change in cognitive performance after being inside a non-rotating optokinetic drum.

Specific Aim 2

Conduct objective and systematic cognitive evaluation tests to study the effects of different optokinetic drum rotation speeds on cognitive performance.

Hypothesis 3

Participants' sleep amount will be disrupted after exposure to the rotating optokinetic drum. In other words, sleep will be most affected after exposure to the fast rotation, intermediately affected after slow rotation, and minimal or without change after being inside a non-rotating optokinetic drum.

Specific Aim 3

Conduct a physiological study to describe the effects of different optokinetic drum rotation speeds on sleep amount.

Methods

Participants

A sample of 8 motion sickness susceptible individuals (*M* = 21.4 years) participated in the study. Participants were all students at Embry-Riddle Aeronautical University. There were 4 males and 4 females in the sample. Participants received $30 for their participation in this study as compensation for their time. Additionally, a bonus of $100 was given to a randomly selected participant.

Materials

Motion Sickness Susceptibility Questionnaire

Susceptibility to motion sickness was part of the selection criteria. The assessment of susceptibility to motion sickness was conducted using the Motion Sickness Susceptibility Questionnaire (MSSQ). The MSSQ was devised and tested in 1991 by Reid (Griffin & Howarth, 2000). The questionnaire contains brief instructions and an initial section on personal details, including age, weight and height. This is followed by 12 questions on experience of motion sickness while traveling in seven forms of transport, a question asking for self-rating of motion sickness susceptibility relative to other people, and

two questions about past and present health. The MSSQ is shown in appendix A. Every participant in this study scored over the 75th percentile of susceptibility to motion sickness.

Consent form

The consent form described the purpose of the study, the expected duration of participation, benefits and risks to the participant, confidentiality agreement, and the voluntary nature of the study. All 8 participants signed the written consent form voluntarily. Refer to appendix B for a copy of the consent form.

Demographic form

Participants completed a demographic form (refer to appendix C) to record general information about themselves.

Automated Neuropsychological Assessment Metrics

Evaluation of cognitive performance was made using the Automated Neuropsychological Assessment Metrics software (ANAM, v.4). The ANAM, is a library of computer-based assessments of cognitive domains including attention, concentration, reaction time, memory, processing speed, and decision-making. ANAM provides clinicians and researchers with data to evaluate an individual's neurocognitive status at a point-in-time and changes in cognitive status over time. ANAM's library of computer-based assessments is designed for a broad spectrum of clinical and research applications and can be configured into a customized set of tests to measure, monitor and manage neurocognitive change from disease (e.g., neurodegenerative diseases), injury (e.g., trauma, blast), exposure (e.g., toxin, ionizing radiation), risk factors (e.g., heat/cold, sleep loss, fatigue), treatment (e.g., medication, rehabilitation), and interventions. ANAM batteries have been utilized in a wide variety of research settings, from medical clinics to space travel, underwater, and in toxic environments (Vista LifeSciences, 2011). The ANAM batteries measures both accuracy and response speed on all tests in the battery.

Switching test. The specific ANAM battery used in this study to assess cognitive performance was the Switching test. The Switching test assesses two cognitive performance domains: directed attention and executive function (Vista LifeSciences, 2011). This test is a combination of the ANAM's Manikin test and the Mathematical Processing test. The purpose of the Manikin test is to assess three-dimensional spatial rotation ability, left-right orientation, problem solving, and attention. The goal of the Mathematical Processing test is to assess basic computational skills, concentration, and working memory. One problem from each test appears on the display. The problems appear simultaneously side-by-side, and the user is directed by means of a red arrow at the bottom of the screen to respond to the problem on the left or on the right (refer to figure 4).

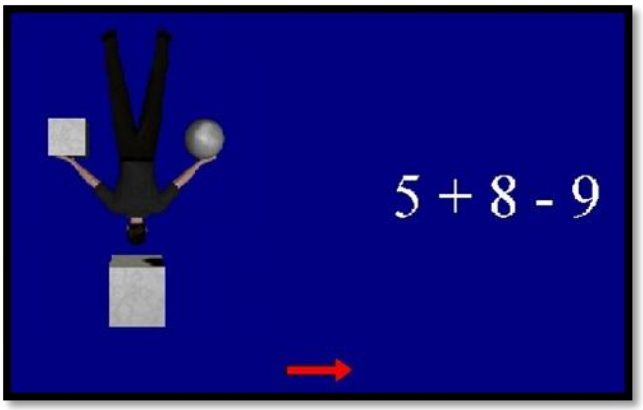

Figure 4. Screen displaying the Switching test.

Responses are entered using a keyboard, as shown in figure 5, with the left hand used for the Manikin test and the right hand used for Mathematical Processing test.

Figure 5. Hand location on the keyboard for the Switching test.

Switching test instructions. Each participant received verbal and written instruction on the use of the Switching test. A copy of the written instruction is included in appendix D.

Switching test performance log. Each participant was given a performance log, in which they recorded the date, time of day, trial number, and the percentage of correct answers. Please refer to appendix E for a copy of this log.

Simulator Sickness Questionnaire

The most widely used measure of motion sickness symptoms in all environments in which motion sickness has been investigated are self-reports of symptoms. The assessment of motion sickness symptoms was conducted using the Simulator Sickness Questionnaire (SSQ), developed by Kennedy, Lane, Berbaum and Lilienthal in 1993. The SSQ has been used extensively in studies of motion sickness symptoms. Currently the SSQ is in usage in many research studies and in journal articles in the scientific literature. The SSQ is a subjective self-report checklist consisting of 16 symptoms that are rated by the participant in terms of degree of severity on a 4-point (“none,” “slight,” “moderate,” and “severe”) Likert scale. These 16 items yield: a nausea scale, an oculomotor scale, and a disorientation scale, which are combined by a series of mathematical computations to produce an overall score (Total scale) encompassing the nausea, oculomotor and disorientation scales. Refer to appendix F for a copy of the SSQ.

Actigraphs

Since motion-induced fatigue, circadian rhythm disruptions, sleep disturbances and sopite symptoms can be long lasting (Kiniorski et al., 2004), the researcher proposes to further evaluate the participants in the duration and quality of their sleep using actigraphs. Actigraphs are watch-sized accelerometers that are worn on the wrist.

These wrist activity monitors are increasingly used to estimate sleep duration in studies where polysomnography would be too burdensome, intrusive, or expensive. A study (Mullaney, Kripke, & Messin, 1982) comparing polysomnography and actigraphy indicated a sleep-wake agreement rate of 94.5% and a correlation of .89. In addition, taking actigraphic measurements is simpler than traditional polysomnography and the wearer can sleep in a more familiar environment. Actigraphy measures sleep onset, duration of sleep and numbers of awakenings.

In this study, participants used a Mini Motionlogger® Actigraph (Ambulatory Monitoring, Inc., Ardsley, NY). Figure 6 shows a photograph of an actigraph.

Figure 6. Mini Motionlogger® actigraph (Ambulatory Monitoring, Inc.)

Sleep/Activity log. Each participant kept a record of daily activities. They recorded the time they spent on bed, the time they remained asleep, and the time they got out of bed. Additionally, they used

this log to record any ingestion of alcohol, caffeine or medications, or engagement in physical exercises. Please refer to appendix G for a copy of this log.

Optokinetic drum

A vection device, the optokinetic drum (OKD), was used in this study. Refer to figure 7 for a photograph of the optokinetic drum. The OKD used in this study is a cylindrical drum 2.1 meters in diameter by 1.6 meters high.

Figure 7. The optokinetic drum.

The inside surface was lined with a “random dots” pattern wallpaper (figure 8). Participants seated in a chair inside the drum. Average viewing distance, as measured from the nasion to the OKD inside surface was 61 cm.

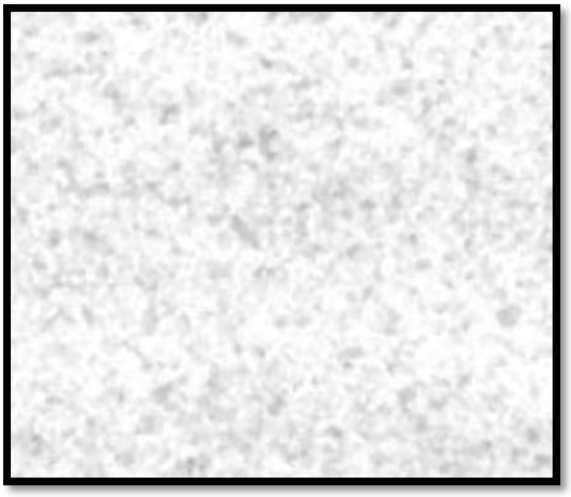

Figure 8. Random dots pattern wallpaper

Experimental Design

The researcher conducted three studies for this project. The design of every study was a counterbalanced within-subjects experimental design. The studies were as follows:

Study 1. Analyzed the effects of different rotation speeds of the optokinetic drum on motion sickness symptoms.

Study 2. Analyzed the effects of different rotation speeds of the optokinetic drum and time on cognitive performance.

Study 3. Analyzed the effects of different rotation speeds of the optokinetic drum and time on sleep amount.

Independent variables

There was one independent variable (IV) common to every study: the rotation speed of the optokinetic drum. The rotation speed of the optokinetic drum had three levels: (1) no rotation (0 RPM), (2) slow rotation speed (5 RPM), and (3) fast rotation speed (10 RPM). A counterbalanced design was used to minimize order effects. The sequence in which the three levels were presented was randomized.

Table 1 shows the order of exposure to each level of the common independent variable, rotation speed of the optokinetic drum.

Table 1

Order of exposure to each level of the common independent variable

Participant	**Order**
1	0 RPM → 5 RPM → 10 RPM
2	5 RPM → 10 RPM → 0 RPM
3	10 RPM → 0 RPM → 5 RPM
4	0 RPM → 10 RPM → 5 RPM
5	5 RPM → 0 RPM → 10 RPM
6	10 RPM → 5 RPM → 0 RPM
7	0 RPM → 5 RPM → 10 RPM
8	5RPM→ 10 RPM → 0 RPM

Another independent variable, time period, was used in the second and third studies. There were five levels of this IV on the second study and three levels on the third study as shown on table 2.

Table 2

Levels of the independent variable “Time” per study

Levels of the IV (Time)	**Second Study**	**Third Study**
1	Baseline	Baseline
2	Immediately after	One day after
3	30 minutes after	Two days after
4	One day after	
5	Two days after	

Dependent measurements

The dependent measurements were: (1) motion sickness symptoms, (2) cognitive performance, and (3) sleep amount. The Simulator Sickness Questionnaire (SSQ) was used to assess motion sickness symptoms. The Switching test of the Automated Neuropsychological Assessment Metric (ANAM) was used to assess cognitive performance. Actigraphs and the sleep/activity log were used to assess participants' sleep amount.

Procedure

Preliminary

Interested potential participants were given the contact information of the research team for additional information. Potential participants received the Motion Sickness Susceptibility Questionnaire (MSSQ) via e-mail. Eligibility for participation was based in part on the MSSQ scores. The researcher invited those individuals who scored over the 75th percentile among the poll of completed questionnaires. Qualified candidates were invited to the laboratory, the Vection and Motion Sensitivity Lab, to discuss in detail the study and their role. During this visit to the lab, each eligible participant took part on an orientation discussing the risks and benefits to them. After written informed consent was given by the individual, the researcher proceeded to collect demographic information. Each participant were also given an actigraph, a sleep/activity log, a USB device containing the Switching test, a Switching test performance log, and several copies of the Simulator Sickness Questionnaire (SSQ). Participants were given a demonstration on the use of the actigraph and Switching test.

Days 1 – 7

Each participant was required to perform a series of trials (3 trials per day, for the first 7 days) of the Switching test before the first optokinetic drum exposure session with the intention to achieve a steady level of performance (at or above the 95% accuracy level).

Participants were also instructed to continuously wear the actigraph from the first day until the last day of the study. Participants wore the actigraphs on the dominant wrist.

Day 8

The first optokinetic drum (OKD) session was scheduled for the 8th day of the study. Participants were welcomed to the lab. Each participant then completed one pre-exposure SSQ and one pre-exposure trial of the Switching test. After that, each participant went inside the OKD and sat in. Participants were reminded that they could stop the session at any time. In the absence of severe symptoms of motion sickness or a desire to stop the session, participants remained inside the OKD for 30 minutes. Intra-exposure SSQs were verbally administered every 2 minutes. The SSQ (post-exposure) was administered again 10, 20 and 30 minutes after the session had ended. Post-exposure evaluation of cognitive performance with the Switching test was made immediately after and 30 minutes after the session.

Days 9 – 10

During these two days participants took one Switching test per day and completed one SSQ per day to follow up cognitive performance and motion sickness symptoms after the first optokinetic drum session.

Day 11

The second optokinetic drum session took place on the 11th day of the study. The research team followed the same procedure as in the first session.

Days 12 – 13

During these two days participants took one Switching test per day and completed one SSQ per day to follow up cognitive performance and motion sickness symptoms after the second optokinetic drum session.

Day 14

The third optokinetic drum session took place on the 14th day of the study. The research team followed the same procedure as in the first and second sessions.

Days 15 – 16

During these two days participants took one Switching test per day and completed one SSQ per day to follow up cognitive performance and motion sickness symptoms after the third optokinetic drum session.

Day 17

On day 17th participants stopped using the actigraphs. Participants handed-in all materials to the researcher and were fully debriefed and thanked.

A summary of daily activities is shown on table 3.

Table 3

Timeline showing activities per day

Day	Activities per day
1	Switching test (3 trials). **Start** wearing the actigraph (contiously).
2	Switching test (3 trials)
3	Switching test (3 trials)
4	Switching test (3 trials)
5	Switching test (3 trials)
6	Switching test (3 trials)
7	Switching test (3 trials).
8	**OKD Session #1** Baseline SSQ Baseline Switching test Inside the OKD: SSQs every 2 minutes Two post-exposure Switching test trials (0 and 30 minutes post-exposure)

	Three post-exposure SSQs (10, 20 and 30 minutes post-exposure)
9	One Switching test and one SSQ
10	One Switching test and one SSQ
11	**OKD Session #2**
	Baseline SSQ
	Baseline Switching test
	Inside the OKD: SSQs every 2 minutes
	Two post-exposure Switching test trials (0 and 30 minutes post-exposure)
	Three post-exposure SSQs (10, 20 and 30 minutes post-exposure)
12	One Switching test and one SSQ
13	One Switching test and one SSQ
14	**OKD Session #3**
	Baseline SSQ
	Baseline Switching test
	Inside the OKD: SSQs every 2 minutes
	Two post-exposure Switching test trials (0 and 30 minutes post-exposure)
	Three post-exposure SSQs (10, 20 and 30 minutes post-exposure)
15	One Switching test and one SSQ
16	One Switching test and one SSQ.
17	**Stop** wearing the actigraph. Return materials to the lab. Debriefing.

Dealing with motion sickness in the laboratory

The researcher kept sick bags, gloves, light snacks, and cleaning products readily available throughout the study. Even without motion sickness symptoms, participants were required to stay in the lab for a minimum of 30 minutes after each optokinetic drum session for observation.

Data collection

Motion sickness symptoms. Each participant kept a record of motion sickness symptoms during off-lab days using the Simulator Sickness Questionnaire (SSQ). During lab days the researcher kept track of the symptoms for each participant. Each symptom included in the SSQ has a particular weight towards a specific scale, please refer to table 4.

Table 4

SSQ – weights for symptoms

Weight for symptoms in each scale			
Symptoms	**Nausea**	**Oculomotor**	**Disorientation**
General discomfort	**1**	**1**	0
Fatigue	0	**1**	0
Headache	0	**1**	0
Eye strain	0	**1**	0
Difficulty focusing	0	**1**	**1**
Increased salivation	**1**	0	0
Sweating	**1**	0	0
Nausea	**1**	0	**1**
Difficulty concentrating	**1**	**1**	0
Fullness of the head	0	0	**1**
Blurred vision	0	**1**	**1**
Dizziness (eyes open)	0	0	**1**
Dizziness (eyes closed)	0	0	**1**
Vertigo	0	0	**1**
Stomach awareness	**1**	0	0
Burping	**1**	0	0

Participants reported the degree to which they experienced each of the above symptoms as one of “none,” “slight,” “moderate” and “severe.” These were scored as 0, 1, 2 and 3, respectively. To

compute the scale scores for each column, the reported value for each symptom was multiplied by the weight in each column and then summed down the columns.

The total SSQ score was obtained by adding the scale scores across the three columns and multiplying by 3.74. Weighted scale scores for each column individually were calculated by multiplying the nausea scale score by 9.54; the oculomotor scale by 7.58; and the disorientation scale by 13.92.

Cognitive performance. Cognitive performance was assessed using the Switching test. Each participant kept a log with the number of trials, dates and percentages correct. The logs were used in conjunction with data files that were automatically saved on the USB-drives. Those data files contained accuracy (in percentages) and mean reaction time (in milliseconds) information for each Switching test trial.

Sleep amount. Sleep data was recorded using actigraphs and sleep-activity logs. The researcher recorded the time each participant spent sleeping. The researcher combined nocturnal sleeping time with diurnal nap time into a total time spent sleeping (in hours).

Results

To review, the researcher studied the effects of different optokinetic drum rotation speeds on motion sickness symptoms, cognitive performance and sleep amount. Some dependent measurements were analyzed using parametric statistical analyses, while others were assessed using non-parametric statistical analyses. All analyses were performed with α set at .05.

Motion sickness symptoms were assessed using the Simulator Sickness Questionnaire (SSQ). The SSQ is a checklist consisting of various symptoms that are rated by the participant in terms of degree of severity on a 4-point Likert scale. This ordinal data was analyzed with a non-parametric analysis, the Friedman test. The Friedman test is the non-parametric alternative to the one-way ANOVA with repeated measures. It is used to test for differences between groups when the dependent variable being

measured is ordinal, interval or ratio. When applicable, significant differences were further analyzed with the post-hoc Wilcoxon Signed-Rank test on the different available combinations.

Cognitive performance and sleep amount were the dependent measurements that were each analyzed parametrically with two-way repeated measures analysis of variance (ANOVA). The purpose of ANOVA is to test for significant difference between three or more group means.

To analyze data, the researcher entered collected data into SPSS (version 19) and conducted several statistical analyses, which are listed below.

1. A series of Friedman tests were conducted to evaluate differences in medians among the experimental conditions regarding motion sickness symptoms. The researcher conducted four Friedman tests, one for each motion sickness symptom scale (total, nausea, oculomotor and disorientation) for each of the time periods listed below, for a total of 40 independent Friedman tests.
    a. Pre-exposure (baseline)
    b. Intra-exposure
        i. 0 to 6 minutes
        ii. 6 to 12 minutes
        iii. 12 to 18 minutes
        iv. 18 to 24 minutes
        v. 24 to 30 minutes
    c. Post-exposure
        i. 0 to 20 minutes
        ii. 30 minutes
        iii. 1 day
        iv. 2 days

2. A pair of within subjects, repeated measures two-way ANOVAs were conducted to evaluate differences in means among the experimental conditions regarding cognitive performance. One test was used to analyze accuracy and the second test was used to analyze mean reaction time. The experimental conditions are shown in table 5.

Table 5

Experimental conditions in the Switching test (accuracy and mean reaction time)

Accuracy and Mean Reaction Time measured at the following time periods	**OKD speed**		
	0 RPM	**5PRM**	**10 RPM**
Baseline	Condition 1	Condition 6	Condition 11
Immediately after the session	Condition 2	Condition 7	Condition 12
30 minutes after the session	Condition 3	Condition 8	Condition 13
One day after the session	Condition 4	Condition 9	Condition 14
Two days after the session	Condition 5	Condition 10	Condition 15

3. A within subjects, repeated measures two-way ANOVAs was conducted to evaluate differences in means among the experimental conditions regarding sleep amount. The experimental conditions are shown on table 6.

Table 6

Experimental conditions in the sleep amount analysis

Seep amount measured at the following time periods	**OKD speed**		
	0 RPM	**5PRM**	**10 RPM**
Baseline	Condition 1	Condition 4	Condition 7
One day after the session	Condition 2	Condition 5	Condition 8
Two days after the session	Condition 3	Condition 6	Condition 9

Graphs in this section show error bars with standard error.

Motion sickness symptoms

Total scale of the SSQ

A Friedman test was conducted to evaluate differences in medians of the total scale of the SSQ before the optokinetic drum sessions (baseline) among the 0 RPM condition (Median = 3.74), the 5 RPM condition (Median = 3.74), and the 10 RPM condition (Median = 9.35). The test was not significant, $\chi^2(2, N = 8) = 2.58$, $p = .275$. Before the optokinetic drum sessions there were no statistically significant differences between the three medians.

A Friedman test was conducted to evaluate differences in medians of the Total scale of the SSQ during the first six (6) minutes of exposure to the optokinetic drum among the 0 RPM condition (Median = 7.48), the 5 RPM condition (Median = 18.70), and the 10 RPM condition (Median = 43.01). Figure 9 shows a graphic representation of the median scores for the Total scale for this particular time period. The test was significant, $\chi^2(2, N = 22) = 13.68$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median total scale score for 0 RPM was significantly smaller than the median total scale score for 5 RPM, $p < .01$, and the median total scale score for 10 RPM, $p < .01$, but

the median total scale score for 5 RPM did not differ significantly from the median total scale score for 10 RPM, p = .073. During the first 6 minutes of exposure, participants in the 0 RPM group experienced significantly less motion sickness symptoms than those in the other groups. There was no significant difference in terms of motion sickness symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more motion sickness symptoms than those in the 0 RPM group.

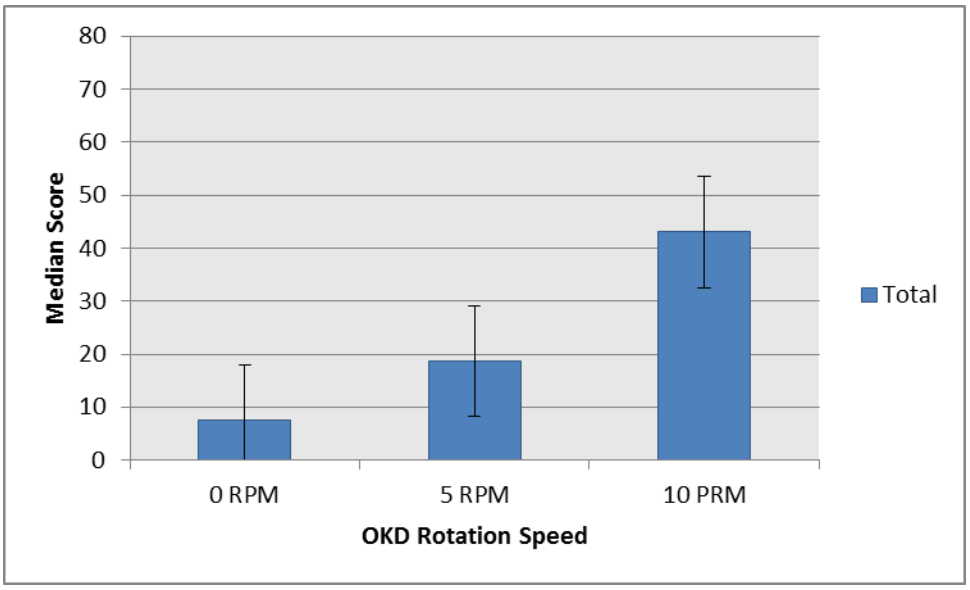

Figure 9. Median scores for the Total scale of the SSQ from 0 to 6 minutes inside the optokinetic drum.

A Friedman test was conducted to evaluate differences in medians of the Total scale of the SSQ from the 6th minute to the 12th minute of exposure to the optokinetic drum among the 0 RPM condition (Median = 3.74), the 5 RPM condition (Median = 22.44), and the 10 RPM condition (Median = 44.88). Figure 10 shows a graphic representation of the median scores for the Total scale for this particular time period. The test was significant, $\chi^2(2, N = 19) = 13.06$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median total scale score for 0 RPM was significantly smaller than the median total scale score for 5 RPM, $p < .01$, and the median total scale score for 10 RPM, $p < .01$, but the median total scale score for 5 RPM did not differ significantly from the median

total scale score for 10 RPM, p = .517. From the 6th minute to the 12th minute of exposure, participants in the 0 RPM group experienced significantly less motion sickness symptoms than those in the other groups. There was no significant difference in terms of motion sickness symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more motion sickness symptoms than those in the 0 RPM group.

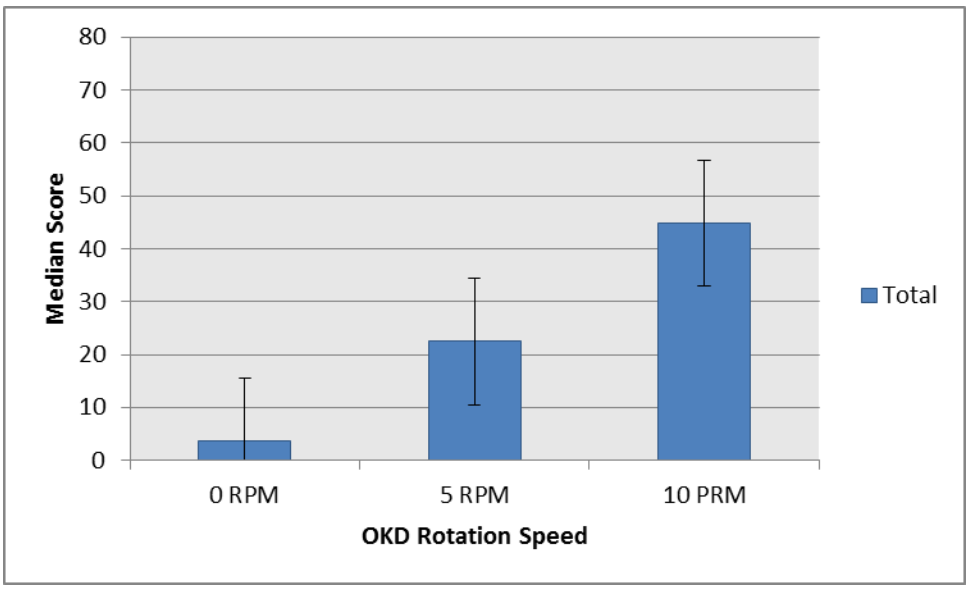

Figure 10. Median scores for the Total scale of the SSQ from 6 to 12 minutes inside the optokinetic drum.

A Friedman test was conducted to evaluate differences in medians of the Total scale of the SSQ from the 12th minute to the 18th minute of exposure to the optokinetic drum among the 0 RPM condition (Median = 3.74), the 5 RPM condition (Median = 33.66), and the 10 RPM condition (Median = 26.18). Figure 11 shows a graphic representation of the median scores for the Total scale for this particular time period. The test was significant, $\chi^2(2, N = 13) = 13.06$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median total scale score for 0 RPM was significantly smaller than the median total scale score for 5 RPM, $p < .01$, and the median total scale score for 10 RPM, $p < .01$, but the median total scale score for 5 RPM did not differ significantly from the

median total scale score for 10 RPM, p = .598. From the 12th minute to the 18th minute of exposure, participants in the 0 RPM group experienced significantly less motion sickness symptoms than those in the other groups. There was no significant difference in terms of motion sickness symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more motion sickness symptoms than those in the 0 RPM group.

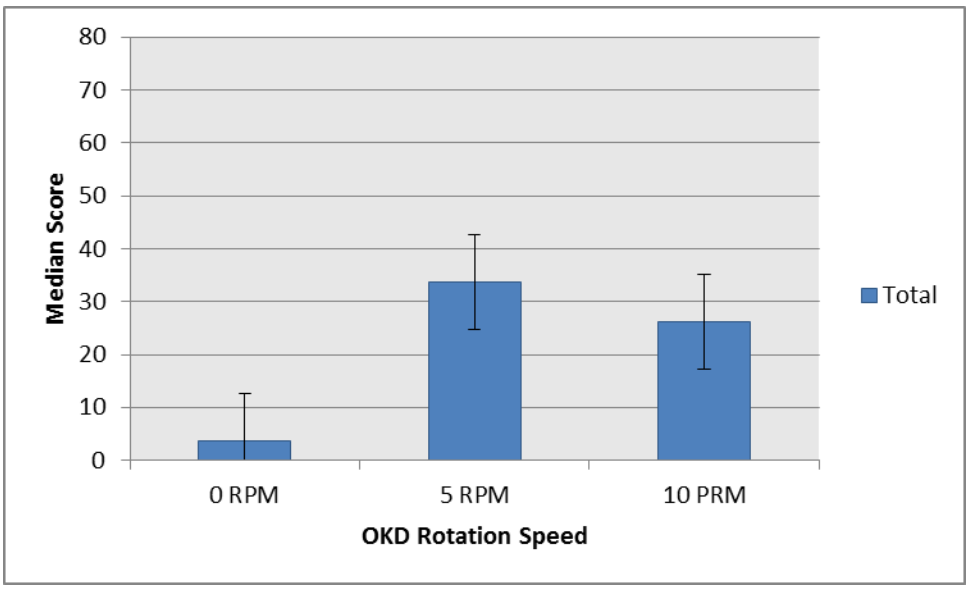

Figure 11. Median scores for the Total scale of the SSQ from 12 to 18 minutes inside the optokinetic drum.

A Friedman test was conducted to evaluate differences in medians of the Total scale of the SSQ from the 18th minute to the 24th minute of exposure to the optokinetic drum among the 0 RPM condition (Median = 0.00), the 5 RPM condition (Median = 3.74), and the 10 RPM condition (Median = 29.92). Figure 12 shows a graphic representation of the median scores for the Total scale for this particular time period. The test was significant, $\chi^2(2, N = 9) = 15.94$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median total scale score for 0 RPM was significantly smaller than the median total scale score for 5 RPM, $p < .01$, and the median total scale score for 10 RPM, $p < .01$. Additionally, the median total scale score for 5 RPM was significantly smaller

than the median total scale score for 10 RPM, p = .011. From the 18th minute to the 24th minute of exposure, participants in the 0 RPM group experienced significantly less motion sickness symptoms than those in the other groups. Participants in the 5 RPM group experienced significantly less motion sickness symptoms than those in the 10 RPM group. Participants in the 10 RPM experienced significantly more motion sickness symptoms than those in the 0 and 5 RPM groups.

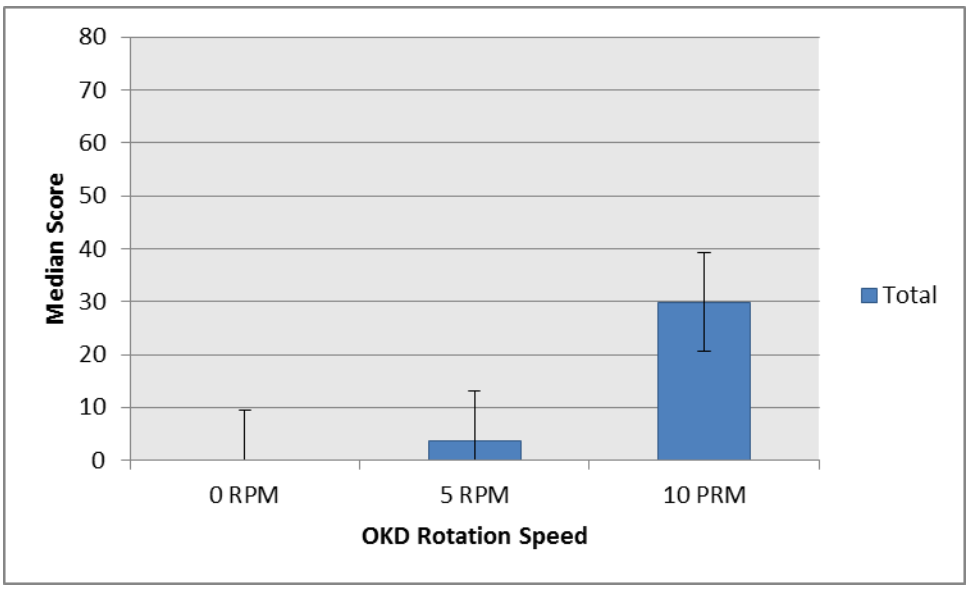

Figure 12. Median scores for the Total scale of the SSQ from 18 to 24 minutes inside the optokinetic drum.

A Friedman test was conducted to evaluate differences in medians of the Total scale of the SSQ from the 24th minute to the 30th minute of exposure to the optokinetic drum among the 0 RPM condition (Median = 0.00), the 5 RPM condition (Median = 7.48), and the 10 RPM condition (Median = 29.92). Figure 13 shows a graphic representation of the median scores for the Total scale for this particular time period. The test was significant, $\chi^2(2, N = 9) = 13.56$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median total scale score for 0 RPM was significantly smaller than the median total scale score for 5 RPM, $p < .01$, and the median total scale score for 10 RPM, $p < .01$. Additionally, the median total scale score for 5 RPM was significantly smaller

than the median total scale score for 10 RPM, p = .015. From the 24th minute to the 30th minute of exposure, participants in the 0 RPM group experienced significantly less motion sickness symptoms than those in the other groups. Participants in the 5 RPM group experienced significantly less motion sickness symptoms than those in the 10 RPM group. Participants in the 10 RPM experienced significantly more motion sickness symptoms than those in the 0 and 5 RPM groups.

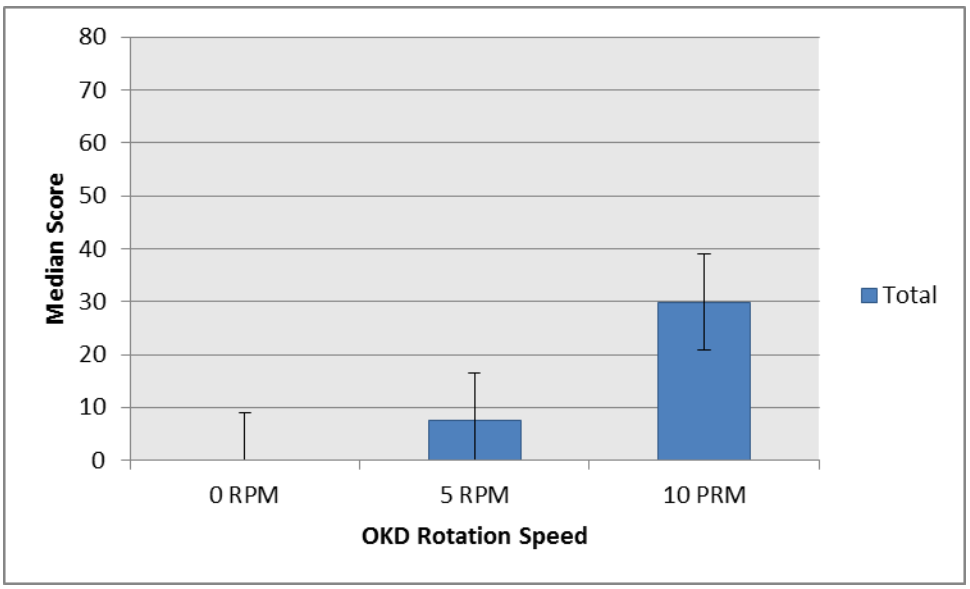

Figure 13. Median scores for the Total scale of the SSQ from 24 to 30 minutes inside the optokinetic drum.

A Friedman test was conducted to evaluate differences in medians of the Total scale of the SSQ after exposure to the optokinetic drum (up to 20 minutes after) among the 0 RPM condition (Median = 0.00), the 5 RPM condition (Median = 7.48), and the 10 RPM condition (Median =9 .35). Figure 14 shows a graphic representation of the median scores for the Total scale for this particular time period. The test was significant, $\chi^2(2, N = 16) = 18.05$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median total scale score for 0 RPM was significantly smaller than the median total scale score for 5 RPM, $p < .01$, and the median total scale score for 10 RPM, $p < .01$. Additionally, the median total scale score for 5 RPM was significantly smaller than the median total scale

score for 10 RPM, p = .04. Immediately after the optokinetic drum session was over and up to 20 minutes after exposure, participants in the 0 RPM group experienced significantly less motion sickness symptoms than those in the other groups. Participants in the 5 RPM group experienced significantly less motion sickness symptoms than those in the 10 RPM group. Participants in the 10 RPM experienced significantly more motion sickness symptoms than those in the 0 and 5 RPM groups.

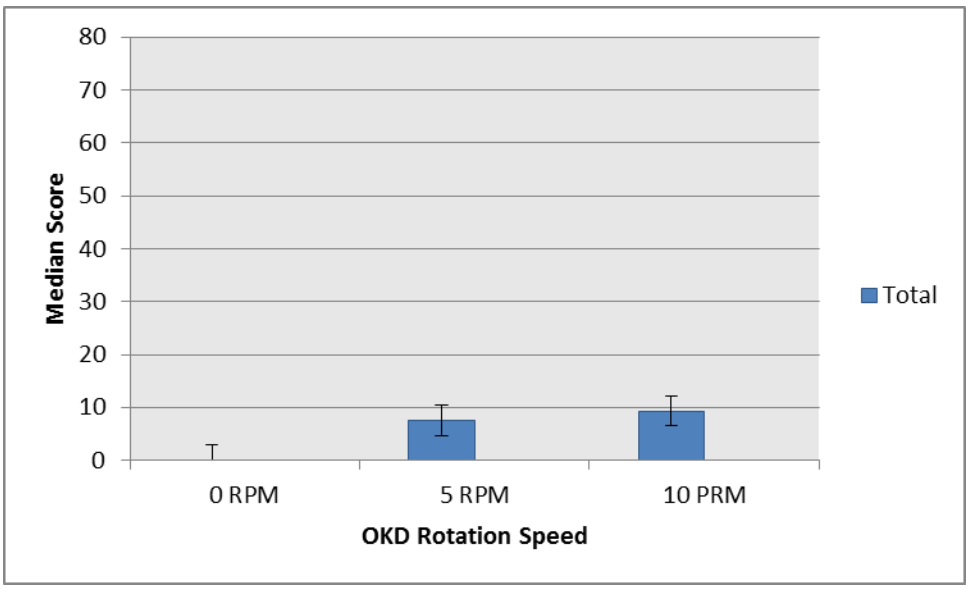

Figure 14. Median scores for the Total scale of the SSQ after exposure to the optokinetic drum up to 20 minutes after.

A Friedman test was conducted to evaluate differences in medians of the total scale of the SSQ after the optokinetic drum sessions (20 to 30 minutes after) among the 0 RPM condition (Median = 3.74), the 5 RPM condition (Median = 14.96), and the 10 RPM condition (Median = 7.48). The test was not significant, $\chi^2(2, N = 8) = 3.39$, p = .183. The motion sickness symptoms experienced 20 to 30 minutes after exposure to the 0 RPM, 5RPM, and 10 RPM conditions were not statistically different from one another.

A Friedman test was conducted to evaluate differences in medians of the total scale of the SSQ after the optokinetic drum sessions (30 minutes to 1 day after) among the 0 RPM condition (Median =

7.48), the 5 RPM condition (Median = 3.74), and the 10 RPM condition (Median = 5.61). The test was not significant, $\chi^2(2, N = 8) = .348$, $p = .840$. The motion sickness symptoms experienced after exposure to the 0 RPM, 5RPM, and 10 RPM conditions were not statistically different from one another for this particular time period.

A Friedman test was conducted to evaluate differences in medians of the total scale of the SSQ after the optokinetic drum sessions (1 to 2 days after) among the 0 RPM condition (Median = 5.61), the 5 RPM condition (Median = 7.48), and the 10 RPM condition (Median = 1.87). The test was not significant, $\chi^2(2, N = 8) = .667$, $p = .717$. The motion sickness symptoms experienced after exposure to the 0 RPM, 5RPM, and 10 RPM conditions were not statistically different from one another for this particular time period.

Nausea, oculomotor and disorientation scales of the SSQ

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ before the optokinetic drum sessions (baseline) among the 0 RPM condition ($Median_{nausea} = 0.00$; $Median_{oculomotor} = 7.58$; $Median_{disorientation} = 0.00$), the 5 RPM condition ($Median_{nausea} = 0.00$; $Median_{oculomotor} = 3.79$; $Median_{disorientation} = 0.00$), and the 10 RPM condition ($Median_{nausea} = 0.00$; $Median_{oculomotor} = 15.16$; $Median_{disorientation} = 0.00$). The tests were not statistically significant for the nausea scale ($\chi^2(2, N = 8) = 1.08$, $p = .584$), the oculomotor scale ($\chi^2(2, N = 8) = 2.00$, $p = .368$), or for the disorientation scale ($\chi^2(2, N = 8) = 1.00$, $p = .607$). Before exposure to the optokinetic drum sessions participants were not experiencing significantly different nausea, oculomotor or disorientation symptoms.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ during the first six (6) minutes of exposure to the optokinetic drum among the 0 RPM condition ($Median_{nausea} = 0.00$; $Median_{oculomotor} = 7.58$; $Median_{disorientation} = 0.00$), the 5 RPM condition ($Median_{nausea} = 9.54$; $Median_{oculomotor} = 22.74$;

$Median_{disorientation}$ = 13.92), and the 10 RPM condition ($Median_{nausea}$ = 9.54; $Median_{oculomotor}$ = 26.53; $Median_{disorientation}$ = 62.64). Figure 15 shows a graphic representation of the median scores for the nausea, oculomotor and disorientation scales for this particular time period. For the nausea scale, the test was significant, $\chi^2(2, N = 22) = 10.07$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median nausea scale score for 0 RPM was significantly smaller than the median nausea scale score for 5 RPM, $p < .01$, and the median nausea scale score for 10 RPM, $p < .01$, but the median nausea scale score for 5 RPM did not differ significantly from the median nausea scale score for 10 RPM, $p = .323$. During the first 6 minutes of exposure, participants in the 0 RPM group experienced significantly less nausea symptoms than those in the other groups. There was no significant difference in terms of nausea symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more nausea symptoms than those in the 0 RPM group. For the oculomotor scale, the test was significant, $\chi^2(2, N = 22) = 10.40$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median oculomotor scale score for 0 RPM was significantly smaller than the median oculomotor scale score for 5 RPM, $p = .024$, and the median oculomotor scale score for 10 RPM, $p < .01$, but the median oculomotor scale score for 5 RPM did not differ significantly from the median oculomotor scale score for 10 RPM, $p = .07$. During the first 6 minutes of exposure, participants in the 0 RPM group experienced significantly less oculomotor symptoms than those in the other groups. There was no significant difference in terms of oculomotor symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more oculomotor symptoms than those in the 0 RPM group. For the disorientation scale, the test was significant, $\chi^2(2, N = 22) = 19.303$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median disorientation scale score for 0 RPM was significantly smaller than the median disorientation scale score for 5 RPM, $p < .01$, and the median disorientation scale score for 10 RPM, $p < .01$. Additionally, the median disorientation scale

score for 5 RPM was significantly smaller than the median disorientation scale score for 10 RPM, p = .016. During the first 6 minutes of exposure, participants in the 0 RPM group experienced significantly less disorientation symptoms than those in the other groups. Participants in the 5 RPM group experienced significantly less disorientation symptoms than those in the 10 RPM group. Participants in the 10 RPM experienced significantly more disorientation symptoms than those in the 0 and 5 RPM groups.

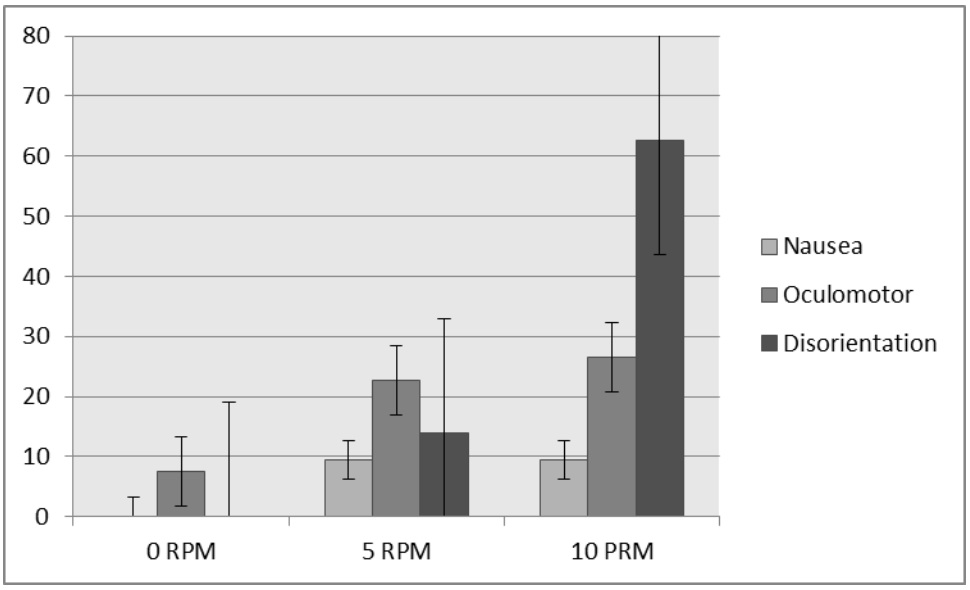

Figure 15. Median scores for the nausea, oculomotor and disorientation scales of the SSQ from 0 to 6 minutes inside the optokinetic drum.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from the 6th minute to the 12th minute of exposure to the optokinetic drum among the 0 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 7.58; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 9.54; $Median_{oculomotor}$ = 22.74; $Median_{disorientation}$ = 27.84), and the 10 RPM condition ($Median_{nausea}$ = 9.54; $Median_{oculomotor}$ = 37.90; $Median_{disorientation}$ = 69.60). Figure 16 shows a graphic representation of the median scores for the nausea, oculomotor and disorientation scales for this particular time period. For the nausea scale, the

test was significant, $\chi^2(2, N = 19) = 8.51$, $p = .014$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median nausea scale score for 0 RPM was significantly smaller than the median nausea scale score for 5 RPM, $p < .01$, and the median nausea scale score for 10 RPM, $p < .01$, but the median nausea scale score for 5 RPM did not differ significantly from the median nausea scale score for 10 RPM, $p = .596$. From the 6th minute to the 12th minute of exposure, participants in the 0 RPM group experienced significantly less nausea symptoms than those in the other groups. There was no significant difference in terms of nausea symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more nausea symptoms than those in the 0 RPM group. For the oculomotor scale, the test was significant, $\chi^2(2, N = 19) = 12.133$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median oculomotor scale score for 0 RPM was significantly smaller than the median oculomotor scale score for 5 RPM, $p < .01$, and the median oculomotor scale score for 10 RPM, $p < .01$, but the median oculomotor scale score for 5 RPM did not differ significantly from the median oculomotor scale score for 10 RPM, $p = .344$. From the 6th minute to the 12th minute of exposure, participants in the 0 RPM group experienced significantly less oculomotor symptoms than those in the other groups. There was no significant difference in terms of oculomotor symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more oculomotor symptoms than those in the 0 RPM group. For the disorientation scale, the test was significant, $\chi^2(2, N = 19) = 18.033$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median disorientation scale score for 0 RPM was significantly smaller than the median disorientation scale score for 5 RPM, $p < .01$, and the median disorientation scale score for 10 RPM, $p < .01$, but the median disorientation scale score for 5 RPM did not differ significantly from the median disorientation scale score for 10 RPM, $p = .296$. From the 6th minute to the 12th minute of exposure, participants in the 0 RPM group experienced significantly less disorientation symptoms than those in the other groups. There was no significant difference in

terms of disorientation symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more disorientation symptoms than those in the 0 RPM group.

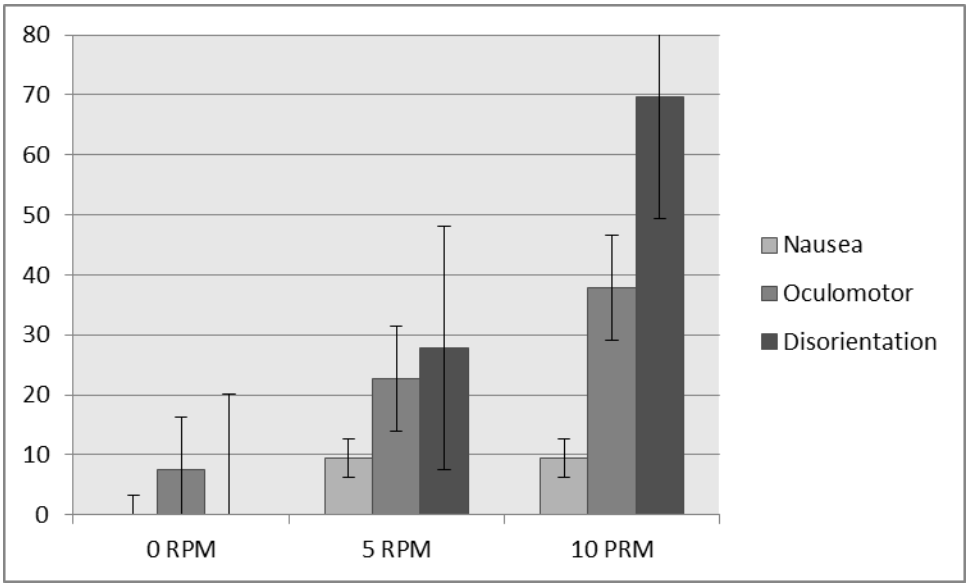

Figure 16. Median scores for the nausea, oculomotor and disorientation scales of the SSQ from 6 to 12 minutes inside the optokinetic drum.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from the 12th minute to the 18th minute of exposure to the optokinetic drum among the 0 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 7.58; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 19.08; $Median_{oculomotor}$ = 30.32; $Median_{disorientation}$ = 41.76), and the 10 RPM condition ($Median_{nausea}$ = 9.54; $Median_{oculomotor}$ = 30.32; $Median_{disorientation}$ = 41.76). Figure 17 shows a graphic representation of the median scores for the nausea, oculomotor and disorientation scales for this particular time period. For the nausea scale, the test was significant, $\chi^2(2, N = 13) = 9.784$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median nausea scale score for 0 RPM was significantly smaller than the median nausea scale score for 5 RPM, $p < .01$, and the median nausea scale score for 10 RPM, $p < .01$, but the median nausea scale score for 5 RPM did not differ significantly from the median nausea

scale score for 10 RPM, p = .822. From the 12th minute to the 18th minute of exposure, participants in the 0 RPM group experienced significantly less nausea symptoms than those in the other groups. There was no significant difference in terms of nausea symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more nausea symptoms than those in the 0 RPM group. For the oculomotor scale, the test was significant, $\chi^2(2, N = 13) = 11.737$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median oculomotor scale score for 0 RPM was significantly smaller than the median oculomotor scale score for 5 RPM, $p < .01$, and the median oculomotor scale score for 10 RPM, $p < .01$, but the median oculomotor scale score for 5 RPM did not differ significantly from the median oculomotor scale score for 10 RPM, $p = .944$. From the 12th minute to the 18th minute of exposure, participants in the 0 RPM group experienced significantly less oculomotor symptoms than those in the other groups. There was no significant difference in terms of oculomotor symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more oculomotor symptoms than those in the 0 RPM group. For the disorientation scale, the test was significant, $\chi^2(2, N = 13) = 13.351$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median disorientation scale score for 0 RPM was significantly smaller than the median disorientation scale score for 5 RPM, $p < .01$, and the median disorientation scale score for 10 RPM, $p < .01$, but the median disorientation scale score for 5 RPM did not differ significantly from the median disorientation scale score for 10 RPM, $p = .942$. From the 12th minute to the 18th minute of exposure, participants in the 0 RPM group experienced significantly less disorientation symptoms than those in the other groups. There was no significant difference in terms of disorientation symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more disorientation symptoms than those in the 0 RPM group.

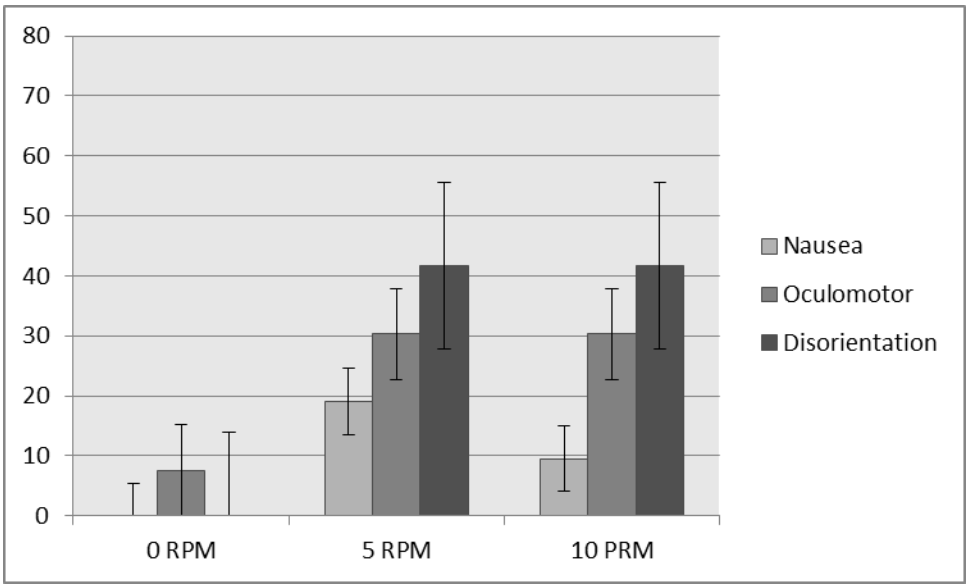

Figure 17. Median scores for the nausea, oculomotor and disorientation scales of the SSQ from 12 to 18 minutes inside the optokinetic drum.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from the 18th minute to 24th minute of exposure to the optokinetic drum among the 0 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 0.00; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 7.58; $Median_{disorientation}$ = 0.00), and the 10 RPM condition ($Median_{nausea}$ = 9.54; $Median_{oculomotor}$ = 37.90; $Median_{disorientation}$ = 27.84). Figure 18 shows a graphic representation of the median scores for the nausea, oculomotor and disorientation scales for this particular time period. For the nausea scale, the test was significant, $\chi^2(2, N = 9) = 12.286$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median nausea scale score for 0 RPM was significantly smaller than the median nausea scale score for 5 RPM, $p < .01$, and the median nausea scale score for 10 RPM, $p < .01$, but the median nausea scale score for 5 RPM did not differ significantly from the median nausea scale score for 10 RPM, $p = .053$. From the 18th minute to the 24th minute of exposure, participants in the 0 RPM group experienced significantly less nausea symptoms than those in the other groups. There

was no significant difference in terms of nausea symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more nausea symptoms than those in the 0 RPM group. For the oculomotor scale, the test was significant, $\chi^2(2, N = 9) = 13.231$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median oculomotor scale score for 0 RPM was significantly smaller than the median oculomotor scale score for 5 RPM, $p < .01$, and the median oculomotor scale score for 10 RPM, $p < .01$. Additionally, the median oculomotor scale score for 5 RPM was significantly different from the median oculomotor scale score for 10 RPM, $p = .015$. From the 18th minute to the 24th minute of exposure, participants in the 0 RPM group experienced significantly less oculomotor symptoms than those in the other groups. Participants in the 5 RPM group experienced significantly less oculomotor symptoms than those in the 10 RPM group. Participants in the 10 RPM experienced significantly more oculomotor symptoms than those in the 0 and 5 RPM groups. For the disorientation scale, the test was significant, $\chi^2(2, N = 9) = 9.00$, $p = .011$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median disorientation scale score for 0 RPM was significantly smaller than the median disorientation scale score for 5 RPM, $p = .011$, and the median disorientation scale score for 10 RPM, $p < .01$, but the median disorientation scale score for 5 RPM did not differ significantly from the median disorientation scale score for 10 RPM, $p = .083$. From the 18th minute to the 24th minute of exposure, participants in the 0 RPM group experienced significantly less disorientation symptoms than those in the other groups. There was no significant difference in terms of disorientation symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more disorientation symptoms than those in the 0 RPM group.

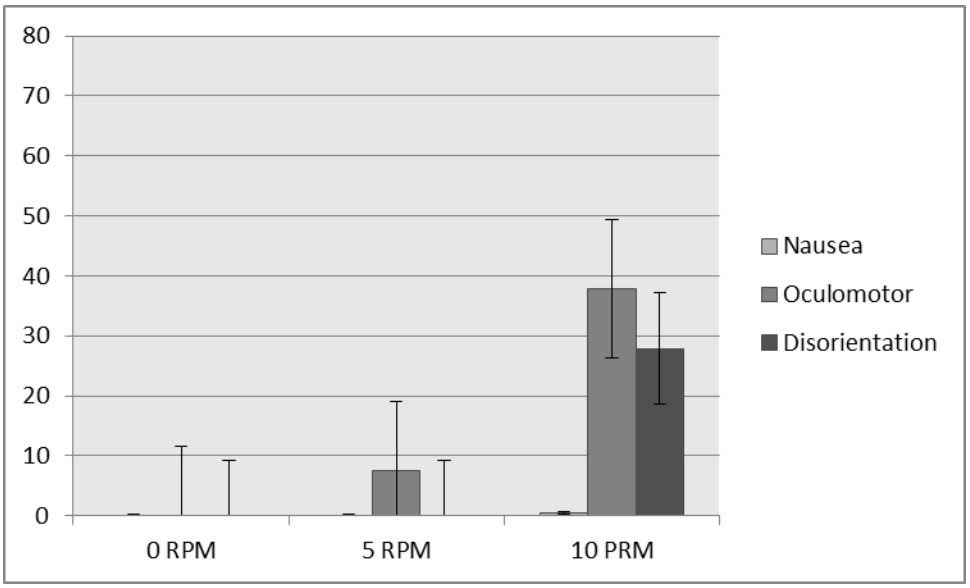

Figure 18. Median scores for the nausea, oculomotor and disorientation scales of the SSQ from 18 to 24 minutes inside the optokinetic drum.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from the 24th minute to the 30th minute of exposure to the optokinetic drum among the 0 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 0.00; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 7.58; $Median_{disorientation}$ = 13.92), and the 10 RPM condition ($Median_{nausea}$ = 9.54; $Median_{oculomotor}$ = 37.90; $Median_{disorientation}$ = 27.84). Figure 19 shows a graphic representation of the median scores for the nausea, oculomotor and disorientation scales for this particular time period. For the nausea scale, the test was significant, $\chi^2(2, N = 9) = 10.571$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median nausea scale score for 0 RPM was equal to the median nausea scale score for 5 RPM, so no pairwise comparison was made. The median nausea scale score for 0 RPM was significantly different than the median nausea scale score for 10 RPM, $p < .01$. Additionally, the median nausea scale score for 5 RPM was significantly different from the median nausea scale score for 10 RPM, $p = .046$. From the 24th minute to the 30th minute of exposure, participants in the 10 RPM group

experienced significantly more nausea symptoms than those participants in the 5 or 0 RPM groups. Participants in the 0 and 5 RPM groups experienced the same level of symptoms. For the oculomotor scale, the test was significant, $\chi^2(2, N = 9) = 12.00$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median oculomotor scale score for 0 RPM was significantly smaller than the median oculomotor scale score for 5 RPM, $p < .01$, and the median oculomotor scale score for 10 RPM, $p < .01$. Additionally, the median oculomotor scale score for 5 RPM was significantly different from the median oculomotor scale score for 10 RPM, $p = .024$. From the 24th minute to the 30th minute of exposure, participants in the 0 RPM group experienced significantly less oculomotor symptoms than those in the other groups. Participants in the 5 RPM group experienced significantly less oculomotor symptoms than those in the 10 RPM group. Participants in the 10 RPM experienced significantly more oculomotor symptoms than those in the 0 and 5 RPM groups. For the disorientation scale, the test was significant, $\chi^2(2, N = 9) = 11.142$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median disorientation scale score for 0 RPM was significantly smaller than the median disorientation scale score for 5 RPM, $p = .011$, and the median disorientation scale score for 10 RPM, $p < .01$, but the median disorientation scale score for 5 RPM did not differ significantly from the median disorientation scale score for 10 RPM, $p = .083$. From the 24th minute to the 30th minute of exposure, participants in the 0 RPM group experienced significantly less disorientation symptoms than those in the other groups. There was no significant difference in terms of disorientation symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more disorientation symptoms than those in the 0 RPM group.

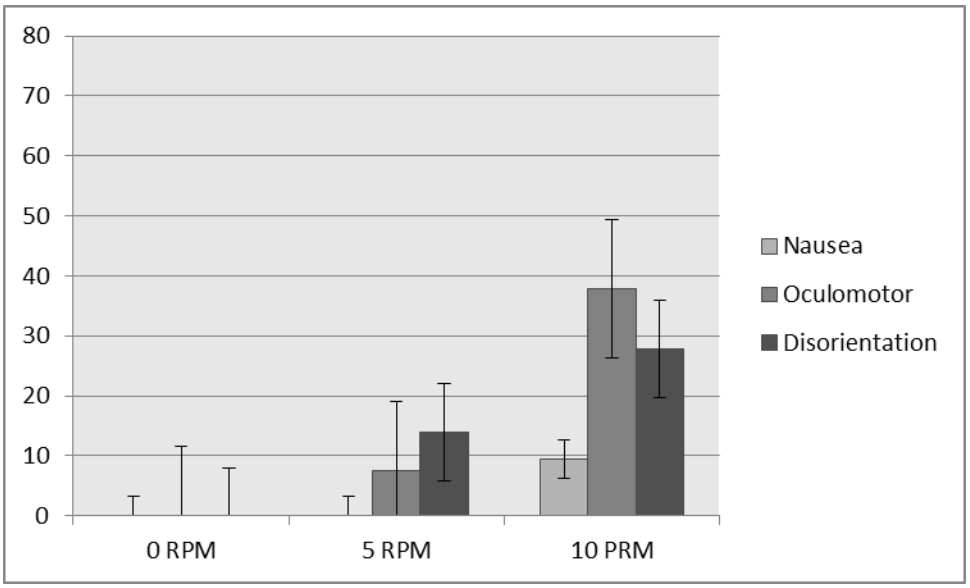

Figure 19. Median scores for the nausea, oculomotor and disorientation scales of the SSQ from 24 to 30 minutes inside the optokinetic drum.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from immediately after exposure to the optokinetic drum up to 20 minutes after, among the 0 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 3.79; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 4.77; $Median_{oculomotor}$ = 15.16; $Median_{disorientation}$ = 0.00), and the 10 RPM condition ($Median_{nausea}$ = 4.77; $Median_{oculomotor}$ = 15.16; $Median_{disorientation}$ = 0.00). Figure 20 shows a graphic representation of the median scores for the nausea, oculomotor and disorientation scales for this particular time period. For the nausea scale, the test was significant, $\chi^2(2, N = 16) = 11.029$, $p < .01$. Follow-up pairwise comparisons were conducted using a Wilcoxon Signed Rank Test. The median nausea scale score for 0 RPM was significantly smaller than the median nausea scale score for 5 RPM, $p < .01$, and the median nausea scale score for 10 RPM, $p = .010$, but the median nausea scale score for 5 RPM did not differ significantly from the median nausea scale score for 10 RPM, $p = .365$. From immediately after exposure to the 20th minute after exposure, participants in the 0 RPM group experienced significantly less nausea symptoms than those in the other

groups. There was no significant difference in terms of nausea symptoms between participants in the 5 RPM and 10 RPM, but participants in both groups experienced significantly more nausea symptoms than those in the 0 RPM group. For the oculomotor scale, the test was not statistically significant, $\chi^2(2, N = 16) = 4.762$, $p < .092$. At this particular time period, participants in each of the groups were experiencing the same level of oculomotor symptoms, statistically speaking. For the disorientation scale, no post-hoc test was conducted because there were no disorientation symptoms, no differences, at this particular time period for neither of the groups.

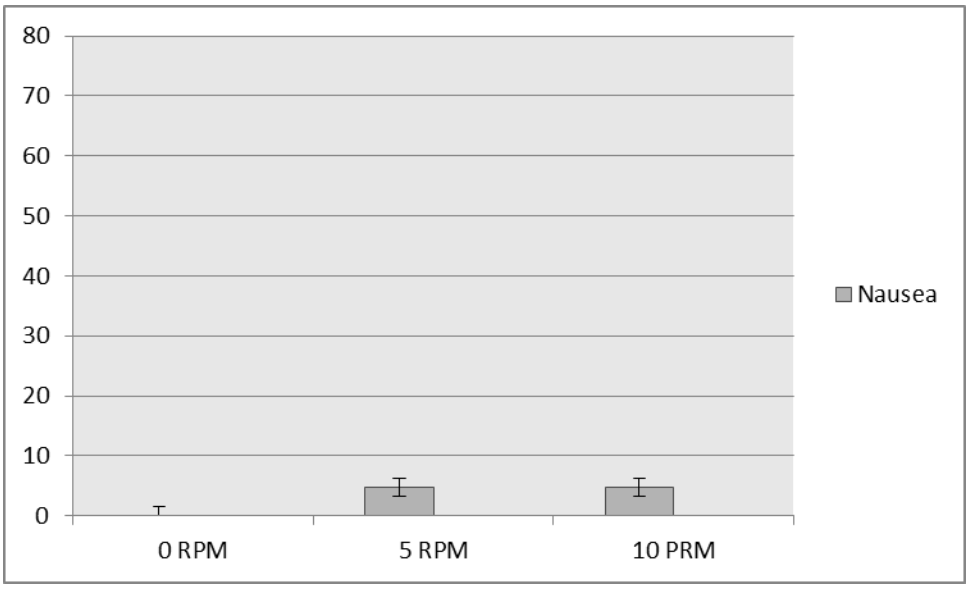

Figure 20. Median scores for the nausea, oculomotor and disorientation scales of the SSQ immediately after the optokinetic drum session up to 20 minutes after.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from the 20th minute to the 30th minute after the optokinetic drum sessions among the 0 RPM condition ($Median_{nausea} = 0.00$; $Median_{oculomotor} = 7.58$; $Median_{disorientation} = 0.00$), the 5 RPM condition ($Median_{nausea} = 9.54$; $Median_{oculomotor} = 15.16$; $Median_{disorientation} = 6.96$), and the 10 RPM condition ($Median_{nausea} = 4.77$; $Median_{oculomotor} = 15.16$; $Median_{disorientation} = 0.00$). None of the three Friedman tests were significant: (1) nausea scale, $\chi^2(2, N = 8)$

= 2.923, p = .232, (2) oculomotor scale, $\chi^2(2, N = 8) = 1.043$, p = .593, and (3) disorientation scale, $\chi^2(2, N = 8) = 4.00$, p = .135. There were no statistically significant differences between the groups in terms of the SSQ nausea, oculomotor or disorientation scales.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from 30 minutes to 1 day after the optokinetic drum sessions among the 0 RPM condition ($Median_{nausea}$ = 4.77; $Median_{oculomotor}$ = 11.37; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 3.79; $Median_{disorientation}$ = 0.00), and the 10 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 7.58; $Median_{disorientation}$ = 0.00). None of the three Friedman tests were significant: (1) nausea scale, $\chi^2(2, N = 8) = .400$, p = .819, (2) oculomotor scale, $\chi^2(2, N = 8) = 6.36$, p = .727, and (3) disorientation scale, $\chi^2(2, N = 8) = 1.00$, p = .607. There were no statistically significant differences between the groups in terms of the SSQ nausea, oculomotor or disorientation scales.

A set of Friedman tests were conducted to evaluate differences in medians of the nausea, oculomotor and disorientation scales of the SSQ from 1 to 2 days after the optokinetic drum sessions among the 0 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 11.37; $Median_{disorientation}$ = 0.00), the 5 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 15.16; $Median_{disorientation}$ = 0.00), and the 10 RPM condition ($Median_{nausea}$ = 0.00; $Median_{oculomotor}$ = 3.79; $Median_{disorientation}$ = 0.00). None of the three Friedman tests were significant: (1) nausea scale, $\chi^2(2, N = 8) = 1.500$, p = .472, (2) oculomotor scale, $\chi^2(2, N = 8) = .737$, p = .692, and (3) disorientation scale, $\chi^2(2, N = 8) = 3.500$, p = .174. There were no statistically significant differences between the groups in terms of the SSQ nausea, oculomotor or disorientation scales.

A summary of the SSQ results can be found on Table 7.

Table 7

Summary of SSQ results

Time Period	SSQ Scales			
	Total	**Nausea**	**Oculomotor**	**Disorientation**
Baseline	No significant difference	No significant difference	No significant difference	No significant difference
0 to 6 minutes	More symptoms during 5 and 10 RPM compared to 0 RPM. Same level of symptoms for 5 and 10 RPM groups.	More nausea symptoms during 5 and 10 RPM compared to 0 RPM. Same level of nausea symptoms for 5 and 10 RPM groups.	More oculomotor symptoms during 5 and 10 RPM compared to 0 RPM. Same level of oculomotor symptoms for 5 and 10 RPM groups.	More disorientation symptoms during 10 RPM. Intermediate disorientation symptoms during 5 RPM. Fewer disorientation symptoms during 0 RPM.

6 to 12 minutes	More symptoms during 5 and 10 RPM compared to 0 RPM. Same level of symptoms for 5 and 10 RPM groups.	More nausea symptoms during 5 and 10 RPM compared to 0 RPM. Same level of nausea symptoms for 5 and 10 RPM groups.	More oculomotor symptoms during 5 and 10 RPM compared to 0 RPM. Same level of oculomotor symptoms for 5 and 10 RPM groups.	More disorientation symptoms during 5 and 10 RPM compared to 0 RPM. Same level of disorientation symptoms for 5 and 10 RPM groups.
12 to 18 minutes	More symptoms during 5 and 10 RPM compared to 0 RPM. Same level of symptoms for 5 and 10 RPM groups.	More nausea symptoms during 5 and 10 RPM compared to 0 RPM. Same level of nausea symptoms for 5 and 10 RPM groups.	More oculomotor symptoms during 5 and 10 RPM compared to 0 RPM. Same level of oculomotor symptoms for 5 and 10 RPM groups.	More disorientation symptoms during 5 and 10 RPM compared to 0 RPM. Same level of disorientation symptoms for 5 and 10 RPM groups.

18 to 24 minutes	More symptoms during 10 RPM. Intermediate symptoms during 5 RPM. Fewer symptoms during 0 RPM.	More nausea symptoms during 5 and 10 RPM compared to 0 RPM. Same level of nausea symptoms for 5 and 10 RPM groups.	More oculomotor symptoms during 10 RPM. Intermediate oculomotor symptoms during 5 RPM. Fewer oculomotor symptoms during 0 RPM.	More disorientation symptoms during 5 and 10 RPM compared to 0 RPM. Same level of disorientation symptoms for 5 and 10 RPM groups.
24 to 30 minutes	More symptoms during 10 RPM. Intermediate symptoms during 5 RPM. Fewer symptoms during 0 RPM.	More nausea symptoms during 10 RPM. Same level of nausea symptoms for 0 and 5 RPM, both significantly lower than 10 RPM.	More oculomotor symptoms during 10 RPM. Intermediate oculomotor symptoms during 5 RPM. Fewer oculomotor symptoms during 0 RPM.	More disorientation symptoms during 5 and 10 RPM compared to 0 RPM. Same level of disorientation symptoms for 5 and 10 RPM groups.

0 to 20 minutes (post-exposure)	More symptoms during 10 RPM. Intermediate symptoms during 5 RPM. Fewer symptoms during 0 RPM.	More nausea symptoms during 5 and 10 RPM compared to 0 RPM. Same level of nausea symptoms for 5 and 10 RPM groups.	No significant difference	No significant difference
20 to 30 minutes (post-exposure)	No significant difference	No significant difference	No significant difference	No significant difference
30 minutes to 1 day (post-exposure)	No significant difference	No significant difference	No significant difference	No significant difference
1 to 2 days (post-exposure)	No significant difference	No significant difference	No significant difference	No significant difference

Cognitive performance

A set of two-way repeated measures within-subjects analysis of variance (ANOVA) were conducted to compare the effect of different rotation speeds of the optokinetic drum on: (1) accuracy, and (2) mean reaction time, on the Switching test.

Accuracy. A two-way repeated measures within-subjects analysis of variance (ANOVA) was conducted to compare the effect of different rotation speeds of the optokinetic drum on accuracy on the Switching test. There were two independent variables (I.V.) in this analysis. The first I.V. was the rotation speed of the optokinetic drum. The first I.V. had three levels: 0 RPM, 5 RPM, and 10 RPM. The second I.V. was the particular timing on which accuracy was measured. There were five levels of the second I.V.: baseline, immediately after the OKD session, 30 minutes after exposure, 1 day after exposure, and 2 days after exposure to the OKD. The dependent variable (DV) was accuracy (percentage correct) on the Switching test. There were 8 (*N*=8) participants total. Table 8 shows the descriptive statistics.

Table 8

Descriptive Statistics

	Mean	*sd*	*n*
0 RPM, baseline	98.82	1.691	8
0 RPM, immediately after	98.82	1.691	8
0 RPM, 30 minutes after	97.20	1.347	8
0 RPM, 1 day after	97.57	1.975	8
0 RPM, 2 days after	97.34	2.522	8
5 RPM, baseline	98.63	3.402	8
5 RPM, immediately after	98.63	3.402	8

5 RPM, 30 minutes after	96.60	4.571	8
5RPM, 1 day after	97.08	3.596	8
5 RPM, 2 days after	97.42	3.962	8
10 RPM, baseline	97.42	3.458	8
10 RPM, immediately after	97.42	3.458	8
10 RPM, 30 minutes after	95.17	4.524	8
10 RPM, 1 day after	97.67	1.857	8
10 RPM, 2 days after	97.73	2.675	8

After running the analysis, it was found that the OKD speed of rotation main effect was not statistically significant, $F(2,14) = 1.039$, $p = .380$. The main effect for the particular timing on which accuracy was measured was not statistically significant, $F(4,28) = 2.558$, $p = .061$. Finally the interaction between speeds of rotation by the particular timing on which accuracy was measured was not statistically significant, $F(8,56) = .876$, $p = .542$. Based on the previous analysis, it can be concluded that the mean accuracy was not statistically different between the groups after exposure to a particular speed of rotation of the OKD, and accuracy did not changes significantly during the course of this study.

Mean reaction time. A two-way repeated measures within-subjects analysis of variance (ANOVA) was conducted to compare the effect of different rotation speeds of the optokinetic drum on the mean reaction time on the Switching test. There were two independent variables (I.V.) in this analysis. The first I.V. was the rotation speed of the optokinetic drum. The first I.V. had three levels: 0 RPM, 5 RPM, and 10 RPM. The second I.V. was the particular timing on which accuracy was measured. There were five levels of the second I.V.: baseline, immediately after the OKD session, 30 minutes after exposure, 1 day after exposure, and 2 days after exposure to the OKD. The dependent variable (DV) was

the mean reaction time (in milliseconds) on the Switching test. There were 8 (*N*=8) participants total. For descriptive statistics, see Table 9.

Table 9

Descriptive Statistics

	Mean	*sd*	*n*
0 RPM, baseline	1546.47	359.386	8
0 RPM, immediately after	1546.47	359.386	8
0 RPM, 30 minutes after	1637.84	438.305	8
0 RPM, 1 day after	1602.69	297.051	8
0 RPM, 2 days after	1593.57	326.368	8
5 RPM, baseline	1653.52	431.848	8
5 RPM, immediately after	1653.52	431.848	8
5 RPM, 30 minutes after	1750.46	581.033	8
5RPM, 1 day after	1629.77	484.270	8
5 RPM, 2 days after	1620.45	366.832	8
10 RPM, baseline	1722.27	625.519	8
10 RPM, immediately after	1722.27	625.519	8
10 RPM, 30 minutes after	1690.72	565.661	8
10 RPM, 1 day after	1652.39	482.544	8
10 RPM, 2 days after	1626.37	400.091	8

After running the analysis, it was found that the OKD speed of rotation main effect was not statistically significant, $F(2,14) = .604$, $p = .561$. The main effect for the particular timing on which mean

reaction time was measured was not statistically significant, $F(4,28) = .675$, $p = .615$. Finally the interaction between speeds of rotation by the particular timing on which accuracy was measured was not statistically significant, $F(8,56) = .638$, $p = .742$. Based on the previous analysis, it can be concluded that the mean reaction time was not statistically different between the groups after exposure to a particular speed of rotation of the OKD, and the mean reaction time did not changed significantly during the course of this study.

Sleep amount

A two-way repeated measures within-subjects analysis of variance (ANOVA) was conducted to compare the effect of different rotation speeds of the optokinetic drum on sleep amount. There were two independent variables (I.V.) in this analysis. The first I.V. was the rotation speed of the optokinetic drum. The first I.V. had three levels: 0 RPM, 5 RPM, and 10 RPM. The second I.V. was the particular timing on which sleep amount was measured. There were three levels of the second I.V.: baseline, 1 day after exposure to the OKD, and 2 days after exposure to the OKD. The dependent variable (DV) was the amount of time (in hours) participants were asleep. There were 8 (N=8) participants total. For descriptive statistics, see Table 10.

Table 10

Descriptive Statistics

	Mean	*sd*	*n*
0 RPM, baseline	7.5	1.51186	8
0 RPM, 1 day after	6.5	2.13809	8
0 RPM, 2 days after	8.0	2.44949	8
5 RPM, baseline	8.5	2.67261	8

5RPM, 1 day after	7.5	2.72554	8
5 RPM, 2 days after	7.5	3.0706	8
10 RPM, baseline	6.8	1.38873	8
10 RPM, 1 day after	7.6	1.68502	8
10 RPM, 2 days after	8.1	3.39905	8

After running the analysis, it was found that the OKD speed of rotation main effect was not statistically significant, $F(2,14) = .662$, $p = .531$. The main effect for the particular timing on which sleep amount was measured was not statistically significant, $F(2,14) = .552$, $p = .588$. Finally the interaction between speeds of rotation by the particular timing on which sleep amount was measured was not statistically significant, $F(4,28) = .648$, $p = .633$. Based on the previous analysis, it can be concluded that the mean amount of sleep was no different after exposure to a particular speed of rotation of the OKD, and sleep amount did not changed significantly for the subsequent two days after exposure to the OKD.

Discussion

The purpose of this study was to determine the effects of different optokinetic drum rotation speeds on motion sickness symptoms, cognitive performance and sleep amount.

Motion sickness symptoms

To examine the effects of different optokinetic drum rotation speeds on motion sickness symptoms, the researcher used the Simulator Sickness Questionnaire. A summary of the SSQ results can be found in Table 10.

The results can be interpreted as follows. The baseline SSQ scores for all scales were not significantly different from one another. Significant differences started to emerge after exposure to the optokinetic drum. In terms of the total scale, for the first 18 minutes of exposure, the 5 and the 10 RPM

sessions were equally effective in inducing motion sickness symptoms, more than in the 0 RPM group. The total scale of the SSQ is based on the 16 items (symptoms) in the questionnaire (refer to Appendix F). From the 18th minute on to 20 minutes after the session, the 10 PRM condition was more effective than the 5 RPM condition in inducing symptoms of motion sickness, and the 5 RPM condition was more effective than the 0 RPM condition in inducing symptoms of motion sickness. It can be concluded that the 10 RPM condition is the most effective for studying motion sickness symptoms, especially if the sessions last more than 18 minutes. There was no difference in motion sickness symptoms after 20 minutes post-exposure between the groups. In other words, differences between the groups were only evident during exposure to the optokinetic drum and shortly after.

In terms of the nausea scale, for the first 24 minutes of exposure, the 5 and the 10 RPM sessions were equally effective in inducing nausea symptoms more than in the 0 RPM group. The nausea scale accounted for general discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness, and burping. From the 24th minute to the 30th minute of exposure, the 10 RPM group experienced more nausea symptoms than the 0 and 5 RPM groups. At this time period, nausea symptoms were not significantly different between the 0 and 5 RPM groups. After the session and up to 20 minutes after, the 5 and 10 RPM group experienced more nausea symptoms than those in the 0 RPM group. The overall tendency in terms of the nausea scale was the development of nausea symptoms at the same level for the 5 and 10 RPM conditions. There was no difference in nausea symptoms after 20 minutes post-exposure between the groups. In other words, differences between the groups were only evident during exposure to the optokinetic drum and shortly after.

In terms of the oculomotor scale, for the first 18 minutes of exposure, the 5 and the 10 RPM sessions were equally effective in inducing oculomotor symptoms, more than in the 0 RPM group. The oculomotor scale accounted for general discomfort, fatigue, headache, eye strain, difficulty focusing, difficulty concentrating, and blurred vision. From the 18th minute of exposure to the 30th, oculomotor

symptoms were highest for the 10 RPM session, intermediate for the 5 RPM, and lowest for the 0 RPM. A speed of rotation of 10 RPM is the most effective speed for inducing oculomotor symptoms. The oculomotor symptoms were at the same level after the sessions, independently of the rotating speed.

In terms of the disorientation scale, for the first 6 minutes of exposure, disorientation symptoms were highest for the 10 RPM session, intermediate for the 5 RPM, and lowest for the 0 RPM. The disorientation scale accounted for difficulty focusing, nausea, fullness of the head, blurred vision, dizziness with eyes open, dizziness with eyes closed, and vertigo. From the 6^{th} minute to the 30^{th} minute, the 5 and the 10 RPM sessions were equally effective in inducing oculomotor symptoms, more than in the 0 RPM group. The disorientation symptoms were at the same level after the sessions, independent of the rotating speed.

The first hypothesis stated that the severity of motion sickness symptoms was going to be different during and after exposure to the optokinetic drum. The hypothesis was that the severity of motion sickness symptoms was going to be worst during and after exposure to the 10 RPM condition, intermediate during and after the 5 RPM condition, and minimal or asymptomatic during and after exposure to the 0 RPM condition. During and after exposure to the 0 RPM condition, participants experienced minimal, if any, symptoms of motion sickness. At certain time periods, during and after exposure to the 10 RPM condition, participants experienced the most symptoms of motion sickness, more symptoms than during and after 5 or 0 RPM conditions. Nonetheless, most of the time, the level of motion sickness symptoms was equivalent during and after exposure to both the 5 and 10 RPM conditions. In other words, most of the time, exposure to either the 5 or 10 RPM conditions was equally effective in inducing motion sickness symptoms. Hence, this first hypothesis was partially supported by this study. The researcher recommends using the 10 RPM condition because at some time periods, this condition was the most effective in inducing motion sickness symptoms. The researcher also

recommends using other novel and naturalistic wallpaper patterns in the future to see if there is a significant difference in terms of the induction of motion sickness symptoms.

Cognitive performance

To examine the effects of different optokinetic drum rotation speeds on cognitive performance, the researcher used the Switching test of the ANAM battery. The purpose of the Switching test was to assess directed attention and executive function. More specifically, to assess three-dimensional spatial rotation ability, left-right orientation, problem solving, attention, basic computational skills, concentration, and working memory.

This study measured accuracy and mean reaction time executing the Switching test to see if the optokinetic drum sessions induced cognitive performance decline. The second hypothesis stated that there was going to be a decline in cognitive performance after the optokinetic drum sessions, and that that decline was going to be more pronounced after the 10 RPM condition, intermediate after the 5 RPM condition, and none or minimal after the 0 RPM condition. The baseline accuracy and mean reaction time were not significantly different among the conditions, meaning that participants were performing at the same level. The second hypothesis was rejected because the baseline accuracy and mean reaction time were not significantly different to the accuracy and mean reaction time recorded immediately after the session, 30 minutes after the session, and one and two days after the sessions.

Evaluation of cognitive performance comprised two combined cognitive tasks (manikin test and mathematical processing test) designed to be applied with a computer. Assessment took place in their natural academic setting. These results suggest that given a motivating short-term task and maintaining routine conditions, different speeds of rotation of the optokinetic drum does not affect the accuracy or mean reaction time of the Switching test of participants when assessed after the sessions.

Future studies trying to assess the effects of optokinetic drum sessions on cognitive performance should attempt to test all domains of cognitive performance, not just directed attention or

executive function. For future studies, the researcher suggests using all test and modules of the Automated Neuropsychological Assessment Metrics, as shown in table 11.

Table 11

ANAM assessment library

ANAM^{4TM} Test and Modules	Cognitive Domains
2-Choice Reaction Time	Processing speed and alternating attention
Code Substitution – Learning	Complex scanning, visual tracking, and attention
Code Substitution – Delayed (Recognition)	Learning and delayed visual recognition memory
Go/No-Go	Response inhibition
Logical Relations - Symbolic	Reasoning and verbal syntax
Manikin	Three-dimensional spatial rotation ability, left-right orientation, problem solving, and attention
Matching Grids	Visuo-spatial processing
Matching to Sample	Spatial processing and visuo-spatial working memory
Math Processing	Computational skills, concentration, and working memory
Memory Search	Verbal working memory, immediate recognition, and attention
Procedural Reaction Time	Reaction time and processing efficiency
Pursuit Tracking	Visuo-motor control

Running Memory Continuous Performance Test	Attention, concentration, and working memory
Simple Reaction Time	Attention and visuo-motor response timing
Spatial Processing	Spatial processing ability and visuo-spatial working memory
Standard Continuous Performance Task	Sustained attention, concentration, and working memory
Stroop	Processing speed, selective attention, interference, and executive functioning
Switching	Directed attention and executive function
Tapping	Motor skill and reaction time
Tower Puzzle	Visuo-spatial ability, motor control, rule adherence, spatial planning, and strategy development and execution

Using all tests in the battery might allow researchers to pinpoint more precisely the specific cognitive functioning domain affected by exposure to the optokinetic drum, if any.

Sleep amount

To examine the effects of different optokinetic drum rotation speeds on sleep amount, the researcher used two sleep amount recording strategies. The first, actigraphs, permitted an objective non-invasive assessment of sleep amount. The second, a sleep/activity log, permitted an easy way to determine the total time spent sleeping.

Sleep disturbances, fatigue and drowsiness are among the cardinal symptoms of the Sopite syndrome. Sopite syndrome is a disturbance caused by motion characterized by drowsiness and mood

changes that may occur without the classic symptoms of motion sickness. Because Sopite symptoms are often subtle, it is important to assess for their presence. The third and last hypothesis stated that the sleep amount was going to be disrupted after exposure to the optokinetic drum. It was hypothesized that the level of disruption was going to be worst after the 10 RPM condition, intermediate after the 5 RPM condition, and none or minimal after the 0 RPM condition.

This study measured sleep amount to see if the optokinetic drum sessions induced sleep disturbance as one of the characteristics symptoms of the Sopite syndrome. The baseline amount of sleep was not significantly different among the conditions. Before exposure to the optokinetic drum, participants have the same level of sleep amount. The third hypothesis was rejected because the baseline amount of sleep was not significantly different to the sleep amount recorded one and two days after the sessions.

Studying sleep among the student population is challenging because sleep may be voluntarily sacrificed due to social and academic factors. It can be speculated that participants were inclined to sleep more after a rotating optokinetic drum session but decided not to sleep more due to academic and social factors.

In future studies assessing Sopite syndrome symptoms after optokinetic drum exposure, researchers should carefully select the target population and specific symptom they would like to assess. The researcher would like to recommend selecting a sample from a population with a more stable and regular sleep hygiene habits. The researcher also recommends assessing other symptoms of the Sopite syndrome, like mood changes, in future studies.

Conclusion

Having discussed the effects of different rotation speed settings of the optokinetic drum on motion sickness symptoms, cognitive performance and sleep amount, it's useful to now identify ways that may be used to further investigate motion sickness paradigms.

This study demonstrated that the optokinetic drum is a useful tool to induce motion sickness symptoms. People can experience motion sickness in everyday scenarios like traveling (land, air, maritime), use of high-fidelity simulators, video games, amusement park rides, space travel, and virtual reality, just to name a few. Sometimes studying motion sickness in certain domains can be expensive and technically complex, space sickness for example. The optokinetic drum provides an inexpensive and reliable tool to investigate motion sickness symptoms. Researchers limited in funds could use the optokinetic drum as an analog environment to study motion sickness symptoms. Since it is now demonstrated that motion sickness symptoms can be produced in the optokinetic drum, future research may focus on prevention. Prevention may be categorized into one of several measures: pharmacological treatment, biofeedback or autogenic training, behavioral measures, and adaptation.

Future studies could assess the effectiveness of anticholinergics, antihistamines, serotonin receptor antagonist, and other pharmacological agents and interventions in the prevention of motion sickness induced by the optokinetic drum.

Due to the potential problems associated with antimotion medications, a more permanent treatment may be a more plausible strategy. Desensitization therapy is currently used within aviation and space travel and it is based upon relieving a person's state of arousal associated with previous unpleasant responses to a provocative motion environment. In desensitization therapy, the individuals are placed in increasingly intense motion environments over time with concurrent psychotherapeutic treatments to help allay their fears and anxiety (Benson, 1999). Future studies could assess the role of desensitization in the optokinetic drum and relate it to desensitization in other environments.

A variety of behavioral measures can be undertaken to avoid or moderate the onset of motion sickness. Future studies could try to identify preventive behavioral measure against motion sickness.

The most potent therapeutic measure is adaptation to the provocative motion. This is “nature’s” own cure and is the preferred method of preventing sickness (Benson, 1999). Adaptation formally refers to the increase in tolerance to a nauseogenic stimulus that occurs over a period of several days or even weeks of repeated exposure (Stott 1991). Perhaps future studies could assess adaptation and see if it translates from the optokinetic drum setting to other nauseogenic environments.

Possessing knowledge of the effects of the optokinetic drum parameters on motion sickness symptoms, cognitive performance, and sleep amount allows us to develop new and innovative design characteristics to moderate the effects of provocative motion and environments on research participants. In the future, this may lead to enhanced effectiveness and performance, and more importantly, to the safety of individuals as a whole.

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Appendix A

Motion Sickness Susceptibility Questionnaire (MSSQ)
(Reid, 1991; as cited in Griffin & Howarth, May 2000)

MOTION SICKNESS SUSCEPTIBILITY QUESTIONNAIRE

INSTRUCTIONS

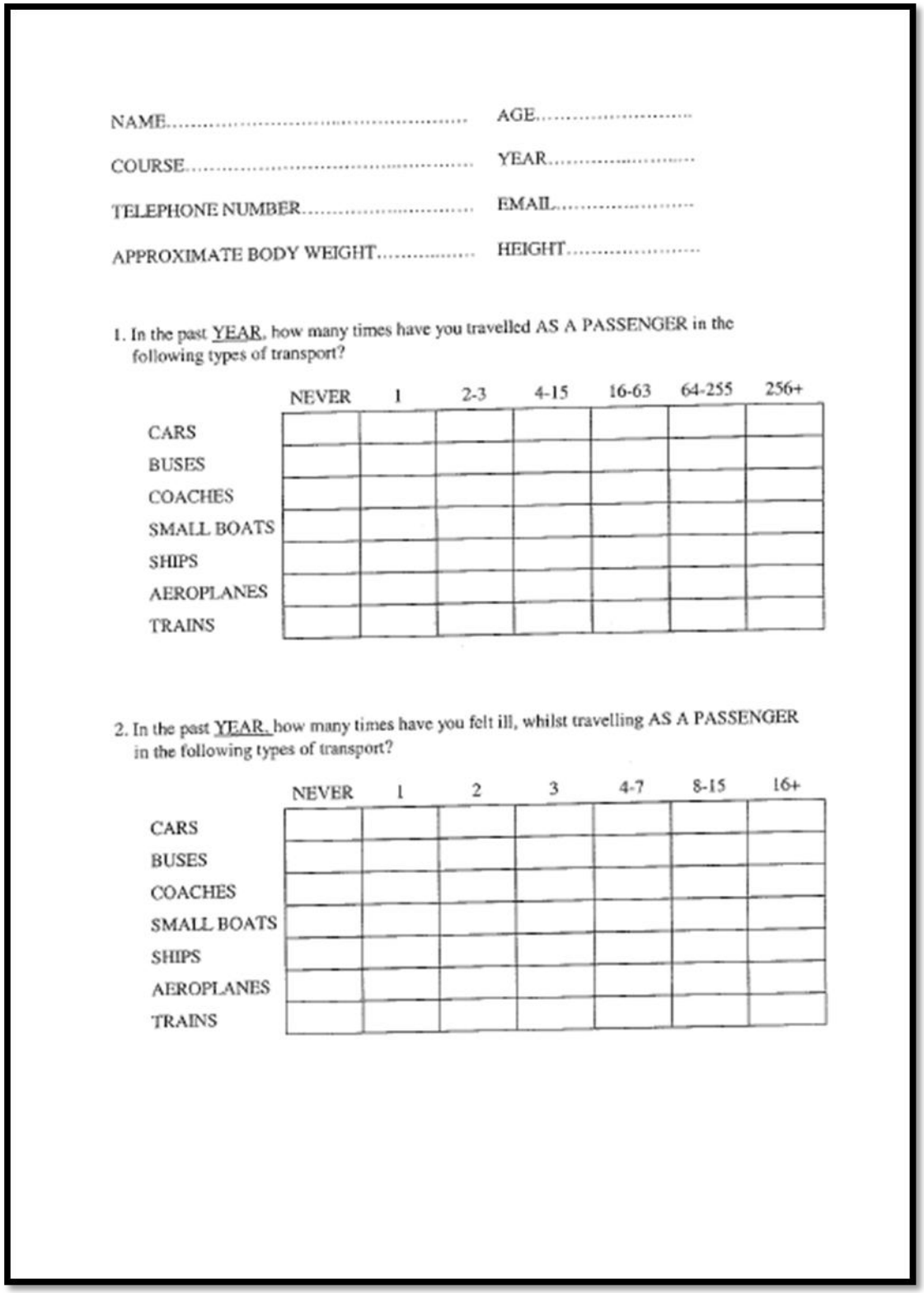
This questionnaire is primarily concerned with: (i) your susceptibility to motion sickness, and (ii) what types of motion are most effective in causing this sickness.

Please read the questions carefully and answer them ALL by either TICKING or FILLING IN the boxes which most closely correspond to you as an individual.

All the information you give is CONFIDENTIAL and will be used for research purposes only.

Thank you very much for your co-operation.

Figure 1A. Page one of the MSSQ.



NAME..... AGE.....

COURSE..... YEAR.....

TELEPHONE NUMBER..... EMAIL.....

APPROXIMATE BODY WEIGHT..... HEIGHT.....

1. In the past YEAR, how many times have you travelled AS A PASSENGER in the following types of transport?

	NEVER	1	2-3	4-15	16-63	64-255	256+
CARS							
BUSES							
COACHES							
SMALL BOATS							
SHIPS							
AEROPLANES							
TRAINS							

2. In the past YEAR, how many times have you felt ill, whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	1	2	3	4-7	8-15	16+
CARS							
BUSES							
COACHES							
SMALL BOATS							
SHIPS							
AEROPLANES							
TRAINS							

Figure 2A. Page two of the MSSQ.

3. In the past YEAR, how many times have you VOMITED whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	1	2	3	4-7	8-15	16+
CARS							
BUSES							
COACHES							
SMALL BOATS							
SHIPS							
AEROPLANES							
TRAINS							

4. Do you EVER feel HOT or SWEAT whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

5. Do you EVER suffer from HEADACHES whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

Figure 3A. Page three of the MSSQ.

6. Do you EVER suffer from LOSS/ CHANGE OF SKIN COLOUR (go pale) whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

7. Do you EVER suffer from MOUTH WATERING whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

8. Do you EVER feel DROWSY whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

Figure 4A. Page four of the MSSQ.

9. Do you EVER feel DIZZY whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

10. Do you EVER suffer from NAUSEA (stomach discomfort, feeling sick) whilst travelling AS A PASSENGER in the following types of transport?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

11. Have you EVER vomited whilst travelling AS A PASSENGER in the following types of transport?

	NO	YES
CARS		
BUSES		
COACHES		
SMALL BOATS		
SHIPS		
AEROPLANES		
TRAINS		

Figure 5A. Page five of the MSSQ.

12. Would you avoid any of the following types of transport beacuse of motion sickness ?

	NEVER	OCCASIONALLY	OFTEN	ALWAYS
CARS				
BUSES				
COACHES				
SMALL BOATS				
SHIPS				
AEROPLANES				
TRAINS				

13. Which of the following best describes your SUSCEPTIBILITY to motion sickness?

MUCH LESS THAN AVERAGE	
LESS THAN AVERAGE	
AVERAGE	
MORE THAN AVERAGE	
MUCH MORE THAN AVERAGE	

14. Have you ever suffered from any serious illness or injury ?

NO ☐ YES ☐

15. Are you under medical tretament or suffering a disability affecting daily life. ?

NO ☐ YES ☐

Figure 6A. Page six of the MSSQ.

Appendix B

Demographic Form

Thank you for your participation in this research project.
Your answers will remain completely anonymous.

ID # _____ Age _____ Gender _____ Weight _____ Preferred hand _____
(left or right)

Occupation _____ FAA Medical class _____
(if student: state academic level) (if applicable)

Do you wear glasses now? _____ No ____ Yes
If Yes: _____ All the time _____ Sometimes _____ Only for computer
_____ Only for distance _____Only for reading

Medical conditions & Medications (prescribed or over-the-counter):
_____
_____
_____
(Use the back if necessary)

Have you had any history of ear infection or inner ear disorders? If yes, briefly explain:
_____
_____

How many hours of sleep do you get on an average night? _____

Do you think you are getting enough sleep? Please explain:
_____
_____
_____

Ethnicity (select one)
_____American Indian or Alaska Native
_____Hawaiian or Other Pacific Islander
_____Asian or Asian American
_____Black or African American
_____Hispanic or Latino
_____Non-Hispanic White
_____Other (specify): _____

Comments:
_____
_____
_____

Appendix C

Informed Consent Form

Embry-Riddle Aeronautical University

Wilfredo Rodríguez-Jiménez, B.S., Principal Investigator
Jonathan French, Ph.D., Advisor
Thesis Research: "The Effects of Different Optokinetic Drum Rotation Speeds on Motion Sickness Symptoms, Cognitive Performance and Sleep Patterns"

This Informed Consent Form has two parts:

- Information Sheet (to share information about the study with you)
- Certificate of Consent (for signatures if you choose to participate)

You will be given a copy of the full Informed Consent Form

Part I: Information Sheet

Introduction
I am Wilfredo Rodríguez-Jiménez, graduate student at Embry-Riddle Aeronautical University. I am doing research on vection and motion sensitivity as part of my thesis project. I am going to give you information and invite you to be part of this research. You do not have to decide today whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research. This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them of me.

Purpose of the research
Vection refers to the perception of self-motion induced by visual stimuli. The purpose of the study is to characterize certain features of a vection device in terms of motion sickness, sleep patterns, and cognitive performance. Results from this research may have practical implications for equipment design, especially for virtual reality devices and simulators.

Type of Research Intervention
This research will involve your participation answering questionnaires, taking cognitive performance test, and recording your awake/sleep cycle before and after exposure to the optokinetic drum.

Participant Selection
You are being invited to take part in this research because we feel that you can contribute much to our understanding and knowledge of vection induced symptoms.

Voluntary Participation
Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may change your mind later and stop participating even if you agreed earlier.

Duration & Procedures
This research takes place over 17 days in total. During that time, you will visit our Lab (room LB-374) three times for the optokinetic drum sessions.

We are asking you to help us learn more about vection induced symptoms. We are inviting you to take part in this research project. If you accept, you will be asked to perform certain activities per day for 17 days, as follows:

Day	Activities	Time commitment
1	Switching test (3 trials). Start wearing the actigraph continuously until the end of the study.	30 minutes
2	Switching test (3 trials)	30 minutes
3	Switching test (3 trials)	30 minutes
4	Switching test (3 trials)	30 minutes
5	Switching test (3 trials).	30 minutes
6	Switching test (3 trials)	30 minutes
7	Switching test (3 trials)	30 minutes
8	**Lab day: Optokinetic drum session #1**	1.5 hours
9	Switching test (1 trial) + SSQ	12 minutes
10	Switching test (1 trial) + SSQ	12 minutes
11	**Lab day: Optokinetic drum session #2**	1.5 hours
12	Switching test (1 trial) + SSQ	12 minutes
13	Switching test (1 trial) + SSQ	12 minutes
14	**Lab day: Optokinetic drum session #3**	1.5 hours
15	Switching test (1 trial) + SSQ	12 minutes
16	Switching test (1 trial) + SSQ.	12 minutes
17	Stop wearing the actigraph. Bring materials to the lab.	Varies

Activity	Description
Switching test	The Switching test is a computerized cognitive performance test. Takes approximately 10 minutes per trial. There are two types of questions: (1) simple calculation and (2) perceptual orientation.
Actigraph	An actigraph is a watch-sized device that records whether you are awake or sleeping.
SSQ	Simulator Sickness Questionnaire: questionnaire to rate 16 symptoms based on severity.
Optokinetic drum sessions	Lab day: this day you will go to room LB-374 (Lehman Building). Activities during each session: - Pre-exposure SSQ - Pre-exposure Switching test - Optokinetic drum session (maximum time: 30 minutes) SSQs while in the drum (every 2 minutes) - 2 Post-exposure Switching test (immediately and 30 minutes after) - 3 Post-exposure SSQs (10, 20 and 30 minutes after)

Risks

By participating in this study it is possible that you could develop motion sickness. Motion sickness symptoms include, but are not limited to, general discomfort, fatigue, headache, eyestrain, difficulty focusing or concentrating, increased or reduced salivation, sweating, nausea, dizziness, vertigo, or stomach awareness. However, we will follow you closely and keep track of any symptoms or any problems.

Benefits
There may not be any benefit for you but your participation is likely to help us better understand the effects of vection and motion sickness on cognitive performance and sleep. Society may benefit due to practical implications of this research for equipment design, especially for virtual reality devices and simulators.

Reimbursements
We will give you $10 for you participation in each optokinetic drum session. Reimbursements will take place on day #8, #11, and #14. A raffle ticket will be given on day #17. A $100 prize will be given away among those participants who participate in all 17 days of the study.

Confidentiality
We will not be sharing your identity or information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is.

Sharing the Results
Confidential information will not be shared with anybody outside the research team. The knowledge that we get from this research will be available to you, upon request. Overall results will be published and available to you and the general public. No personal information will be shared on the final thesis report.

Right to Refuse or Withdraw
You do not have to take part in this research if you do not wish to do so. You may also stop participating in the research at any time you choose. It is your choice and all of your rights will still be respected.

Who to Contact
If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact any of the following:

Mr. Wilfredo Rodríguez-Jiménez, Principal Investigator
E-mail: vection**.**lab@gmail.com
Text: (661) 261-4877
Skype: wilfredo_rodz

Dr. Jonathan French, Advisor
Phone: (386) 226-6384
E-mail: frenc70f@erau.edu

IRB Approval
This thesis project has been reviewed and approved by the Institutional Review Board of Embry-Riddle Aeronautical University, which is a committee whose task it is to make sure that research participants are protected from harm.

Part II: Certificate of Consent

I have been invited to participate in this research about the effects of vection and different rotating speeds of the optokinetic drum on motion sickness symptoms, cognitive performance, and sleep patterns.

I have read the foregoing information. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Print Name of Participant _____

Signature of Participant _____

Date _____
Month/day/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands the foregoing information. I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this consent form has been provided to the participant.

Print Name of Researcher/person taking the consent _____

Signature of Researcher /person taking the consent _____

Date _____
Month/day/year

Appendix D

The Switching Test Instructions

The Switching test is our cognitive assessment tool. It is a test that is entirely contained on a small USB computer plug-in device which you will be assigned upon entering the study. The Switching test is a challenging task but we are confident you will learn to do it quickly and accurately within the first 7 days of the study.

Once started, the Switching test takes about 10 minutes.

Steps

1. Plug in USB device to a USB port (Ψ) on any computer.
   (It is self contained so you can practice it on any computer)

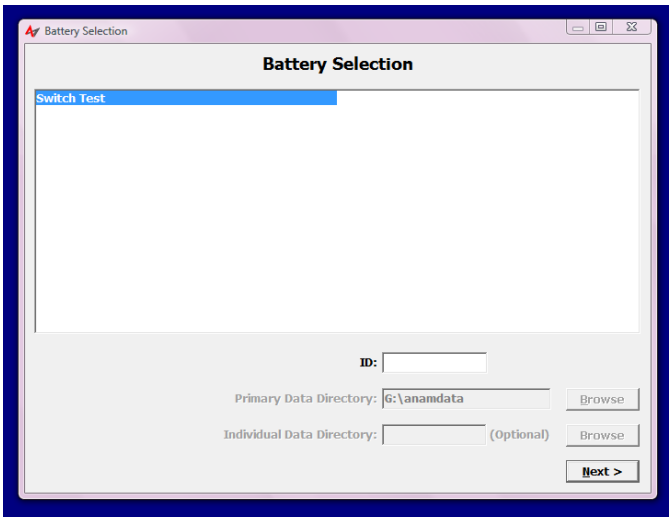
2. Go to "My Computer"

3. Double-click on "RIDATA_#" (black USB device) or "LEXAR_#" (blue USB device). The "#" is the number on your USB device.

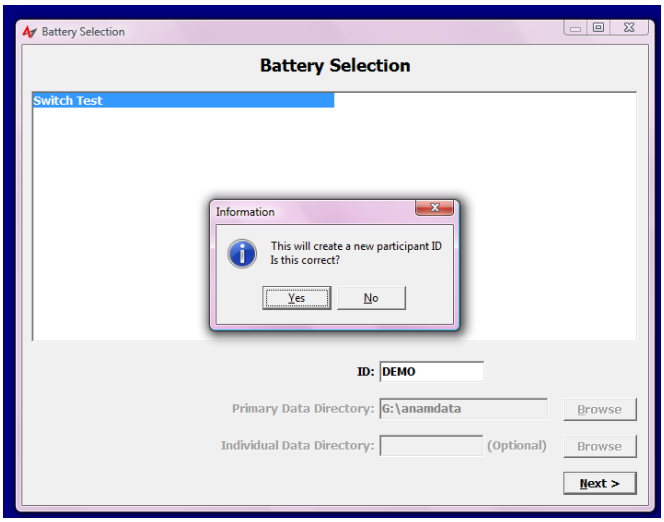
4. Double-click the folder called "**ANAM_HAL_SWTC**"

5. Double-click the file called "**ANAMmenu.exe**" This will execute the test on your computer. The screen will display a very brief animation:

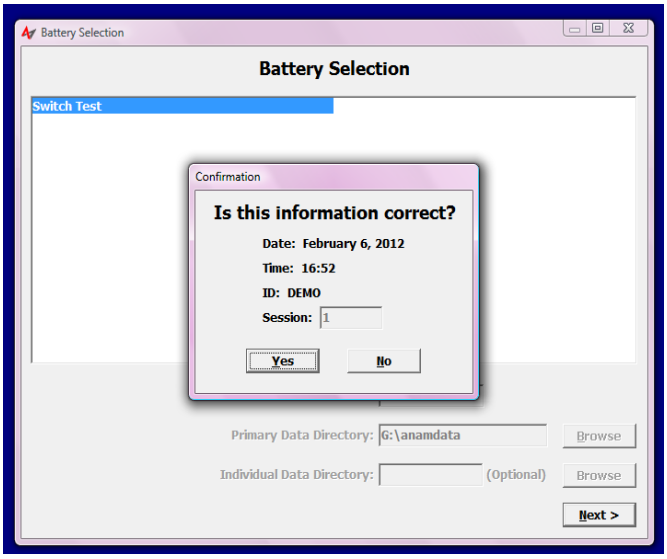
6. Following the animation, in the "Battery Selection" window, add you ID # _____. Click "Next"



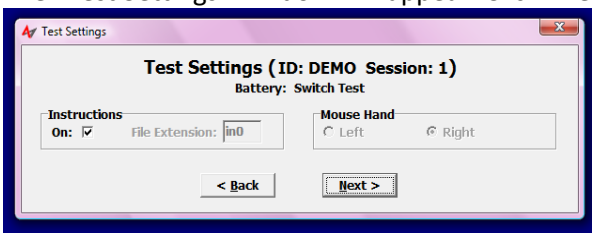
7. The first time you use the software and your ID # an “Information” window will appear. Click “Yes”.



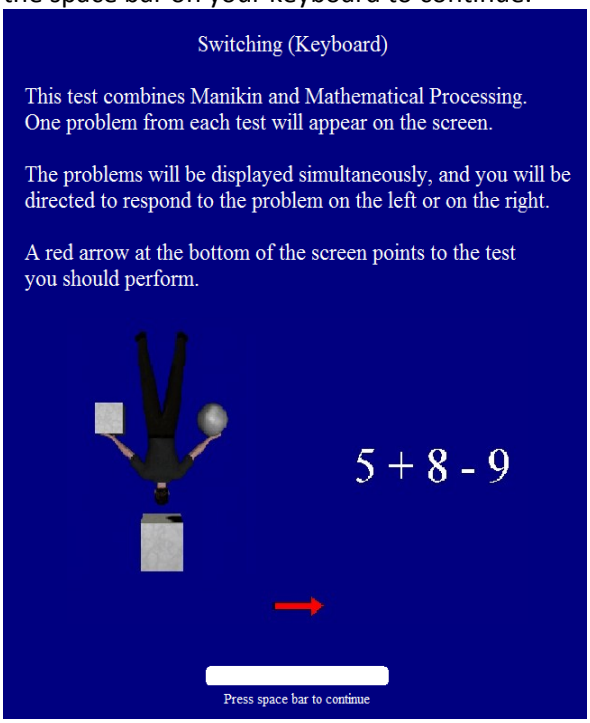
8. Verify you ID # on the “Confirmation” window. Click “Yes” if correct.



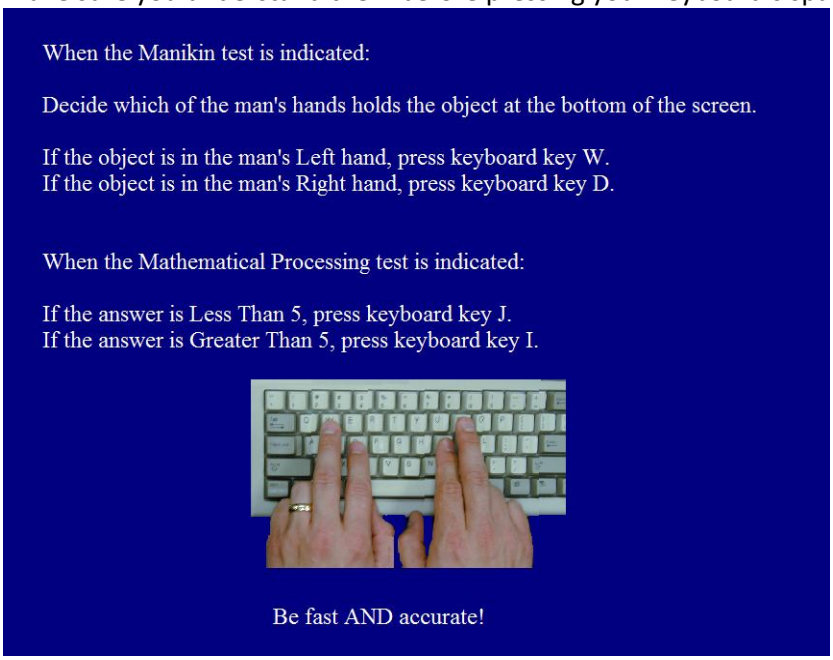
9. The “Test Settings” window will appear. Click “Next”



10. A description about the Switching test will appear. Please take a moment to read them. Press the space bar on your keyboard to continue.

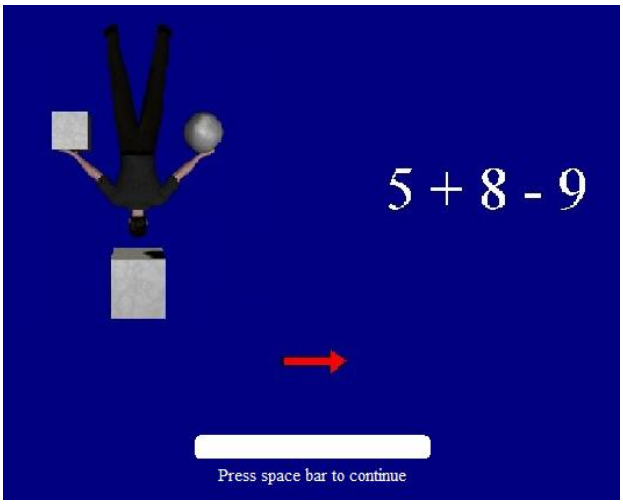


11. The next window will display actual **Instructions** for the test. Take a moment to read them. Make sure you understand them before pressing your keyboard's space bar.

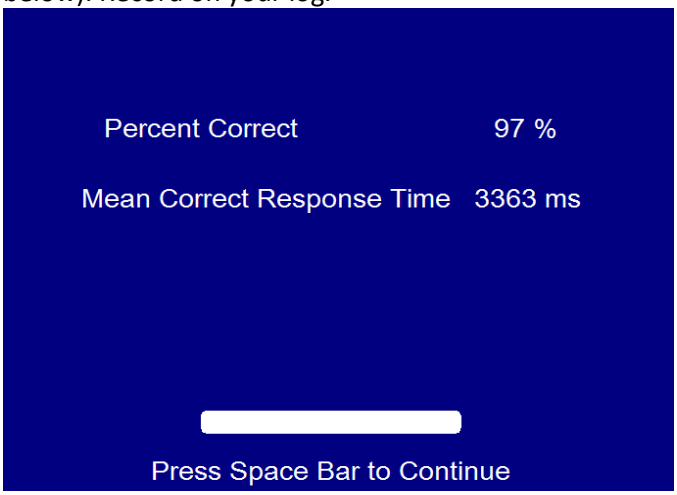


12. The next window will display the name of the test, "Switching". Press space bar to start the test.

13. A red arrow will indicate the task that needs to be answered. The red arrow will switch back and forth between the tasks so your job is to pay attention to when the switch occurs and answer the correct task. Be sure to answer quickly because the program only gives you a few seconds before it moves onto the next question.



14. After finishing the test, a window will display the percent of correct answers (see a sample below). Record on your log.



15. Remove USB device from your computer: Click on the "Safely Remove Hardware" icon. Select the name of the device to be removed.

If you would like more information about the Switching test or any task in this study, please feel free to contact **Wilfredo Rodríguez-Jiménez**:

E-mail: vection.lab@gmail.com

Text: (661) 261-4877

Thank you for your interest and participation!

Appendix E

Switching Test Performance Log

ID # ______

Date	Trial #	Time	Percent Correct	Comments

Appendix F

Simulator Sickness Questionnaire (SSQ)
(Kennedy, Lane, Berbaum, & Lilienthal, 1993)

ID _____
Date _____
Time_____

Instructions:
Please mark below if any of the symptoms apply to you now.
The following marks are acceptable: ☑ ☒ ■

Symptom	None	Slight	Moderate	Severe
General discomfort	☐	☐	☐	☐
Fatigue	☐	☐	☐	☐
Headache	☐	☐	☐	☐
Eyestrain	☐	☐	☐	☐
Difficulty focusing	☐	☐	☐	☐
Increased salivation	☐	☐	☐	☐
Sweating	☐	☐	☐	☐
Nausea	☐	☐	☐	☐
Difficulty concentrating	☐	☐	☐	☐
"Fullness of the head"	☐	☐	☐	☐
Blurred vision	☐	☐	☐	☐
Dizziness eyes open	☐	☐	☐	☐
Dizziness eyes close	☐	☐	☐	☐
Vertigo	☐	☐	☐	☐
Stomach awareness	☐	☐	☐	☐
Burping	☐	☐	☐	☐

Appendix G

Sleep/Activity Log