GENDER DIFFERENCES IN SUSCEPTIBILITY TO VECTION-INDUCED MOTION SICKNESS AND GASTRIC MYOELECTRIC ACTIVITY

by

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Abstract

The researcher expected to find that women show higher incidence of and greater severity in symptoms of motion sickness (SMS). In Phase 1, 485 subjects reported on their previous incidence of motion sickness between ages 12-25 on various forms of motion. Analysis of variance (ANOVA) indicated women reported significantly greater incidence of motion sickness than men did. In Phase 2, each of 47 subjects viewed an optokinetic rotating drum for 8-minute baseline (BL) and 16-minute drum rotation (DR) periods. During DR, subjects' subjective SMS were measured. ANOVA on SMS scores showed no significant gender difference in severity of SMS. Subjects' electrogastrograms (EGGs) and the ratios of spectral intensity at 4-9 cycles/min (cpm) between DR and BL periods, gastric tachyarrhythmia, were also obtained. ANOVA appropriate for equal or unequal variance depended on the results of Levene's test for homogeneity of variance. Results indicated women reported more incidence of motion sickness history. Men and women did not differ in subjective symptoms of motion sickness when exposed to motion stimuli. Men developed more severe gastric tachyarrythmia during motion than women did. Subjective reports of previous motion sickness incidence may not accurately indicate gastric tachyarrhythmia during motion.

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Introduction

Motion sickness has been commonly defined as the syndrome provoked by transportation systems. The symptoms of motion sickness may include pallor, dizziness, headache, salivation, sweating, stomach awareness, stomach discomfort, nausea, and vomiting (Graybiel & Lackner, 1983).

Species experiencing this phenomenon have included humans, horses, monkeys, sheep, some birds, and codfish (Treisman, 1977). The incidence and severity of motion sickness has not been constant across all human beings for different forms of motion (Reason & Brand, 1975). Susceptible individuals have experienced motion sickness during various forms of motion such as automobiles, trains, aircraft, sea vehicles, and fair rides (Reason and Brand). Unusual and disorienting environments may produce the responses of motion sickness including carsickness, airsickness, seasickness, and spacesickness (Yardley, 1992).

Because the vestibular system may be found in all existent vertebrates and vertebrate fossil remains, its central pathways have been considered important in the sensory control of behavior (Goldberg and Fernandez, 1989). It has been generally believed that vestibular, visual, and somatosensory inputs coordinate to promote the sensation of self-motion. Specifically, they help to stabilize the eyes in relation to surroundings and to coordinate the eyes, head, and body during movements such as walking, running, and turning (Goldberg & Fernandez).

In the early half of this century, researchers described overstimulation of the vestibular system as being responsible for one's perception of motion speed, position, illusion, and gravity (Yardley, 1992). However, this explanation failed to explain the inducement of motion sickness in various situations without active stimuli or physical movement (e.g. cineramas) (Yardley).

The results of studies provided strong evidence that a vestibular mechanism promotes vomiting as a result of physiological disturbance produced by toxins. After removal of the vestibular apparatus in both ears, 56 of 108 dogs failed to vomit after exposure to 4 poisons which produce vomiting (Crampton, 1990). Reason and Brand (1975) reported that destroyed nerves or receptors within the vestibular system removed motion sickness. In contrast, stimulating the vestibular system induced motion sickness. Unfamiliar linear accelerations which present vertically in boats and ships created sea sickness.

In the mid-1970's Reason and Brand (1975) stated that motion sickness seemed to result from conflicting sensory inputs. According to this explanation, the interaction of the vestibular system and the central nervous system may produce motion sickness symptoms because the input from one system can provide misleading predictions for another system. Specifically, vestibular inputs may indicate no self-motion while visual inputs may indicate self-motion. The resulting sensory conflict would become assessed for conformity with the established patterns of previous experience. Nonconformity of inputs with the established pattern may generate a series of motion sickness symptoms.

Treisman (1977) provided an evolutionary theory for the cause of motion sickness. The researcher postulated that vomiting may function as a defense against having poisons in the stomach. Specifically, absorbed toxins produce physiological disturbances which provoke vomiting. As a mechanism of evolutionary survival value, motions may promote physiological disturbances which cause motion sickness. According to general belief, an individual's organization of movements within a space include the coordination of visual, vestibular, and proprioceptive systems. Stimulation involved in peculiar motions may exceed the vestibular system's dynamic capacity and promote it to send distorted information. The brain would recognize that these inputs conflict with those from vision indicating motion or from proprioception. Nausea and vomiting may result. When one type of perceptual input, that of the vestibular system, repeatedly misleads predictions for the other, motion sickness may result.

The labyrinthine sense organs of the vestibular system include the cristae of the semicircular canals and the utricular maculae. According to Tyler and Bard (1949), the sense organs of the canals may respond to angular accelerations and the utricular maculae are the receptors stimulated by linear accelerations. Stimulation of the cristae would result in nystagmus. The vestibular nerve, located in the primary sensory neurons of hair cells, includes afferent axons which synapse with neurons in the cerebellum (Crampton, 1990). Then, axons of the vestibular nuclei synapse with neurons in the cerebral cortex, would produce the nausea and vomiting of motion sickness. Yardley (1992) classified motion sickness symptoms according to origin. Disturbance of perceptual and sensorimotor activities involving the vestibular system resulted in dizziness. Autonomic symptoms, also of perceptual origin, included pallor, salivation, sweating, nausea, and vomiting.

Previous researchers have measured motion sickness symptoms from both subjective report and physiological measures. Cowings, Naifeh, and Toscano (1990) found that converging indicators produced a better assessment of motion sickness experienced by subjects than a single assessment.

Past researchers have used a motion sickness questionnaire (MSQ) to anticipate subject susceptibility to motion sickness during air travel. Tyler and Bard (1949) reported a high correlation between susceptibility revealed by a questionnaire and susceptibility to motion sickness on aircraft, swings, or other experimental devices during training of military candidates. Lentz and Collins (1977) investigated the relationship between motion sickness susceptibility scores and behavioral characteristics such as age changes, motion experience, familial susceptibility, use of motion medication, muscular coordination, willingness to participate in motion experiments, flying experience, phobias, visual motion effects, and use of alcohol. The researchers reported that the use of a questionnaire yields valid results and recommend its use. Reason and Brand (1975) concluded that use of questionnaires provides accurate information on the frequency and severity of motion sickness symptoms across a broad range of motion sickness-inducing conditions.

Other studies have determined that use of a motion sickness questionnaire predicts motion sickness within simulator environments containing visual stimuli to induce sickness. Immobile subjects view moving stimuli and react to the conflicting cues with symptoms. A strong relation between history of motion sickness and induced motion sickness was found in the use of a simulator flight training apparatus with head and body movements (Powell, Beach, Smiley, & Russell, 1962). The score on a biographical questionnaire was also found to be positively and significantly related to the rate at which sensation persistence increased as a function of stimulus duration after viewing the rotation of a spiral disc (Reason, 1968).

In addition, there were high correlations between past history of motion sickness scores and motion sickness scores while viewing a rotating optokinetic drum (Hu, Glaser, Hoffman, Stanton, & Gruber, 1995; Reason & Brand, 1975). Fifty percent of subjects showed a shift in their normal gastric myoelectric activity to 4-9 cpm, tachygastria during exposure to a rotating optokinetic drum (Stern, Hu, Leblanc, & Koch, 1992). Different optokinetic drum rotation speeds have been shown to impact motion sickness symptoms. Hu, Stern, Vasey, & Koch, (1989) studied the results of subjects sitting in a cylindrical drum with alternating black and white vertical stripes on the inner surface which rotated at various degrees per second (deg/s). Drum speed of 60 deg/s showed the highest level of vection. The spatial frequency of vertically striped rotating drums was also shown to relate to the severity of vection-induced motion sickness (Hu, et al, 1997). Six, 12, 24, 48, and 96 pairs of black and white stripes were used. Results indicated that subjects viewing 24 pairs reported stronger circular vection, significantly more severe SMS, and greater ratios of EGG 4-9 cpm spectral intensity between DR and BL during exposure to a rotating optokinetic drum.

Stationary subjects viewing a rotating visual field experienced greater illusory self-motion and increase in motion sickness symptoms than subjects who physically rotated with a stationary visual field (Yardley, 1992). The removal of visual stimuli during physical movement for monkeys produced a decrease in susceptibility to motion sickness (Allen, Meyer, & Lanham, 1995).

Researchers have found circular vection, the perception of self-motion without actual physical movement, to occur in individuals while viewing stimuli in circular motion (Allen, Meyer, & Lanham, 1995; Brand, Dichgans, & Koenig, 1973). Individuals experiencing circular vection reported motion sickness symptoms. Electrogastrogram (EGG) responses also showed an increase in activity. Researchers have reported that approximately 60% of healthy human subjects experience motion sickness symptoms which are provoked by circular vection (Stern, Koch, Leibowitz, Shupert, & Stewart, 1985; Stern, Koch, Stewart, & Lindblad, 1987).

Researchers have also demonstrated that gastric myoelectric activity shifts from EGG activity of 3 cycles per minute (cpm) to between 4 and 9 cpm, when provoked by optokinetic rotation (Hu, Grant, Stern, & Koch 1991; Hu, Stern, & Koch 1991; Stern, Koch, Leibowitz, Shupert, & Stewart, 1985; Stern, Koch, Stewart, & Lindblad, 1987). These previous studies have shown that the shift occurred during the progression and increase of vection-induced motion sickness.

Investigation concerning the reliability of the EGG signal in the tachygastria bandwidth, 3.8 to 10.0 cpm, used EGG data 5 and 15 hours after a meal and immediately after a meal on two 30-minute occasions, at least 7 days apart, for 30 minutes of EGG recording. A variance of 3.5% was found across occasions, between Day 1 and Day 2 (Jokerst et al., 1996). High reliability was also found for different conditions (hours after eating) with 0.07% variance.

Spectral analysis techniques have been used for EGG results. Stern, Koch, Stewart, and Lindblad (1987) applied a method of quantifying gastric dysrhythmia, running spectral analysis, to the EGG signal. The digitization process decomposed the EGG into a sum of sinusoidal components. Then a statistical program plotted the spectral analysis.

Researchers have found variables involved in motion sickness to include individual differences in susceptibility. Some individuals exposed to motion experience no symptoms and others may experience symptoms during one form of motion but not another (Tyler & Bard, 1949). Reason (1968) conducted a study to determine predisposing sensory traits involved in individual differences in susceptibility to motion sickness. According to Reason, individuals reported different time durations in feeling the after-effects of fixing their eyes on a spiral. Individuals transducing the stimulus at lower spiral intensity levels reported that they felt after-effects for a longer time period than individuals transducing the stimulus at higher intensity levels.

Adaptation to motion sickness has been defined as the rate of individual adjustment to conditions producing sensory arrangement (Reason, & Brand, 1975). Repeated exposures to a situation provoking sensory mismatch began a decrease in and eventual absence of motion sickness symptoms (Graybiel and Knepton, 1978). The time necessary for incoming stimuli to the vestibular system and the visual system to be perceived as compatible and conform with established input patterns decreased with repeated exposures (Reason & Brand). For example, a progressive decrease in motion sickness accompanied repeated exposure to forms of motions such as airplanes and swings (Graybiel and Knepton, 1978).

Yardley & Bard (1949) reported that adaptation to motion stimuli occurred in 95% of susceptible individuals. Adaptation did not occur in chronically sick individuals. In addition, normal individuals varied in rates of adaptation to motion environments (Reason & Brand, 1975). Slow adapters reported a more severe history of motion sickness.

The results of using questionnaires in research have suggested that age is a factor in susceptibility to motion sickness. Reason (1968) used a questionnaire survey of motion sickness incidence and found incidence declined with age. While women reported greater incidence before the age of 12, both men and women reported lower incidence after the age of 12 on cars, buses or coaches, and ships. Small boats and trains were reported to be less effective in promoting motion sickness.

According to a questionnaire and interviews concerning carsickness with one or both parents, monozygotic and dizygotic twin girls showed higher incidence than twin boys (Bawkin, 1971). Bawkin did not specify subject ages, acting as a limitation to the study. According to interviews and mailed questionnaires with one or both parents, girls suffered motion sickness more frequently than boys at the age of 3 years (Abe, Amatomi, & Kajiyama, 1970). Girls were also found to suffer motion sickness more frequently in childhood and later in life than males.

More recent research (Lentz and Collins, 1977) indicated that more college women than men report motion sickness on motion sickness history questionnaires on 20 different forms of motion. However, these results may have been due to social gender differences in symptom reporting rather than gender differences in motion sickness susceptibility. Although previous research results have shown gender differences in parental interview reports, car sickness history questionnaire replies, and motion sickness questionnaire responses, the studies did not determine gender differences in a vection-induced nauseogenic environment.

Mirabile and Ford (1982) reported that women are more susceptible to motion sickness than men in a real nauseogenic environment with head movements. This previous research stimulated the vestibular system, but failed to induce motion sickness by means of circular vection and consequent sensory mismatch. Hamid (1990) found no gender difference in motion sickness for individuals exposed to visual movement while sitting in a chair. However, the researcher stated that there was difficulty with gathering data on motion sickness history for this study and did not compare reports of previous incidence of motion sickness, subjective SMS, and physiological recordings. In addition, subjects within this study had the mean age of 45 years. Previous research has not examined gender differences in susceptibility to motion sickness according to physiological data within a lower age range.

Stern, Hu, LeBlanc, and Koch (1993) used the converging indicators of subjective malaise report and objective physiological differences between men and women in an aviation environment between 1966 and 1991. Results indicated that women may be more susceptible to motion sickness than men. Results also indicated that Chinese women are more susceptible than European-American and African-American subjects in a vection-induced nauseogenic environment. However, Stern did not specify if the non-Chinese subjects were men or women. In addition, the lack of systematic data for male Asian subjects resulted in inconclusive gender across the Chinese culture.

The importance of gender as a variable in determining motion sickness susceptibility promotes questions of etiology. Treisman (1977) proposed that a rotating optokinetic drum creates sensory mismatch in a manner similar to that of ingested toxins creating disturbance in sensory input or motor control. Motion sickness may be an adaptive reaction to inappropriate stimuli such as those found in the environments of unfamiliar forms of motion. Women may require less exposure to a toxin or inappropriate environment than men to experience nausea and vomiting.

Previous studies have not clearly demonstrated gender differences in susceptibility to vection-induced motion sickness. The purpose of the present study was to investigate gender differences in susceptibility to vection-induced motion sickness within a nauseogenic environment.

We investigated gender differences in motion sickness susceptibility measured by motion sickness history questionnaires (MSQs) and symptoms of vection-induced motion sickness. The current research investigated gender differences through the following methods:

(1) The researcher attempted to replicate previous findings that women report higher incidence of motion sickness than men on motion sickness history questionnaires (MSQs). In the present study, the same individuals

responded to a MSQ on 8 forms of motion: cars, buses, trains, airplanes, boats, ships, swings, and amusement rides. One MSQ section focused on motion sickness experience before the age of 12 years. The accompanying MSQ section focused on motion experience between the ages of 12 and 25 years. MSQ scores were compared between genders.

(2) Twenty-four men and 23 women were selected from the questionnaire respondents to investigate gender differences in severity of vection-induced SMS and gastric tachyrhythmia within a rotating optokinetic drum. The converging indicators of subjective motion sickness symptom reports and objective physiological recording were used as motion sickness severity indexes and compared between genders.

Method

Participants

Initially, 485 Humboldt State University student volunteers, 198 men and 287 women, completed a motion sickness questionnaire (MSQ). Subject ages ranged from 18 to 25 years. Gender differences in responses were assessed.

From this initial subject set, 24 males and 23 females were selected for further testing. To eliminate the influence of adaptation to motion sickness, subjects were screened prior to Phase 2 to ensure no previous exposure to a rotating optokinetic drum.

Previous researchers have demonstrated age differences on motion sickness susceptibility (Tyler and Bard, 1949; Reason and Brand, 1975). Therefore, the present research used a limited age range between 18 and 25 years. In addition, age was closely matched across genders prior to subject participation in Phase 2.

Because previous research has shown Chinese ethnicity to relate to motion sickness susceptibility (Stern, Hu, LeBlanc, & Koch, 1993) and because of the particular ethnic distribution of university students on this campus, Chinese subjects were not included in this study. Subjects were mostly Caucasian in ethnicity. The number of men from each ethnicity was closely matched with a nearly equal number of women for participation Phase 2.

Researchers have found that history of motion sickness correlates with the severity of motion sickness induced by a rotating optokinetic drum (Reason & Brand, 1975). In Phase 2, the lower range of scores for previous motion sickness were closely matched across genders. The lowest 85.29% of MSQ scores for men, relative to other men, and the lowest 84.31% for women, relative to other women, were used across genders. Due to a great variability of scores on the high range, it was not possible to closely match high MSQ scores across genders. Therefore, subjects scoring in the high MSQ range were not selected for Phase 2.

Materials

Reason's 1968 Motion Sickness Questionnaire (MSQ) was used in Phase 1 (see Appendix A). The MSQ consisted of 2 age categories. The first section contained items regarding motion sickness experience before the age of 12. The second section contained items on motion sickness between the ages of 12 and 25 years.

Both sections included items on frequency of individual exposure to 8 different types of motion: cars, buses, trains, airplanes, boats, ships, swings, and amusement rides. Subjects were also asked to report on incidence of feeling motion sick and incidence of actually being motion sick (e.g. vomiting) on each of these forms of motion.

In Phase 2, the circular vection drum consisted of a metal cylinder which was 70 cm in height and 50 cm in diameter. Over the interior surface, 24 pairs of 1.9 cm (5.7 degree) black and 3.1 cm (9.3 degree) white vertical stripes were illuminated with a 40 W incandescent light bulb. Drum rotation occurred at a speed of 60 deg/s. Binocular observations were made by a subject sitting on a chair in the center of the drum.

Graybiel, Wood, Miller, and Cramer's (1968) criteria for diagnosing the severity of subjective motion sickness symptoms (SMS) were used according to the method described by Reason and Brand (1975). SMS were separated into 2-minute blocks. The maximum symptom scores during drum rotation were compared for 8 groups. The highest symptom scores during the rotation period were compared with those during other subjects' sessions.

The electrogastrogram (EGG) functioned as a cutaneous measure of gastric myoelectric activity. Three silver-silver chloride electrodes (UFI, Model 1081 Biode, Moro Bay, CA) were attached to the upper abdomen. One active electrode was placed 3 cm left from the umbilicus. Another active electrode was placed approximately between 1/2 and 1/4 cm above the navel and 5 cm right from the midline. One reference electrode was positioned 5 cm right of the midline between the umbilicus and xiphoid. The electrodes were connected to a Physiography amplifier (Physiography, Model Four-A) with frequency band of 0.008 Hz - 0.3 Hz. Amplifier EGG signals relayed to the Physiography chart recorder in order to document subject responses. The paper speed was 1 mm/s. Electrodes were connected to an 8 channel analog/digital conversion system with sampling rate at 4.67 Hz which sent EGG data to a computer.

Procedure

Archival data from previous motion sickness research conducted at the Psychology Department of Humboldt State University constituted most of the data for Phase 1. A set of questionnaires from a previously established pool was collected at the Humboldt State University Department of Psychology Motion Sickness laboratory. In addition, volunteers from classrooms in the Department of Psychology were recruited for participation.

Subjects were screened prior to participation in Phase 2 to exclude those with health risks. To insure that both male and female subjects did not have visual problems, nervous system disorders, gastrointestinal diseases, or possible pregnancy, the researcher reviewed a health status questionnaire with subjects when scheduling for Phase 2 (Appendix B). Any subjects who had health concerns or were uncertain about health status were excluded from participating in the study.

Research assistants aided subjects of the same gender during Phase 2. Male research assistants were scheduled for male subjects. Female research assistants were scheduled for female subjects. Research assistants had been instructed to remain as quiet as possible and were not visible to subjects sitting in the optokinetic drum. Training included instructing research assistants to not behave differently between individual subjects.

Before participation in this study, each subject completed a consent form which outlined possible physiological discomfort, subject benefits, voluntary participation, and ability to withdraw at any time from the study (Appendix C). The researcher informed each subject that there was an option to request stopping drum rotation, to close eyes, or to withdraw participation when feeling discomfort that was not endurable during the study. No subject received financial reimbursement for participation in the study. Subjects who participated in Phase 2 received extra credit slips for classes.

Within a private suite of a laboratory in the Psychology Department, each of 47 subjects viewed an optokinetic rotating drum for 8-minute baseline (BL) and 16-minute drum rotation (DR) periods. Subject EGGs were continuously recorded through the BL and the DR periods. Subjects' ratios of spectral intensity at 4-9 cpm between DR and BL periods, as measures of gastric tachyarrhythmia, were also obtained as an index of motion sickness. During DR, subjects' SMS were measured.

At the termination of each session, the subject was debriefed regarding the importance of the study and the significance of their contribution (Appendix D).

Results

In Phase 1, 485 subjects (198 men and 287 women) showed the following demographic characteristics. Analysis of variance for age and gender indicated that males and females did not significantly differ on their age. Subjects showed mean and standard deviation ages of 19.90 ± 2.80 years for men and 20.03 ± 1.92 years for women. A chi-square test indicated that the proportions of ethnicity were not significantly different for males and females. Subjects self-reported predominantly caucasian ethnicity with 72.73% for men and 66.20% for women (see Table 1).

MSQ scores were compared between genders. Analysis of variance (ANOVA) was used to compare males and females on each and all of the dependent measures of motion sickness susceptibility. In each comparison, the F test appropriate for equal or unequal variance was used depending upon the results of prior Levene's tests for homogeneity of variance.

Subjects reported on their previous experience with 8 different forms of specific motion (see Figure 1 & 2). Men reported significantly more travel experience than females before 12 years of age on buses, trains, airplanes, boats, and ships (see Table 2). Men also reported more travel experience than females between ages 12-25 on trains and boats (see Table 3). Due to the varying exposure of individuals to specific forms of motion, some subjects indicated no previous exposure to one or more forms of motion. The scores of these subjects were dropped out of statistical calculation for motion sickness incidence on that form of motion.

ANOVA on total, the sum of feeling and actual, motion sickness history scores indicated women reported higher incidence of motion sickness. Significant gender differences were found for motion sickness between ages 0-12, $F(1,482) = 26.90$, $p < .001$, and between ages 12-25, $F(1,468) = 45.02$, $p < .001$.

Specifically, subjects reported on their incidence of feeling motion sickness between ages 0-12 and ages 12-25 on the various forms of motion. Analysis of results indicated that women reported significantly higher incidence of feeling motion sickness before the age of 12 than men did, $F(1,472) = 13.10$, $p < .001$ (see Table 4). Analysis of results indicated that women reported greater incidence of feeling motion sickness between ages 0-12 than men during travel by cars, buses, swings, amusement rides (see Figure 3).

Women also reported significantly higher incidence of feeling motion sickness between ages 12-25, $F(1,479) = 57.76$, $p < .001$ (see Table 5). Women also reported greater incidence of feeling motion sickness between ages 12-25 than men during travel by cars, buses, trains, airplanes, boats, ships, swings, amusement rides (see Figure 4).

In addition, ANOVA on actual motion sickness before the age of 12 between indicated significant gender differences with women making greater reports than men, $F(1,480) = 4.97$, $p < .05$ (see Table 6). Women reported more incidence of actual motion sickness between ages 0-12 than men during travel by cars and buses (see Figure 5). Women also reported significantly more actual motion sickness between ages 12-25, $F(1,454) = 12.82$, $p < .001$ (see Table 7). Women reported more incidence of actual motion sickness between ages 12-25 than men during travel by cars, buses, ships, small boats (see Figure 6).

There were 24 men and 23 women continuing from Phase 1 to Phase 2. Subject demographic variables showed the following characteristics. Analysis of variance confirmed that men and women in Phase 2 did not differ significantly on age. Mean age and standard deviation for subjects was 20.63 ± 2.16 for men and 20.57 ± 1.97 for women. Ethnicity was predominantly Caucasian (79.2% men and 78.3% women) according to self-reports (see Table 8). A chi-square test for subject ethnicity and gender in Phase 2 confirmed that the men and women did not significantly differ in their proportion of ethnicity groups. Analysis of variance verified that there were no significant differences in MSQ scores across genders for the Phase 2 subjects. Mean and standard deviation for MSQ scores of both genders was 19.17 ± 18.02 for men and 25.39 ± 19.82 for women.

Symptoms experienced by subjects during DR included warmth, sweating, increasing/decreasing salivation, dizziness, headaches, drowsiness, awareness of stomach, discomfort in stomach, and nausea. Seven subjects (4 men and 3 women) experienced severe physiological discomfort during the study. The participation of these subjects was terminated. The subjective SMS and EGG recordings of these participants were used as data with scores at termination continued through time groups.

Analysis of variance on subjective SMS scores showed men and women reported no significant difference in severity of motion sickness symptoms while viewing drum rotation, $F(1,47) = .09$, $p > .05$ (see Figure 7). Mean and standard deviation of SMS scores were 4.60 ± 3.13 for men and 4.72 ± 4.09 for women (see Table 9).

Running spectral analysis was used to analyze the EGGs. A Fourier analysis were conducted to gain spectral estimates. The first 4 minutes of EGG data constituted the first epoch. For a 240 second section of the EGG signal, each epoch represented the spectral intensity (i.e., spectral density in uv/hz) function. Each following spectral intensity function's data window included the final 75% or 180 seconds of the preceding window and the next 60 seconds of digitized signal. The yield was a running spectral plot with each consecutive line containing 60 seconds of new information. Frequency bins were .0042 Hz wide. For selected frequency bands, spectral intensities were obtained: .5 to 2.25 cpm, 2.5 to 3.75 cpm, and 4.0 to 9.0 cpm. The sum of baseline period spectral intensities were divided by 8. The rotation period was divided by 16. EGG .5 to 2.25 cpm, 2.5 to 3.75 cpm, and 4-9 cpm spectral intensity measures per minute were obtained. The ratio of spectral intensity between the baseline and the drum rotation periods were calculated.

Unusual increases or decreases in right and left electrode data indicated body shift by subjects. The electrode reading with less disruption for each subject, either right or left, was used as data for statistical analysis.

Analysis of variance on ratios of spectral intensity at EGG 4-9 cpm activity between DR and BL periods revealed men developed significantly more severe abnormal gastric tachyarrhythmia than women did, $F(1,45) = 4.41$, $p < .05$ (see Table 10). Means and standard deviations for ratios of spectral intensity at EGG 4-9 cpm were 20.96 ± 17.67 for men and 10.85 ± 15.21 for women (see Figure 8).

These results indicated three conclusions. Women reported more incidence of motion sickness history than men did. Men and women did not differ in subjective symptoms of motion sickness when exposed to motion stimuli. Men

developed more severe gastric tachyarrythmia during motion developed more severe gastric tachyarrythmia during motion than women did during exposure to a nauseogenic environment.

Table 1. Percentages of Male and Female MSQ Subjects Classified by Ethnicity (N=485)

Ethnicity	Men	Women
Not Answered	13.6%	16.0%
Native American	3.0%	2.4%
Asian/Pacific Islander	1.0%	3.5%
Afro-American	1.5%	.7%
Hispanic	5.1%	7.7%
Caucasian	72.7%	66.2%
More than One Ethnicity	3.1%	3.5%
Total	100.0%	100.0%

Table 2. Gender Differences in Experience with Various Forms of Motion before 12 Years of Age, with Men Showing Greater Experience

Form of Motion	F	df	P
Buses	4.71	415	.013*
Trains	10.43	317	.001***
Airplanes	12.18	435	.001***
Boats	10.43	409	.001***
Ships	6.81	234	.010**

* Significant difference at $p < .05$

** Significant difference at $p < .01$

*** Significant difference at $p < .001$

Table 3. Gender Differences in Experience with Various Forms of Motion between 12 and 25 Years of Age, with Men Showing Greater Experience

Form of Motion	F	df	P
Trains	12.46	316	.001***
Boats	8.59	338	.004**

** Significant difference at $p < .01$

*** Significant difference at $p < .001$

Table 4. Gender Differences in Incidence of Feeling Motion Sickness with Various Forms of Motion before the Age of 12, with Women Reporting More Incidence

Form of Motion	F	df	P
Cars	23.52	481	.001***
Buses	12.46	433	.001***
Swings	12.11	459	.001***
Amusement Rides	11.90	470	.001***
Total	13.10	472	.001***

*** Significant difference at $p < .001$

Table 5. Gender Differences in Incidence of Feeling Motion Sickness with Various Forms of Motion between Ages 12 and 25, with Women Reporting More Incidence

Form of Motion	F	df	P
Cars	61.78	481	.001***
Buses	43.03	451	.001***
Trains	10.89	317	.001***
Airplanes	5.76	300	.017*
Boats	7.29	354	.007**
Ships	10.76	158	.001***
Swings	19.54	449	.001***
Amusement	19.10	458	.001***
Total	57.76	479	.001***

* Significant difference at $p < .05$

** Significant difference at $p < .01$

*** Significant difference at $p < .001$

Table 6. Gender Differences in Incidence of Actual Motion Sickness with Various Forms of Motion before the Age of 12, with Women Reporting More Incidence

Form of Motion	F	df	P
Cars	9.00	438	.003**
Buses	8.53	431	.004**
Total	4.97	480	.026*

* Significant difference at $p < .05$

** Significant difference at $p < .01$

Table 7. Gender Differences in Incidence of Actual Motion Sickness with Various Forms of Motion between Ages 12 and 25, with Women Reporting More Incidence

Form of Motion	F	df	P
Cars	22.47	472	.001***
Buses	16.48	346	.001***
Ships	7.34	123	.008**
Total	12.82	454	.001***

** Significant difference at $p < .01$

*** Significant difference at $p < .001$

Table 8. Percentages of Male and Female Subjects in a Rotating Optokinetic Drum Classified by Ethnicity (N=47)

Ethnicity	Men	Women
Afro-American	4.2%	4.4%
Hispanic	8.3%	8.7%
Caucasian	79.2%	78.3%
More than One Ethnicity	8.3%	8.6%
Total	100.0%	100.0%

Table 9. Mean and Standard Deviation of Subjective Motion Sickness Symptoms during Eight Drum Rotation Time Periods for Men and Women

Minutes	Men	Women
2	2.21±2.30	2.39±2.48
4	3.63±2.48	3.04±3.39
6	4.25±2.66	4.39±3.76
8	4.67±5.96	4.91±4.35
10	5.08±2.90	5.39±4.40
12	5.38±3.23	5.57±4.38
14	5.88±3.28	5.78±4.22
16	5.75±3.67	6.26±4.29
Total	4.72±4.09	4.60±3.13

Table 10. Gender Difference in Electrogastrogram (EGG) Measure, with Men Experiencing More Gastric Tachyarrhythmia than Women

F	df	P
4.41	45	.041*

* Significant difference at $p < .05$

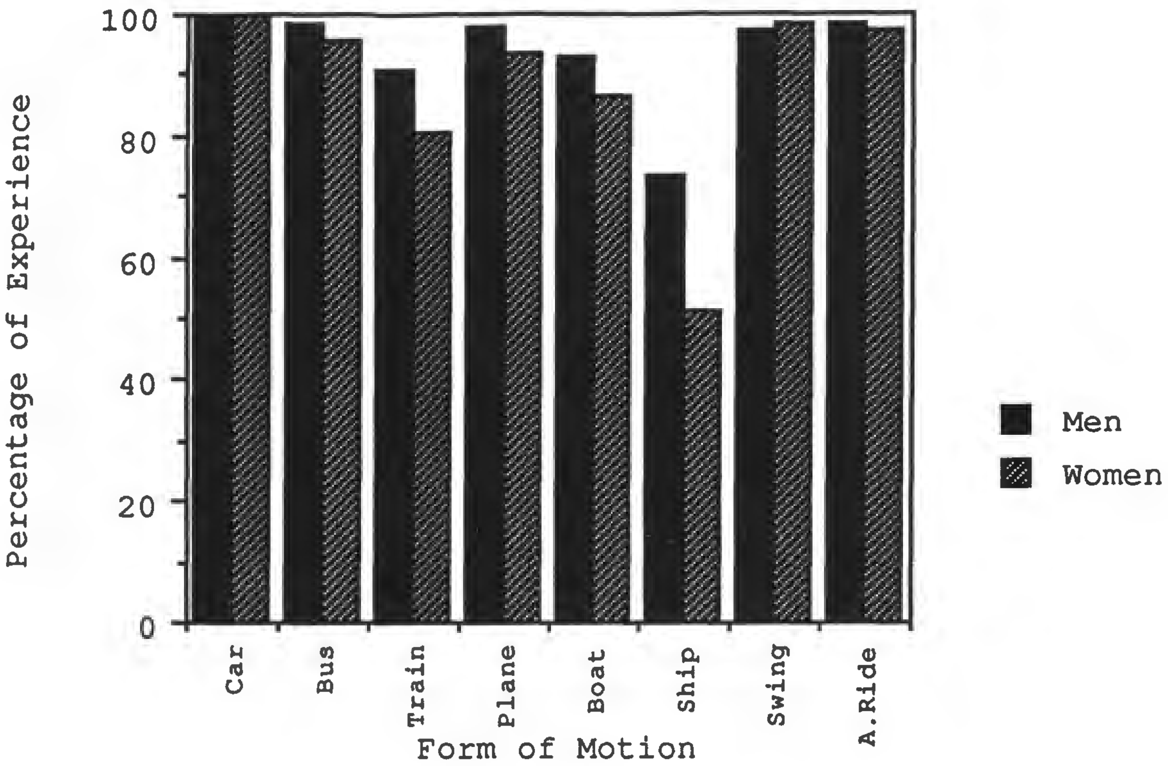

Figure 1. Experience with Various Forms of Motion in Men and Women before 12 Years Old

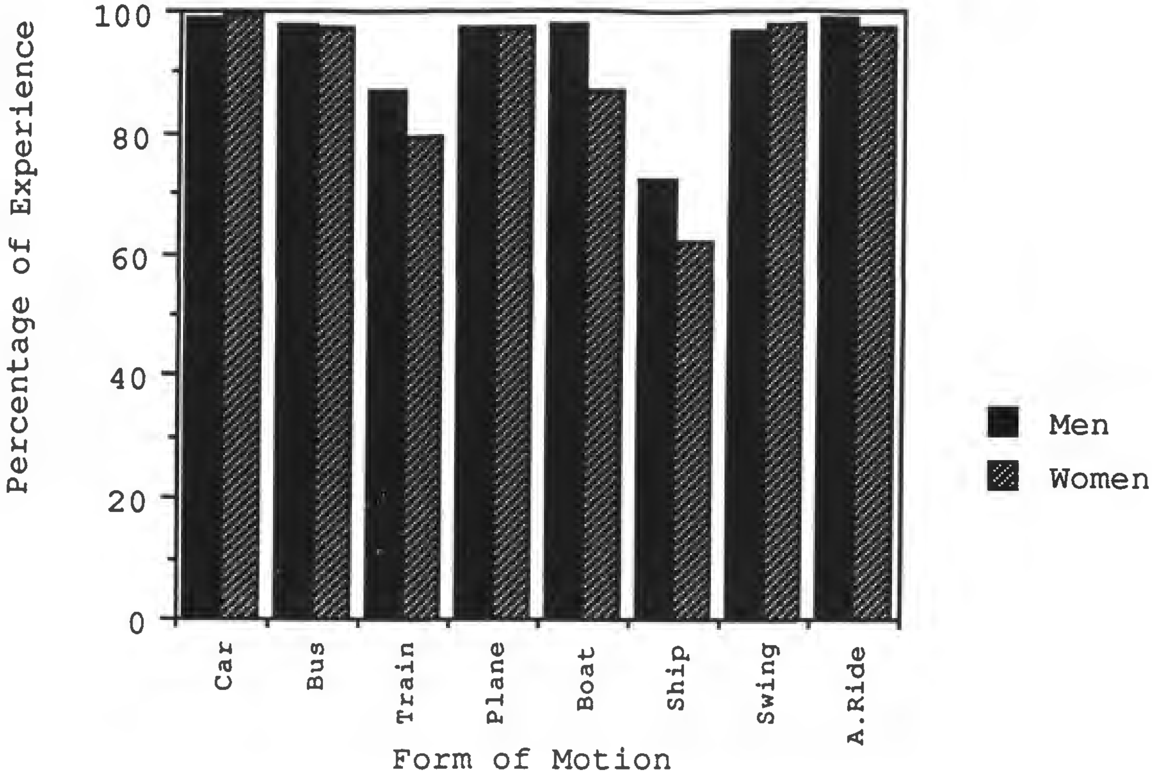

Figure 2. Experience with Various Forms of Motion in Men and Women between 12 and 25 Years Old

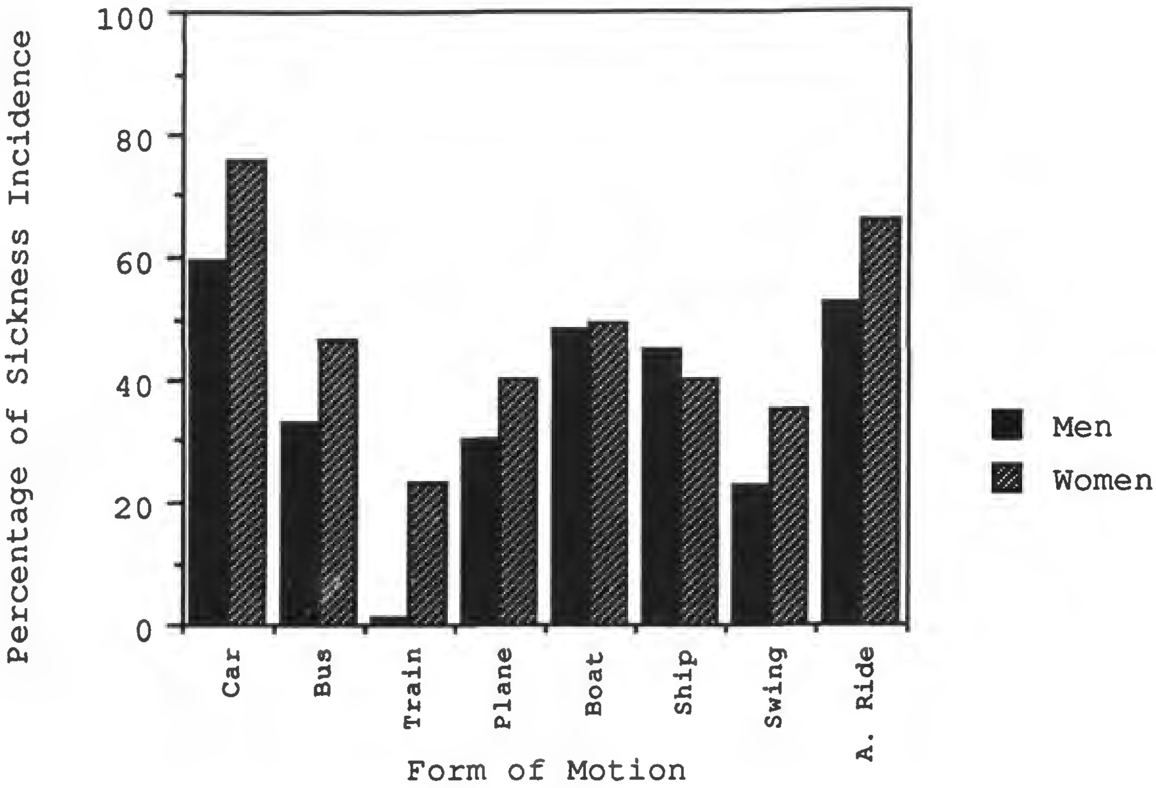

Figure 3. Percentage of Men and Women
Who Felt Motion Sick before 12 Years Old

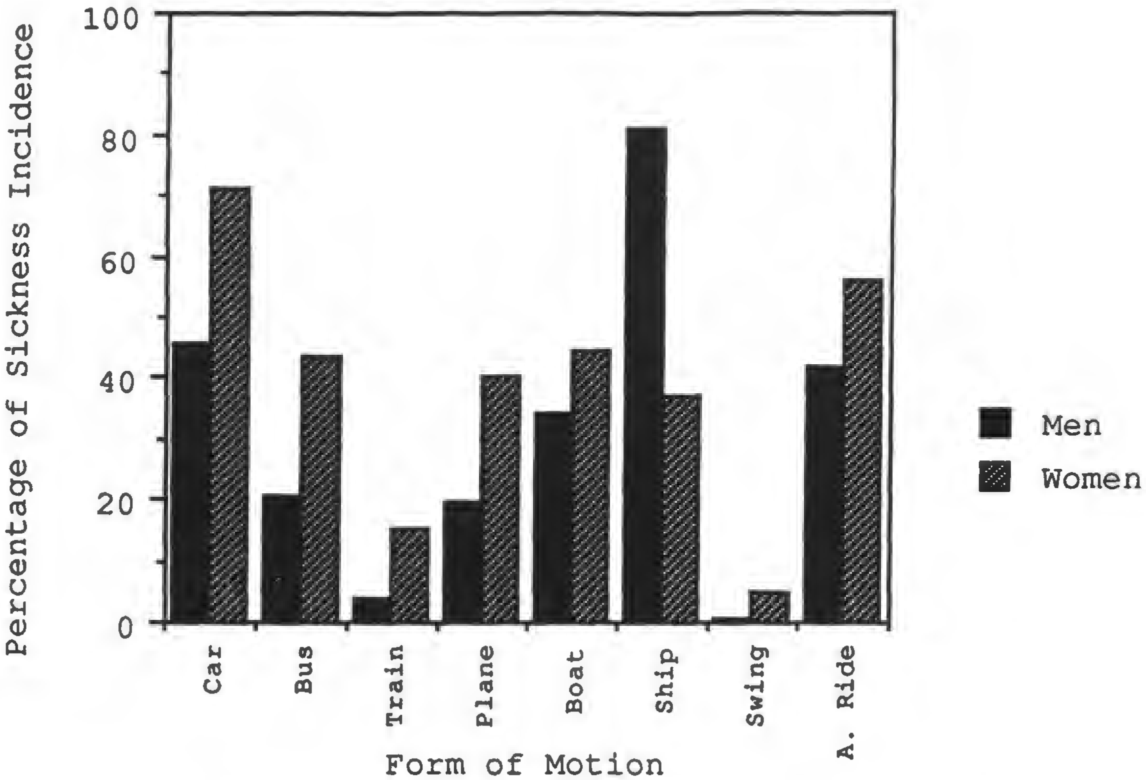

Figure 4. Percentage of Men and Women
Who Felt Motion Sick between 12 and 25 Years Old

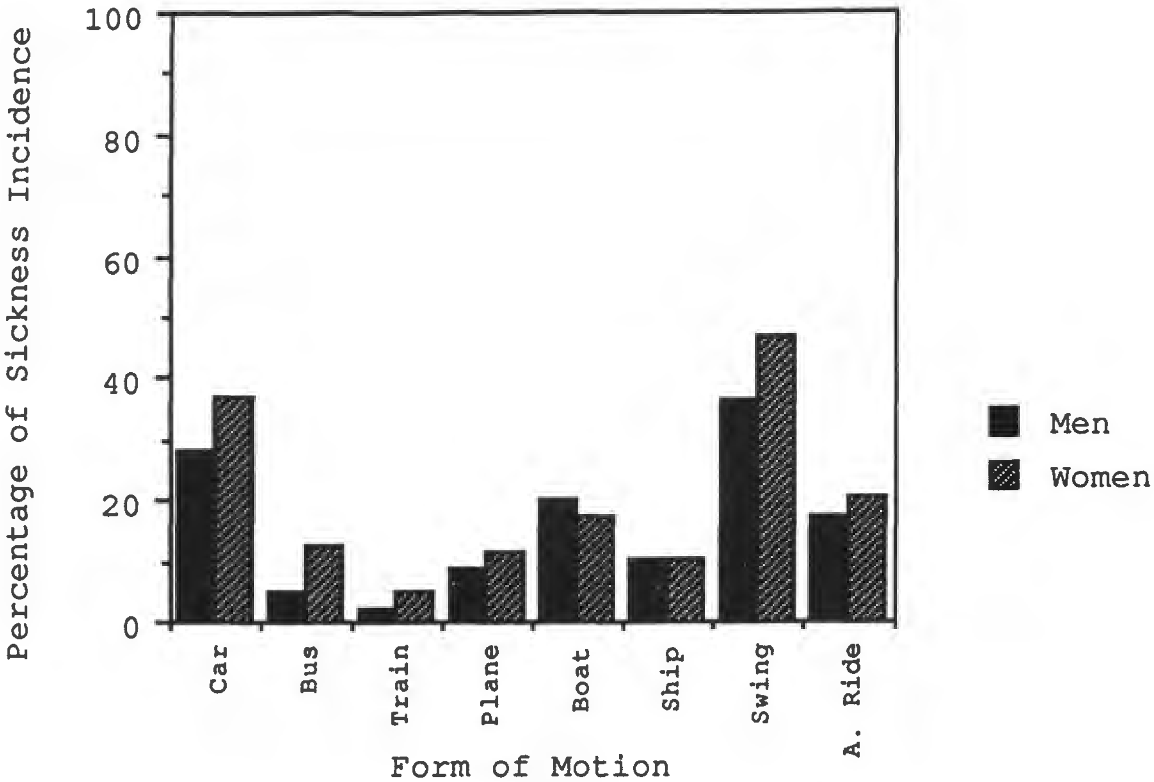

Figure 5. Percentage of Men and Women Actually Motion Sick before 12 Years Old

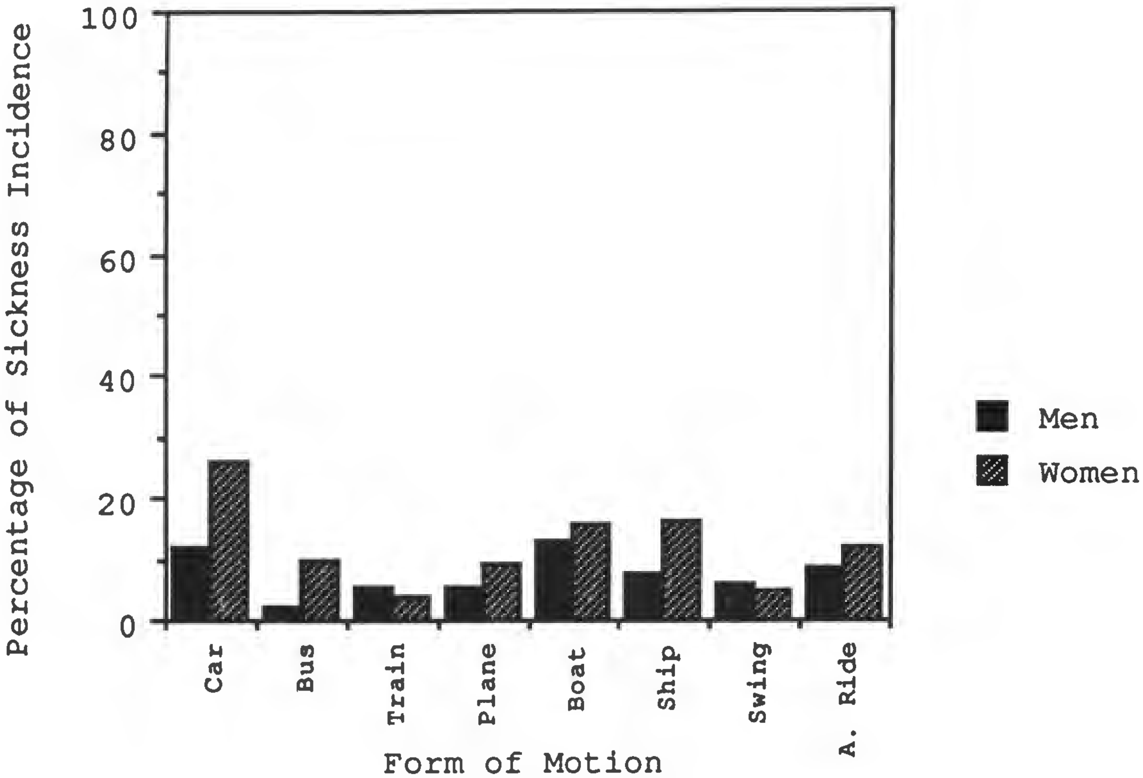

Figure 6. Percentage of Men and Women Actually Motion Sick between 12 and 25 Years Old

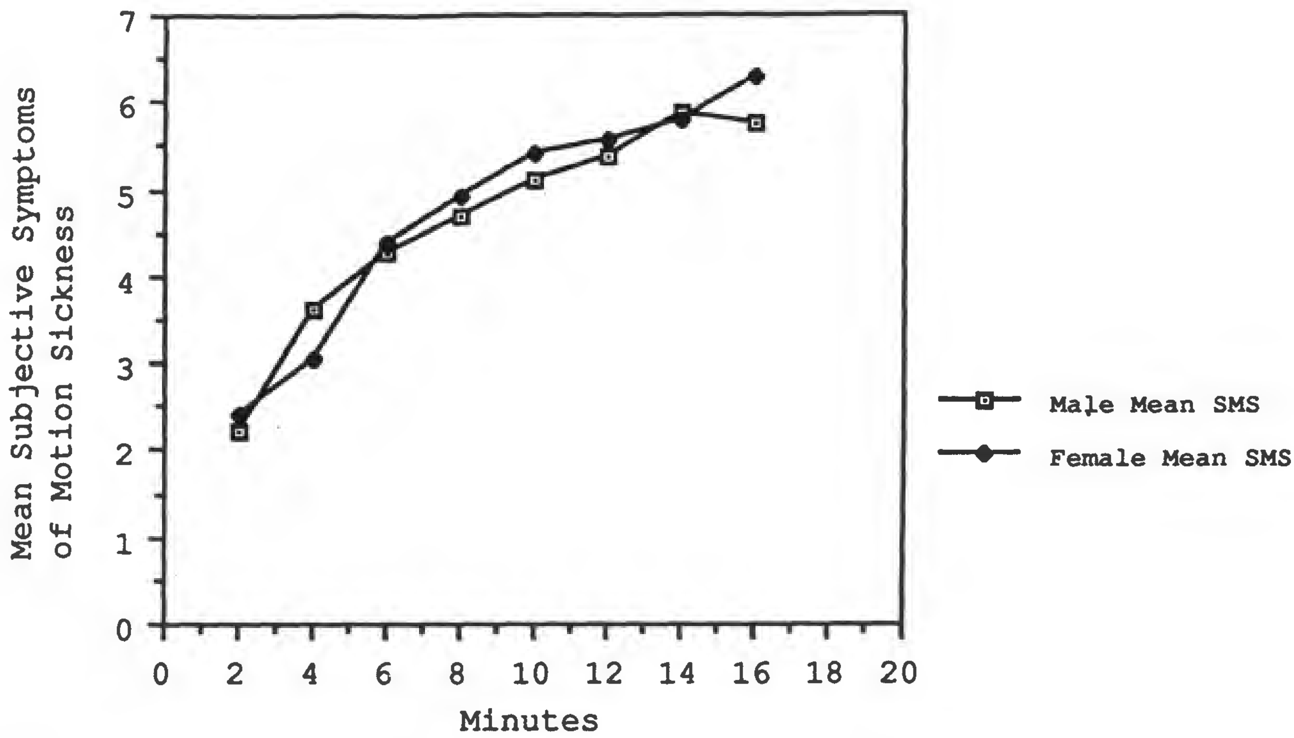

Figure 7. Subjective Symptoms of Motion Sickness in Men and Women at Different Minutes in the Rotating Drum

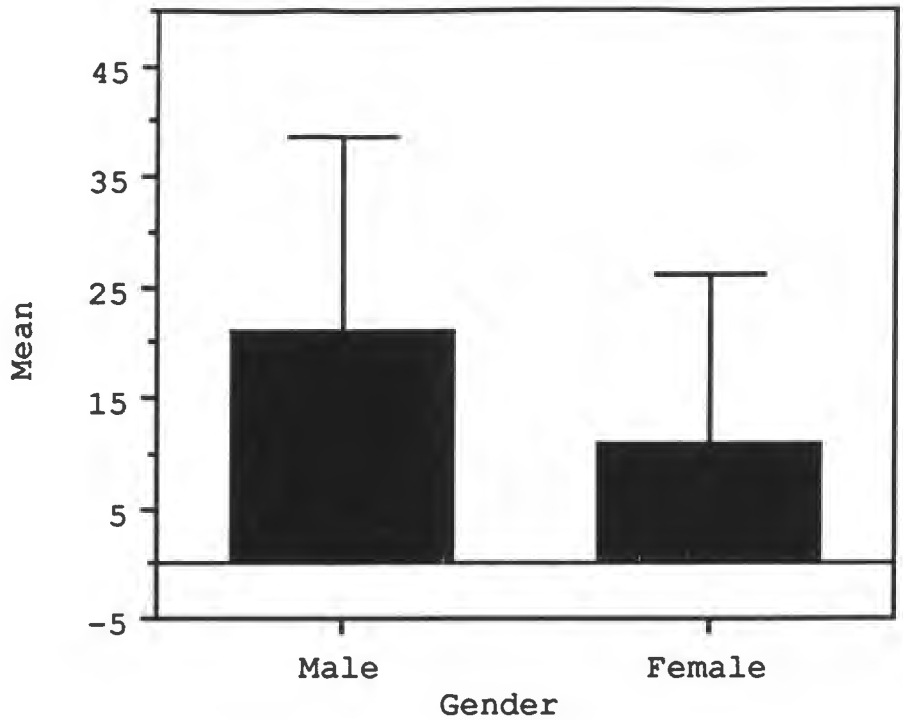

Figure 8. Electrogastrogram Means shown by bar Heights and Standard Deviations Shown by Brackets for Men and Women

Discussion

This study investigated gender differences in motion sickness susceptibility scores from a questionnaire on previous incidence of motion sickness, from gastric myoelectric activity induced by a rotating optokinetic drum, and from subjects' subjective symptom ratings.

The results of this research reconfirm the findings of previous researchers (Reason, 1986; Bawkin, 1971; Abe, Amatomi, & Kajiyama, 1970; Lentz & Collins, 1977). A relation was found between gender and incidence of motion sickness as reported on motion sickness questionnaires. Compared to men, women reported a greater incidence of previously feeling SMS on 4 forms of motion before the age of 12 years and 8 forms of motion between 12 and 25 years old. Women also reported higher incidence of actual SMS history on 2 forms of motion before the age of 12 and on 3 forms of motion between the ages of 12 and 25 years. This research confirms previous findings that an individual may be resistant to the formation of motion sickness symptoms on one form of motion but not on another.

The results of the present study also indicate individual susceptibility to motion sickness may vary with age (compare Figure 1 and 2, Figure 3 and 4, and Figure 5 and 6). Compared to incidence of feeling motion sick and actual motion sickness before the age of 12 years, women reported higher incidence during more forms of motion between the ages of 12 and 25 years.

Gender differences on subjective motion sickness symptoms during drum rotation were not found. However, EGG readings indicated that men showed greater gastric tachyarrythmia than women did. Possible explanations for this discrepancy need to be addressed.

Symptoms of extreme anxiety resemble those experienced during motion sickness (Marks, 1969). Tucker and Reinhardt (1966) found airsick students in flight training to experience more subjective anxiety. Sixty percent of SMS episodes experienced by airsick subjects occurred during the first five flights when vestibular stimulation was minimal. The researchers hypothesized that subjects experienced emotion sickness rather than motion sickness and concluded that declining anxiety may produce adaption to a nauseogenic environment. Specifically, a person who feels uncertain of their position within an environment may have a heightened level of arousal during vestibular input into the central nervous system. Because the level of anxiety decreases, a person experiences less arousal and becomes less susceptible to vestibular stimuli.

Reason and Brand (1975) argued that the phenomenon of adaptation may not be fully explained by Tucker and Reinhardt's findings, however anxiety may exacerbate the development of motion sickness. Tyler and Bard (1949) also contended that factors of psychopathology have only a secondary influence on the development of motion sickness symptoms, possibly affecting the behavior of individuals during motion sickness. Results of the present study indicate that women may report greater incidence of motion sickness, although they do not experience greater tachyarrhythmia.

Van Hasselt and Hersen (1994) reported on epidemiological studies which indicated that in childhood, adolescence, and adulthood, women show a greater prevalence of meeting criteria for diagnostically and clinically relevant anxiety disorder than men do. Because women tend to experience more anxiety than men throughout their lifetime, a greater number of women than men may report more severe symptoms of motion sickness.

The questionnaire method assessed motion sickness experience over a wide range of provocative conditions, unlike actual exposure techniques used in experimental research. Men experienced more exposure to 5 forms of motion before the age of 12 years and 2 forms of motion between the age of 12 and 25. Men experienced more exposure to nauseogenic environments, however men reported less previous incidence of motion sickness. EGG data indicate that men are more physiologically susceptible to motion sickness, although they reported less incidence of prior motion sickness on the MSQ.

Hamid (1990) conducted research using questionnaires and interviews with one or more parents of children experiencing motion sickness. These children had at least one family member who experienced motion sickness at the time of study, suggesting inheritance of motion sickness susceptibility. Hamid reported difficulty with forming pedigrees and suggested that genetics may be a factor in motion sickness. In addition, Abe, Amatomi, and Kajiyama (1970) used a physical and behavioral deviations questionnaire which was regularly used at a clinic called Check-up for Three Year Old Children. Researchers observed that parents who had suffered from childhood motion sickness had significantly more susceptible children. Matings of both parents with motion sickness had the highest incidence of susceptible children. Observations suggest a polygenic inheritance for motion sickness susceptibility, rather than simple Mendelian dominant or recessive, autosomal, or sex-linked inheritance. In the present study, the etiology of men experiencing greater susceptibility to gastric tachyarrythmia in motion sickness may be partly related to genetic components.

Reason and Graybiel (1972) found a correlation between extraversion-introversion and subjective reports of decline in well-being before rotation of stimuli. Introverts, monitoring of their internal state, showed more disturbance by exposure to the stimuli before viewing movement and adapted at a slower rate during rotation than extroverts. Slow adapters also report more severe history of motion sickness and greater reduction in well-being before optokinetic exposure than fast adapters. In addition, slow adapters tend to be more introverted. Women who are introverted may experience slower adaptation than men who tend to be more extraverted, promoting women to report more incidence of previous motion sickness than men do.

The results of this study suggest possible social factors for gender differences in the reporting of previous motion sickness. Men may have been taught to not express their symptoms of motion sickness. In contrast, women's reports of symptoms may be more socially acceptable.

The present study includes the following practical implications. Subjectively reports of previous motion sickness incidence may not be an accurate indicator of actual gastric tachyarrhythmia during motion. For example, more women than men may be selected out of pilot training programs because of women's higher reports in previous incidence of motion sickness. However, women may not actually experience greater symptoms of motion sickness and gastric tachyarrhythmia.

Limitations of the study included subjects' limited experience on ships resulting in less reliable data and statistical results in this form of motion. Future research may investigate the relation of gender differences in susceptibility to motion sickness with anxiety, introversion, and extraversion of subjects, before and during exposure to nauseogenic stimuli. Research on anxiety, introversion, and extroversion during adaptation may also provide needed information. Cowings, Naifeh, and Toscano (1990) proposed that multiple autonomic nervous system responses provide the most accurate characterization of motion sickness. The results of the present study suggest future research which includes both heart rate and skin conductance. Investigating gender differences in susceptibility to motion sickness by using subjects with a greater incidence of motion sickness history, with higher scores on the MSQ, may yield different results. In addition, collecting data on subjective ratings of vection during drum rotation may enhance information on gender differences in experiencing vection during exposure to a nauseogenic environment.

The results of the present study indicate the following. Women reported a greater incidence of previously feeling SMS than men did. Men and women did not differ on reported motion sickness symptoms during drum rotation. EGG readings indicated that men experienced greater gastric tachyarrythmia during drum rotation than women did.

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Appendix A

MOTION SICKNESS QUESTIONNAIRE

Note: If you are under 18, please do not respond to this survey.

Please read the following paragraph before you fill out the motion sickness questionnaire.

The questionnaire you are going to finish is part of our research project, "The correlation between motion sickness history and the severity of symptoms of visually-induced motion sickness".

The purpose of this questionnaire is to screen subjects for participation in the above research project. However, your participation of this survey questionnaire is voluntary. You might refuse to participate, or withdraw at any time. The act of your responding to the survey does not obligate you to participate in future experimentation. Your answers on the survey will be kept confidential.

NAME: ____________________ PHONE ____________________
NUMBER: ______________
AGE: _____
GENDER: _____ HEIGHT: _____
APPROXIMATE BODY WEIGHT: ______________

Section A: All the questions in this section refer only to your childhood experience of motion sickness (if any), where childhood is defined as the period **prior to 12 years of age**. It is quite possible that you will have difficulty in recalling childhood motion sickness. Nevertheless, please try to answer the questions to the best of your ability.

1) Indicate approximately how often you travelled on each type of transportation below (before age 12) by using one of the numbers:

0-no experience, 1-less than 5 trips, 2-between 5 and 10 trips,
3-more than 10 trips

CARS	BUSES	TRAINS	AIRPLANES	BOATS	SHIPS	SWINGS	AMUSEMENT RIDES (describe)
___	___	___	___	___	___	___	___

Consider only those types of transport that you have marked 1,2, or 3 above (e.g., those you have travelled on), go on to answer the two questions below. (Use the following letters to indicate the appropriate category of response):

N- never R- rarely S- sometimes F- frequently A- always

2) How often did you feel sick while travelling (e.g., queasiness or nausea)?

CARS	BUSES	TRAINS	AIRPLANES	BOATS	SHIPS	SWINGS	AMUSEMENT RIDES (describe)
___	___	___	___	___	___	___	___

3) How often were you actually sick while travelling (e.g. vomiting)?

CARS	BUSES	TRAINS	AIRPLANES	BOATS	SHIPS	SWINGS	AMUSEMENT RIDES (describe)
___	___	___	___	___	___	___	___

Section B: This section is concerned with your experience of motion sickness (and travel) **between your age of 12 to 25 years.**

1) Indicate approximately how often you travelled on each type of transportation below (from 12 years old to 25 years old) by using one of the numbers:

0-no experience, 1-less than 5 trips, 2-between 5 and 10 trips,
3-more than 10 trips

CARS	BUSES	TRAINS	AIRPLANES	BOATS	SHIPS	SWINGS	AMUSEMENT RIDES (describe)
___	___	___	___	___	___	___	___

Consider only those types of transport that you have marked 1,2, or 3 above (e.g., those you have travelled on), go on to answer the two questions below. (Use the following letters to indicate the appropriate category of response):

N- never R- rarely S- sometimes F- frequently A- always

2) How often did you feel sick while travelling (e.g., queasiness or nausea)?

CARS	BUSES	TRAINS	AIRPLANES	BOATS	SHIPS	SWINGS	AMUSEMENT RIDES (describe)
___	___	___	___	___	___	___	___

3) How often were you actually sick while travelling (e.g., vomiting)?

CARS	BUSES	TRAINS	AIRPLANES	BOATS	SHIPS	SWINGS	AMUSEMENT RIDES (describe)
___	___	___	___	___	___	___	___

The following information is optional, but very valuable for us.
Are you: American Indian/Native Alaskan, Asian/Pacific Islander, Black, Hispanic, Caucasian, Others. Please circle one.

Appendix B

Health Questionnaire

State the following prior to questions. Answers to health status questions will be kept confidential. Participation in the study is voluntary and you are permitted to leave the experiment at any time.

The following questions about the subjects' health condition are required before the subject signs the consent form and participates in research. If the subject answers that they meet any of the following conditions, participation in the experiment will be terminated.

1. vision problems
2. previous or current central nervous system disorders or symptoms. Examples include tumors, severe headaches, and seizures
3. gastrointestinal disease or symptoms. Examples include stomach ulcer, stomach discomfort, and abdominal pain.
4. cardiovascular disorders. Examples include irregular heart beat, hypertension, and anemia
5. possible pregnancy (asked with female only).

Appendix C

CONSENT TO ACT AS RESEARCH SUBJECTS

I hereby agree to participate in a Humboldt State University Psychology Department study conducted by Alexandrea H. Klose (Graduate Student) and overseen by Dr. Senqi Hu (Associate Professor).

I understand that participation in this study involves following the procedures involved in one session for 24 minutes in a private laboratory room at the Department of Psychology.

I have read and understand the following information regarding this study. Viewing an optokinetic rotating drum may produce feelings of self-rotation. After sensing self-rotation for several minutes, susceptible people may develop mild symptoms of motion sickness. Examples include dizziness, warmth, and gastric discomfort.

The purpose of this study is to further investigate the etiology involved in susceptibility to motion sickness. The results of this study may provide a better understanding of motion sickness etiology and incidence. Subjects will learn about the general mechanisms involved in motion sickness. Society will better understand motion sickness etiology and possible ways to reduce motion sickness incidence among men and women.

I understand that the procedures in this study pose no psychological risks and very minimal physiological risks to subjects. Subjects who are allergic to electrode gel may develop slightly red skin which may itch for 2 hours. The probability of this allergic reaction is less than 3 in 100. Susceptible subjects may experience an illusion of bodily movement and experience some mild physical discomfort like dizziness, warmth, and stomach discomfort while viewing the slowly rotating drum. The discomfort may occur in the last 3 or 4 minutes during the drum rotation period.

In case of experiencing discomfort, I have the option to request stopping drum rotation, close eyes, or terminate participation when feeling discomfort that is not endurable during the experiment. If I experience severe physiological discomfort during or after the experiment, I will be taken to or referred to the Humboldt State University health center for observation or medication.

The above information was explained to me by ______________________. I understand that he/she will answer any questions I may have concerning the procedures at any time in the study. I understand that participation is voluntary. I also understand that I may decline to partake in the study and that I may withdraw from it at any time without jeopardy. I understand that in the cases of declining or withdrawal, the experimenter will terminate my participation in the experiment. I understand that, if I have any questions, problems, or concerns about this study, I can contact Dr. Senqi Hu in his office, 120 HGH, phone 826-5262, or call his home phone 839-5908.

I understand that there will be no monetary compensation for participation in this study.

______________________________ ____________________

Subject signature Date

Appendix D

HUMBOLDT STATE UNIVERSITY

Department of Psychology

DEBRIEFING

Title of the Project: GENDER DIFFERENCES IN SUSCEPTIBILITY TO VECTION-INDUCED MOTION SICKNESS AND GASTRIC MYOELECTRIC ACTIVITY

The purpose of this study is to examine gender differences in motion sickness susceptibility as measured by the following:

1. motion sickness history questionnaire (MSQ), AND
2. electrogastrogram recordings of gastric activity.

Physiological readings are taken to determine whether male and female subjects in an optokinetic drum display different severity of vection-induced motion sickness symptoms.

Subjects often experience circular vection, illusory self-motion, while viewing certain large and moving stimuli, such as an optokinetic drum, rotating around them. Some people experience a similar feeling while reading in a car, and astronauts experience a similar feeling in a weightless environment.

Circular vection has been shown to provoke subjective (self-reporting) and physiological (EGG) responses to motion in susceptible subjects. Previous research has suggested that the peripheral nervous system, the central nervous system, and neuroendocrine hormones are involved in the development of motion sickness symptoms. The vestibular system may play an important role in visually-induced motion sickness. However, the mechanisms involved in the development of motion sickness is not fully understood.

The gastric symptoms you experienced were recorded as amounts of electrogastrogram (EGG) activity. Previous studies have shown that nausea is associated with an increase in the frequency of gastric myoelectric activity from 3 cycles per minute (cpm) to 4-9 cpm (tachyarrhythmia). In the present study, we recorded the amount of EGG activity from the 4-9 cpm as a physiological index of the degree of motion sickness.

Thank you for participating in this research. If you have severe motion sickness reactions, you may contact Humboldt State University's Health Center (826-3146). Any further questions or comments may be directed to Professor Senqi Hu (826-5262) of Humboldt State University's Psychology Department.

Appendix E

Human Subject Approval Letter

Humboldt State University

College of Behavioral and Social Sciences

MEMORANDUM

DATE: April 23, 1996

TO: Senqi Hu, Professor of Psychology
Alexandrea H. Klose, Student Investigator

FROM: Lee H. Bowker, Interim Chair
Committee for the Protection of Human Subjects in Research

SUBJECT: Your Proposal: "Gender Differences in Susceptibility to Vection-Induced Motion Sickness and Gastric Myoelectric Activity"

Thank you for submitting your proposal, "Gender Differences in Susceptibility to Vection-Induced Motion Sickness and Gastric Myoelectric Activity," for research using human subjects. I am able to provide expedited review for your proposal because risk is minimal, and is properly handled in the research design, which has been approved in previous protocols by the full Committee.

This memo constitutes formal approval of your research proposal. This approval is for one calendar year, and will expire on April 23, 1997. If you find it necessary to continue your research beyond this date, please apply for renewed approval in enough time in advance of this date to prevent interruptions in your project. If your research plan must be altered, please notify this office according to the policies established for Humboldt State University.

Thank you for your careful attention to the protection of the human subjects of your research.

LHB:lhm
cc: Members of the Committee for the Protection of Human Subjects in Research:
Chris Hopper, Health and Physical Education
Susan Armstrong, Philosophy
Beverly Nachem, Nursing
Terrie Jordan, Disabled Students
Leslie Foote, Arcata Family Medical Group
Warren Carlson, Psychology
Jean Perry, Office for Research and Graduate Studies
Patrick Wenger, Anthropology

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