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Sex and Virtual Reality: Posture and Motion Sickness

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SEX AND VIRTUAL REALITY:
POSTURE AND MOTION SICKNESS

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ABSTRACT

It is well established that exposure to virtual motion environments (VME) can elicit postural instability (PI) in addition to motion sickness (MS). While research has found sex differences in motion sickness, the results of experimental studies are equivocal regarding these differences, and previous studies utilizing VME have failed to address the factor of sex differences in terms of hormonal fluctuations, which may also be instrumental in behavioral responses to VME, such as PI. The intent of this investigation was to determine whether exposure to VME, during various phases of the menstrual cycle (premenstrual, permenstrual, ovulation) would reveal sex differences in MS and PI during some phases, but not others. The first experiment involved men and women completing Daily Living Logs for a period of 40 days to provide a baseline for any sex differences (and for women, menstrual phase differences) in motion related activity and symptomatology. The second experiment involved 24 participants (6 men) viewing a rotating Archimede's spiral for a period of twenty minutes. Exposures were timed to place each woman in three phases of her menstrual cycle; men were exposed by yoking their exposure time to a female counterpart. Multiple measures of PI and MS were recorded before, after and during exposure. Results of the first experiment found no significant effects of sex or phase upon symptomatology, revealing no support for the theory of a reporting bias as influencing sex differences in MS or PI elicited in the laboratory. The second experiment found no significant effect of sex of phase upon any of the PI measures, but found significant interaction effects of sequence and phase, as

well as sequence and sex, upon reported magnitude ratings of illusory self-motion perception. There were also significant effects of sex found upon measures of MS, with women reporting more discomfort to exposure to motion stimulation, as compared to men. There were no significant effects of phase upon any of the MS measures. While these findings show no support for a reporting bias influencing the sex differences found experimentally induced MS, it yields no evidence to support a hormonal influence on these differences.

CHAPTER I: INTRODUCTION

Sex differences have always been a popular topic among scientists and nonscientists alike. Research has sometimes addressed this issue in terms of physiological as well as psychological sex differences between men and women. As occupational margins between men and women have narrowed, thoughtful consideration of these differences has become necessary, encouraging the incorporation of human factors in order to maintain and improve occupational performance and safety. In addition, as many workplaces become increasingly automated and require fewer human participants, these factors become highly important, particularly within dynamic motion environments.

Challenges encountered within dynamic motion environments have the potential to compromise not only cognitive task performance, but physical performance measures as well. These physical tasks include a variety of perceptual-motor skills, some of which may involve gross as well as fine motor skills such as manual dexterity, fine manipulation, and ocular smooth pursuit, saccades or fixation. In addition, any deficits to gross motor performance may compromise both postural stability as well as locomotion, and possibly lead to accidents or injuries. In combination with the trend of a reduced number of human participants employed in dynamic motion environments, it is essential to address any significant differences in these types of perceptual-motor tasks as the critical number of employees within these types of work environments dwindles.

Somatic complaints have also accompanied exposure to such dynamic environments. Many who have traveled over land, at sea or in the air have experienced severe discomfort. This adverse reaction to motion environments has been termed motion sickness (MS) (Dichgans & Brandt, 1973; Money, 1970; Reason & Brand, 1975). The use of the term MS has been attributed to Irwin (1881) who suggested that seasickness might better be called MS because "not only does it occur on lakes and even on rivers, but as is well know, a sickness identical in kind may be induced by various other motions than that of turbulent water …". MS has been elicited by way of a diverse assortment of motion and simulated motion environments, characterized by a broad spectrum of ill effects, the susceptibility to which has been found to be more prevalent in women than in men (Nieuwenhuijsen, 1958; Reason & Brandt, 1975).

Sex Differences

Research has revealed a number of physiological differences between men and women, both within reproductive and non-reproductive body systems. The reproductive system of women is distinct from that of men within a multitude of measures. Sexual differentiation of the external and internal genitalia has been found to be dependent upon activity of the endocrine system, which also influences the development of a sexually differentiated neurological system (Gorski, 2000).

Sex hormones have been found to be highly influential in the development of a number of brain and reproductive structures. As early as the stage of testes

differentiation during embryonic development, hormones produced by the testes (müllerian duct inhibiting hormone, testosterone, and dihydrotestosterone) begin to govern development of both male internal and external genitalia; the absence of the testes stimulates the development of female genitalia (Gorski, 2000; Neal, 2002). In addition, while the hormone estrogen has been found to be necessary for the masculinization of the brain, it is also highly instrumental in the development of the female brain (Gorski, 2000; Neal, 2002). During the critical period of development, these types of hormones have been found to induce organizational effects on the brain (Sanders & Wenmoth, 1998). Such structural distinctions in the human nervous system have included: size differences in a number of nuclei of the stria terminalis, anterior hypothalamus, preoptic area, and spinal cord (larger in men than women); size differences in the corpus collosum, anterior commissure, and massa intermedia (larger in women as compared to men); shape differences in the corpus callosum (more bulbous in women) and suprachiasmatic nucleus (more elongated in women); and greater asymmetry in the planum temporale in men (Gorski, 2000). In addition, research has also shown significant sex differences in musculoskeletal development and peripheral motor system behavior as well (Field & Pellis, 1998). However, whether central nervous system differences, such as these, influence more peripheral systems, or whether peripheral differences influence neural development, is still unknown.

Research has found that not only does the endocrine system have an organizing effect during development; hormones such as those described above also have an activating effect as the individual develops into adulthood (Field &

Pellis, 1998; Neal, 2002). The endocrine system in women regulates the ovarian cycle. The ovarian cycle begins with the onset of menstruation and continues through day four of the typical female menstrual cycle. During this stage there is a slight increase in follicular stimulating hormone, as well as lowered levels of both estrogen and progesterone (Gorski, 2000; Neal, 2002). This stage is followed by the proliferative stage, which continues to around day fourteen of the average female cycle. During this stage there is a surge in luteinizing hormone, as well a slight increase in follicular stimulating hormone, and increased levels of estrogen (Gorski, 2000; Neal, 2002). This stage culminates with ovulation. The secretory stage follows through around day twenty-one of the cycle. This stage is dominated by increased levels of progesterone, a drop in luteinizing hormone and decreased levels of estrogen (Gorski, 2000; Neal, 2002). The final stage is the luteolytic phase, which continues until the onset of the following cycle. This stage involves a leveling of the luteinizing hormone, estrogen and progesterone, and a slight increase in levels of follicular stimulating hormone (Gorski, 2000; Neal, 2002). In the follicular phase, estrogen has been found to be secreted at a rate of 60 g/day; by the ovulatory phase, estrogen often reaches a secretion rate of 400 to 900 g/day; and during the luteal phase, approximately 300 g/day of estrogen are secreted (Gill, 1985).

Reproductive hormones may be measured in a number of different manners of both sampling and processing methodology (Snowden & Ziegler, 2000). While blood and urine samples have been the routine means of measuring hormone levels, these methods are costly in that blood samples

require venipuncture, a licensed professional is needed to collect and store the specimen, and urine samples require special handling to prevent contamination of the hormones. Feces, while another means of sampling for reproductive hormones, is messy in more than one meaning of the word. This type of sample captures hormones accumulated over an extended period of time, and thus is not specific to the time of collection. Lastly, saliva sampling is another means of measuring reproductive hormones. This type of measure, in addition to having the advantage of being non-invasive and easy to collect and handle, has been found to correlate well with free levels of circulating hormones. Estradiol, a hormone readily sampled through saliva, has been found to be a highly physiologically active form of estrogen readily available for analysis of estrogen levels in female subjects (Becker, et al, 2004; Gill, 1985).

While most animal studies look at dependent variables in terms of the above four stages of the menstrual cycle, research on human participants has divided the cycle into three, rather than four stages (Fridén, Hirschberg, Saartok, Bâckström, Leanderson & Renström, 2003; Larsen, Anniko, Nakagawa & Watanabe, 1998; Sanders & Wenmoth, 1998). These stages are entitled the early follicular or permenstrual phase (day 2-5 of cycle), the ovulatory phase (day 11-14 of cycle), and the mid-luteal or premenstrual phase (day 18-21 of cycle) (Fridén, et al, 2003; Grunfeld, et al, 1998; Grunfeld & Gresty, 1998; Neal, 2002).

Both sex and phase of the female menstrual cycle have been implicated in differences found in a number of behavioral measures. Significant sex differences have been found in the organization of complex motor behavior

patterns in many different species of mammals (Field & Pellis, 1998), including humans (Fridén, et al, 2003; Larsen, et al, 1998).

Sex and phase have also been predictive of cognitive functioning, women performing better than men on verbal tasks, men scoring higher than women on mathematical and visual-spatial tasks, with significant changes occurring in these measures over the course of the menstrual cycle (Sanders & Wenmoth, 1998). Greater asymmetry has been found between the sexes in right hemisphere tasks (mathematical and visual-spatial) and left hemisphere tasks (verbal tasks) when estrogen levels are high (ovulation phase). Similarly, reduced asymmetry has been found between men and women when estrogen levels are low (mid-luteal or permenstrual phase). Performance measures have found improved spatial abilities in women during menstruation, as compared to ovulation, with better performance when estrogen levels are low rather than high (Hampson & Kimura, 1992).

Other studies have found the sex of the individual to also be predictive of self-orientation perception, women with a tendency to be more field dependent than men (Darlington & Smith, 1998; Scholar & Smith, 1990; Tremblay, Elliot & Starkes, 2004). However, contrary to those findings, a recent study conducted in our laboratory found that in terms of in self-orientation judgments, while men were significantly better when descending to 90° both with eyes open and closed, women were significantly more accurate than men with their eyes closed when ascending to 75° and 105° angles, and were more accurate than men at the 105° angle with their eyes open (May, Flanagan, Foss, Simineaux & Dobie, 2005).

Research has also found measures of the autonomic division of the peripheral nervous system, such as heart rate, to show a significant effect of phase of the female menstrual cycle in young women (Leicht, Hirning & Allen, 2003; McCarthy & Becker, 2002; Mercuro, Podda, Pitzalis, Zoncu, Macia, Melis & Rosano, 2000; Yildirir, Kabakci, Akgul, Tokgozoglu & Oto, 2002). In addition, recent studies have revealed significant effects of sex in measures of postural balance, with older women being more stable than older men, and younger women being less posturally stable than younger men (Larsen, et al, 1998). Another study further revealed a significant effect of menstrual phase upon postural stability, with women being less stable during the mid-luteal (premenstrual) phase, when estrogen is low (Fridén, et al, 2003).

Research in sports medicine has also revealed significant sex differences in the rates of sports related injury, with women sustaining far more knee injuries than men (Chandy & Grana, 1985; Gray, et al. 1985; Hewett, 2000; Hewett, et al., 1996; Huston & Wojtys, 1996; Zelisko, Noble & Porter, 1982; Malone, et al, 1993). One theory proposed to explain this phenomenon implicates female reproductive hormones, such as estrogen, progesterone, and relaxin (Chandy & Grana, 1985; Huston & Wojtys, 1996; Zelisko, Noble & Porter, 1982; Haycock & Gillette, 1976).

Estrogen has been found to directly influence the female neuromuscular systems, by increasing joint laxity and muscle fatigue, and slowing muscle relaxation (Booth & Tipton, 1970). Levels of estradiol have been found to be positively related to muscle fatigue as well as negatively related to ligament

strength and speed of muscle relaxation (Florini, 1986; Sarwar, Beltran & Rutherford, 1996). Estrogen also exerts its influence on neuromuscular systems indirectly via its effects on performance (Lebrun, 1994). Decreased skill performance has been found in women during the midluteal phase (Posthuma, et al, 1987) and decreased injury rates during the permenstrual phase (Wojtys, et al, 1998; Myklebust, et al, 1998). By stabilizing reproductive hormone levels to prevent the ovulatory surge, findings such as these appear to diminish when oral contraceptives are utilized (Moller-Nielson J, Hammar, 1989; Moller-Nielson J, Hammar, 1991).

Motion Sickness

Studies have approached sex and motion sickness from a number of perspectives, and have generally found sex to be significantly related to MS susceptibility. Differences between men and women have been measured in terms of group differences in motion exposure, fitness, history of MS, in addition to episodes of MS and changes correlating with different stages within the female menstrual cycle.

A survey study conducted by Lentz and Collins (1977) revealed that self-reported susceptibilities to MS indicated less experience with various motion situations as compared to those who report low susceptibility to MS. In addition, while they found a greater proportion of women report high susceptibility to MS as compared to men, this difference was not statistically significant. However, recent investigation has found that while women report more sickness, this

difference cannot be accounted for by lack of experience, as there are no significant differences in physical activities prior to age 18 (Dobie, McBride, Dobie Jr. & May, 2001).

In terms of diagnosed impairments, MS in women has been related to levels of neuroticism, as well as related to vestibular disturbances (Bick, 1983). Again, however, a study found that while women report MS more often than men, this cannot be accounted for by differences in physical activities prior to age 18, which could be seen as an indicator of physical health and fitness (Dobie, et al., 2001). A survey of over 4000 college students found that while women report more susceptibility to MS, men rated themselves as having more muscular coordination which may account for this difference (Lentz & Collins, 1977). In addition, report of symptoms of migraine has been found to covary with the report of MS, more often in women than in men, which may also be a predictive indicator for MS (Grunfeld, Price, Goadsby & Gresty, 1998).

The most robust sex difference revealed in the literature shows that women report a greater history of MS, as compared to men (Crush, 1976; Abe, Amatomi & Kajiyama, 1970; Bakwin, 1971; Deich & Hodges, 1973; Mirabile Jr. & Ford, 1982; Park, 1998; Sharma & Aparma, 1997; Turner & Griffin, 1999; Yardley, 1989). Women report a greater history of MS in a dynamic motion medium (Mirabile, 1972; Mirabile, Glueck & Stroebel, 1979; Park & Hu, 1999). This difference has been explained from a biological perspective; a difference of the common emetic pathway, functioning for survival of the species exposed to a noxious motion environment (Golding, 1998). However, these data could also be

the result of a reporting bias, women more apt to report somatic discomfort. A study on Suncus Murinus found an effect of sex of the monkey upon sickness elicited from low frequency motion stimulation, with male subjects having a higher frequency, and shorter latency to onset of emesis (Matsuki, Wang, Okada, Tamura, Ikegaya, Lin, Hsu, Chaung, Chen & Saito, 1997). These findings could be explained by the lack of social inhibition existing within these monkeys, the contribution of which in human subjects may prevent their reporting discomfort or emesis, thereby contributing to the sex differences found in human studies.

A few other human studies, however, have also failed to find significant differences in history of MS between men and women (Grunfeld, et al., 1998; Hamid, 1991). Some have actually found a higher incidence of reported history in men (Grunfeld & Gresty, 1998). These findings are unusual though, and could be attributable to a number of different experimental factors. Women tend to report a greater history of, and have been found more susceptible to, MS as compared to men, both in laboratory studies and in non-laboratory based motion environments, often with subjects reporting a history of MS (Flanagan, May, Dobie, Dunlap & Blancaneau, 2002; Aust, Hordinsky & Schmelzer,1980; Collins & Lentz, 1977; Gahlinger, 2000; Hearon, Fischer & Dooley, 1998; Lawther & Griffin, 1988; Mirabile & Glueck, 1980; Stanney, Kennedy, Drexler & Harm, 1999; Turner, Griffin & Holland, 2000). However, these results have also been found in subjects with little to no reported history of MS (Flanagan, May & Dobie, 2005). While one study addressing the interaction between the sex of the subject and that of the experimenter failed to show a significant interaction of these factors

upon MS, this did not preclude the discovery of a main effect of sex of subject upon report of MS symptomatology (Jokerst, Fazio, Gianaros, Stern & Koch, 1999).

Once again, some studies have failed to find significant differences in the incidence in symptomatology between women and men, even in the presence of significantly different histories of MS (Cheung, Money & Jacobs, 1990; Clark & Steward, 1973; Cooper, Dunbar & Mira, 1997; Hu, Glaser, Hoffman, Stanton & Gruber, 1996; Owen, Leadbetter & Yardley, 1998; Sharma, 1980; Ungs, 1989; Woodman & Griffin, 1997). These findings however, may be attributable to the influence of a self-selection process, in which sensitive women may not choose to participate in this sort of experiment. For example, a survey of students over the course of the semester revealed that although in the beginning of semester there were no significant differences between levels of susceptibility or sex for those choosing to participate in MS research, later in the semester non-susceptibles were significantly more likely to volunteer than susceptibles; women more willing to volunteer than men (Lentz & Collins, 1977). In addition, while one study reported a tendency for women to be slightly more sensitive during Coriolis stimulation, which was not statistically different from men, the author noted that this might have been due to the influence of the selection process, in which sensitive women might not choose to volunteer for this sort of experiment (Woodman & Griffin, 1997).

A recent study conducted in our laboratory replicated the findings that women report a greater history of MS than men, when interrogated with MS

history questionnaires (Flanagan, May & Dobie, 2005). In these analyses, we also examined the hypothesis that those reporting that they are prone to MS are less likely to volunteer for MS provocative experiments than those who are MS resistant. We found that MS prone individuals were actually more likely to volunteer for motion experiments if they felt they might benefit from such experience. Using a subset of these participants, men and women were exposed, during two separate sessions, to visually-elicited apparent motion, with and without voluntary head motion (pseudo-Coriolis stimulation). Results of this study revealed women reported significantly more MS during and after exposure to either condition, but they exhibited less tolerance with head movements, than with head restriction. These results indicate that laboratory manipulations that are more provocative of MS and measures of tolerance to provocative stimulation reveal reliable sex differences. However, this study failed to address the possible influence of the female menstrual cycle, which may contribute to sex differences elicited in measures of MS.

Grunfeld and colleagues conducted investigations into the relationship between the female menstrual cycle and episodes of MS (Grunfeld, et al., 1998; Grunfeld & Gresty, 1998). While they found decreased MS during ovulation, days 13-15 of the menstrual cycle in women participating in an around the world yacht race, they neglected to look at fluctuations in reporting of other somatic complaints which might also have varied across the course of the menstrual cycle, without the contribution of a dynamic motion environment.

However, studies conducted by Cheung and colleagues (Cheung & Hofer, 2002; Cheung, Heskin, Hofer & Gagnon, 2001) failed to find significant differences in the incidence of symptomatology in women as a function of the phase of their menstrual cycle. One of their studies found these differences to be related to participants' level of anxiety upon stimulation (Cheung, Heskin, Hofer & Gagnon, 2001). These findings may be compromised by underlying symptoms of the female menstrual cycle, the severity of which have been found to wax and wane over its normal monthly course (Brooks-Gunn & Ruble, 1992; Woods, 1999). Most women report changes in both their bodies and their moods that seem to vary with the course of their menstrual cycle. These changes are often considered a normal part of being a woman (Woods, et al, 1987). A substantial body of literature supports the existence of such menstrual cycle fluctuations (Palmer, Lambert & Richards, 1991; Sveinsdotter & Backstrom, 2000). While an abundant amount of research has been conducted upon these types of symptoms within samples from clinical populations (i.e., Premenstrual Syndrome and Premenstrual Dysmorphic Disorder), manifestations of less severe fluctuations which occur in non-clinical populations that do not suffer from debilitating symptoms and who do not seek treatment for these cyclical changes, is of more interest to the area of research of motion perception as they may be implicated in the reporting of MS.

These studies underscore the need to clarify the factors contributing to sex differences in MS. Questions remain as to whether these findings are attributable to physiological factors, such as menstrual phases, to reporting

characteristics, such as frequency of somatic complaints, or to a combination of these factors.

Postural Stability

Sex differences have also been described in reference to gross motor skills, such as postural stability. Studies conducted in our laboratory have replicated many previous research investigations, in revealing a higher incidence of postural instability (PI), both in men and women, during exposure to visually elicited apparent motion compared to static scenes (Bles & Kapteyn, 1977; Bronstein, 1986; Cobb & Nichols, 1998; Diener, Horak & Nashner, 1988; Guerraz, Sakellari, Burchill & Bronstein, 2000; Kapteyn & Bles 1977; Previc, 1992; Reason, Wagner & Dewhurst, 1981; Reinhardt-Rutland, 1981; White, Post & Leibowitz, 1980). This difference was also found to be exacerbated when the base of support was unstable (Flanagan, May & Dobie, 2004a; Flanagan, May & Dobie, 2004b; Stoffregen, Bardy, Merhi & Ouillier, 1994). Furthermore, PI has been found to be greater on motion platforms when visual information about the relative motion of platform and the static world is removed (Dobie, May & Flanagan, 2003). However, these studies failed to address the factor of sex as possibly contributing to these postural measures. While other researchers have reported another difference in posture having to do with men and women exposed to similar types of dynamic motion environments, these differences have been traditionally discussed in terms of physical sex differences having to do with body type (i.e., height, weight, muscle tone) (Larsen, et al, 1998; Lyons,

1992). In addition, some studies have failed to find significant sex differences in PI, even in posturally challenging environments (Owen, Leadbetter & Yardley, 1998). However, this study failed to look at the factor of hormonal fluctuations which might be another important factor influencing the data.

Recent research conducted by Fridén, et al (2003) suggests that postural differences such as these may be linked to hormonal fluctuations, which co-occur with phases of the female menstrual cycle. Their study measured balance in 13 healthy women at three times during two concurrent menstrual cycles. They first tested participants during the early follicular phase, day 3-5 of their cycle. The second test occurred during the ovulatory phase, detected by luteinizing hormone surge identified in blood samples (around day 11-14 of their cycle). The final test session was during the mid-luteal phase, seven days after each participant's ovulatory phase. Postural sway was measured in terms of ankle disc movement recorded while balancing on the dominant leg, and knee-joint kinesthesia in terms of reported perception of exogenous knee flexion/extension while blindfolded. In addition, these researchers also measured ratings of premenstrual syndrome by way of a Cyclicity Diagnoser scale (consisting of mood, somatic, social, and occupational parameters), which was completed every day throughout the experimental period. These symptoms were examined for an increase in at least 3 negative symptoms during 9 premenstrual days as compared to 9 mid-follicular days. As may be expected, this study revealed an increased incidence of physical symptoms in participants, particularly during the

permenstrual phase (early follicular phase) and premenstrual phase (mid-luteal phase).

Of interest however, this study found that balance measures revealed both significantly higher levels of postural sway as well as knee-joint kinesthesia in women classified as having premenstrual syndrome (Fridén, et al, 2003). There was also an effect of phase elicited upon PI, with an increase in postural sway during the early follicular period, for both women with and without premenstrual syndrome, as well as an interaction of phase with premenstrual syndrome classification, with the highest levels of postural sway found with premenstrual syndrome subjects during the mid-luteal phase. These findings were discussed by the researchers in terms of the positive relationship between levels of estrogen and postural stability measures in women. However, the sequence of their experimental sessions was not counterbalanced. Therefore, these data may be compromised, as there may be an influence of motor learning upon this measure.

In addition, as mentioned previously, research in sports medicine has also revealed significant sex differences in the rates of sports related injuries, with women sustaining far more knee injuries than men (Hewett, 2000). Studies have implicated female reproductive hormones, such as estrogen, as influencing the female neuromuscular system (Chandy & Grana, 1985; Huston & Wojtys, 1996; Zelisko, Noble & Porter, 1982; Haycock & Gillette, 1976). Levels of estrogen have been found to be positively related to muscle fatigue, as well as negatively related to ligament strength and speed of muscle relaxation (Booth & Tipton,

1970; Sarwar, Beltran & Rutherford, 1996). Estrogen exerts it's influence on neuromuscular systems indirectly via its effects on sport performance (Lebrun, 1994; Lebrun, 1993), with decreased skill performance found in women during the mid-luteal phase (Posthuma, et al, 1987) and decreased injury rates during the permenstrual phase (Wojtys, et al, 1998; Myklebust, et al, 1998). By stabilizing reproductive hormone levels to prevent the ovulatory surge, findings such as these appear to diminish when oral contraceptives are utilized (Moller-Nielson J, Hammar, 1989; Moller-Nielson J, Hammar, 1991). These studies have vast implications to the influence of hormonal fluctuation upon other measures of PI.

There are a number of factors that have yet to be addressed in the area of PI. For instance, endocrine studies have not addressed the issue of postural response to additional challenges, such as dynamic or virtual motion environments. In addition, kinesiology studies that have utilized virtual motion environments have similarly failed to address the factor of hormonal fluctuations, which may also be instrumental in behavioral responses, such as PI. Once again, these studies underscore the need to clarify the factors contributing to sex differences in PI. Again, questions remain as to whether these findings are attributable to menstrual phases, body type, or to a combination of these factors.

Experimental Rationale

The intent of this investigation was to determine whether exposure to virtual motion environments, during various phases of the menstrual cycle

(premenstrual, permenstrual, ovulation) would reveal sex differences in postural stability and MS during some phases, but not others. Two experiments were conducted to assess these postulates. The first experiment looked at baseline symptoms of discomfort, removed from specific motion exposure. This study involved men and women asked to fill out daily living logs for a period of 40 days, in order to provide a baseline for any symptoms later elicited upon exposure to motion related activity. In addition, this study examined both the sex of the participant and phase (premenstrual, permenstrual, ovulation) differences in these data. The second experiment looked at the influence of sex and phase upon postural and symptom measures in response to exposure to visually depicted motion stimulation within the laboratory environment. This experiment involved asking male and female participants to view a rotating Archimede's spiral for a maximum duration of twenty minutes. Exposures were timed to place each woman in each of the three previously mentioned phases of her menstrual cycle (the men exposed by yoking their exposure time to a female counterpart) as the factors of sex and phase were examined in reference to their effects upon various measures of motion perception. The results of this investigation will reveal whether previous experimental attempts to support reported sex differences in MS and PI are dependent upon what phase of the menstrual cycle women are experiencing when exposed to provocative motion stimulation.

CHAPTER II: METHODS

Experiment 1

The aim of this study was to gather information that might be useful in generating answers to questions regarding the relationship between sex and phase of the female menstrual cycle and different aspects of daily living, specifically daily activities, feelings of wellness and discomfort, and consumption habits. We utilized Daily Living Logs (DLL's) to attempt to determine if fluctuations in these three factors varied as a function of sex and phase of the menstrual cycle.

Participants

24 university students served as participants. Men and women ages 18-40 years were included. This population was used because it was representative of the young adult population, within their reproductive phase of life, which we wished to study. Effect sizes from previous studies were computed to determine the minimum sample size necessary to produce a significant effect with a power of 0.80 (Keppel, 1991). However, these effect sizes were viewed as conservative estimates of the variability in DLL responses that were expected in participants in the proposed investigation. The sample number proposed was based upon the results of a study conducted by Dobie et al. (2001), which indicated significant sex differences in motion sickness history in both youth and young adult populations, with F (1, 437) = 31.83, $p < 0.0001$, and an effect size

computed as 0.210 for the youth population, and F (1, 475) = 6.91, $p < 0.009$, and an effect size computed as 0.130. The proposed investigation involved repeated measures of symptoms of distress, which was hypothesized to elicit a stronger effect than that elicited by a single sample from a given population.

Access to population was gained through undergraduate classes at UNO. Participation was limited to classes whose instructors allow extra credit for participation. Consent for callback was obtained from a brief medical questionnaire (see Appendix) completed by the subject through his or her undergraduate course. Participation in this experiment was limited to those students who report no history of visual or vestibular impairments, epilepsy, current pregnancy, or recent illness, and were in their usual state of health according to self-report on the medical history questionnaire. Consent (see Appendix) was obtained from each participant immediately prior to the onset of his or her participation in the study. Approval for this portion of the study was obtained from the University of New Orleans' All University Committee on the Use of Human Subjects (see Appendix).

General Experimental Procedures

The initial phase of this experiment utilized a brief medical questionnaire (see Appendix) to select a sample of self-reported healthy subjects. Those healthy individuals interested in participating further were then invited to take part in the second phase of the study. Consent was obtained from each participant with the appropriate written consent form (see Appendix) prior to beginning the

second phase of the study, in which they were asked to complete a series of DLL's (see Appendix) each day, over the course of the following calendar month.

DLL's were used for participants to indicate certain aspects of their activities of daily living, once a day for the following forty days. The DLL's consisted of three parts, the first part an activities checklist; the second part, a consumption checklist; the third part, a symptom checklist. The design of the DLL's was based upon previous studies conducted by Dobie, et al (2001), looking at variables such as activities and motion sickness history in student populations, and a study by Weller and Weller (2002), which investigated symptoms of discomfort related to the female menstrual cycle. Students were instructed to return the completed forms to the project director every day, by submitting a paper log in person on a daily basis, or by completing and submitting their logs online. The online questionnaires were posted on our laboratory website, and interested students were instructed how to utilize this means of participation. The results of each online questionnaire submitted were then forwarded to our laboratory's email account on a daily basis. Responses were submitted under the heading of a code, which the participants individually selected in the laboratory, and were confidential. The importance of timeliness was emphasized to each of the participants, in addition to the fact that they could withdraw their consent and halt their participation in this study at any time, if they should so request. Participants were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992).

A 3 x 2 x 3 factorial, mixed repeated measures design was used. The first independent variable, a within subjects variable, was phase of the month (phase/trial). Responses of both men and women were grouped into three sections. The sorting of these three samples was related to specific phases of the female menstrual cycle, consisting of: early follicular phase (eFP); ovulatory phase (OP); mid-luteal phase (mLP). The exact timing of these was based upon the average length of the female menstrual cycle (28 days), and the average time during which these three phases tend to occur. For example, eFP was established between days 2-5, OP was set between days 11-14, and mLP encompassed days 18-21 of cycle (Fridén, et al, 2003; Grunfeld, et al, 1998; Grunfeld & Gresty, 1998; Neal, 2002). Female participants' menstrual cycles were normalized to the 28 day cycle, and the sampling periods were taken based upon these normalized cycles. The responses from the male participants were grouped by yoking their data to a female counterpart [i.e., yoked to eFP of matched female (~ eFP); yoked to OP of matched female (~ OP); yoked to mLP of matched female (~ mLP)].

The second independent variable, a between subject factor, was the sex group of the participants (either male or female). The final independent variable, a within subjects factor, was sequence. Participants completed the DLL's at three different times of their cycle, with some completing the DLL's first during eFP/~eFP (sequence 1), some during OP/~OP (sequence 2), and some beginning during mLP/~mLP (sequence 3).

Three dependent variables were measured: sum of the activities checklist; sum of the consumption checklist; and sum of the daily symptom checklist (see Table 1 below). However, the main variable of interest was the symptom checklist, to examine how MS symptoms changed over the cycle to determine how much contamination occurred in MS measures in the following experiment.

Table 1. Experiment 1: Dependent Measures

	Variable Measures
Daily Activities	Sum of Activities Checklist
Daily Consumption	Sum of Consumption Checklist
Daily Symptoms	Sum of Symptom Checklist

Experimental Hypotheses

1. A significant main effect of sex of the individual [sex group] upon all three DLL measures;
2. A significant main effect of phase of the menstrual cycle [phase/trial] upon all three DLL measures in the group of women alone;

3. A significant interaction effect of sex group and phase/trial upon all three DLL measures; and
4. No significant effect of sequence upon any of the three DLL measures.

Experiment 2

The aim of this study was to gather information that might be useful in generating answers to questions regarding the relationship between phases of the female menstrual cycle, posture, and feelings of well being.

Participants

24 university students (6 men) served as participants. Men and women ages 18-30 were included. This population was used because it was representative of the young adult population within their reproductive phase of life, which we wished to study. Effect sizes of previous studies have been computed to determine the minimum sample size necessary to produce a significant effect with a power of 0.80 (Keppel, 1991). However, these effect sizes were viewed as conservative estimates of the variability in MS and PI responses that might be expected in participants in the proposed investigation. The sample number proposed was based upon the results of three studies: a study conducted by Flanagan, et al. (2004a), which indicated significant differences in PI and MS in a sample of 8 young adults exposed to visual motion stimulation, with F (1, 8) = 13.33, $p < 0.01$, with an effect size computed as 0.743 (see Figure 1), and with F (2, 7) = 40.57, $p < 0.001$, with an effect size computed

as 0.903 for MS; a study conducted by Grunfeld, et al (1998), which found a significant effect of sex and menstrual phase upon MS in women exposed to prolonged periods of ship motion, with F (2, 15) = 50.38, $p < 0.001$, with an effect size computed as 0.870; and a study conducted by Fridén, et al (2003), which indicated a significant effect of menstrual phases upon symptoms of discomfort and PI measures in a sample of 8 women. The current study involved repeated measures of symptoms of distress, MS, and PI, which were hypothesized to elicit a stronger effect than those elicited by a single sample from a given population.

Access to population was again gained through undergraduate classes at UNO. Participation was limited to classes whose instructors allow extra credit for participation. Consent for callback was obtained from a brief medical questionnaire (see Appendix) completed by the subject through his or her undergraduate course. Participation in this experiment was similarly limited to those students who reported no history of visual or vestibular impairments, epilepsy, current pregnancy, or recent illness, and were in their usual state of health according to self-report on the medical history questionnaire. In addition, female participants were also restricted to those reporting normal menstrual cycles, and those not currently taking any form of hormonal contraceptive within three months of their participation in this study. Consent (see Appendix) was obtained from each participant immediately prior to the onset of his or her participation in the study. These participants were also asked to refrain from consuming alcoholic beverages or taking medications for the 24-hour period preceding the experiment. In addition, subjects were asked to reschedule their

session within a three day period, if they felt that they were not in their usual state of fitness. Once again, all information was confidential and participants were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992). Approval for this portion of the study was obtained from the University of New Orleans' All University Committee on the Use of Human Subjects (see Appendix).

General Experimental Procedures

After obtaining informed consent, height (cm) and weight (kg) of subjects were measured and recorded as possible covariates. Subjects were asked to participate barefoot and to wear a safety helmet during each session.

A 3 x 2 x 3 factorial, mixed repeated measures design was used. Participants were instructed to stand between a pair of handlebars with their feet 30.5 cm apart, at a distance of 45.75 cm from a viewing screen with both feet firmly planted on the floor. Participants were instructed to look towards this screen, upon which an image of a rotating spiral was rear projected, and to stand in an upright posture during all experimental conditions, but to grab the handlebars if they began to feel unsteady. The image projected, which was viewed binocularly, consisted of alternating light and dark spirals (with luminance values of 1.2 and 5.7 candles per meter squared, and a contrast value of 38%) projected onto the viewing screen, an Archimede's spiral rotating at 10 rpm, subtended 95° of visual angle presented for a maximum duration of twenty minutes.

The first independent variable, a within subjects variable, was testing phase/trial. Both men and women were tested three times. The timing of these sessions was related to specific phases of the female menstrual cycle. Exposures were timed to place each woman in specific phases of her menstrual cycle. These consisted of: early follicular phase (eFP); ovulatory phase (OP); mid-luteal phase (mLP).

Once again, the exact timing of these sessions was based upon the average length of the female menstrual cycle (28 days), and the average time during which these three phases tend to occur. For example, eFP was established between days 2-5, OP was set between days 11-14, and mLP encompassed days 18-21 of cycle (Fridén, et al, 2003; Grunfeld, et al, 1998; Grunfeld & Gresty, 1998; Neal, 2002). Female participants' menstrual cycles were normalized to the 28 day cycle, and the sampling periods were taken based upon these normalized cycles. Men were exposed to the provocative stimulus by yoking their exposure time to a female counterpart [i.e., yoked to eFP of matched female (~ eFP); yoked to OP of matched female (~ OP); yoked to mLP of matched female (~ mLP)].

The timing of each of the three phases of female participants' menstrual cycles were estimated for the purpose of scheduling each of their experimental sessions. As mentioned previously, these sessions were scheduled to expose women to the motion stimulus during: menstruation (2 to 5 days after the onset of their cycle); ovulation (13 to 15 days prior to the predicted onset of their next cycle); and in the mid-luteal phase (6 to 8 days prior to the predicted onset of

their next cycle). The predicted onset dates were derived by the average lengths of each participant's last two cycles and projecting that average to the future cycle. The actual onset date was subsequently noted during the experimental sessions, with any modifications to future sessions being made in response to the new average length of the participant's menstrual cycle.

As mentioned previously, while reproductive hormones may be measured in a number of different manners of both sampling and processing methodology (Snowden & Ziegler, 2000), routine means of measuring hormone levels, such as via blood and urine samples, were not utilized because of the cost and inconvenience involved in this type of method of hormone assessment. Saliva sampling has been shown to have the advantages of being non-invasive, as well as easy to collect and handle, and been found to correlate well with free levels of circulating hormones. Estradiol, a hormone readily sampled through saliva, has been found to be a highly physiologically active form of estrogen readily available for analysis of estrogen levels in female subjects (Becker, et al, 2004; Gill, 1985).

In that estradiol may be easily measured by way of salivary hormone assessments (Ilya, McLure & Farhat, 1999; Vuorento & Huhtaniemi, 1992), which also has the attribute of being able to be conveniently stored for long periods of time in a cool environment, hormone levels were assessed in this manner, to confirm that sessions were testing female participants during the appropriate time of their menstrual cycle. Saliva samples were collected prior to each experimental session from each of the female participants. Saliva was collected by way of a passive drool method, which involved the women drooling saliva into

a 2.0 milliliter cryovial. These vials were subsequently stored in a –20°C freezer until data collection was complete. Saliva samples for the OP and mLP sessions were then transported in dry ice, to Salimetrics, LLC for analysis of salivary estradiol levels by enzyme immunoassay. Salimetrics reports the minimal concentration of estradiol that can be distinguished is 1.0 pg/mL; the magnitude of the saliva-serum correlation, r (18) =0.71, $p < 0.001$. These analyses were specific and sensitive to the low levels of hormones normally found in this type of sampling technique. Further data analysis was then limited to those women whose salivary estradiol analyses confirmed that they were tested at the appropriate time of their menstrual cycle.

The second and third independent variables, between subject factors, were sex group of the participants (men or women) and sequence of conditions. The sequence of exposure was partially counterbalanced across subjects (see Table 2 below). with a third of the participants experiencing their first session during eFP/~eFP (sequence 1), a third experiencing their first session during OP/~OP (sequence 2), and the remaining third experiencing their first session during mLP/~mLP (sequence 3).

Four dependent variables were measured simultaneously during each experimental session: illusory motion perception, head movement, body movement, and motion sickness (MS) (see Table 3 below). Prior to each session, subjects were instructed to stand with their eyes closed for five seconds, and then with their eyes open viewing a blank viewing screen for five seconds, while baseline measures of head movement, body movement, illusory motion

perception, and MS were recorded. Subjects were then instructed to close their eyes while the stimulus was being initiated, told to open their eyes with the onset of rotation of the Archimede's spiral.

Head movement was measured by way of an electromagnetic, six-degree-of-freedom, tracking device (3SPACE: InsideTRAK by Polhemus). A transmitter was placed on top of the participant's safety helmet, and a receiver placed 9.5 inches (24.13 cm) immediately above the subject's head. Signals indicative of

Table 2. Experiment 2: Partial Counterbalancing of Experimental Conditions

Sequence #	***Female Subjects***	***Male Subjects***	***1st***	***2nd***	***3rd***
1	E2W-4, E2W-7, E2W-10*****, E2W-13*****, E2W-16*****, E2W-23	*E2M-4, E2M-7*	eFP *~eFP*	OP *~OP*	mLP *~mLP*
2	E2W-2, E2W-5*****, E2W-11, E2W-14, E2W-17*****, E2W-21	*E2M-5, E2M-8*	OP *~OP*	mLP *~mLP*	eFP *~eFP*
3	E2W-3, E2W-12*****, E2W-15, E2W-18*****, E2W-19, E2W-24	*E2M-3, E2M-6*	mLP *~mLP*	eFP *~eFP*	OP *~OP*

eFP: early follicular phase

OP: ovulatory phase

mLP: mid luteal phase

~ eFP: yoked to eFP of matched female

~ OP: yoked to OP of matched female

~ mLP: yoked to mLP of matched female

***** Salivary Estradiol Levels Confirmed Timing of OP and mLP

displacement of the transmitter in reference to the receiver were relayed, collected, and recorded on a Base 386 computer. These measures were taken once every other minute for a duration of 8 seconds, at a sampling frequency of 50 Hz. Variance of linear movements of the participant's head (surge and sway) recorded over the course of each experimental session, and the latency to the onset of these two movements entailed four measures of head movement (see Table 3).

Body movement was measured by way of an AMTI AccuSway force plate platform (4.4 cm in height by 50 cm^2). Similar to head movement, these

Table 3. Experiment 2: Dependent Measures

	Variable Measures			
Illusory Motion Perception	Latency to onset of Illusory motion perception	Duration of Illusory motion perception	Magnitude of perceived surge	Magnitude of perceived sway
Head Movement	Variance of linear surge head movement		Variance of linear sway head movement	
Body Movement	Variance in center of pressure	Mean velocity of center of pressure	Length of sway path	Area of sway path
Motion Sickness (MS)	Tolerance for stimulation	Magnitude ratings of MS	Difference Score of Symptom Checklist	

measures were taken once every other minute for a duration of 8 seconds, at a sampling frequency of 50 Hz. Variance in center of pressure, mean velocity of center of pressure, length and area of sway path recorded over the course of each experimental session entailed four measures of body movement (see Table 3).

MS was measured by way of magnitude ratings (scale of 0 = none, to 10 = maximum) of feelings of motion sickness verbally obtained from the subject once every minute for the 20 minute maximum duration of each experimental session. This term was verbally described to the subjects by the experimenter as any feelings of discomfort. The maximum magnitude rating of motion sickness constituted one measure of MS. In addition, MS was also assessed by way of the amount of time the participant was willing to endure exposure to the experimental stimulus (tolerance time), as well as the difference score between the symptom checklist completed after minus the symptom checklist completed before the experimental session (see Table 3).

Experimental Hypotheses

1. A significant main effect of sex group upon all MS measures;
2. A significant main effect of phase/trial upon all MS measures in the group women alone;
3. A significant interaction effect of sex group and phase/trial upon all MS measures;
4. No significant effect of sequence upon any of the MS measures;

5. A significant main effect of sex group upon all PI measures;
6. A significant main effect of phase/trial upon all PI measures in the group of women alone;
7. A significant interaction of sex group and phase/trial upon all PI measures;
8. No significant effect of sequence upon any of the PI measures.

CHAPTER III: RESULTS

All analyses were performed using SPSS for Windows (version 11.5). The dependent variables were submitted to multivariate analysis of variance, as well as multiple analyses of variance separately conducted on each dependent variable, to determine any significant differences in DLL's, MS, or PI existing between the independent variables over the three experimental conditions. Tests subsequent to analysis of variance were employed as appropriate.

Experiment 1

A total of 80 individual participants submitted 1,608 DLL's (58 paper logs) over the course of the fall and spring semesters. The following analyses utilized data only from those surveys completed by the 32 participants (27 women) who completed a series of at least 40 DLL's. Table 4 shows a summary of some of the descriptive and demographic data regarding these participants.

As mentioned previously, DLL submissions were sorted into three phases, correlating with different periods of the female menstrual cycle. The exact timing of these were based upon the average length of the female menstrual cycle (28 days), and the average time during which these three phases tended to occur. Each female participant's menstrual cycle was normalized to the 28 day cycle, and the sampling periods were taken based upon the normalized cycle. For example, eFP was established between days 2-5, OP was set between days 11-14, and mLP encompassed days 18-21 of cycle (Fridén, et al, 2003; Grunfeld, et

al, 1998; Grunfeld & Gresty, 1998; Neal, 2002). The responses from the male participants were grouped by yoking their data to a female counterpart [i.e., yoked to eFP of matched female (~ eFP); yoked to OP of matched female (~ OP); yoked to mLP of matched female (~ mLP)]. In addition, as five of the female participants failed to indicate either menstrual cramping or bleeding on any of their 40 DLL's, these data were coded as a separate group, labeled Menses Not Specified (MNS), for the analyses of the entire group of participants (men, women and MNS), and were not used in the analysis of the group of women alone.

Table 4. Experiment 1: Descriptive Summary of Participants by Sex Group

		Women	**Women MNS**	**Men**
Sample Size	*N* (%)	22 (68.9)	5 (15.6)	5 (15.6)
Age	Mean (SD)	20.5 (3.5)	20.2 (2.5)	22.4 (4.8)
Race	*N* (%)			
	Asian	2 (9.1)	0	0
	Black	3 (13.6)	0	0
	Hispanic	1 (4.5)	5 (100)	5 (100)
	White	6 (72.7)	0	0
Sequence	*N* (%)			
1. eLP-OP-mLP		7 (31.8)	MNS	NA
2. OP-mLP-eLP		9 (40.9)		
3. mLP- eLP-OP		5 (22.7)		
Length Menstrual Cycle	Mean (SD)	28.2 (6.5)	MNS	NA

MNS : Menses Not Specified **NA:** Not Applicable

Data for each subject were reduced by generating the sum of each measure for the four day period that encompassed each of the three phases. In addition, the sum of the activity checklist excluded the number of hours spent sleeping, which was analyzed separately, as this was considered an indication of a more passive measure of lethargy, rather than activity. Therefore, a total of four measures were analyzed to evaluate any significant effects of sex group, phase/trial or sequence.

Daily Activities Checklist

Sum of the Daily Activity Data are shown in Table 5. Analysis of variance of the sum of the activities failed to reveal a significant main effect of sex group

Table 5. Experiment 1: Sum of Daily Activity Data (4 days)

Group	**Phase/Trial** Mean (SD)		
Women	**eFP/~eFP**	**OP/~OP**	**mLP/~mLP**
Menses Specified	69.2 (21.1)	68.9 (18.3)	73.3 (23.5)
Menses Not Specified	*76.6 (24.4)*	*70.2 (18.2)*	*75.6 (18.0)*
Men	*71.2 (21.2)*	*75.2 (18.3)*	*73.8 (12.5)*

Italicized scores based upon data from days 2-5, 11-14, 18-21, as these subjects made no report of menstrual bleeding, either because it was not specifically reported or it was not applicable.

or phase/trial, nor any significant interaction of these two variables. In addition, analyses also failed to reveal any significant effect of sequence, neither in women alone, nor in the entire participant group as a whole.

Sleep

Mean number of hours of sleep for the different experimental phases are shown in Table 6 below. Analyses for this measure were performed only for the data from the 30 participants who reported sleep data for all three phases. Analysis of variance of sleep failed to reveal a significant main effect of sex group, phase/trial or sequence, neither in women alone, nor in the entire participant group as a whole.

Table 6. Experiment 1: Mean Hours of Sleep (4 days)

Group	**Phase/Trial** Mean (SD)		
Women	**eFP/~eFP**	**OP/~OP**	**mLP/~mLP**
Menses Specified	6.93 (2.26)	7.04 (2.69)	7.44 (2.56)
Menses Not Specified	*6.25 (1.99)*	*6.65 (1.22)*	*7.10 (0.68)*
Men	*7.25 (2.26)*	*7.38 (1.58)*	*6.98 (2.07)*

Daily Consumption Checklist

Sum of the Daily Consumption Checklist for the different experimental phases are shown in Table 7 below. As Mauchly's test of sphericity of these data revealed a significant effect of phase/trials, for the entire group [Mauchly's W = 0.753, $p < 0.025$] as well as for women alone [Mauchly's W = 0.477, $p < 0.001$], the Greenhouse-Geisser factor was subsequently used to correct for this effect. However, analysis of variance of Daily Consumption data failed to reveal a significant main effect of sex group, phase/trials or sequence, neither in women alone, nor in the entire participant group as a whole.

Table 7. Experiment 1: Sum of Daily Consumption Data (4 days)

Group	**Phase/Trial** Mean (SD)		
Women	**eFP/~eFP**	**OP/~OP**	**mLP/~mLP**
Menses Specified	22.23 (25.7)	18.27 (18.8)	19.05 (22.2)
Menses Not Specified	*26.0 (37.5)*	*28.4 (38.6)*	*27.2 (47.6)*
Men	*14.2 (12.9)*	*15.0 (11.4)*	*13.4 (8.23)*

Daily Symptom Checklist

Sum of the Daily Symptom Checklist for the different experimental phases are shown in Table 8 below. Once again, as Mauchly's test of sphericity of these data revealed a significant effect of phase/trials, for the entire group [Mauchly's

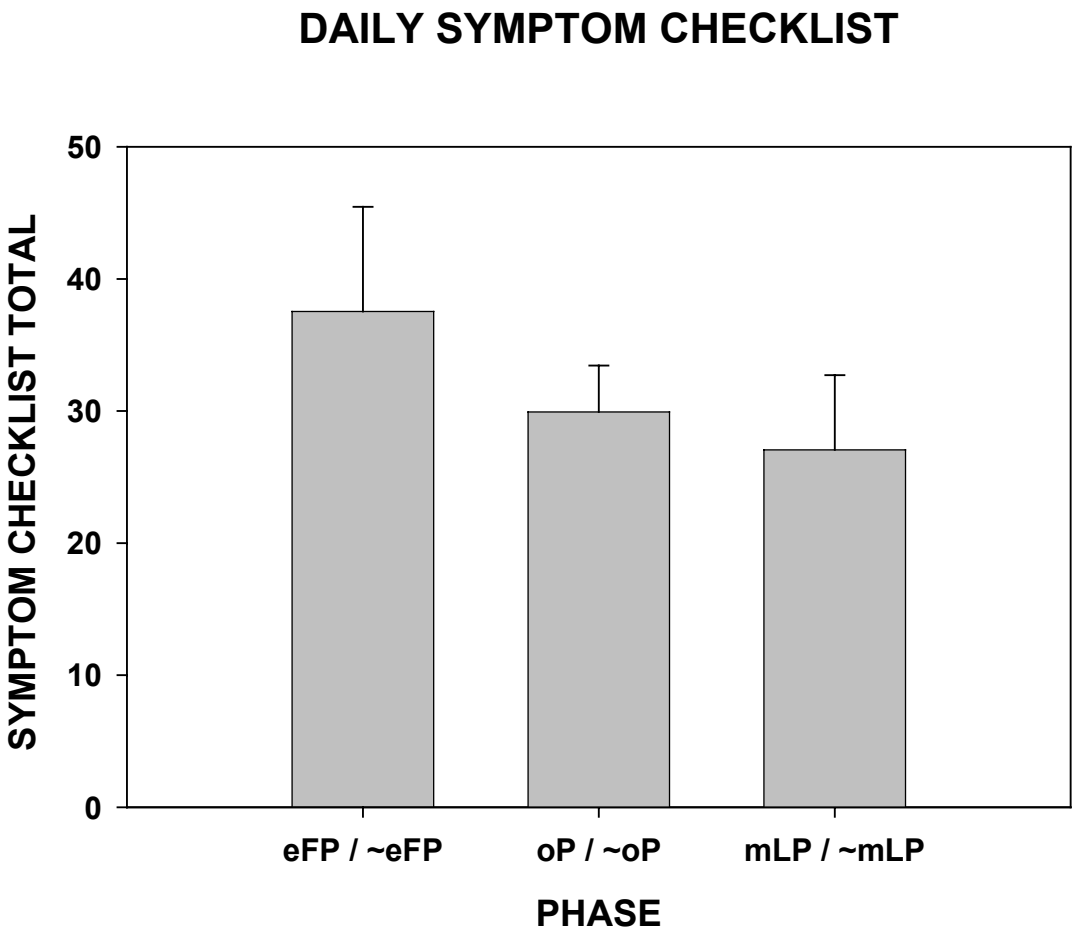
W = 0.606, p < 0.001] as well as for women alone [Mauchly's W = 0.531, p < 0.003], the Greenhouse-Geisser factor was subsequently used to correct for this effect. Analysis of variance of Daily Consumption data failed to reveal a significant main effect of sex or sequence, neither in women alone, nor in the entire participant group as a whole.

While there was not a statistically significant effect of phase upon this measure [*F* (2, 34.268) = 2.904, *p* < 0.090, eta 0.133, power 0.432], Figure 1 reveals greater amounts of symptomatology apparent in women during the eFP/~eFP phase as opposed to the oP and mLP phase conditions. These findings indicate that this analysis might be able to attain levels of significance with a larger sample size.

Table 8. Experiment 1: Sum of Daily Symptom Data (4 days)

Group	**Phase/Trial** Mean (SD)		
Women	**eFP/~eFP**	**OP/~OP**	**mLP/~mLP**
Menses Specified	53.2 (38.0)	37.0 (33.9)	38.4 (27.7)
Menses Not Specified	*31.4 (10.6)*	*26.4 (8.47)*	*21.8 (13.5)*
Men	*28.0 (14.7)*	*26.4 (10.0)*	*21.0 (8.28)*

Figure 1. Sum of four day periods of daily symptom ratings of female participants plotted as a function of phase of the female menstrual cycle. In this and subsequent figures, vertical error bars represent 1± SE.



Experiment 2

Of the thirty-two individuals (eight men) who began participation in the second portion of this study, only 24 subjects (6 men) completed all three experimental sessions. Once again, these sessions were partially counterbalanced to control for an effect of sequence (see Table 2 discussed previously). All measures of each of the dependent variables (see Table 3

discussed previously) underwent Analyses of Variance. These data were sorted into three groups based upon two factors: sex and salivary estradiol levels. One group consisted of all 6 male participants; a second group was limited to those female subjects whose salivary estradiol levels confirmed that they were tested during the appropriate time of their menstrual cycle, to test during OP and mLP [group of women with phases confirmed (C)], and the third group consisted of those female subjects whose salivary estradiol levels failed to confirm that they were tested during the appropriate time of their menstrual cycle [group of women with phases unconfirmed (U)].

Examination of the results of salivary estradiol samples revealed that only seven of the eighteen women had hormone levels confirming that they were in fact tested at the appropriate time to sample the target phases of their menstrual cycles, with low levels of salivary estradiol during the mid-luteal phase, and higher levels during the ovulatory phase. See Table 9 for levels of salivary

Table 9. Experiment 2: Women Participants Salivary Estradiol Levels

Group	**Salivary Estradiol (pg/ml)** Mean (SD)	
Women	**OP/~OP**	**mLP/~mLP**
Phases Confirmed (C)	11.8 (4.50)	7.37 (3.63)
Phases Not Confirmed (U)	8.78 (2.53)	11.05 (1.66)
Samples Insufficient Or Contaminated	36.4 (53.9)	13.69 (6.70)

Table 10. Experiment 2: Summary Descriptive Data of Participants

		Women Phases Confirmed	**Women Phases Unconfirmed**	**Men**
Sample Size	*N*	7	11	6
Age	Mean (SD)	20.3 (1.98)	21.9 (3.91)	25.8 (7.52)
Height (cm)	Mean (SD)	165.4 (4.70)	162.5 (7.12)	180.9 (6.98)
Weight (kg)	Mean (SD)	66.8 (9.55)	62.2 (16.0)	84.72 (15.4)
Race	*N*			
	Asian	0	2	0
	Black	1	0	1
	Hispanic	1	1	0
	White	5	8	5
Sequence	*N*			
1. eLP-OP-mLP		3	3	2
2. OP-mLP-eLP		2	4	2
3. mLP-eLP-OP		2	4	2
Length Menstrual Cycle	Mean (SD)	27.2 (2.79)	29.6 (3.26)	NA

estradiol present in the female participants, and Table 10 for a summary of demographic data and group membership. Further analysis of the data was restricted to two groups: men and women with confirmed menstrual phases.

Lastly, as the results of Experiment 1 revealed no statistically significant effect of sex or phase upon any single dependent variable, there was no need subtract the influence of these variables from the data gathered in Experiment 2.

Illusory Motion Data

1. Latency Time

Latency times to the report of illusory motion are shown in Table 11. As Mauchly's test of sphericity of these data revealed a significant effect of repeated trials, for analysis of both groups [Mauchly's $W = 0.020$, $p < 0.001$], as well as for the analysis of the group of women with confirmed (C) phases alone [Mauchly's $W = 0.005$, $p < 0.001$], the Greenhouse-Geisser factor was subsequently used to correct for this effect. However, analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the group of women alone, nor between both groups of participants.

Table 11. Experiment 2: Illusory Motion Data: Latency to Onset of Illusory Motion

Group	**Latency to Onset of Illusory Motion (seconds)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	18.4 (5.7)	19.4 (7.2)	189.9 (168.4)
Men	*244.2 (191.3)*	*263.8 (188.5)*	*253.3 (189.8)*

2. Duration

Duration times of the report of illusory motion are shown in Table 12. Once again, as Mauchly's test of sphericity of these data revealed a significant effect of repeated trials, for analysis of both groups [Mauchly's W = 0.026, $p < 0.001$] as well as for the group of women alone [Mauchly's W = 0.008, $p < 0.001$], the Greenhouse-Geisser factor was subsequently used to correct for this effect. However, again, analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the group of women, nor of both groups of participants viewed together.

Table 12. Experiment 2: Illusory Motion Data: Duration of Illusory Motion

Group	**Duration of Illusory Motion (seconds)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	1181.6 (5.7)	1180.6 (7.2)	981.6 (166.9)
Men	*955.8 (191.3)*	*936.2 (188.5)*	*946.7 (189.8)*

3. Magnitude of Perceived Surge

Magnitude of perceived surge data are shown in Table 13. Mauchly's test of sphericity showed no significant effects of repeated measures on these measures, neither in the split analysis of the C group of women alone, nor in the

Table 13. Experiment 2: Illusory Motion Data: Magnitude of Perceived Surge

Group	Magnitude of Surge (0 to 10, none to maximum) Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)			
- maximum rating	5.14 (1.10)	4.29 (1.02)	4.00 (1.05)
- final rating	3.71 (1.02)	2.29 (0.81)	3.29 (1.17)
Men			
- maximum rating	*3.50 (0.99)*	*1.50 (0.81)*	*1.67 (0.84)*
- final rating	*1.00 (0.63)*	*1.17 (0.79)*	*0.67 (0.49)*

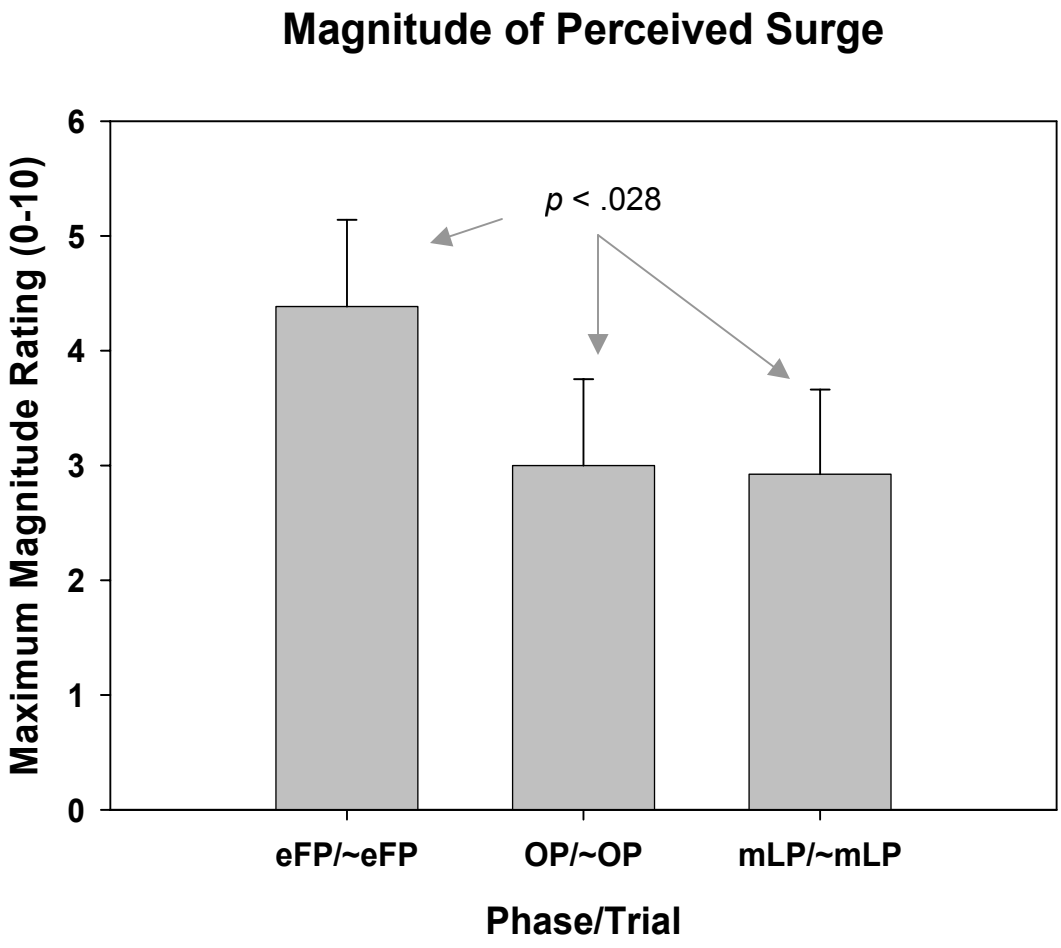
analysis of both groups of participants viewed together. Analysis of variance of these measures revealed a significant effect of phase/trials upon the measure of maximum magnitude rating of perceived surge [F (2, 14) = 4.020, p < 0.042, eta 0.365, power 0.618] within both groups of participants. Figure 2 shows the increased magnitude ratings of perceived surge elicited in during the initial period (eFP/~eFP) as compared to the two other phases. Post hoc analyses reveal these differences to lie specifically between the eFP/~eFP condition, and the other two phase/trial conditions, with Tukey's p < .028. .Analysis of this group of data failed to reveal any further effects of sex group or sequence.

While there was not a statistically significant main effect of phase/trials upon the measure of maximum magnitude rating of perceived surge in the analyses of women alone, the data appear to be approaching levels of

significance [F (2, 8) = 3.714,p < 0.072, eta 0.481, power 0.509]. Figure 3 shows the increased magnitude ratings of perceived surge elicited in women during the early follicular period as compared to the two other phases. Women report a stronger perception of forward/backwards motion when they are menstruating as opposed to the two other experimental phases.

In addition, while analysis of the women alone failed to reveal a significant main effect of sequence upon either of these measures, there was a significant

Figure 2. Maximum magnitude rating of perceived surge in both men and women plotted as a function of phase/trial.



interaction effect, of phase with sequence, upon the measure of maximum magnitude of perceived surge [F (4, 8) = 4.245, p < 0.039, eta 0.690, power 0.695]. Figure 4 shows menstruating women (eFP) encountering their first experimental session to perceive a significantly greater magnitude of surge as compared to women encountering their first session during their ovulatory (oP) or mid luteal phases (mLP). Post hoc analyses reveal these differences to lie between a number of factors (see significant Tukey's p values on Figure 4

Figure 3. Maximum magnitude rating of perceived surge in women plotted as a function of phase of the female menstrual cycle.

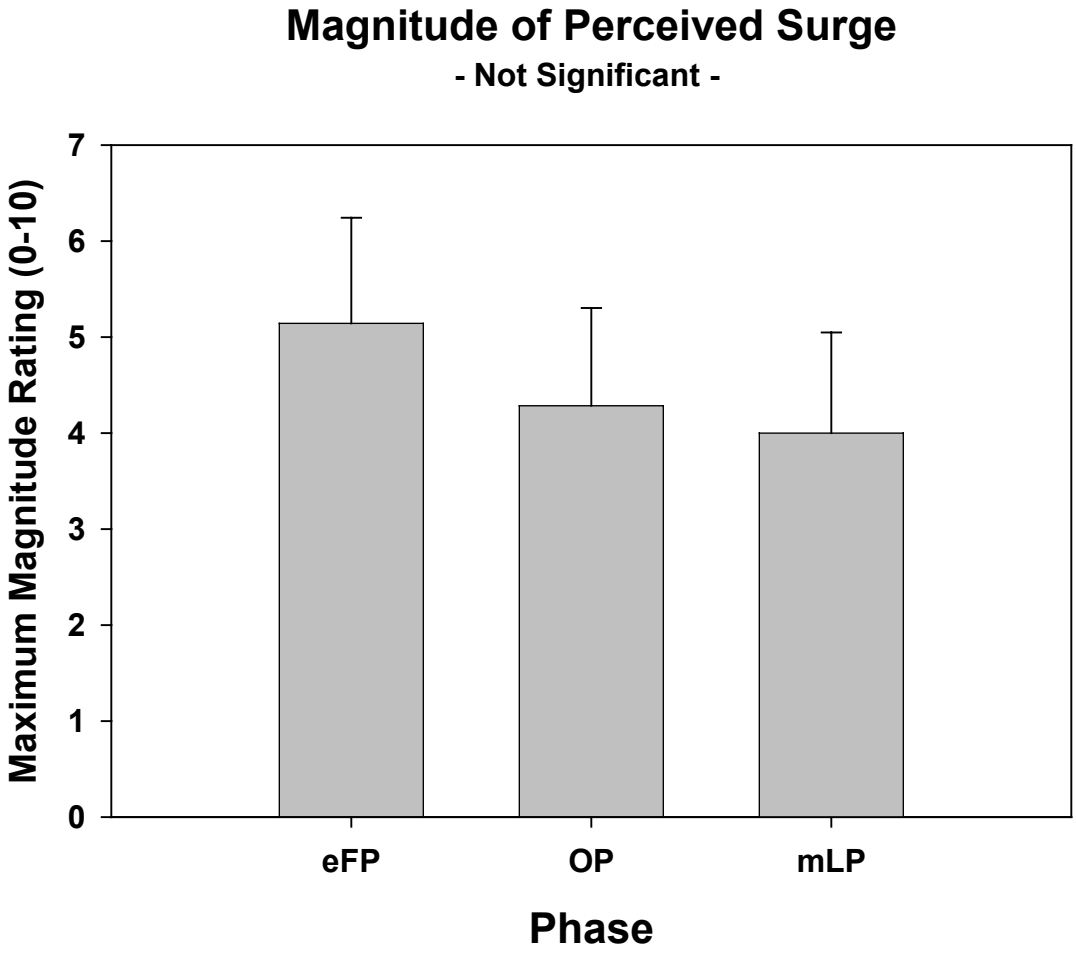
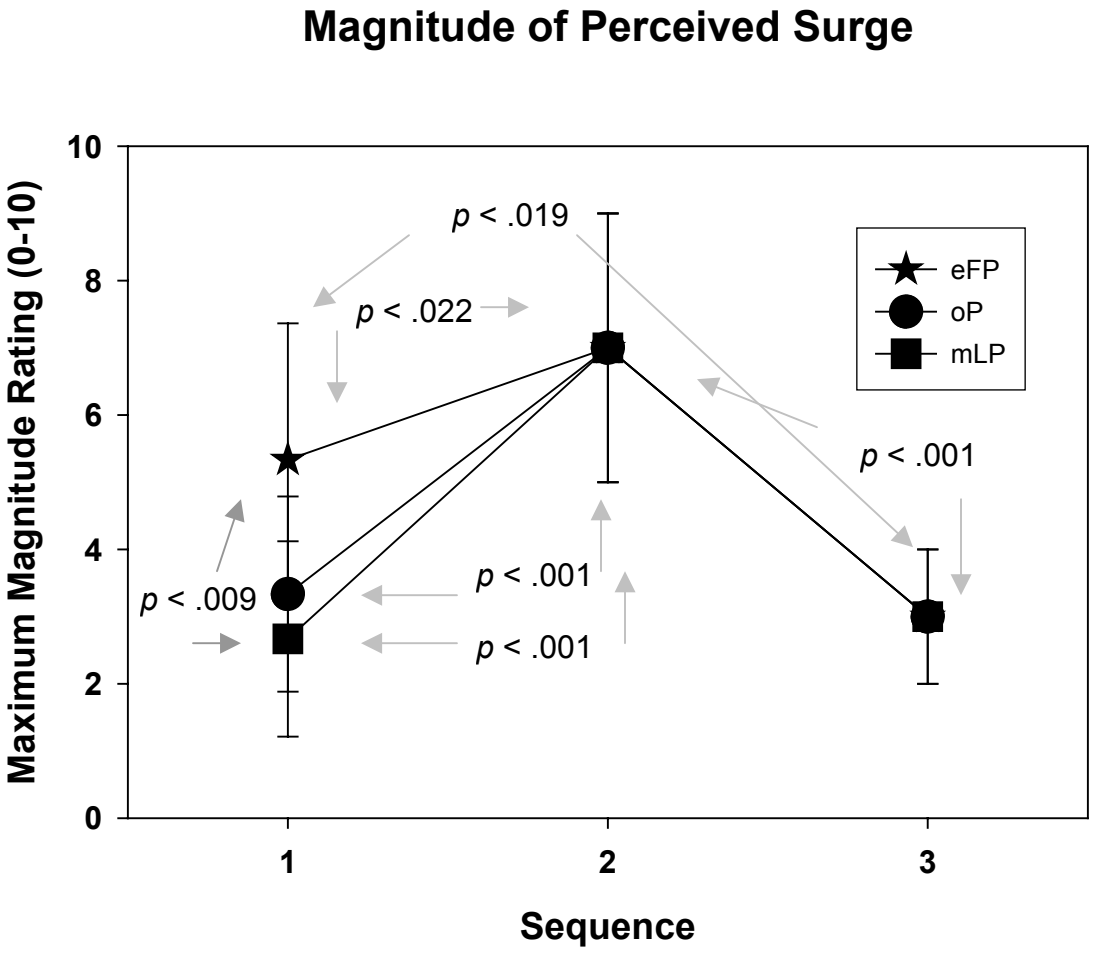


Figure 4. Maximum magnitude rating of perceived surge in women plotted as a function of sequence of experimental sessions and phase of the female menstrual cycle.



above). This figure elucidates how these differences appear to be focused upon the first sequence condition, not elicited with women encountering their second or third experimental sessions.

4. Magnitude of Perceived Sway

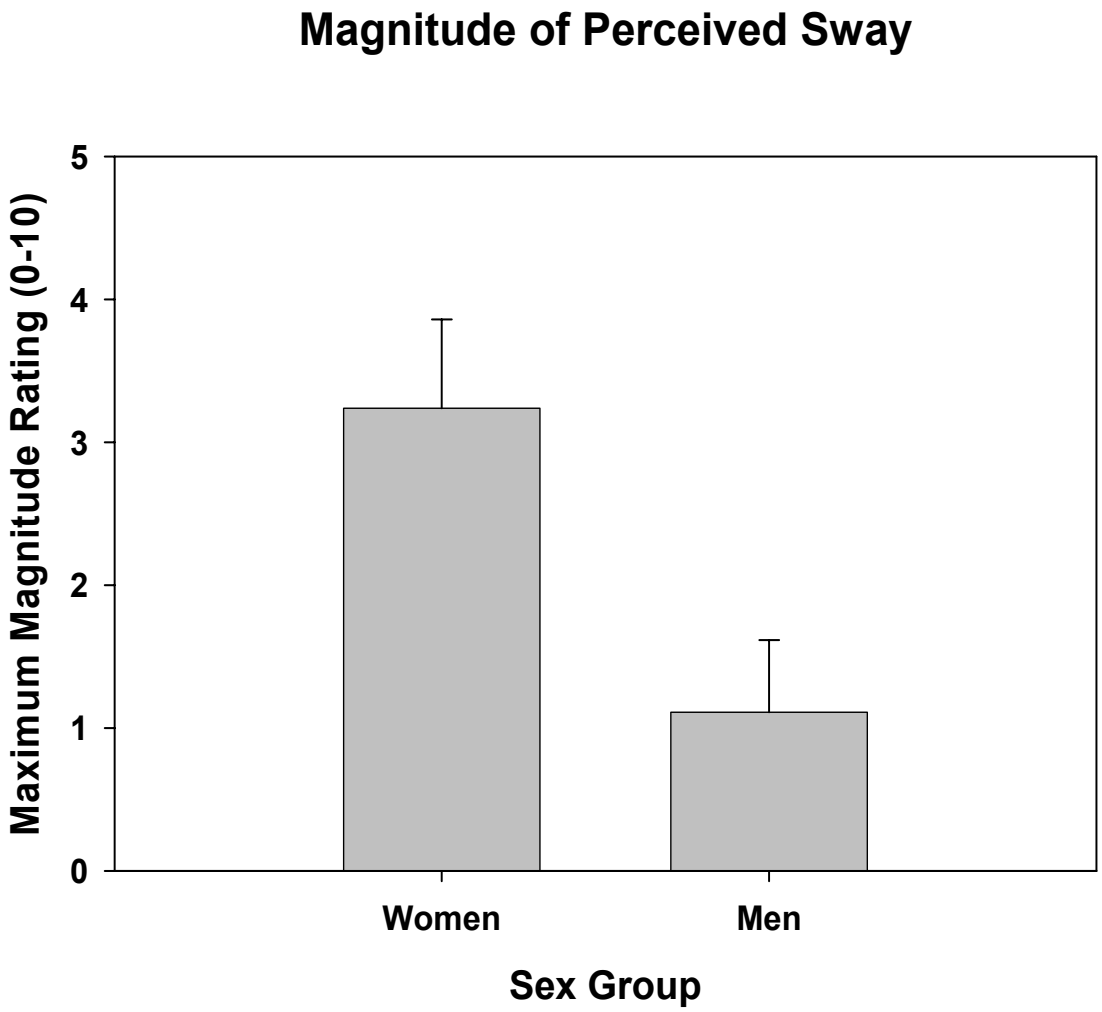
Magnitude of perceived sway data are shown in Table 14. Once again, Mauchly's test of sphericity revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Analysis of variance of this measure failed to reveal a significant main effect of phase/trial or sequence, nor any significant interaction of these variables, in analyses of the group of women alone. However, there were interesting findings revealed in the analyses of the data of both men and women viewed together.

Between subjects analysis of variance of the maximum measure of perceived sway revealed a significant main effect of sex group [F (1, 7) = 13.457,

Table 14. Experiment 2: Illusory Motion Data: Magnitude of Perceived Sway

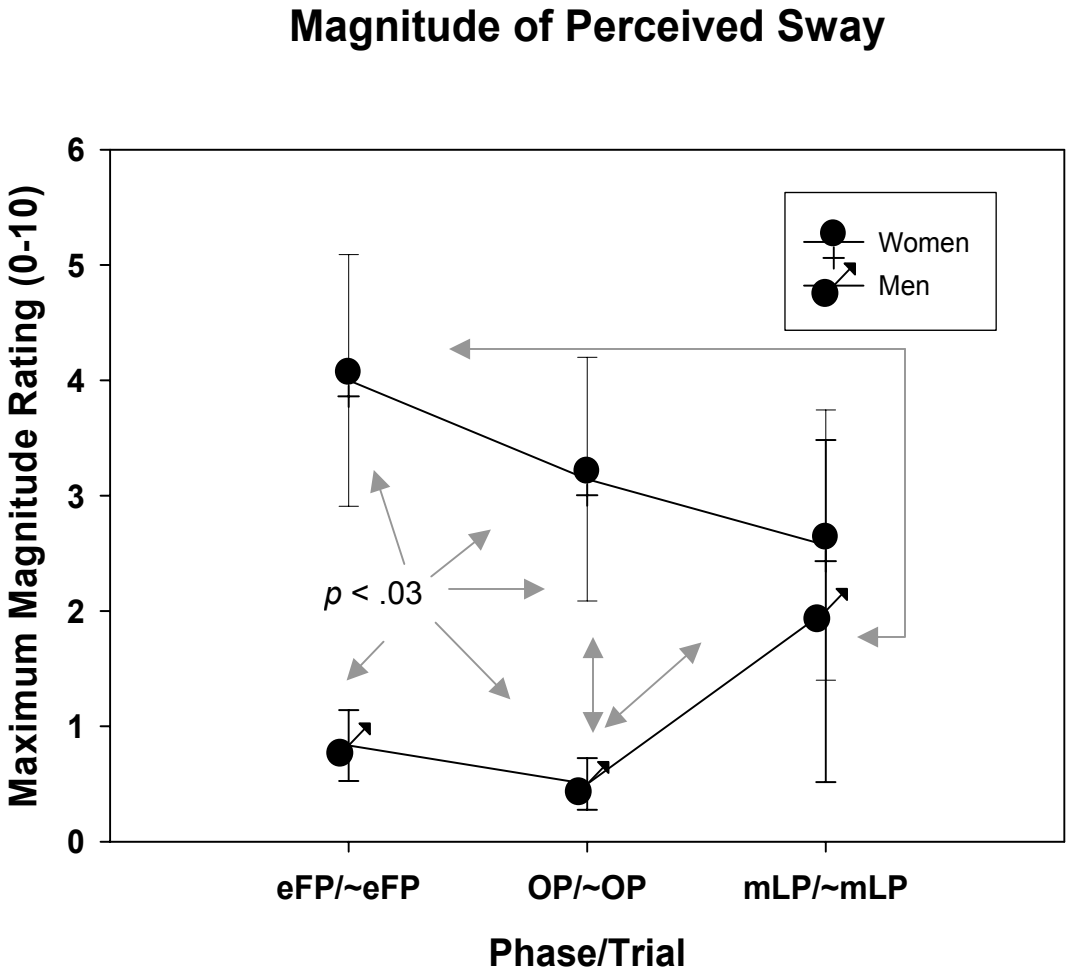
Group	**Magnitude of Sway (0 to 10, none to maximum)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)			
- maximum rating	4.00 (1.09)	3.14 (1.06)	2.57 (1.17)
- final rating	2.14 (0.77)	1.00 (0.44)	2.57 (1.17)
Men			
- maximum rating	*0.83 (0.31)*	*0.50 (0.22)*	*2.00 (1.48)*
- final rating	*0.17 (0.17)*	*0.17 (0.17)*	*0.00 (0.00)*

Figure 5. Maximum magnitude rating of perceived sway plotted as a function of sex group of participants.



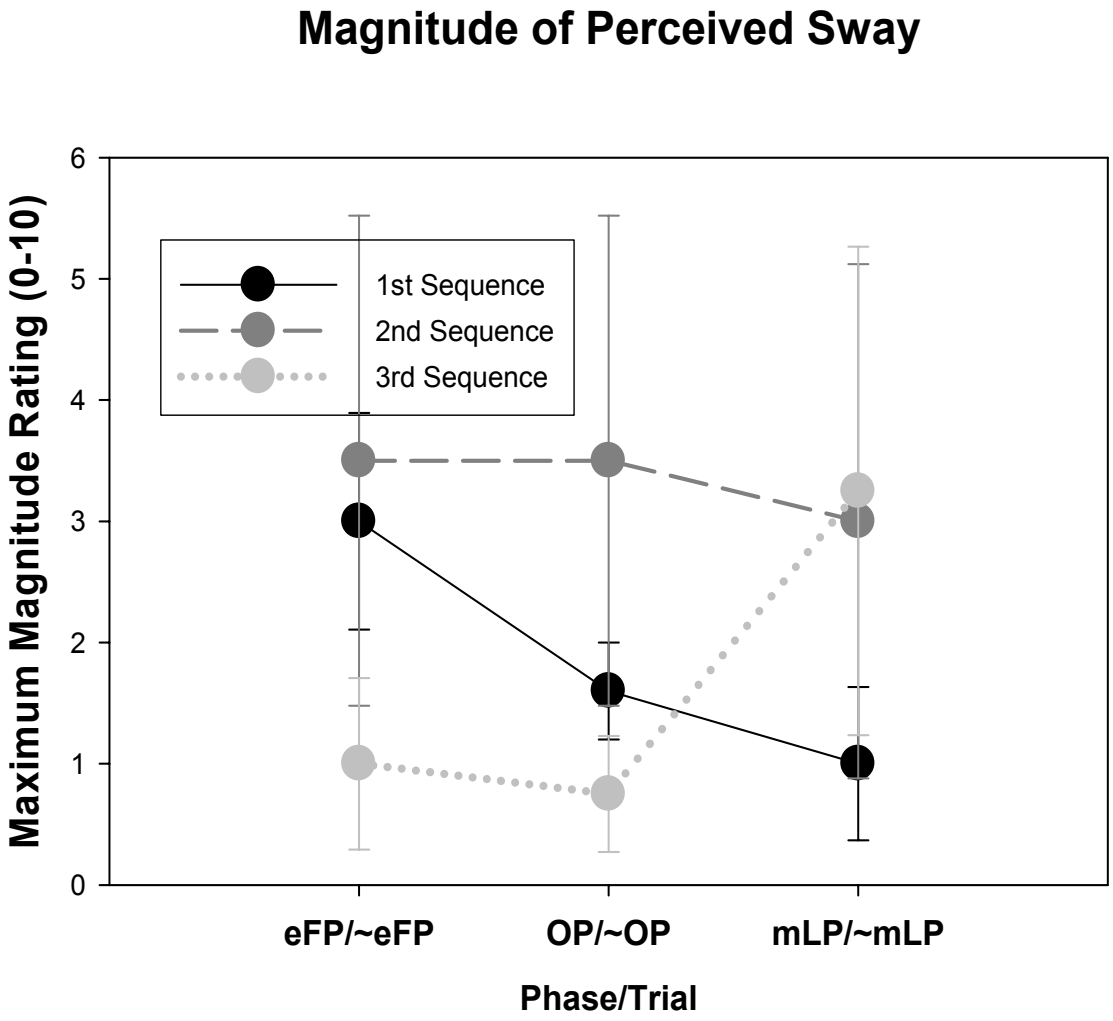
$p < 0.008$, eta 0.658, power 0.880]. Figure 5 shows the greatest levels of perceived sway to be reported in women as opposed to men. Additional interaction effects include significant sex group by trials interaction [F (2, 14) = 4.089, $p < 0.040$, eta 0.369, power 0.626], as well as sequence by trials [F (4, 14) = 4.198, $p < 0.019$, eta 0.545, power 0.803], and a significant three-way interaction of sex by sequence by trials [F (2, 14) = 3.995, $p < 0.023$, eta 0.533,

Figure 6. Maximum magnitude rating of perceived sway plotted as a function of phase/trial by sex group.



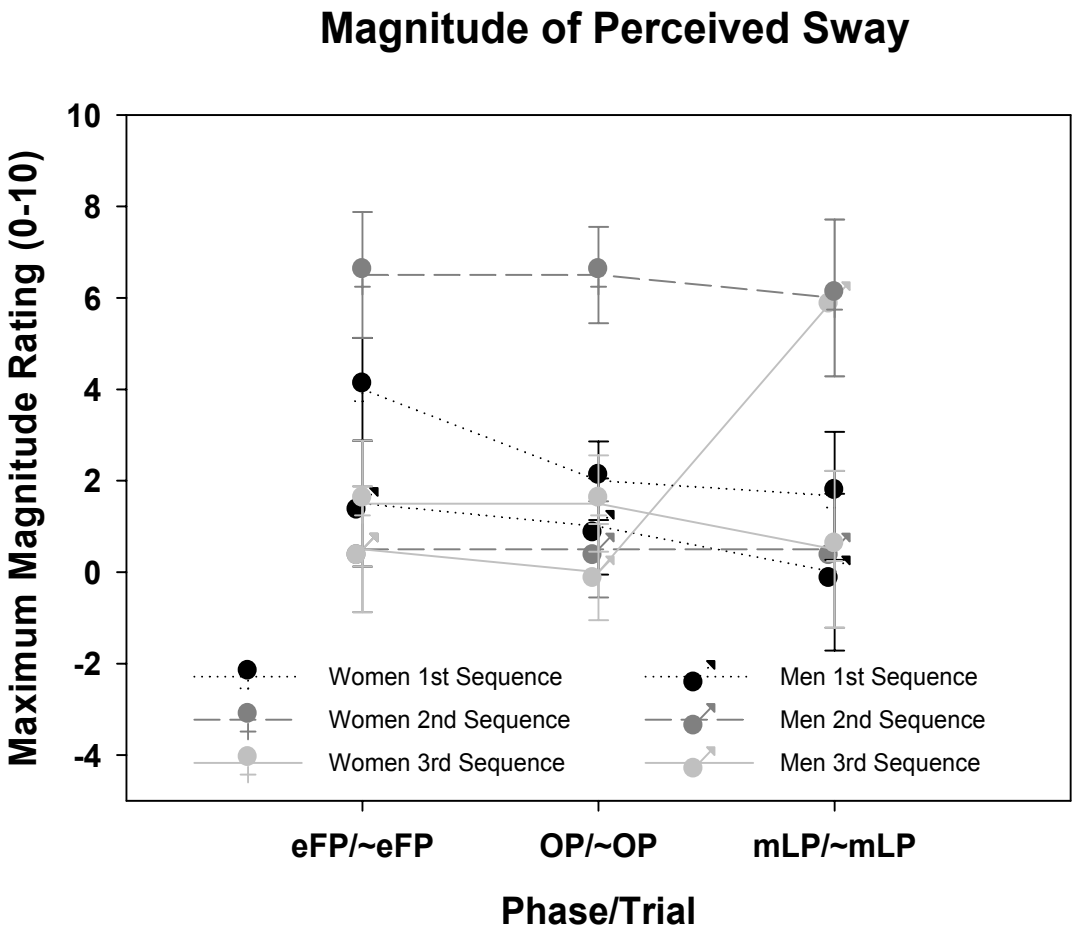
power 0.781]. Figure 6 illustrates the sex group by phase/trial interaction. Post hoc analyses reveal a number of significant differences (Tukey's $p < .03$) between many levels of these factors. The data reveal a steady decrease among the female participants across the phase conditions, which is absent in repeated trials within the male participants. Figure 7, which depicts the phase/trial by sequence interaction, shows a decrease in reported sway

Figure 7. Maximum magnitude rating of perceived sway plotted as a function of phase/trial by sequence of experimental sessions.



between the first and second sessions, among all sequence conditions regardless of which phase/trial participants are experiencing. Post hoc analyses reveal the significant differences to lie between the OP/~OP trials of the second and first sequence conditions (Tukey's $p < .05$), as well as eFP/~eFP of the second sequence condition and the OP/~OP of the first sequence condition (Tukey's $p < .05$). Figure 8, depicting the significant three way analysis,

Figure 8. Maximum magnitude rating of perceived sway plotted as a function of phase/trial by sex group and sequence of experimental sessions.



illustrates the largest magnitudes of perceived sway to be found with women during eFP or OP in the second sequence condition. Post hoc analyses reveal significant differences (Tukey's $p < .01$) between all phases of women in the second sequence condition and all other data (aside from eFP in the 1st sequence condition and mLP in the 3rd sequence condition). Post hoc analyses also find women in these two conditions data (eFP in the 1st sequence condition

and mLP in the 3rd sequence condition) to be significantly different from all the remaining data points (Tukey's $p < .01$).

Head Movement Data

1. Linear Surge

Linear surge head movement data are shown in Table 15. Mauchly's test of sphericity revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the group of women analyzed alone, nor between both groups of participants.

Table 15. Experiment 2: Head Movement Data: Linear Surge Head Movement

Group	**Variance of Linear Surge (cm)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	0.52 (0.29)	0.23 (0.13)	.003 (0.19)
Men	*0.62 (0.36)*	*-0.01 (0.46)*	*0.40 (0.36)*

Table 16. Experiment 2: Head Movement Data: Linear Sway Head Movement

Group	**Variance of Linear Sway (cm)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women w/Confirmed Phases	0.42 (1.08)	1.11 (0.62)	0.35 (0.98)
Men	*-0.02 (0.60)*	*0.62 (0.82)*	*1.01 (0.65)*

2. Linear Sway

Linear sway head movement data are shown in Table 16. Mauchly's test of sphericity again revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Once again, analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the women alone, nor with both men and women.

Body Movement Data

1. Variance in Center of Pressure

Variance in center of pressure data are shown in Table 17. Once again, Mauchly's test of sphericity revealed no significant effects of repeated measures

Table 17. Experiment 2: Body Movement Data: Center of Pressure (COP)

Group	**Variance of COP (cm)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	0.04 (0.009)	0.04 (0.007)	0.06 (0.01)
Men	*0.03 (0.004)*	*0.03 (0.003)*	*0.03 (0.004)*

upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the women alone, nor between both groups of participants.

2. Mean Velocity of Center of Pressure

Mean velocity in shift of center of pressure data are shown in Table 18. Mauchly's test of sphericity revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Once again, however, analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the group of women alone, nor between both groups of participants.

Table 18. Experiment 2: Body Movement Data: Mean Velocity of COP

Group	**Mean Velocity of COP (cm/sec)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	0.28 (0.04)	0.27 (0.03)	0.29 (0.05)
Men	*0.21 (0.012)*	*0.26 (0.06)*	*0.25 (0.06)*

3. Length of Sway Path

Mean length of sway path data are shown in Table 19. Mauchly's test of sphericity revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. However, again, analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any

Table 19. Experiment 2: Body Movement Data: Length of Sway Path

Group	**Length of Sway Path (cm)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	2.28 (0.35)	2.15 (0.27)	2.32 (0.36)
Men	*1.65 (0.08)*	*2.05 (0.46)*	*2.03 (0.45)*

Table 20. Experiment 2: Body Movement Data: Area of Sway Path

Group	**Area of Sway Path (cm^2)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	0.30 (0.11)	0.20 (0.07)	0.37 (0.20)
Men	*0.10 (0.03)*	*0.16 (0.05)*	*0.22 (0.09)*

significant interaction of these variables, in analyses of the women alone, nor in between male and female participants.

4. Area of Sway Path

Mean area of sway path data are shown in Table 20. Mauchly's test of sphericity revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. In addition, once again, analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables, in analyses of the women alone, nor with both men and women.

Motion Sickness Data

1. Tolerance

Tolerance time data are shown in Table 21. Mauchly's test of sphericity again revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Analysis of variance of these data failed to reveal a significant main effect of sex group or phase/trial, nor any significant interaction of these two variables. In addition, analyses also failed to reveal any significant effect of sequence, neither in analyses of the group of women alone, nor in the entire participant group as a whole.

Table 21. Experiment 2: Motion Sickness Data: Tolerance for Stimulation

Group	**Tolerance Time (seconds)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	1200 (0)	1200 (0)	1171 (28)
Men	*1200 (0)*	*1200 (0)*	*1200 (0)*

2. Magnitude of MS

Magnitude of MS data are shown in Table 21. Once again, Mauchly's test of sphericity revealed no significant effects of repeated measures upon these measures, neither in women alone, nor in the analysis of both groups considered simultaneously. Within subjects analysis of variance of this measure in men and women failed to reveal a significant main effect of phase or sequence, nor any significant interaction of these variables. However, there were interesting findings revealed in the between groups analyses.

Between subjects analysis of variance of the final reported magnitude rating of MS in both men and women, revealed a significant main effect of sex group [F (1, 7) = 5.988, p < 0.044, eta 0.461, power 0.559]. Figure 9 shows

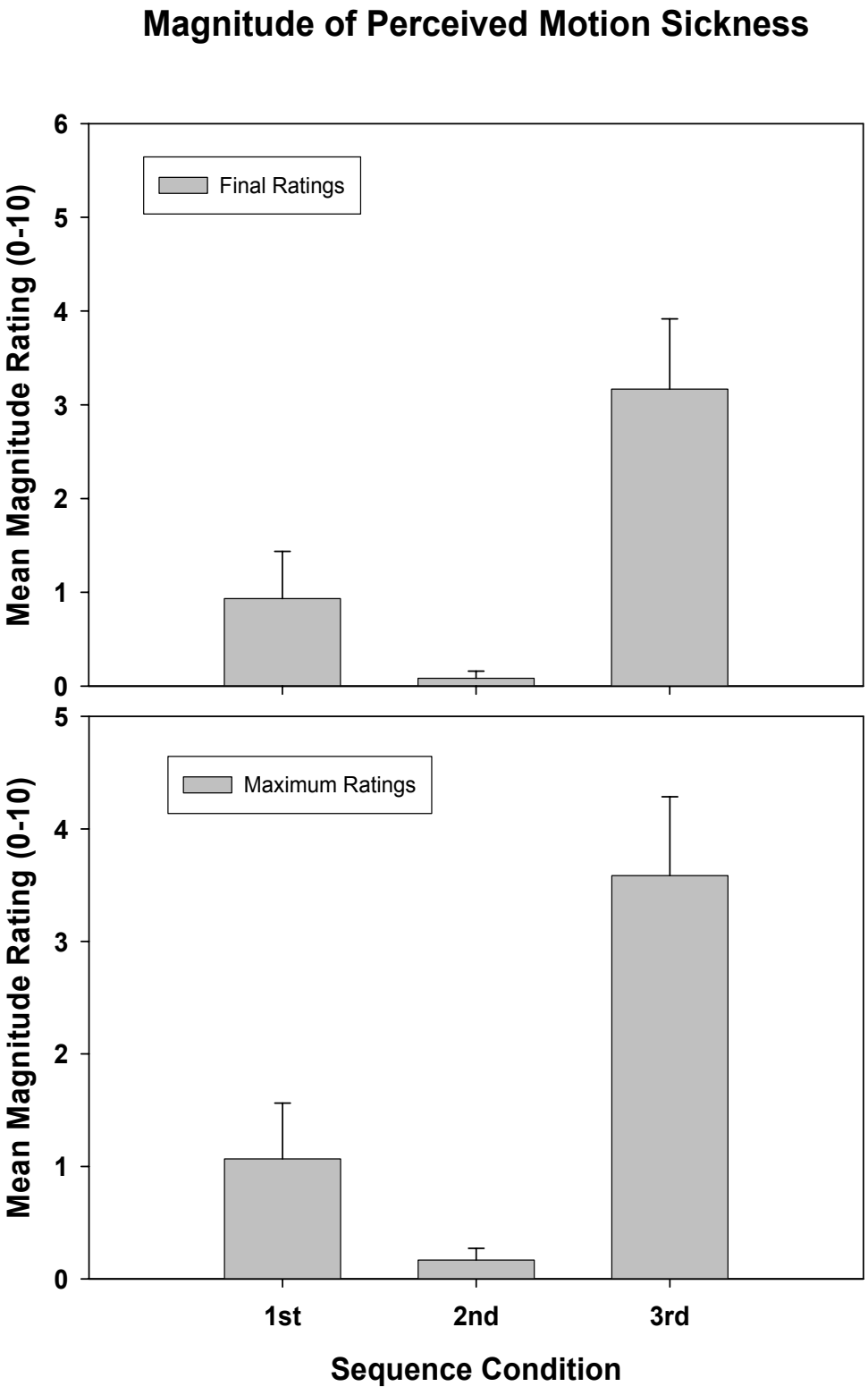
Table 22. Experiment 2: Motion Sickness Data: Magnitude of MS

Group	**Magnitude of MS (0 to 10, none to maximum)** Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)			
- maximum rating	2.57 (1.23)	1.71 (0.97)	2.57 (1.15)
- final rating	2.57 (1.23)	1.57 (1.00)	2.57 (1.15)
Men			
- maximum rating	*0.67 (0.33)*	*0.67 (0.33)*	*0.83 (0.83)*
- final rating	*0.17 (0.17)*	*0.33 (0.21)*	*0.50 (0.50)*

Figure 9. Maximum magnitude rating of MS plotted as a function of sex group of participants.

women to report far higher ratings of MS as compared to the male participants. Further analysis revealed an additional main effect of sequence upon both the maximum and final magnitude rating of MS [F (2, 7) = 5.233, p < 0.041, eta 0.599, power 0.634; F (2, 7) = 4.897, p < 0.047, eta 0.583, power 0.604]. Figure 10 shows the greatest final and maximum report of perceived MS to be found in the 3rd sequence condition. However, post hoc analyses revealed no

Figure 10. Final and maximum magnitude rating of MS in both sex groups plotted as function of sequence of experimental conditions.



statistically significant differences between these conditions, neither in the final nor maximum magnitude rating measures..

In analyses of the group of women alone, while neither within or between subjects analysis of variance revealed any significant effects of trial/phase nor sequence, there was a marginal effect of sequence upon both measures in the between subjects analyses [F (2, 4) = 4.548, p < 0.093, eta 0.695, power 0.435, and F (2, 4) = 4.778, p < 0.087, eta 0.705, power 0.452]. Figure 11 shows that women in the third sequence of experimental sessions (mLP, then eFP, lastly oP) appear to report the greatest magnitudes of discomfort in the study, as compared to the other two sequence conditions, in both the final as well as the maximum reported magnitude measures..

3. Difference Score

Table 21 shows the difference score data from the symptoms of discomfort questionnaires completed before versus after each experimental session. As Mauchly's test of sphericity of these data reveal significant effect of trials, for analysis of both groups of participants [Mauchly's W = 0.233, p < 0.013] as well as for the analysis of the group of women alone [Mauchly's W = 0.036, p < 0.007], the Greenhouse-Geisser factor was subsequently used to correct for this effect. Analysis of variance of this measure failed to reveal a significant main effect of sex group, phase/trial, or sequence, nor any significant interaction of these variables in analyses both men and women. However, while there was

Figure 11. Final and maximum magnitude rating of MS in women plotted as a function of sequence of experimental sessions.

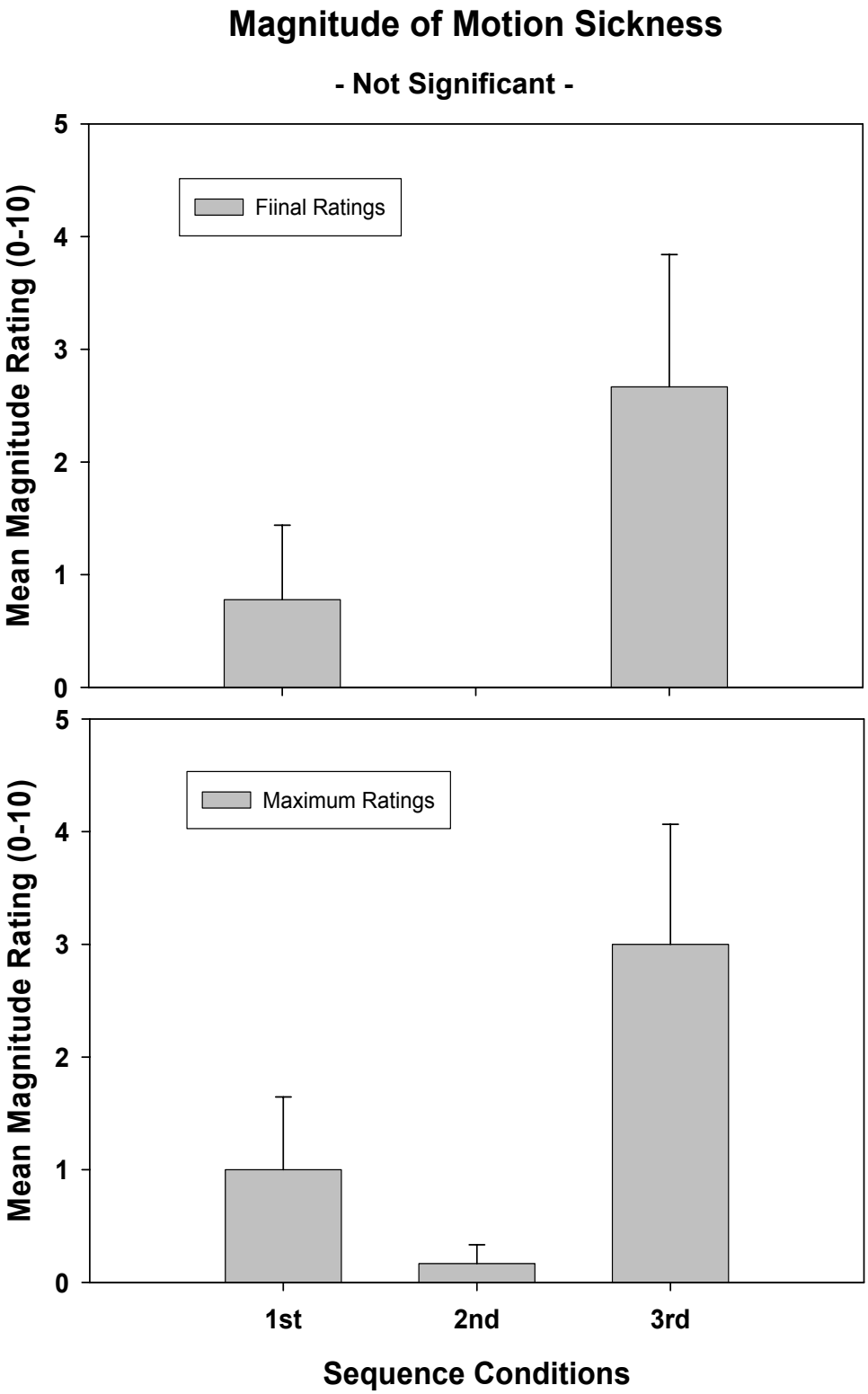
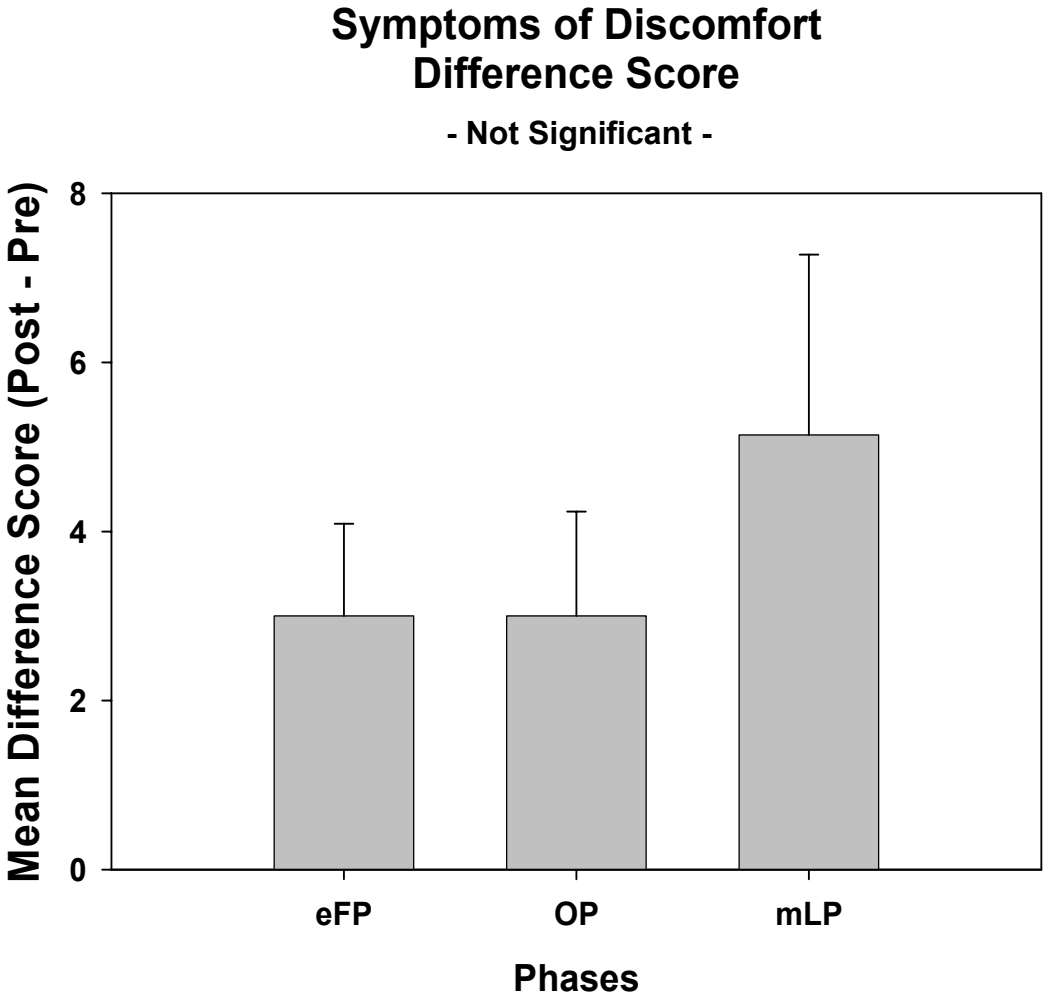


Table 23. Experiment 2: Motion Sickness Data: Difference Score of Symptom Checklist

Group	Difference Score Of Symptom Checklist Mean (SD)		
	eFP/~eFP	**OP/~OP**	**mLP/~mLP**
Women (C)	2.71 (1.02)	3.00 (0.93)	5.43 (2.27)
Men	*1.17 (0.40)*	*1.50 (0.56)*	*2.67 (2.12)*

not a statistically significant main effect of phase/trials upon this measure in the group of women analyzed alone, the data appear to be approaching levels of significance [F (2, 8) = 4.514, p < 0.082, eta 0.530, power 0.438]. Figure 12 reveals the increased difference scores elicited in women during the eFP as opposed to the two other phases of their menstrual cycle.

Figure 12. Difference Score of Symptom Checklist, rating of MS in women plotted as a function of menstrual phase conditions.



CHAPTER IV: DISCUSSION

Experiment 1

Hypothesis # 1: Sex Group → DLL

- Fail to reject null hypothesis. Analyses failed to reveal a significant main effect of sex of the individual [sex group] upon any of the three DLL measures.

Hypothesis # 2: Phase/Trial → DLL

- Fail to reject null hypothesis. Analyses failed to reveal any significant effects of phase of the menstrual cycle [phase/trial] upon any of the three DLL measures, neither in all three groups or in the group of women alone.

Hypothesis #3: Sex Group x Phase/Trial → DLL

- Fail to reject null hypothesis. Analyses failed to reveal significant interaction effects of sex group and phase/trial upon any of the three DLL measures.

Hypothesis # 4: Sequence → DLL

- Reject null hypothesis and accept alternative hypothesis. As hypothesized, analyses failed to reveal a significant effect of sequence upon any of the three DLL measures.

Little or no support was found for the hypotheses initially proposed in this study. The only alternative hypothesis that was accepted was that there were no significant effects of sequence found upon any of the three DLL measures. The

data revealed no other statistically significant effects of any of our two major independent variables.

There were no significant differences revealed between men and women on any of the DLL measures. In reference to symptoms of discomfort, these findings are in direct contradiction to a bulk of studies both in the literature as well as in our laboratory. While closer examination of these data show that women do tend to report a greater number and severity of symptoms of discomfort, these differences were not statistically significant.

In addition, there were no significant differences in any of the DLL measures as a function of phase of the menstrual cycle, even when examining the group of women alone. While closer examination of these daily symptom data shows an increased report of symptoms of discomfort during menstruation (eFP), this difference did not reach a level of statistical significance.

The results of this portion of the study therefore did not find support for the theory that sex and cyclical differences in dynamic motion environments may be due to a reporting bias, as similar sex differences in symptoms of discomfort were not reported in the absence of motion stimulation. In that these data failed to reveal significant effects of the independent variables in Experiment 1, there was no reason to subtract the influence of these factors from data gathered in Experiment 2.

Experiment 2

Hypothesis # 1: Sex Group → MS

- Reject null hypothesis and accept alternative hypothesis. As hypothesized, analyses revealed a significant main effect of sex group upon magnitude ratings of MS.

Hypothesis # 2: Phase/Trial → MS

- Fail to reject null hypothesis. Analyses failed to reveal any significant effects of phase of the menstrual cycle [phase/trial] upon any of the MS measures, neither in all three groups or in the group of women alone.

Hypothesis # 3: Sex Group x Phase/Trial → MS

- Fail to reject null hypothesis. Analyses failed to reveal any significant interaction effects of sex group with phase/trial upon any of the MS measures, neither in all three groups or in the group of women alone.

Hypothesis # 4: Sequence → MS

- Fail to reject null hypothesis. Analyses revealed a significant effect of sequence upon the measures of magnitude ratings of MS.

Hypothesis # 5: Sex Group → PI

- Reject null hypothesis and accept alternative hypothesis. As hypothesized, analyses revealed a significant interaction effect of sex group upon magnitude ratings of illusory motion.
- Fail to reject null hypothesis. Analyses failed to reveal any significant effects of sex group upon any body movement measure.

- Fail to reject null hypothesis. Analyses failed to reveal any significant effects of sex group upon any head movement measure.

Hypothesis # 6: Phase/Trial → PI

- Reject null hypothesis and accept alternative hypothesis. As hypothesized, analyses revealed a significant interaction effect of phase/trial with sequence upon magnitude ratings of illusory motion.
- Fail to reject null hypothesis. Analyses failed to reveal any significant effects of phase/trial upon any body movement measure.
- Fail to reject null hypothesis. Analyses failed to reveal any significant effects of phase/trial upon any head movement measure.

Hypothesis # 7: Sex Group x Phase/Trial → PI

- Reject null hypothesis and accept alternative hypothesis. Analyses revealed a significant three way interaction effect of sex group and phase/trial with sequence upon the measures of magnitude ratings of illusory motion.
- Fail to reject null hypothesis. Analyses failed to reveal any significant interaction effects of sex group and phase/trial upon any body movement measure.
- Fail to reject null hypothesis. Analyses failed to reveal any significant interaction effects of sex group and phase/trial upon any head movement measure.

Hypothesis # 8: Sequence → PI

- Fail to reject null hypothesis. Analyses revealed significant interaction effects of sequence with both sex group, as well as phase/trial, and a three way interaction of these factors upon magnitude ratings of illusory motion.
- Reject null hypothesis and accept alternative hypothesis. As hypothesized, analyses failed to reveal any significant effects of sequence upon any body movement measure.
- Reject null hypothesis and accept alternative hypothesis. As hypothesized, analyses failed to reveal any significant effects of sequence upon any head movement measure.

While there was not support found for all hypotheses initially proposed, this portion of the study found greater support than the previous segment of the study. Contrary to previous studies in the areas of posture and joint stability, there was no significant effect of the major independent variables (neither sex group nor phase/trial) revealed in any of our objective measures of PI.

However, both sex group and phase/trial were significantly involved in magnitude ratings. There were significant interaction effects found with these and the factor of sequence upon measures of magnitude ratings of perceived illusory motion. The greatest reported magnitude of sway was found in the second session of the group of women, whose second session was confirmed by salivary estradiol analysis to occur during their period of ovulation.

In addition, measures of MS also revealed significant effects of sex group. Women were found to have both a greater reported magnitude of MS, as well as a larger difference score on symptom checklists completed before versus after each experimental session.

As the sequence of experimental conditions were counterbalanced to control for an effect of order of experimental sessions upon the dependent variables, a significant effect of sequence upon these measures was not expected. However, this factor was found to significantly contribute to a number of interaction effects, both with phase/trial and sex group, upon magnitude ratings of illusory motion. The third sequence (mLP-eFP-OP) appearing to elicit higher magnitude ratings of MS as compared to the other two experimental sequences.

Conclusions

The results of Experiment 1 were surprising in that they did not replicate the fluctuations in symptomatology, which have been found to normally occur over the course of the menstrual cycle within many non-clinical samples of women (Brooks-Gunn & Ruble, 1992; Woods, 1999). A substantial body of literature supports the existence of such menstrual cycle fluctuations (Palmer, Lambert & Richards, 1991; Sveinsdotter & Backstrom, 2000), yet this study found no significant effects of phase upon measures of symptoms of discomfort. Although analyses of variance failed to find a significant influence of this factor upon any the Daily Symptom measure, both the effect sizes and observed power

Table 24. Experiment 1: Summary Table of Results of Analysis of Variance of Daily Symptom Data

Source	df	F	Sig.	Partial Eta Squared	Observed Power
Phase/Trial within Sex Groups	2	2.869	0.065	0.096	0.539
Phase/Trial by Sex Group	2	0.021	0.979	0.001	0.053
Error	54				
Phase/Trial within Women (C)	2	2.904	0.067	0.133	0.534
Error	38				

values for these data were rather low (see Table 24). This suggests that it might be possible to attain a level of significance with a much larger sample of women, particularly if it is possible to confirm the phases of their menstrual cycles.

In addition, although we did not find a significant interaction between the independent variables (sex group and phase/trial) in Experiment 2 (which would indicate an integration of these components within the mechanisms of MS and PI), the other significant effects of these factors, when viewed in combination with the data from Experiment 1, suggest that the sex differences in MS measures elicited may still be a feature of more than a reporting bias. As the second experiment revealed a significant sex difference in levels of reported discomfort, which was not found during the baseline portion of the study (the first

experiment) there appear to be differences between men and women, that are elicited upon exposure to motion stimulation, which may not be merely a factor of differing reporting styles.

Questions also continue to persist as to why this study failed to replicate previous research investigating the influence of the menstrual cycle upon measures of PI. As mentioned previously, research in sports medicine has revealed significant sex and phase differences in the rates of sports related injuries, implicated female reproductive hormones in PI (Hewett, 2000). As levels of estrogen have been found to be negatively related to different aspects of biomechanical stability (Booth & Tipton, 1970; Sarwar, Beltran & Rutherford, 1996), increased PI was expected to occur during periods of confirmed ovulation. However, the current findings may be attributable to the specific methods of measuring PI in the present study, which utilized center of pressure and head movement measures, which were not used in above-mentioned studies.

In addition, while the second experiment failed to find any significant influence of phase of the menstrual cycle upon MS, it does not preclude this as a contributing factor. The main effect of sex group upon MS measures, which replicated a number of studies previously conducted in our laboratories (Flanagan, May & Dobie, 2002, 2004a, 2004b, 2005), indicates that there may be other sex-related factors, which have yet to be fully addressed.

There were a number of weaknesses in the present study that may have influenced the outcome elicited. For instance, although 18 women participated in this portion of the study, saliva analysis found the success rate of our sampling

technique to be 38.9%; only seven of the women sampled confirmed to have been tested at the appropriate time to sample the target phases of their menstrual cycles, with low levels of salivary estradiol during the mid-luteal phase, and higher levels during the ovulatory phase. A more precise sampling method might enable a higher rate of successful exposure, thereby enabling a larger sample to contribute to the data set entering the final stages of analyses. Although analyses of variance failed to find a significant influence of this factor upon any of the MS measures, both the effect sizes and observed power values for these data were rather low (see Table 25). This suggests that it might be possible to attain a level of significance with a much larger sample of women tested during their confirmed phases of their menstrual cycles. This may explain why we failed to replicate the findings of Grunfeld and colleagues (Grunfeld, et al., 1998; Grunfeld & Gresty, 1998), who found decreased MS during ovulation of 34 female participants in a 9 month yacht race.

As mentioned previously, however, there have been a number of studies conducted by Cheung and colleagues (Cheung & Hofer, 2002; Cheung, Heskin, Hofer & Gagnon, 2001), which have also failed to find significant differences in the incidence of symptomatology in women as a function of the phase of their menstrual cycle. They suggested that differences in MS elicited between men and women might be related to participants' level of anxiety upon stimulation (Cheung, Heskin, Hofer & Gagnon, 2001). Therefore, it might be appropriate to measure levels of anxiety and levels of salivary cortisol in future studies, which

Table 25. Experiment 2: Summary Table of Results of Analysis of Variance of Motion Sickness Data

Source	Measure	df	F	Sig.	Partial Eta Squared	Observed Power
Phase/Trial within both Sex Groups						
	Tolerance	2	0.412	0.670	0.056	0.104
	Maximum MS	2	0.383	0.689	0.052	0.100
	Final MS	2	0.580	0.573	0.076	0.127
	Difference Score	2	1.600	0.156	0.233	0.363
Phase/Trial by Sex Group						
	Tolerance	2	0.412	0.670	0056	0.104
	Maximum MS	4	0.256	0.778	0.035	0.083
	Final MS	4	0.620	0.552	0.081	0.133
	Difference Score	2	0.126	0.883	0.018	0.062
Error		14				
Phase/Trial within Women (C)						
	Tolerance	2	0.500	0.624	0.111	0.106
	Maximum MS	2	0.456	0.649	0.102	0.101
	Final MS	2	0.713	0.519	0.151	0.132
	Difference Score	2	4.514	0.082	0.540	0.438
Error		8				

clarify another possible factor contributing to the sex differences found with motion stimulation.

In conclusion, this study has yielded a challenge. Through its allusion to statistical significance, power and effect size, form appears to be lying just below the surface of these data. The influence of these factors upon responses to virtual motion stimulation can be further clarified with continued investigation. Future studies may address more precise periods of the female menstrual cycle, as well increased sample size of female participants. In addition, incorporating measures of anxiety, as well as different methods of measuring PI and MS may further elucidate any sex or phase differences in these types of responses to virtual motion environments.

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Appendix A:

Medical History Screening Questionnaire

Please check the appropriate response (A or B).

□ A. I would like to complete this questionnaire and I understand that I may be contacted in the future to participate in research experiments.

Name (please print): _____

Email address: _____ Telephone #: _____

□ B. While I would like to complete the questionnaire, I **do not** wish to be contacted in the future to participate in research experiments.

Please answer each of the questions below to indicate whether you have ever had any of the following medical conditions, noting when the condition started and whether it persists currently.

Condition	No	Yes	Date of Onset	Current (Y/N)
Visual Condition, If yes, please specify:				
Vestibular (balance) Condition, If yes, please specify:				
Heart Condition, If yes, please specify:				
Neurological Condition, If yes, please specify:				
Psychiatric Condition, If yes, please specify:				
Head Injury				
Epilepsy (seizures)				
Chronic Pain, If yes, specify type:				
Any Current Medication? birth control hormone supplements insulin other, If yes, please specify:				
Females: - Pregnancy - Menstrual Irregularity or Pain If yes, please specify: 1st day of your last menstrual per please specify:				

Age: _____ **Gender** (check one) : □ Male □ Female

Predominant Ethnic Origin (check one): □ White, non-Hispanic □ African-American, Black □ Hispanic □ Native American □ Asian or Pacific Islander (including Indian sub-continent) □ Choose not to respond

Appendix B:

Daily Living Study Informed Consent Form

Appendix B

UNIVERSITY of NEW ORLEANS

CONSENT FORM

1. *Title of Research Study:* Daily Living Study

2. *Project Directors*: Moira B. Flanagan, M.S.
James G. May, Ph.D.
Psychology Dept., 2001Geology-Psychology Building, UNO 280-6770

3 *Purpose*
The purpose of this experiment is to examine changes in daily activities and feelings of well-being throughout a monthly cycle.

4. *Procedures*
In this study you will be asked to complete a series of questionnaires related to your activities of daily living. You will initially be asked to complete a brief questionnaire regarding your general state of health. You will be given instructions as to how to complete a series of Daily Living Logs (D.L.L.'s). The first part will consist of a daily activities checklist, the second part, a consumption checklist; the third part, a daily symptom checklist. You will be asked to complete these questionnaires once a day for 40 days. Completed forms must be submitted every day, and can be turned in electronically (via email) or in person (to the psychology department). It is very important that the questionnaires be completed on a daily basis. However, your participation in this study will be halted at any time, if you so request.

5. *Potential Risks or Discomforts*
Some people may become uncomfortable completing these questionnaires on a daily basis. However, if at any point you become so uncomfortable that you cannot continue, your participation in the study can be terminated. If you wish to discuss these or any other discomforts you may experience, you may call the Project Director at the phone number listed above.

6. *Potential Benefits to You or Others*
As a participant, you may gain valuable knowledge and/or awareness of your own daily living fluctuations, as well as learn more about research in the field of psychology.

7. *Alternative Procedures*
Your participation is entirely voluntary and you may withdraw consent and terminate participation at any time without consequence. In addition, your instructor has indicated alternative means for your involvement with research within the psychology department.

8. *Protection of Confidentiality*
Your confidentiality will be ensured through the assignment of a code to your data.

I have been fully informed of the above-described procedure with its possible benefits and risks and I have given permission for participation in this study.

_____	_____	_____.
Signature of Subject	**Name of Subject (Print)**	**Date**
_____	_____	_____.
Signature of Person Obtaining Consent	**Name of Person Obtaining Consent**	**Date**

Appendix C:

Daily Living Logs

Please return completed questionnaires to the Psychology Department in the Geology-Psychology Building, room 2001 attention Moira Flanagan or email to mflanaga@uno.edu

DAILY LIVING LOGS

Dr. Jim May's Laboratory in Department of Psychology at the University of New Orleans would like to invite you to become involved in furthering our understanding of the relationship between different aspects of daily living. Your participation in these studies may further your own understanding of these processes, as well as possibly earn you extra credit in your psychology course.

The data collected in these questionnaires will be used for research purposes only, and full confidentiality will be maintained. Individual responses will never be released to anyone not involved in the conduct of these projects.

The code given to your data will be _____

Please make note of this code on each log you complete. Your assistance in keeping your records confidential is appreciated.

These logs are designed to survey prospective participants' personal experiences. The aim of this study is to gather information that may be useful in generating answers to questions regarding the relationship between different aspects of daily living. The logs are divided into three parts, an *"Activity Checklist", a "Consumption Checklist",* and a *"Symptom Checklist"*.

The first part (*Activity Checklist*) relates to the types of activities you may have engaged in within the past 24 hours.

The second part *(Consumption Checklist)* asks about different foods, beverages, and medications that you might have consumed within the past 24 hours.

The third part (*Symptom Checklist*) records any feelings of discomfort you may have experienced within the past 24 hours.

These logs must be returned to the experimenter every 24-hours for forty days.

Responses may be :

- emailed to mflanaga@uno.edu,
- completed online at http://www.geocities.com/mbflanagan2002/dll.html,
- or submitted at the psychology department office (GP 2001), to the attention of Moira Flanagan.

Appendix C

Personal Code: _____

Date: _____

D. L. L. ACTIVITY CHECKLIST

Please respond to the list of activities by indicating the amount of time that you spent engaged in the specific activity within the last 24 hours.

If you did NOT engage in that activity, leave the response area blank.

If you DID engaged in that activity, indicate the amount of time you spent on the activity, rounding UP to the nearest whole hour.

ACTIVITIES	**TIME**	**ACTIVITIES**	**TIME**
Exercise activities	**# hours**	**Transportation activities**	**# hours**
Baseball / Softball		Airplane riding	
Basketball		Automobile riding	
Bicycle riding		Bicycle riding	
Calisthenics		Bus riding	
Cheerleading		Driving (automobile, bus, truck, …)	
Dancing		Elevator riding	
Football		Escalator riding	
Gymnastics		Large boat riding (ships, …)	
Hockey		Small boat riding (canoe, rafts, …)	
Martial arts		Streetcar riding	
Running / Jogging		Train riding	
Skating / Blading		Walking	
Skiing			
Soccer		**Miscellaneous activities**	**# hours**
Swimming		Amusement park rides	
Tennis		Computer or video games	
Volleyball		In Class / Studying / Reading	
Walking		Merry-go-rounds	
Weight lifting		Shopping (grocery, clothes, etc…)	
Wrestling		Sleeping / Napping / Resting	
Yoga / Pilates		Swing / Hammocks	
Other, please specify:		Socializing	
		Television home-viewing	
		Movies (movie theaters and IMAX)	
		Work, please specify title:	

Appendix C

Personal Code: _____

Date: _____

D. L. L. CONSUMPTION CHECKLIST

Please respond to the list of substances listed below, indicating if you have consumed any of these within the past 24 hours.

If you did NOT consume any of a substance, leave the response area blank.

If you DID consume the substance, please indicate the approximate quantity that you ingested (for example, 3 beverages, 2 cigarettes, ...).

SUBSTANCES	QUANTITY
Alcoholic Beverages i.e. beer, wine, mixed drinks	
Caffeinated Beverages i.e., coffee, tea, soft drinks	
Tobacco Products i.e., cigarettes, cigars, pipes	
Drugs or Medications prescription, please specify:	
non-prescription, please specify:	
other, please specify:	

Appendix C

Personal Code: _____

Date: _____

D. L. L. SYMPTOM CHECKLIST

Please respond to the list of symptoms below, indicating any feelings of discomfort you may have experienced within the past 24 hours.

If you did NOT have the symptom, leave the response area blank.

If you DID experience the symptom, please rate the extent of the symptom. The response ratings are:

1 = Slight 2 = Moderate 3 = Severe

SYMPTOMS	RATING	SYMPTOMS	RATING	SYMPTOMS	RATING
Achiness		Drowsiness		Muscle Cramps	
Anxiety		Earache		Muscle Soreness	
Belching		Faintness		Nausea	
Bloating/ Swelling		Fatigue		Nervous	
Body warmth		Feverish		Pain, specify	
Boredom		Fullness of head			
Breast tenderness		General discomfort		Queasy	
Breathing difficulties		Headache		Restless	
Chills		Heartburn		Sighing/ yawning	
Cold sweating		Hearing problems		Sneezing	
Confusion		Increased salivation		Sore throat	
Congestion		Indigestion		Stomach awareness	
Constipation		Insomnia		Stuffy head	
Cough		Irritability		Vision problem	
Dental irritation		LOSS of appetite		Vomiting	
Depression		Menstrual Bleeding		Weakness	
Diarrhea		Menstrual Cramps		Other, specify	
Dizziness		Migraine			

Appendix D:

Motion Perception Experiment Informed Consent Form

Appendix D

UNIVERSITY of NEW ORLEANS

CONSENT FORM

1. *Title of Research Study:* Motion Perception Experiment

2. *Project Directors*: Moira B. Flanagan, M.S.
James G. May, Ph.D.
Psychology Dept., 2001Geology-Psychology Building, UNO 280-6770

3. *Purpose*
The purpose of this experiment is to examine changes motion perception at three different times in a single month.

5. *Procedures*
In this study you will be asked to come into our laboratory for 40 minute sessions, on three separate occasions over the next month. You will wear a safety helmet and stand barefoot on a small platform while watching a rotating spiral for no more than 20 minutes. We will measure your head and body movement, and you will be asked to complete brief questionnaires before and after each session. However, if at any point you become uncomfortable and feel that you cannot continue, your participation in the study can be terminated.

5. *Potential Risks or Discomforts*
Some people may become uncomfortable watching this type of visually depicted motion. If at any point you become so uncomfortable that you feel that you cannot continue, your participation in the study can be terminated. If you wish to discuss these or any other discomforts you may experience, you may call the Project Director at the phone number listed above.

6. *Potential Benefits to You or Others*
As a participant, you may gain valuable knowledge and/or awareness of your own fluctuations in motion perception, as well as learn more about research in the field of psychology.

9. *Alternative Procedures*
Your participation is entirely voluntary and you may withdraw consent and terminate participation at any time without consequence. In addition, your instructor has indicated alternative means for your involvement with research within the psychology department.

10. *Protection of Confidentiality*
Your confidentiality will be ensured through the assignment of a code to your data.

I have been fully informed of the above-described procedure with its possible benefits and risks and I have given permission for participation in this study.

Signature of Subject	**Name of Subject (Print)**	**Date**
Signature of Person Obtaining Consent	**Name of Person Obtaining Consent**	**Date**

Appendix E:

Human Subject Review Committee Forms

University Committee for the Protection of Human Subjects in Research
University of New Orleans

Form Number: 03SEP04
(please refer to this number in all future correspondence concerning this protocol)

Principal Investigator: Moira Flanagan Title: Doctoral Candidate

Faculty Supervisor: James G. May *(if PI is a student)*

Department: Psychology College: Science

Project Title: Daily Living Study

Date Reviewed:

Dates of Proposed Project Period From 08/20/2004 to 08/20/2005

**approval is for one year from approval date only and may be renewed yearly.*

Note: Consent forms and related materials are to be kept by the PI for a period of three years following the completion of the study.

Approval Status	Date
☐ Full Committee Approval	
☑ Expedited Approval	9-1-04
☐ Continuation	
☐ Rejected	

☐ The protocol will be approved following receipt of satisfactory response(s) to the following question(s) within 15 days:

Committee Signatures:

Laura Scaramella

Laura Scaramella, Ph.D. (Chair)
Pamela Jenkins, Ph.D.
Anthony Kontos, Ph.D.
Betty Lo, M.D.
Richard B. Speaker, Ph.D.
Gary Talarchek, Ph.D.
L. Allen Witt, Ph.D.

☐

University Committee for the Protection of Human Subjects in Research
University of New Orleans

Campus Correspondence

Moira Flanagan
Jim May, Ph.D.
Department of Psychology
GP 2001

9/3/2004

RE: Daily living study

IRB#: 03SEP04

The IRB has deemed that the proposed research project is compliant with current University of New Orleans and Federal regulations. Please use current UNO letterhead for your consent form.

Be advised that approval is only valid for one year from the approval date. Any changes to the procedures or protocols must be reviewed and approved by the IRB prior to implementation. Use the IRB# listed on the first page of this letter in all future correspondence regarding this proposal.

If an adverse, unforeseen event occurs (e.g., physical, social, or emotional harm), you are required to inform the IRB as soon as possible after the event.

Best of luck with your project!
Sincerely,

Laura Scaramella, Ph.D.
Chair, University Committee for the Protection of Human Subjects in Research

University Committee for the Protection of Human Subjects in Research
University of New Orleans

Form Number: 05NOV04

(please refer to this number in all future correspondence concerning this protocol)

Principal Investigator Moira Flanagan **Title:** Doctoral Candidate

Faculty Supervisor: James May *(if PI is a student)*

Department: Psychology **College:** Science

Project Title: Motion Perception: a Behavioral Experiment

Date Reviewed:

Dates of Proposed Project Period From 11/01/2004 to 11/01/2005

approval is for one year from approval date only and may be renewed yearly.

Note: Consent forms and related materials are to be kept by the PI for a period of three years following the completion of the study.

Approval Status	Date
☐ Full Committee Approval	
☑ Expedited Approval	11/1/04
☐ Continuation	
☐ Rejected	

☐ **The protocol will be approved following receipt of satisfactory response(s) to the following question(s) within 15 days:**

Committee Signatures:

Laura Scaramella, Ph.D. (Chair)

Pamela Jenkins, Ph.D.

Anthony Kontos, Ph.D.

Betty Lo, M.D.

Richard B. Speaker, Ph.D.

Gary Talarchek, Ph.D.

L. Allen Witt, Ph.D.

☐

University Committee for the Protection of Human Subjects in Research
University of New Orleans

Campus Correspondence

Moira Flannagan
Dr. Jim May

November 12, 2004

RE: Motion perception: A behavioral experiment

IRB# 05NOV04

The IRB has deemed that the proposed research project is now in compliance with current University of New Orleans and Federal regulations.

Be advised that approval is only valid for one year from the approval date. Any changes to the procedures or protocols must be reviewed and approved by the IRB prior to implementation. Use the IRB# listed on the first page of this letter in all future correspondence regarding this proposal.

If an adverse, unforeseen event occurs (e.g., physical, social, or emotional harm), you are required to inform the IRB as soon as possible after the event.

Best of luck with your project!
Sincerely,

Laura Scaramella, Ph.D.
Chair, University Committee for the Protection of Human Subjects in Research

VITA

Moira Flanagan was born in Alexandria, Virginia, where she began her travels internationally with her family, as a daughter of a U.S. Diplomatic service officer. Moira received a Bachelor of Science degree in Sociology from Virginia Tech in 1993, with a minor in Psychology. She earned a Master of Science degree from the University of New Orleans in Applied Biopsychology in 2001. As a doctoral student, Moira's academic and professional achievements have been recognized both locally and internationally. She received the UNO Crescent City Doctoral Scholarship (2003-2005), the Young Investigator Award from the Space Medicine Branch of the Aerospace Medical Association (2003), UNO Distinguished Graduate Student, Certificate of Commendation (2003), the UNO LEQSF Fellowship (1999-2003), and two Travel Awards from the Neuroscience Center of Excellence of the Louisiana State University Health Science Center School of Medicine (2001-2002). She has also published a number of research articles in peer-reviewed journals, and has presented the results of her research a numerous local, national, and international conferences. She has attained a wealth of experience through her employment with the National Biodynamics Laboratory, and is also currently working with the Tulane University Medical School in the Department of Psychiatry and Neurology as a Medical Research Associate. Her current research interests focus upon various aspects of motion perception, including biomechanics and kinesiology (such as how the head and body move in response to perceived motion), eye movement responses to

motion, and the influence of sex and hormones to these measures. Moira aspires to continue her research endeavors in these areas, as she begins her pursuit of a post doctoral research position.