Classroom Technology and Motion Sickness

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Dedication

This work is dedicated to my father Maurice A. Mayo. As a young immigrant from the Philippines, he ventured to Minneapolis-St. Paul in search of the American Dream and the goal to earn a high school diploma. He eventually achieved the American Dream, but was not able to fulfill his educational goals. Earning this PhD at the University of Minnesota is for you, Dad.

Abstract

This study was spurred by reports of a presentation software application causing symptoms of motion sickness in classroom and training environments. Many educators use presentation applications to help convey ideas and concepts related to course learning objectives. Thus, presentations that make learners ill can have a serious consequence on learning. Two experiments were conducted to investigate the influence of classroom presentations with different optic flow characteristics on symptoms of motion sickness. In Experiment 1, college-aged students were exposed to either a low optic flow (LOF) presentation or a high optic flow (HOF) presentation. In Experiment 2, students were exposed to either a HOF presentation or a moderate optic flow (MOF) one. In both experiments, students completed a Simulator Sickness Questionnaire (SSQ) (Kennedy, Lane, Berbaum, and Lilienthal, 1993) before and after instruction to assess severity of motion sickness. In addition, in both experiments, students completed a quiz that assessed learning. Wilcoxon Matched-Pairs Signed Rank Tests were conducted to determine differences in ranking of PRE- and POST-SSQ scores. Differences in quiz scores between groups were assessed using independent samples *t*-tests. In Experiment 1, participants who viewed a HOF presentation experienced a significant increase in simulator sickness symptoms, while those who viewed a LOF presentation did not. In Experiment 2, participants in both HOF and MOF groups experienced a significant increase in simulator sickness symptoms. In both experiments, no differences in quiz scores between groups were found. These results suggest that moderate to high amounts of optic flow can cause an increase in symptoms of motion sickness in individuals who view animated instructional presentations.

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CHAPTER 1

Introduction and Literature Review

The influence of visually induced motion sickness (VIMS) on performance has been an interest to scientists for several decades. Research has confirmed that virtual reality simulations (Kennedy, Berbaum, & Lilienthal, 1997; Kennedy, Fowlkes, & Lilienthal, 1993; Stanney & Hash, 1998; Stoffregen, Hettinger, Haas, Roe, & Smart, 2000), video games (Merhi, Faugloire, & Stoffregen, 2007; Stoffregen, Faugloire, Yoshida, Flanagan, & Merhi, 2008), and the operation of hand held mobile devices such as smart phones and tablets (Stoffregen, Chen, & Koslucher, 2014) can cause nausea or increase motion sickness symptoms. Recently, anecdotal evidence suggests symptoms of motion sickness have emerged in technologies used in educational settings. Students attending classroom lectures or training seminars have reported experiencing motion sickness symptoms after viewing highly animated instructional presentations.

The use of presentation technology in educational settings is prevalent. Many textbook publishers offer Microsoft PowerPoint (PPT) presentations as part of their ancillary materials, and most instructors use PPT or similar applications to create their own instructional presentations. Also, to support faculty, most institutes of higher education provide instruction on the use of PPT. For example, the University of Minnesota's Center for Teaching and Learning (2010) provides a tutorial on Active Learning with PPT. Other institutions such as the University of Pennsylvania (Communication Within the Curriculum, n.d.), Vanderbilt (Center for Teaching, n.d.), and University of Oregon (Teaching Effectiveness Program, 2015, September 14) provide content on how to use PPT effectively. In addition to providing support for the use of PPT, some post-secondary institutions provide guidance on the use of other presentation software applications such as Apple's Keynote and/or Prezi.

Over the last two decades, the use of technology tools in educational settings has increased. Before the release of PPT, classroom instructional content was generally presented visually via blackboards, dry-erase boards, paper handouts, slides, overhead projectors, or video. Now, instruction can be delivered using technologies that have visual properties that resemble virtual reality, video games, and other dynamic visual formats. The Horizon Report, which reflects the collaboration between The New Media Consortium (NMC) and the Educause Learning Initiative, identifies emerging educational technology that potentially will influence teaching and learning in higher education. In 2011, the Horizon Report (Johnson, Smith, Willis, Levine, & Haywood, 2011) listed augmented reality and game-based learning as emerging technologies, and games and gamification were discussed in 2013 (Johnson et al., 2013).

Contemporary first-person video games give rise to motion sickness in approximately 30% of users (Stoffregen et al., 2008). Incidence is higher among people who passively watch games as opposed to those who actively play them (Chen, Dong, Chen, & Stoffregen, 2012; Dong, Yoshida, & Stoffregen, 2011). Given the large numbers of people who are exposed to classroom technologies, even a low rate of motion sickness could result in large numbers of sufferers. Panjwani, Gupta, Samdaria, Curtell, and Toyama (2010) reported that over 6 million teachers use PPT worldwide. If each of these teachers taught 25 students, approximately 150,000,000 students would be exposed to presentation technology. In addition, over 50 million individuals are now users of Prezi

(Prezi Blog, 2014), an application that allows users to create presentations with increased levels of visual motion animation. If 250,000 (or 0.5%) of Prezi users create presentations for educational or training purposes, and if they teach approximately 25 students, then 6.25 million students would be exposed to potentially nauseogenic animation. If 5% of students exposed to Prezi experienced motion sickness symptoms, then there would be 312,500 people suffering from motion sickness in educational and training settings. Given that the purpose of instruction is to enable students to achieve learning objectives, classroom presentations that make people sick can hinder students from achieving those goals.

Theories of Motion Sickness

The most widely accepted explanation for the etiology of motion sickness is based on sensory rearrangement theory, also known as sensory conflict theory (Reason, 1978; Reason & Brand, 1975). This theory suggests that motion sickness is the result of a discrepancy between sensory inputs from the visual and vestibular system and stored internal programs generated based on previous interactions with the environment (Reason, 1978). Motion signals transmitted by the visual, vestibular and non-vestibular proprioceptors conflict with each other and hence with what is expected. This conflict results in motion sickness because the current stimulation does not match the stored expectations.

With respect to VIMS, sensory conflict might occur in the absence of inertial motion when visually induced motion is not validated by vestibular inputs. Hettinger, Berbaum, Kennedy, Dunlap, and Nolan (1990) performed one of the first studies confirming that provocative visual stimuli could induce motion sickness. After completing a pre-motion sickness questionnaire, participants were exposed to a fixed-based visual flight simulator that displayed aerial self-motion. After exposure, participants reported whether or not they experienced illusory self-motion (i.e., vection) and completed a post-motion sickness questionnaire. Hettinger et al. (1990) found that 80% of individuals (8 out of 10) who reported experiencing vection also experienced motion sickness. In contrast, only 20% of individuals (1 out of 5) who reported experiencing no vection became sick. The researchers suggested that heredity and experience moving in the world might determine if an individual experienced VIMS. Specifically, some people who were exposed to provocative visual stimuli may have been more susceptible to motion sickness than others, and moving in an environment created a tight coupling between the visual and sensory (e.g., vestibular and proprioceptive) systems. A novel situation where visual inputs were not consistent with vestibular or proprioceptive inputs caused motion sickness.

One of the criticisms of sensory conflict theory is that while it offers an explanation for motion sickness, it has low predictive validity regarding which "sensory rearrangements will result in sickness symptoms and which will not, and it is unclear as to what constitutes a sensory rearrangement" (Draper, Viirre, Furness, & Gawron, 2001, p. 130). Ricco and Stoffregren (1991) provided an alternate theory to explain motion sickness etiology – postural instability theory. They postulated that the root cause of motion sickness was related to changes in the constraints that influence postural control, not sensory conflict with internal models. Posture subserves goal directed movement; thus the ability to maintain postural control is necessary to accomplish goals. Individuals can experience motion sickness in novel situations that disrupt postural control.

According to postural instability theory, some situations such as operating a simulator or playing a video game may compromise control of the head and torso. In these situations, the visual stimuli, which represent simulations of observer motion, destabilize posture. The observer must search for a new postural control strategy to stabilize the head and torso. If an appropriate strategy is not found, VIMS can occur. Postural instability theory accepts the premise that motion sickness occurs in settings where changes in the patterns of multiple sensory stimulation are likely to occur. However, Riccio and Stoffregen (1991) also considered the ecology of the interaction between animal and environment in these nauseogenic situations.

Motion Sickness Phenomena

Motion sickness is the term used to describe the many signs and symptoms felt by animals exposed to certain types of motions (Hettinger et al., 1990; Money, 1970). These motions are generally associated with modes of transportation such as ships, trains, automobiles, and aircrafts. The earliest documented evidence for this malady can be found as far back as the ancient Greeks. In his work *On the Nature of Man*, Hipprocates wrote, “sailing on the sea shows that motion disorders the body” (Money, 1970, p. 2).

Other forms of transit have also been linked to motion sickness. For instance, travel via domesticated animals can be nauseogenic (Guignard & McCauley, 1990). During the 19th century, some individuals riding in carriages or stagecoaches experienced motion sickness as they crossed the North American continent to settle the West (Helmich, 2008). In addition, people riding on camels and elephants have also reported experiencing motion sickness (Guignard & McCauley, 1990). Interestingly, people riding on horses rarely report experiencing motion sickness. Another form of transportation that has been associated with motion sickness is passive travel. In this situation, a seated individual who is carried by people walking in unison (generally in a ceremonial procession) experiences motion sickness.

Clearly, individuals have experienced motion sickness in a variety of settings across the millennia. With the exception of traveling across country in stagecoach, all of the above mentioned modes of transportation are still viable methods for travel. Remarkably, these modes share a commonality with respect to movement characteristics – low frequency oscillatory movement within the range of 0.1 to 1.0 Hz (Guignard & McCauley, 1990).

Visually Induced Motion Sickness (VIMS)

VIMS is a unique variant of motion sickness. According to Smart, Stoffregen, and Bardy (2002), VIMS is a side effect of "exposure to optical depictions of inertial motion" pg. 451. Thus, it is related to motion that is seen and not felt. In contrast, motion sickness related to travel is associated with physical oscillations of a vehicle, animal, or carrying device.

VIMS is not a new phenomena. Wood (1895) reported that the Haunted Swing, a carnival-like attraction that exposed seated patrons to oscillating visual motion, caused several customers to experience dizziness and nausea. However, the prevalence of VIMS has recently increased in training and entertainment settings. Cutting-edge hardware and software technology used in training simulators, video games, and movies that create realistic visual images is the likely cause of VIMS.

While the environment in which these two forms of motion sickness may differ (i.e., in-motion versus stationary), traditional forms of motion sickness and VIMS share a commonality with respect to what is felt and what is viewed. Similar to motion sickness associated with travel, low frequency oscillations are related to VIMS. However, in the case of VIMS, low frequency oscillations of optic motion can cause nausea or an increase in motion sickness symptoms. Hettinger et al. (1990) reported that individuals observing visual patterns between 0.15 and 0.25 Hz while seated in a flight simulator experienced VIMS. In addition, Stoffregen and colleagues have found that participants exposed to oscillating visual stimuli ranging between 0.0167 and 0.3100 Hz experienced motion sickness (Smart et al., 2002; Villard, Flanagan, Albanese, & Stoffregen, 2008). Moreover, Diels and Howarth (2013) reported that VIMS peaked between the ranges of .2 and .4 Hz when individuals viewed optic flow oscillations in the fore-aft direction.

Measurement of VIMS

The Simulator Sickness Questionnaire (SSQ) developed by Kennedy et al. (1993) is one instrument commonly used to assess VIMS. It measures symptoms associated with VIMS that occur in simulators or simulator-like environments such as fatigue, headache, eyestrain, nausea, difficulty concentrating, and vertigo. The SSQ has been used in a variety of contexts. For instance, scientists have used the SSQ to assess symptoms of motion sickness that might arise as the result of playing video games (Dong et al., 2011; Merhi et al., 2007; Stoffregen et al., 2008), interacting with mobile technology (Pölönen, Järvenpää, & Häkkinen, 2012; Stoffregen et al., 2014), watching 3-D movies (Solimini, 2013), and operating military aircraft (Kennedy et al., 1997; Stoffregen et al., 2000) or vehicular training simulators (Lee, Yoo, & Jones, 1997; Mourant & Thattacherry, 2000).

The SSQ is a validated instrument that was developed specifically to assess motion sickness that occurs in simulated training environments. Prior to the implementation of the SSQ, the Pensacola Motion Sickness Questionnaire (MSQ) was the instrument used to assess motion sickness in real and simulated training environments (Kennedy et al., 1993). However, many of the variables assessed by the MSQ were not applicable to training in simulators. For example, vomiting or emesis an important sign of motion sickness rarely occurs in a simulated environment. To determine the variables specific to simulator sickness, Kennedy et al. (1993) assessed 1,119 pairs of pre- and post-test MSQ data from 10 simulator locations. Variables included on the MSQ not associated with simulator sickness were eliminated. Kennedy et al. (1993) then performed a factor analysis to create symptom clusters or independent subscales. The analysis revealed three dimensions: *oculomotor*, *disorientation*, and *nausea*. The oculomotor dimension includes symptoms that are associated with the visual system such as eyestrain, difficulty focusing, blurred vision, and headache. In contrast, the disorientation dimension includes factors such as dizziness and vertigo, while the nausea dimension contains factors related to gastrointestinal distress such as feelings of nausea, stomach awareness, increased salivation and burping.

The SSQ is given twice during an experiment – prior to the presentation of visual stimuli and immediately afterward. The initial presentation of the questionnaire enables participants to become familiar with symptoms of motion sickness and provides baseline data to compare pre- and post-motion sickness symptom states (Bonnet, Faugloire, Riley, Bardy, & Stoffregen, 2006; Dong et al., 2011; and Stoffregen & Smart, 1998). Scores for each dimension and an index of *Total Severity* (TS), a score that represents a weighted average of the three dimensions, can be calculated. According to Kennedy et al. (1993), the maximum TS that can be achieved on the SSQ is ~300. However, much lower scores are typically reported and can be associated with simulator sickness symptoms. For example, Kennedy et al. (2003) reported that TS scores between 10 and 15 identify a simulator associated with significant symptoms, while a TS score between 15 and 20 identifies a more troublesome simulator. A score greater than 20 indicates a problem simulator. In these situations, participants might not feel sick, but analysis of the SSQ scores indicate an increase in symptoms of simulator sickness. With respect to the use of the SSQ to measure motion sickness in video games, Stoffregen et al. (2008) reported that high TS score are only reported when participants expressed that they felt motion sick. Kennedy et al. (1993) reported that the distribution of SSQ scores tend to be skewed. Since scores are not normally distributed, non-parametric tests are used to compare within and between group pre- and post-test scores.

Optic Flow and Motion Sickness

The situations and contexts where motion sickness occurred due to non-inertial factors share one commonality – individuals were exposed to optic flow. Optic flow refers to the spatio-temporal pattern of light rays that impinges on the retina. This concept was introduced by Gibson (1950) to describe the visual information perceived by an animal as it moved in its environment. Visual stimuli observed by an animal can translate in a variety of directions, rotate about different axes, and expand and contract. Gibson (1957) identified six parameters of optic motion: (a) vertical translation, (b) horizontal translation, (c) enlargement (i.e., looming or zooming) or reduction (i.e., contracting), (d) horizontal foreshortening, (e) vertical foreshortening, and (f) rotation.

While listed as separate phenomena, these factors can also be integrated. For instance, an individual may perceive an object translate horizontally while it simultaneously enlarges. Under certain conditions, viewing specific types of optic motion can cause feelings of motion sickness**.**

However, an animal is not required to locomote to experience optic flow. Using a moving room, Lee and colleagues (Lee & Aronson, 1974; Lee & Lishman, 1975) first demonstrated that individuals would make postural adjustments in response to the optic stimuli produced by the moving room. Lee and Aronson (1974) found that when infants were exposed to optic flow that expanded toward them (i.e., the room moved toward them), they fell backward. When the room moved away from them (i.e., optic flow contracted), the infants fell forward. Using the same paradigm, Lee and Lishman (1975) found that adults also compensated posturally in response to optic flow. However, in their experiments adults did not fall; they swayed backward in response to expanding optic flow, specifying forward motion, and forward in response to contracting optic flow specifying backward motion.

Clearly, optic flow can profoundly influence balance, but can it induce motion sickness? Researchers have empirically examined the relationship between optic motion and motion sickness and the answer is yes. Using a flight simulator, Stoffregen et al., (2000) demonstrated that motion sickness or symptoms of motion sickness could occur when individuals viewed visual stimulations that oscillated in the roll axis. Keshavarz and Hecht (2011) reported similar findings when individuals were exposed to one of three computer generated roller coaster rides. While all three roller coaster rides included translational movement in the sagittal direction, the conditions varied in the axis of rotational motion. One group was exposed to visual stimuli primarily in the pitch axis, another group was exposed to visual motions primarily about pitch and roll axes, and a third group was exposed to visual stimuli primarily in the pitch, roll, and yaw axes. All three conditions elicited an increase in severity of motion sickness symptoms. These findings suggested that viewing rotating movements could elicit motion sickness or symptoms of motion sickness.

Other types of optic motions such as vertical oscillations and expanding and contracting visual stimuli may be related to motion sickness or an increase in motion sickness symptoms. Bubka, Bonato, and Palmisano (2007) investigated the relationship between expanding and contracting optic flow on simulator sickness. In their experiment, individuals viewed two visual patterns on a desktop computer monitor with monocular vision and the conditions were viewed at separate times. In one condition, the optic flow of the visual stimuli expanded toward the individual. In the other condition, the visual stimuli contracted away from the individual. Bubka et al. (2007) reported that expanding optic flow was related to an increase in motion sickness compared to contracting optic flow. In a follow up study, Palmisano, Bonato, Bubka, and Folder, (2007) found that vertical oscillating radial optic flow produced more motion sickness than non-oscillating radial flow displays.

Motion Sickness in Educational and Training Settings

Simulators and virtual reality environments have been used extensively in education and training settings. For instance, they have been used to train surgeons to perform laparoscopic surgery techniques (Ali, Mowery, Kaplan, & DeMaria, 2002; Rosenberg, Landsittel, & Averch, 2005; Rosser et al., 2007), to evaluate and to train pilots (Jones, Kennedy, & Bittner, Jr., 1981), to teach levee patrollers to inspect for structural damages that may cause levees to fail (Harteveld & Bidarra, 2007), to help stroke patients improve motor function (Cameirão, Badia, Oller, & Verschure, 2010; Holden, Todorov, Callahan, & Bizzi, 1999), and to teach middle school children concepts related to astronomy (Chen, Yang, Shen, & Jeng, 2007) and mathematics (Bai, Pan, Hirumi, & Kebritchi, 2012; Ke, 2008).

Training simulators and virtual reality environments provide a number of benefits to individuals learning new skills. According to Magill and Anderson (2013) benefits of these devices include: (a) enabling learners to practice without concern for the costs of accident associated with practice in real environments, (b) allowing trainers to more easily control specific characteristics of the training environment, and (c) permitting learners to practice for longer durations and intensity. In addition, Kennedy, Lilienthal, Berbaum, Baltzley, and McCauley (1989) indicated that flight simulators enable trainees to experience emergency training situations, can provide trainees with knowledge of performance feedback, and can reduce operational costs.

However, while simulators and virtual reality environments provide many training benefits, VIMS is a negative side-effect for some participants who interact with these technological devices. In these situations, the optic flow designed into the system to create a realistic experience or a sense of presence caused VIMS. Kennedy and his colleagues (Kennedy et al., 1989, 1997) and Stoffregen et al. (2000) reported that participants exposed to optic flow while operating flight simulators experienced motion sickness. In the context of driving simulators, Brooks et al. (2010), Lee et al., (1997), and Mourant and Thattacherry (2000) reported similar findings. Some classroom technologies can now display optic flow characteristics traditionally associated with simulators and virtual environments. For example, research conducted by Stoffregen et al. (2014) demonstrated that playing a video game on a computer tablet caused motion sickness.

A case of VIMS was reported to have occurred at a school setting in Japan on July 8th, 2003 (Kuze & Ukai, 2008; Ujike, 2007; Ujike, Ukai, & Nihei, 2008). According to reports, 36 junior high school students were hospitalized for motion sickness like symptoms after viewing a 20-minute video. To investigate the possible causes that led to students experiencing VIMS, Ujike et al. (2008) surveyed the students who watched the video, interviewed school officials, and assessed the environment where the video was presented. The authors found that headache, nausea, and cold sweat were the motion sickness symptoms reported most frequently. In addition, they suggested that the severity of VIMS was related to visual angle as those who sat in the front row and middle of the room reported greater amounts of symptom severity than students who sat in the back row. Moreover, those who concentrated more on the content experienced greater motion sickness; however, student interest did not influence motion sickness severity.

Recently, students attending classroom lectures or training seminars have reported experiencing motion sickness symptoms after viewing highly animated instructional presentations (Conboy, Fletcher, Russell, & Wilson, 2012). Instructional presentations that make people sick are problematic given that the purpose of instruction is to enable students to achieve learning objectives. The presentation software that is anecdotally linked to motion sickness in the learning environment is Prezi.

This software application allows instructors to create fascinating, animated presentations where objects can translate or pan across the screen, rotate, zoom out, and contract relative to the visual display. This feature allows instructors and designers to create presentations with greater visual motion compared to traditional presentation software such as PowerPoint. In addition, instructors and designers can arrange content spatially enabling students to see how concepts are connected. Conboy et al. (2012) conducted a focus group on the effectiveness of Prezi to facilitate learning in undergraduate students. They reported that some students liked Prezi because it functioned "like a mind map" which enabled them to integrate concepts. Another finding was that students found Prezi to be more engaging. However, the authors cautioned that student engagement in this context might be associated with Prezi's novelty. Moreover, Virtanen, Myllärniemi, and Wallander (2013) reported that students who used Prezi to complete assignments felt that the application facilitated brainstorming and enabled them to make connections with course content. However, while this technology may permit an instructor to create captivating presentations and enable students to better understand concepts, anecdotal reports have also linked Prezi presentations to motion sickness.

After Prezi's release to market, several technology bloggers reported either personally experiencing motion sickness symptoms or accounts of individuals experiencing sickness. Leberecht (2009) of CNET indicated several Prezi presentations that he viewed included transitions that caused him to experience dizziness. In addition, Wired blogger Allain (2010) reported that viewing a Prezi presentation induced headache, a symptom of motion sickness. Moreover, Salter (2012, June 28), a blogger for The Chronicle of Higher Education mentioned that Prezi often "gets a bad reputation for causing motion sickness." Walton (2011) coined the phrase "Death by motion sickness in Prezi" to describe the nauseogenic effects of Prezi. In addition to these reports from bloggers, Conboy et al. (2012) reported that some students participating in their focus group indicated that they experienced dizziness while using Prezi. Brown University (2014) presents a list of eight reasons why faculty should not use Prezi. Students experiencing motion sickness is one reason listed.

Since its release in 2009, the number of Prezi users has grown substantially. In December 2011, Prezi announced that they reached 5 million users (Prezi, 2011, December 9). Two years later, Bort (2013) reported that over 30 million individuals used Prezi. In November 2014, Prezi (Prezi Blog, 2014) announced that over 50 million individuals use the application. Given the number of users, millions of students in educational and training settings could be exposed to nauseogenic visual motion. As such, anecdotal evidence is not sufficient to allow instructors and designers to create pedagogically and andragogically sound presentations that take advantage of Prezi's features. Controlled experimental research is needed to determine the risk or prevalence of motion sickness associated with presentations with high optic flow, and to determine factors that may affect (i.e., increase or decrease) that risk.

The Present Study

Rationale for the Study

Motion sickness can affect individuals in a variety of settings and can occur in situations without physical motion related to travel. The culprit in many of these settings is optic flow. Empirical research has been conducted to understand the factors related to motion sickness in flight or vehicle simulators, virtual reality environments, and video games. The reports of individuals experiencing motion sickness or symptoms of motion sickness while observing a presentation created in Prezi are speculative. The reports have not been verified through scientific research.

Purpose of the Study

The purpose of this study was three-fold. The first purpose was to determine whether a lecture presentation that incorporates optic motion could induce VIMS or symptoms of VIMS. While anecdotal evidence has suggested commercial presentation software may cause symptoms of motion sickness, the relationship has not been empirically tested. The second purpose was to evaluate whether elevated motion sickness symptoms would impact academic performance in a classroom setting. The third purpose was to identify strategies that could be used by instructors and/or instructional designers to create presentations with optic flow that will not induce feelings of motion sickness. The objective is not to determine whether Prezi is a good or bad medium for instruction, but to examine how optic flow characteristics could influence motion sickness in classroom environments.

Significance

The use of animation in instruction can enable students to focus on relevant information that can help them attain learning objectives. However, a presentation that induces motion sickness or symptoms related to motion sickness will likely interfere with the learning process. This study may identify strategies to help instructors and designers to create animated presentations that will not induce nausea or feeling of motion sickness to enable their students to attain learning objectives.

Research Questions and Hypotheses

Students and trainees rarely experience motion sickness when viewing a PPT. In contrast, people have reported experiencing motion symptoms while view a presentation designed using Prezi. The optic flow characteristics of some Prezi presentations are the likely cause of these symptoms. Based on the literature that examined the relationship between optic flow and motion sickness, the following predictions were made:

H1: Participants who view a HOF presentation will experience a significant increase in simulator sickness symptoms, while participants who view a LOF presentation will not experience a significant increase in simulator sickness symptoms.

H2: Participants who view a HOF presentation will have lower quiz scores than participants who view a LOF presentation.

H3: Participants who view a HOF presentation will experience a significant increase in simulator sickness symptoms, while participants who view a moderate optic flow (MOF) presentation will not experience a significant increase in simulator sickness symptoms.

H4: Quiz scores will be higher for participants who view a presentation with MOF compared to students who view a HOF instructional presentation.

Note: With respect to H1 and H3, participants who view a HOF presentation will experience a significant increase in simulator sickness as observed in SSQ difference scores, but will not vomit. As indicated by Kennedy et al. (1993), vomiting rarely occurs in simulated environments. In addition, the magnitude of the SSQ scores will be low, but within-group differences for the HOF groups will be significantly different. This prediction is aligned with Kennedy et al.'s (2003) finding that low scores could reveal a problematic simulator that could cause motion sickness.

CHAPTER 2

Experiment 1

Anecdotal evidence suggests that animated instructional presentations may cause feelings of motion sickness during classroom lectures or corporate trainings sessions; however, scientific research has not confirmed or refuted these reports. Experiment 1 was designed to determine whether instructional presentations with HOF characteristics could induce symptoms of motion sickness in a classroom setting. In addition, the effect of viewing a potentially nauseogenic presentation on academic performance was assessed. This study was conducted during Spring Semester 2013 at the University of Minnesota according to procedures approved by the University of Minnesota Institutional Review Board - Study No.: 1211P24423 (see Appendix A).

Two predictions were made: (a) participants who view a HOF presentation will experience a significant increase in simulator sickness symptoms, while participants who view a LOF presentation will not experience a significant increase in simulator sickness symptoms (H1) and (b) participants who view a HOF presentation will have lower quiz scores than participants who view a LOF presentation (H2).

Method

Participants

Sixty-five students (39 Females; 26 males) enrolled in two sections of Kinesiology 3135 – Motor Learning and Control – participated in this experiment. Of the 65 students, 36 participants (22 Females: Mean Age = 20.95, SD = 1.33, 14 Males: Mean Age = 21.36, SD = 1.82) attended the class where the PPT presentation was given and 29 students (17 Females: Mean Age = 20.35, SD = .61, 12 Males: Mean Age = 21.25, SD = 1.60) attended the class where Prezi was used as the presentation media. Using random assignment (i.e., a coin flip), Section 001, which met on Fridays from 9:05 am to 11:00 am, was assigned to the HOF group, while Section 005, which met on Wednesday from 9:05 to 11:00 am, was assigned to the LOF group.

Equipment and Apparatus

Presentation tools. The presentation tools used to examine the relationship between animated instructional presentations and motion sickness were Microsoft PPT and Prezi. PPT was selected as it represents commonly used presentation software in the academic environment. PPT has been available to the general public since its launch in 1990. PPT presentations typically are designed with little animation or optic flow. Students rarely experience symptoms of motion sickness when viewing a PPT presentation. Prezi was chosen because it has been associated with motion sickness in classroom and training environments.

Two features unique to Prezi are its use of zoomable user interface (ZUI) technology and non-linear sequencing of frames. The ZUI technology allows instructors and designers to create presentations with visual motion in X, Y, and Z planes relative to the visual display. The non-linear sequencing feature allows content to be spatially arranged on a "canvas." In contrast to PPT, content is not organized on slides that are shown in a specific sequence. Content is contained within frames, and paths are used to connect frames, which establishes the order of the content. Figure 1 provides an example of how frames are connected by paths. In this example, the navigation results in rightward translation from frames 1 to 2, a leftward diagonal translation from frames 2 to 3, and a rightward translation from frames 3 to 4.

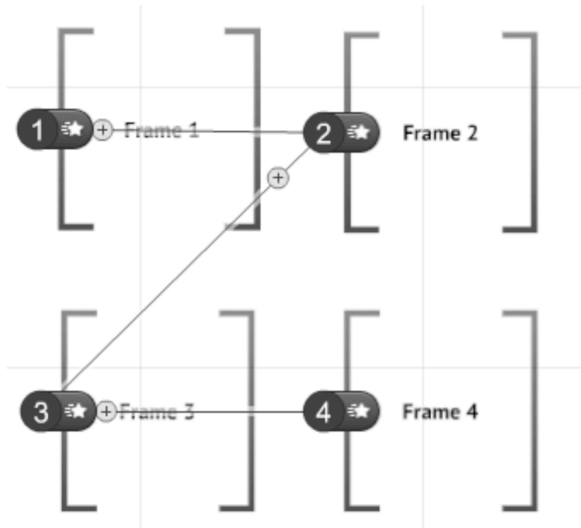

Figure 1: Example of frames connected by paths.

Non-linear sequencing of frames allows instructional content to be organized around themes, concepts, or ideas similar to a concept map. This feature enables instructors to convey relationships between elements. For example, Figure 2 exhibits how frames can be organized to show a concept. When the instructor navigates through this section of the presentation, students would first see the frame that contains the three primary variables that constrain motor behavior – individual, environmental, and task (Newell, 1986). Upon advancing to the next frame, students would see the frame labeled Individual Constraints with its associated components – Structural and Functional. The next path navigation would then advance to the frame Structural followed by Functional. This sequence of showing a main element first, followed by its associated subcategories, would continue until all elements are discussed.

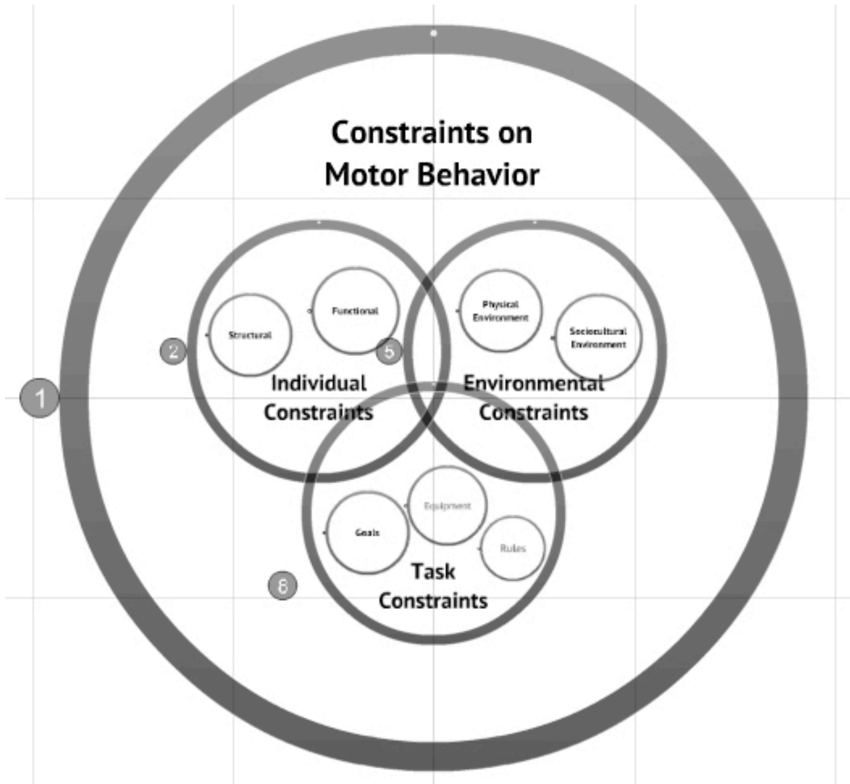

Figure 2: Example of frames organized to demonstrate a concept.

These features allow instructors and designers to create presentations with greater amounts of optic flow compared to traditional presentation software such as PowerPoint. For instance, sequential frames that are arranged haphazardly on the canvas can create an optic flow of translational movements with frequent shifts in direction. Frames ordered in this way would require observers to shift their gaze frequently, which could induce simulator sickness or an increase in symptoms. In addition, paths that connect frames that differ in size would create an optic flow that could consist of one or more of the following optic motions: (a) translation (horizontal, vertical, diagonal, forward, and backward), (b) contraction, and (c) expansion. These optic motions can induce simulator sickness or an increase in simulator sickness symptoms. Figure 3 is a screen shot of the Prezi canvas with frames that are spatially arranged that would create a high amount of optic flow. The path that connects frames 16 and 17 is associated with forward and downward rotation, contraction, and expansion. The next path that connects frames 17 to 18 is associated with forward and leftward translation, rotation, contraction, and expansion. Finally, the path that connects frames 18 and 19 is associated with forward and rightward translation, rotation, contraction, and expansion.

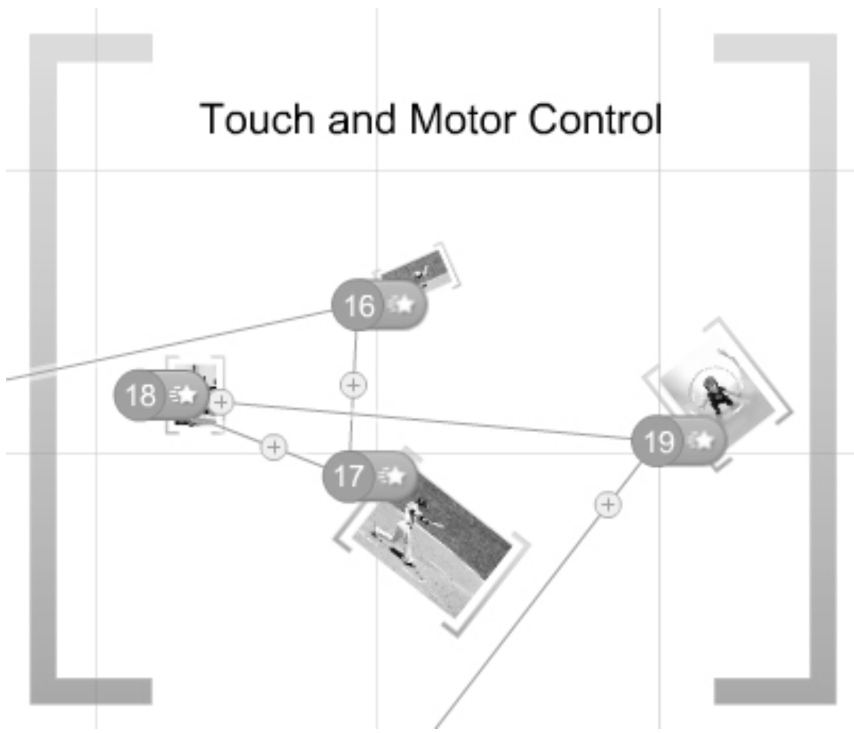

Figure 3: Optic flow movements associated with paths.

Presentation content. Two presentations on the topic "Sensory Components of Motor Control" were designed and developed using PPT and Prezi. The PPT file represented a "typical" presentation given during an in-class lecture. It consisted of text, digital images, and embedded movie clips. Animation included in the PPT file consisted of the *dissolve* setting for text, and *zoom* or *appear* settings for digital images. The optic flow characteristics of the PPT presentation were considered low. The presentation created using Prezi took advantage of Prezi's ZUI technology and non-linear presentation features. This presentation included a variety of animated movements - zooming, contracting, rotation and translation (vertical, horizontal, and diagonal). One or more of these motions could occur when navigating frame-to-frame. In addition, frame-to-frame path sequencing was not spatially organized with respect to content. This created longer translational movements and changes in direction of optic motion. The optic flow characteristics for the Prezi were considered high. Instructional content included in the PPT and the Prezi files were the same.

Classroom environment. The experiments took place in Rapson Hall 54. This classroom was designed to seat 73 students. The configuration of the room consisted of 8 rows of tables. The first 6 rows had 10 seats per row. Due to the position of the audiovisual room, there were fewer seats in the seventh and eighth rows. These rows consisted of seven and six seats respectively. Rows 1 and 2 were positioned at ground level; rows 3, 4, and 5 were elevated 12 inches above ground level; and rows 6, 7, and 8 were elevated 24 inches above ground level.

The audiovisual system projected media onto a screen that was 2.13 m high by 3.66 m wide. The distance from the center of the first row to the projector screen was 3.81 m. The second row was 4.9 m from the screen. Rows 3 through 8 were 6.24 m, 7.56 m, 8.88 m, 10.20 m, 11.52 m, and 12.84 m away from the screen. The screen resolution was set to 1024 x 768.

Measures and Data Analysis

Severity of motion sickness symptoms. The severity of motion sickness symptoms was assessed using the Simulator Sickness Questionnaire (SSQ) created by Kennedy et al. (1993) (see Appendix B). For this experiment, only TS was computed and analyzed since the goal was to determine if a HOF presentation could cause symptoms of motion sickness. Since SSQ data are non-parametric, a two-sample paired Wilcoxon Signed Rank Test was used to compare differences in PRE-SSQ and POST-SSQ within each condition (i.e. class section). Effect Size (ES) was calculated using the equation ES = r = z-score/SQRT (n) based on the recommendation by Pallant (2007). ES was interpreted using Cohen (1988) criteria.

Assessment of learning. A 10-point/10 question multiple-choice quiz was given to assess learning. This method of evaluation was selected because it allowed learning to be assessed in a timely manner. While the quiz was used to assess learning, the scores earned on the quiz did not count toward a student's final grade. These questions were taken from the test bank associated with the textbook Motor Learning and Control: Concepts and Applications (10^{th} Edition) by Magill and Anderson (2013) and were selected because they assessed knowledge of the learning objectives presented at the beginning of the lecture. The test bank is available to instructors who adopt the textbook from McGraw-Hill Education. Independent samples *t*-tests were used to analyze differences in quiz performance between optic flow conditions.

Procedure

Two weeks before the experiment, the investigator recruited participants in both sections of KIN 3135. The investigator provided a general overview of the study, reviewed the Consent Form (see Appendix C), answered questions, and distributed the Consent Form. Students were instructed to read the Consent Form and, if interested in participating, to complete and return it to the investigator one week before Experiment 1.

The investigator collected the Consent Form in each class one week before the experiment.

The experiment took place on Wednesday, February 20th and Friday, February 22nd. On those dates, a packet consisting of PRE- and POST-SSQs, a Demographics Information Form (see Appendix D), and the quiz was placed on each desk. The Demographics Information Form collected information such as age, sex, seat location, video game playing experience, and physical activity experience. Upon entering the classroom, students were informed that they could choose their own seat. They were also instructed to not examine the packet. Prior to the start of the lecture, students were reminded that participation was voluntary and that they could drop out at any time. In addition, they were instructed to look away or close their eyes if they experienced symptoms of motion sickness. Students were then instructed to complete the PRE-SSQ Form and the Demographic Information Form. In addition, they were asked not to view the quiz. The lecture started once both forms were completed. Students were instructed to attend to course material as they would in any other class. Both HOF and LOF presentations were designed to be delivered in approximately 75 minutes. At the end of each lecture, participants completed the POST-SSQ Form followed by the quiz.

Results

Demographic Data

The demographics data is summarized in tables located in Appendix E. These tables provide a summary of video gaming experience and a summary of physical activity with respect to American College of Sports Medicine (ACSM) recommendations for weekly exercise. The data in these tables include information from Experiments 1 and 2.

The data was organized in this manner because many students participated in both experiments. Sports or Physical Activity Experience was not summarized, as there was no consistent pattern in self-reports of physical activities. Due to the small sample size, statistical power is reduced. Therefore, demographic data were not analyzed.

Severity of Motion Sickness Symptoms

The means and 95% confidence intervals for each condition are presented in Figure 4. POST-SSQ scores increased in both LOF and HOF presentation conditions.

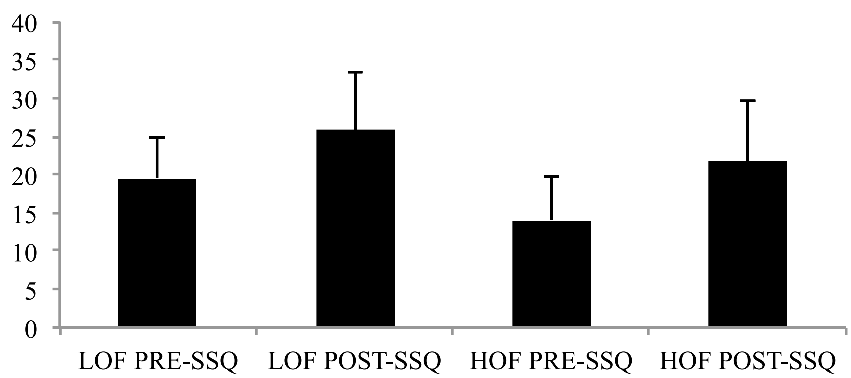

Figure 4: Experiment 1 - Means and 95% Confidence Intervals for each condition.

Wilcoxon Matched-Pairs Signed Ranks Test – LOF Presentation

A Wilcoxon Matched-Pairs Signed Rank Test was conducted to determine differences in the ranking of PRE- and POST-SSQ scores for students who viewed the LOF presentation. Positive and negative ranks based on the difference between POST-SSQ and PRE-SSQ scores, as well as ties, are presented in Table 1. Results of the analysis indicated a non statistically significant differences between PRE- and POST-SSQ scores, $z = -1.805$, $p = .071$, with a moderate effect size (ES = .30). The mean POST-SSQ score (25.868) was not significantly greater than mean PRE-SSQ score

(19.531) for students who viewed the LOF presentation.

Table 1

Ranking of SSQ Data – LOF Presentation (Experiment 1)

Rank	N	Mean Rank	Sum of Ranks
Negative	9[a]	16.11	145.00
Positive	21[b]	15.24	320.00
Ties	6[c]		
Total	36		

Note. a) POST-SSQ < PRE-SSQ, b) POST-SSQ > PRE-SSQ, and c) POST-SSQ = PRE-SSQ

Wilcoxon Matched-Pairs Signed Ranks Test – HOF Presentation

A Wilcoxon Matched-Pairs Signed Rank Test was conducted to determine whether there were differences between the ranking of PRE- and POST-SSQ scores for students who viewed the HOF presentation. Positive and negative ranks based on the difference between POST-SSQ and PRE-SSQ scores, as well as ties, are presented in Table 2. Results of the analysis indicated a statistically significant difference between PRE- and POST-SSQ scores, $z = -2.914$, $p < .05$, with a large effect size (ES = .541). The mean POST-SSQ score (21.795) was significantly greater than PRE-SSQ score (14.057) for students who viewed the HOF presentation.

Table 2

Ranking of SSQ Data – HOF Presentation (Experiment 1)

Rank	N	Mean Rank	Sum of Ranks
Negative	6[a]	5.33	32.00
Positive	15[b]	13.27	199.00
Ties	8[c]		
Total	29		

Note. a) POST-SSQ < PRE-SSQ, b) POST-SSQ > PRE-SSQ, and c) POST-SSQ = PRE-SSQ

Quiz Scores

The class that viewed the LOF presentation had a mean quiz score of 6.64 points, compared to the class that viewed the HOF presentation that had a mean score of 6.17 points (Table 3). The maximum score for this quiz was 10 points. An independent samples *t*-test was conducted to compare quiz scores for students who viewed the HOF presentation and the LOF presentation. The difference between groups was not significant, $t(63) = 1.186$, $p = .240$, $\alpha = .05$. The mean quiz scores for the group who viewed the HOF presentation and the group who viewed the LOF presentation were statistically similar.

Table 3

Mean, Standard Deviation, and Standard Error Mean - HOF and LOF Groups.

Groups	N	Mean	Std. Deviation	Std. Error Mean
HOF	29	6.17	1.671	.310
LOF	36	6.64	1.496	.249

Discussion

Anecdotal reports have suggested that presentations with HOF can cause feelings of motion sickness in students or trainees who view them (Allain, 2010; Conboy et al., 2011; Leberecht, 2009; Salter, 2012). Experiment 1 was designed to verify those reports. In this experiment, one group of students viewed a traditional PPT presentation with LOF properties, while a second group observed a Prezi presentation designed with HOF properties. Both groups completed SSQs prior to viewing each presentation and immediately after the presentation. After completing the POST-SSQ, students answered 10 multiple-choice questions that pertained to the lecture. The two predictions made were: (a) participants who viewed a HOF presentation will experience a significant increase in simulator sickness symptoms, while participants who viewed a LOF presentation will not experience a significant increase in simulator sickness symptoms, and (b) participants who viewed a HOF presentation will have lower quiz scores than participants who view a LOF presentation

The results supported only one of two hypotheses. In support of Hypothesis 1, POST-SSQ scores were significantly higher compared to PRE-SSQ scores for participants who viewed the HOF presentation. There were no significant differences in PRE- and POST-SSQ scores for students who viewed the LOF instructional presentation. While the mean PRE- and POST-SSQ scores were relatively low for both groups (compared to the maximum SSQ score that could be earned), the difference for the HOF group was significant and the effect size for the HOF group was large suggesting that a presentation with HOF characteristics can induce symptoms of motion sickness. As expected, no one vomited. However, while the students who viewed the LOF presentation had higher mean quiz scores, the difference in quiz score performance between LOF and HOF was not significant. Thus, Hypothesis 2 was not supported.

Given that Hypothesis 1 was supported, it was deemed necessary to replicate the influence of a HOF presentation on SSQ values. In addition, a strategy to minimize simulator sickness by reducing optic flow characteristics of an animated presentation was also evaluated. Experiment 2 compared the influence of HOF and MOF presentations on simulator sickness.

CHAPTER 3

Experiment 2

Experiment 1 verified that a presentation incorporating excessive zooming, contracting, rotation, and unorganized translational movements could cause an increase in simulator sickness symptoms. However, the prediction that students viewing a presentation with HOF would have lower quiz scores than students who viewed the LOF presentation was not supported. Experiment 2 was designed to investigate a design strategy that could minimize incidence of motion sickness. Using only the Prezi application, two presentations on the topic "Augmented Feedback" were created. The HOF presentation for this experiment was somewhat similar to the HOF presentation implemented in Experiment 1. It incorporated contracting, zooming, and translational movements of text, digital images, and movie clips, and the frame sequencing was disorganized. However, rotational motion was eliminated and vertical translation was used more frequently compared to horizontal translation. The MOF presentation incorporated similar optic motion characteristics, but contracting and zooming were less pronounced. In addition, horizontal translation was used more frequently compared to vertical translation. The frames were also spatially arranged to reduce frame-to-frame path travel in vertical, horizontal, and diagonal directions.

Two predictions were made: (a) participants who view a HOF presentation will experience a significant increase in simulator sickness symptoms, while participants who view a MOF presentation will not experience a significant increase in simulator sickness symptoms (H3) and (b) quiz scores will be higher for participants who view a presentation with MOF compared to students who view a HOF instructional presentation (H4).

Method

Participants

Sixty-seven students (39 Females; 28 males) participated in Experiment 2. Of the 67 students, 38 participants (23 Females: Mean Age = 21.30, SD = 1.79; 15 Males: Mean Age = 21.27, SD = 1.75) attended the class where the HOF presentation was given and 29 students (16 Females: Mean Age = 20.50, SD = .60; 13 Males: Mean Age = 21.85, SD = 1.77) attended the class where the presentation was designed with MOF. Fifty-one students (28 Females; 23 Males) who participated in Experiment 1 also participated in Experiment 2.

Equipment and Apparatus

As this study took place in an official university class, the presentations were given in the same lecture hall – Rapson 54. The only changes from Experiment 1 were that Prezi was the application used to develop both HOF and MOF presentations.

Measures and Data Analysis

The measures and data analysis used in Experiment 2 were the same as in Experiment 1. However an 11-point/11-question quiz was given because more learning objectives were covered in the lecture.

Procedure

The experiment took place on two days - Wednesday, April 17th and Friday, April 26th. Originally, the experiment was scheduled to take place on the 17th and 19th of April. However, due to inclement weather on April 19th, the second day of testing was moved to

April 26. Given that at least 8-weeks separated Experiments 1 and 2, no issues related to test-retest reliability or saturation were expected. With respect to the SSQ, Kennedy et al. (1993) reported that 2 to 5 days between simulator exposures is an optimal test-retest window because the time interval is sufficiently long to avoid any residual effects of simulator sickness symptoms and short enough to retain adaptation to the simulator device. Since adaptation begins to degrade after 5 days, the 8-week interval between Experiments 1 and 2 is adequate.

With the exception of presentation conditions, the procedures implemented in Experiment 2 were the same as those used in Experiment 1. In Experiment 2, the students enrolled in Section 001 viewed a MOF presentation, while individuals in Section 005 viewed a HOF presentation.

Results

Severity of Motion Sickness Symptoms

The means and 95% confidence intervals for each condition are presented in Figure 5. POST-SSQ scores increased in both MOF and HOF conditions.

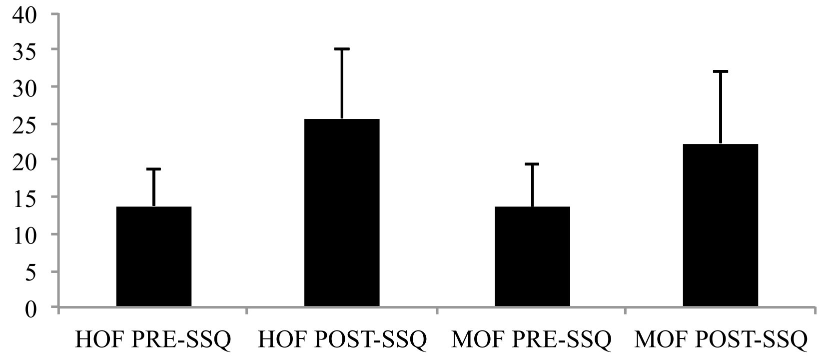

Figure 5: Experiment 2 - Means and 95% Confidence Intervals for each condition.

Wilcoxon Matched-Pairs Signed Ranks Test – HOF Presentation

A Wilcoxon Matched-Pairs Signed Rank Test was conducted to determine whether there was a difference in the ranking of PRE- and POST-SSQ scores for students who viewed the HOF presentation. Positive and negative ranks based on the difference between SSQ-POST and SSQ-PRE scores, as well as ties, are presented in Table 4. Results of the analysis indicated a statistically significant difference between PRE- and POST-SSQ scores, $z = -3.771$, $p < .05$, with a large effect size (ES = .612). The mean POST-SSQ score (25.689) was significantly greater than PRE-SSQ score (13.787) for students who viewed the HOF presentation.

Table 4

Ranking of SSQ Data – HOF Presentation (Experiment 2)

Rank	N	Mean Rank	Sum of Ranks
Negative	6[a]	7.25	43.50
Positive	23[b]	17.02	391.50
Ties	9[c]		
Total	38		

Note. a) POST-SSQ < PRE-SSQ, b) POST-SSQ > PRE-SSQ, and c) POST-SSQ = PRE-SSQ

Wilcoxon Matched-Pairs Signed Ranks Test – MOF Presentation

A Wilcoxon Matched-Pairs Signed Rank Test was conducted to determine whether there was a difference in the ranking of PRE- and POST-SSQ scores for students who viewed the MOF presentation. Positive and negative ranks based on the difference between SSQ-POST and SSQ-PRE scores, as well as ties, are presented in Table 5. Results of the analysis indicated a statistically significant difference between PRE- and POST-SSQ scores, $z = -1.968$, $p < .05$, with a medium effect size (ES = .365). The mean POST-SSQ score (22.311) was significantly greater than PRE-SSQ score (13.541) for students who viewed the MOF presentation.

Table 5

Ranking of SSQ Data – MOF Presentation (Experiment 2)

Rank	N	Mean Rank	Sum of Ranks
Negative	6[a]	8.75	52.50
Positive	14[b]	11.25	157.50
Ties	9[c]		
Total	29		

Note. a) POST-SSQ < PRE-SSQ, b) POST-SSQ > PRE-SSQ, and c) POST-SSQ = PRE-SSQ

Quiz Scores

The class that viewed the MOF presentation earned a mean quiz score of 6.48 points, compared to the class that viewed the HOF presentation that earned a mean score of 6.97 points (Table 6). The maximum value of the quiz was 11 points. To compare scores between MOF and HOF an independent samples *t*-test was conducted. The difference in scores between the two conditions was not significant, $t(65) = 1.260$, $p = .212$, $\alpha = .05$.

Table 6

Mean, Standard Deviation, and Standard Error Mean – MOF and HOF Groups.

Groups	N	Mean	Std. Deviation	Std. Error Mean
MOF	29	6.48	1.617	.300
HOF	38	6.97	1.551	.252

Discussion

In Experiment 1, students who viewed a presentation with HOF characteristics experienced a significant increase in simulator sickness symptoms, while students who viewed a presentation with LOF did not. Experiment 2 was designed to determine if a presentation with MOF characteristics, as well as more spatially organized translational movement could lead to lower simulator sickness scores. In addition, differences in academic performance were assessed between the group that viewed a MOF presentation and the group that viewed the HOF presentation

In this experiment, Section 001 viewed a presentation with MOF properties, while Section 005 observed a presentation designed with HOF properties. Both groups completed SSQs prior to watching each presentation and immediately at the end of the lecture. After completing the POST-SSQ, students answered 11 multiple-choice questions that pertained to the lecture. The two predictions made were: (a) participants who viewed a HOF presentation will experience a significant increase in simulator sickness symptoms, while participants who viewed a MOF presentation will not experience a significant increase in simulator sickness symptoms (H3) and (b) quiz scores would be higher for participants who viewed a presentation with MOF compared to students who view a HOF instructional presentation (H4).

The results did not support either hypothesis. With respect to the first prediction (H3), significant differences in SSQ values were found for both groups. Students who viewed a HOF presentation and students who viewed a MOF presentation experienced significant increases in SSQ values. Similar to Experiment 1, the mean HOF and MOF scores were relatively low and no one vomited. However, the p-value associated with the group that viewed the HOF presentation was extremely low (.000) and the effect size was large (.612). In contrast, the p-value for the group that viewed the MOF presentation was .049 and the effect size was medium (.365). For the second prediction (H4), no significant differences in quiz scores were found between the participants who viewed the MOF presentation and those who viewed the HOF presentation. Interestingly, the average quiz score for the group that viewed the HOF presentation was higher than the group that viewed the MOF presentation.

CHAPTER 4

General Discussion

In two experiments, students attending their regular class meeting viewed lecture presentations of varying levels of optic flow. In Experiment 1, one section of students enrolled in the course Introduction to Motor Learning and Control (KIN 3135) attended a class lecture where a LOF PPT presentation was used to convey lecture content; the other section attended a class where a HOF presentation designed using Prezi was implemented. In Experiment 2, the section that viewed the HOF presentation in Experiment 1 attended a lecture where a MOF Prezi presentation was implemented, and the section that viewed the LOF PPT observed a HOF Prezi presentation. In both experiments, students completed a PRE-SSQ immediately before the presentation, a POST-SSQ immediately after the presentation, and a multiple-choice quiz after completing the POST-SSQ.

Classroom Presentations and Motion Sickness

Anecdotal reports have suggested that Prezi, an application that allows instructors to create animated presentations, can cause symptoms related to motion sickness (Allain, 2010; Conboy et al., 2011; Leberecht, 2009; Salter, 2012, June 28). The results of this study verified the anecdotal reports that presentations with optic motion could cause symptoms related to motion sickness. Across experiments, symptoms of motion sickness increased after viewing lecture presentations with moderate and high optic motion. In Experiment 1, students who viewed a presentation with HOF characteristics had significantly higher POST-SSQ scores compared to their PRE-SSQ scores than students who viewed a LOF presentation. In Experiment 2, students exposed to MOF and HOF presentations exhibited significant increases in POST-SSQ scores compared to their PRE-SSQ scores.

The HOF presentations used in Experiments 1 and 2 were designed to maximize the optic flow characteristics allowable by the application. In Experiment 1, the HOF presentation incorporated rotation, contraction, expansion, and translation (forward, backward, vertical, horizontal, and diagonal). Results from this experiment suggest that these optic motions can cause an increase in simulator sickness symptoms. However, the effects of a specific type of optic flow characteristic on simulator sickness could not be identified, as those variables were not systematically manipulated. This project intended to explore the various optic flow characteristics of a readily available presentation application. The goal was not to examine each feature individually.

The design of the HOF presentation in Experiment 2 was similar to the HOF design in Experiment 1 except that rotational visual motion was eliminated. This decision was based on Keshavarez and Hecht's (2011) finding that movement in the roll axis could elicit motion sickness or cause an increase in motion sickness symptoms. In addition, vertical translation was used more frequently. In comparison, the MOF presentation incorporated the same optic motion features, but included less contraction, expansion, forward, and backward translation and included more horizontal translation (compared to vertical translation).

Without visual motion in the roll axis, both groups of individuals experienced a significant increase in simulator sickness symptoms. However, the HOF group had a much larger effect size compared to the MOF group. Remarkably, the effect sizes for the

HOF presentations in both Experiments 1 and 2 were similar. While optic motion about the roll axis might cause motion sickness or an increase in motion sickness symptoms, this finding suggests that the optic motions of vertical, forward, and backward translation, contraction, and expansion (or a combination of these forms) has an equal effect on symptoms related to visually induced motion sickness.

Presentation Optic Flow and Learning

With respect to student learning, no differences in quiz performance were found between groups in the two experiments. However, an interesting finding is that students enrolled in Section 005 had higher average quiz scores in both experiments compared to students enrolled in Section 001. A possible rationale for this finding is discussed in the section Limitations.

Limitations

While this experiment verified that presentations with high amounts of optic flow could cause an increase in motion sickness symptoms, the findings should be treated with caution. Three limitations potentially could have influenced the results. The first limitation relates to the sample populations in both experiments. The individuals who volunteered to participate in the experiment were students from two sections of the course Motor Learning and Control. Therefore, the population does not represent a true random sample. In addition, the individual who taught the classes in Experiments 1 and 2 was the assigned instructor to one of the two sections of Motor Learning and Control. Consequently, students in Section 001 were taught by their official instructor, while students from Section 005 were taught by a guest lecturer. This element of novelty is a confounding variable that could have influenced student attention and may explain why students from Section 005 achieved higher scores on the quiz assessment in both experiments. Finally, this study lacked a true control group. To investigate the relationship between optic flow characteristics of classroom technology on motion sickness and learning, a no optic flow control group where the instructor uses a blackboard or a white board instead of a presentation technology should have been implemented. While PPT is now considered a traditional presentation tool, it still represents an instructional technology tool.

Design Implications

Findings from this study suggest that moderate to high amounts of optic flow in animated presentations can significantly increase motion sickness symptoms. Thus, when designing instructional presentations using an application that enables one to incorporate optic motion, moderate to excessive amounts should be avoided. If an instructor or designer chooses to include animation it should be purposeful, infrequent, and used with care to avoid unintentional motion sickness. For presentation applications such as Prezi, the use of visual motions such as rotation and expansions should be avoided since they are know optic flow characteristics that can cause motion sickness. In addition, maintaining similar frame dimensions and positioning sequential frames in close proximity can reduce translational motion. Also, given the findings of this research, incorporating horizontal translation rather than vertical translation may reduce symptoms of motion sickness.

Suggestions for Future Research

As previously stated these experiments were exploratory in scope; specific types of optic motion were not systematically manipulated. Future studies should investigate which optic motions or combinations of optic motions might induce motion sickness or cause an increase in motion sickness symptoms. Based on the findings from Experiment 2, a more systematic study comparing a presentation consisting primarily of vertical optic motion with moderate expansion to a presentation consisting primarily of horizontal optic flow with moderate zooming is warranted. Results from this proposed study could provide evidence for a presentation design that does not cause an increase in simulator sickness symptoms.

As identified in the section Limitations, the present experiment utilized a convenience sample. As a result, the findings of this research should not be generalized to a larger population. In order to make conclusions that apply to a broader population, subsequent studies should incorporate random sampling procedures. A second design issue identified was the possible confound related to the investigator who was the official instructor for one of the course sections. This limitation could be addressed by conducting research outside of an official class setting. In addition, with this modification, participants could be randomly assigned to seats throughout the classroom. Since, the current research was conducted in a regular class setting students were allowed to freely choose where they sat. As a result, students were not equally distributed across rows. By having an equal distribution of participants across rows, researchers would be able to examine the effect of field of view (FOV) on visually induced motion sickness.

According to Pausch, Crea, and Conway (1992), FOV is “a spatial property that defines the horizontal and vertical angular dimensions of the display” (p. 347) and can cause motion sickness. Research has shown that wider FOV displays enhance performance, but increases the likelihood of simulator sickness (Pausch et al., 1992). For instance, Kennedy, Lilienthal, Berbaum, Baltzley, and McCauley (1989) reported that flight simulators that provided the greatest FOV were associated with high incidence of motion sickness-like symptoms. Lin, Duh, Parker, Abi-Rached, and Furness (2002) reported that individuals performing in a driving simulator experienced more symptoms of motion sickness as FOV increased, corroborating the relationship between FOV and motion sickness.

Conclusion

This study verified the anecdotal accounts that presentations with optic motion can cause symptoms of motion sickness. Specifically, instructional presentations that incorporate moderate to high amounts of optic flow can cause students to experience significantly elevated levels of simulator sickness. Findings from this study highlight the importance of using sound instructional design strategies when designing and developing instruction. While optic motion in a presentation can make a lecture or training program more interesting to students, it can also make them sick. Based on current findings, individuals who design instructional presentations should not develop and implement instructional presentations with moderate to high amounts of optic flow. However, more systematic research should be conducted to understand if some optic motions or combinations of optic motions might be more or less nauseogenic than others. In addition, environmental factors such as field of view should also be assessed in educational settings. Based on findings from proposed future research, an optimal amount of optic flow for animated presentations may be determined.

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Appendix A

Institutional Review Board Approval

UNIVERSITY OF MINNESOTA

Twin Cities Campus

Human Research Protection Program
Office of the Vice President for Research

D528 Mayo Memorial Building
420 Delaware Street S.E.
MMC 820
Minneapolis, MN 55455

Office: 612-626-5654
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12/18/2012

Anthony M Mayo
University of Minnesota
Dept. of Kinesiology
1900 University Avenue SE
Minneapolis, MN 55455

RE: "The relationship between individual, environmental, and task constraints involved in Prezi use and motion sickness."
IRB Code Number: **1211P24423**

Dear Mr. Mayo

The referenced study was reviewed by expedited review procedures and approved on December 14, 2012. If you have applied for a grant, this date is required for certification purposes as well as the Assurance of Compliance number which is FWA00000312 (Fairview Health Systems Research FWA00000325, Gillette Children's Specialty Healthcare FWA 00004003). Approval for the study will expire one year from that date. A report form will be sent out two months before the expiration date.

Institutional Review Board (IRB) approval of this study includes the consent form dated November 22, 2012.

The IRB would like to stress that subjects who go through the consent process are considered enrolled participants and are counted toward the total number of subjects, even if they have no further participation in the study. Please keep this in mind when calculating the number of subjects you request. This study is currently approved for 150 subjects. If you desire an increase in the number of approved subjects, you will need to make a formal request to the IRB.

The code number above is assigned to your research. That number and the title of your study must be used in all communication with the IRB office.

As the Principal Investigator of this project, you are required by federal regulations to inform the IRB of any proposed changes in your research that will affect human subjects. Changes should not be initiated until written IRB approval is received. Unanticipated problems and adverse events should be reported to the IRB as they occur. Research projects are subject to continuing review and renewal. If you have any questions, call the IRB office at 612-626-5654.

On behalf of the IRB, I wish you success with your research.

Sincerely,

Christina Dobrovolny, CIP
Research Compliance Supervisor
CD/ks

CC: Thomas Stoffregen

Appendix B

Simulator Sickness Questionnaire

Simulator Sickness Questionnaire

ROW: ________ SEAT: ________

The Simulator Sickness Questionnaire

Subject: ____________________________

Circle how much each symptom below is affecting you now.
0 = "not at all" 1 = "mild" 2 = "moderate" 3 = "severe"

1. General discomfort	0	1	2	3
2. Fatigue	0	1	2	3
3. Headache	0	1	2	3
4. Eyestrain	0	1	2	3
5. Difficulty focusing	0	1	2	3
6. Increased salivation	0	1	2	3
7. Sweating	0	1	2	3
8. Nausea	0	1	2	3
9. Difficulty concentrating	0	1	2	3
10. Fullness of head	0	1	2	3
11. Blurred vision	0	1	2	3
12. Dizziness (eyes open)	0	1	2	3
13. Dizziness (eyes closed)	0	1	2	3
14. Vertigo*	0	1	2	3
15. Stomach awareness**	0	1	2	3
16. Burping	0	1	2	3

*Vertigo is experienced as loss of orientation with respect to vertical upright
**Stomach awareness is usually used to indicate a feeling of discomfort that is just short of nausea.

Appendix C

Consent Form

CONSENT FORM

Instructional Technology Tools and Motion Sickness

You are invited to be in a research study examining the influence of classroom instructional presentations on motion sickness. You were selected as a possible participant because you are a healthy adult between the ages of 18 and 65, you are not pregnant, and you have no history of dizziness, balance disorder, or vestibular dysfunction. We ask that you read this form and ask any questions you may have before agreeing to be in the study. This study is being conducted by Anthony M. Mayo, graduate student, School of Kinesiology, University of Minnesota.

Background Information: The purpose of this study is to understand whether classroom instructional presentations can cause motion sickness. Motion sickness can occur with many types of visual technologies, such as video games. This study focuses on the possibility that an animated instructional presentation may cause motion sickness. Not everyone who views an animated instructional presentation becomes motion sick, and we do not expect everyone in this study to become sick.

Procedures: If you agree to be in this study, we will ask you to watch an instructor-led class presentation. After the presentation, we will ask you to provide some demographic information and to complete a symptom report questionnaire. This questionnaire should be returned either at the end of the class or beginning of the next class. If you experience symptoms of motion sickness, you should close your eyes or look away. The total duration of the experiment will not exceed the length of the class period.

Risks and Benefits of Being in the Study: You may experience symptioms of motion sickness. If you experience symptoms of motion sickness, you should close your eyes or look away. There are no direct benefits to participation.

Compensation: You may receive course credit (extra credit), as determined by your instructor.

Confidentiality: The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only researchers will have access to the records.

Voluntary Nature of the Study: Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to withdraw at any time without affecting those relationships.

Contacts and Questions: The researchers conducting this study are Anthony M. Mayo and Thomas A. Stoffregen. You may ask any questions you have now. If you have questions later, you may contact them at the Affordance Perception Action Lab, Cooke Hall 5B. Phone: (612) 624-1025.

If you have any questions or concerns regarding the study and would like to talk to someone other than the researcher(s), contact Patient Relations Department, Mayo Mail Code-310, B310 Mayo Memorial Building, 420 Delaware Street S.E., Minneapolis, Minnesota 55455; telephone (612) 273-5050.

You will be given a copy of this form to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Signature:____ Date:________________

Signature of Investigator: ___________________________________ Date ________________

IRB Code No: I211P24423 Page 1 of 1 Ver. 11.22.12

Appendix D

Demographics Information Form

Demographics Information ParNum:________________

Date:____________________ Seat Location:____________

Age:____________________ Sex:____________________

Video Game Experience

Number of Years:__________

Frequency (Hours per week):_____________

Frequency (Hours per month):____________

Video Game Proficiency (On the scale of 1 to 10, with 1 being a novice and 10 being an expert, circle the number that best describes your gaming ability)

Novice									Expert
1	2	3	4	5	6	7	8	9	10

Physical Activity

Do you currently meet ACSMs current recommendations for weekly exercise? Please answer by circling the appropriate response.

For cardiorespiratory exercise - 30-60 minutes of moderate-intensity exercise (five days per week) or 20-60 minutes of vigorous-intensity exercise (three days per week).	YES	NO
For resistance exercise - train each major muscle group two or three days each week using a variety of exercises and equipment.	YES	NO
For flexibility exercise - at least two or three days each week to improve ROM.	YES	NO
For neuromotor exercise – at least two or three days a week of functional fitness training* 20 to 30 minutes per day. Functional fitness training involves motor skills (balance, agility, coordination and gait), proprioceptive exercise training and multifaceted activities (tai chi and yoga) to improve physical function.	YES	NO

Sports or Physical Activity Experience

Please list the sports and physical activities in which you have regularly participated:

1)___________________________________ 4)___________________________________

2)___________________________________ 5)___________________________________

3)___________________________________

Demographics Information ParNum:________________

For each sport or physical activity that you listed, on a scale of 1 to 10, with 1 being a novice and 10 being an expert, circle the number that best describes your level of proficiency:

Sport or Physical Activity: ___________________

How many hours/week if currently participating in activity?: ________________

Novice									Expert
1	2	3	4	5	6	7	8	9	10

Sport or Physical Activity:___________________________________

How many hours/week if currently participating in activity?: ________________

Novice									Expert
1	2	3	4	5	6	7	8	9	10

Sport or Physical Activity: __________________________________

How many hours/week if currently participating in activity?: ________________

Novice									Expert
1	2	3	4	5	6	7	8	9	10

Sport or Physical Activity: __________________________________

How many hours/week if currently participating in activity?: ________________

Novice									Expert
1	2	3	4	5	6	7	8	9	10

Sport or Physical Activity: __________________________________

How many hours/week if currently participating in activity?: ________________

Novice									Expert
1	2	3	4	5	6	7	8	9	10

Appendix E

Summary of Demographics Data

The tables below provide a summary of responses related to video game experience and current physical activity levels with respect to ACSM recommendations. Since many students participated in both experiments, the tables are organized by class section instead of by experiment. If a student participated in Experiments 1 and 2, only the data reported in Experiment 1 was included in the table to avoid duplication. Sports or Physical Activity Experience was not summarized. There was no consistent pattern in self-reports of physical activities.

Video Game (VG) Experience Self Assessment – Sections 001 and 002

Section	N	% Students with VG Experience	% Students Currently Playing VGs	Hours/Month (Range)	Proficiency (Range)
001	37	62.2 (N = 23)	56.8 (N = 21)	.5 to 80	1 (Novice) to 9 (Near Expert)
005	45	62.2 (N = 28)	37.8 (N = 17)	.5 to 80	1 (Novice) to 10 (Advanced)

Physical Activity Self Assessment – % Meeting ACSM Current Recommendations – Sections 001 and 002

Section	N	Cardio-respiratory Exercise	Resistance Training	Flexibility Exercise	Neuromotor Exercise
001	37	78.4 (N = 29)	56.8 (N = 21)	59.5 (N = 21)	59.5 (N = 22)
005	45	82.2 (N = 37)	55.6 (N = 25)	55.6 (N = 25)	48.9 (N = 22)