The Past, Present and Future of Research in Visually Induced Motion Sickness

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Abstract. While humans have experienced motion sickness symptoms in response to perceived motion from early history through the present day, motion sickness symptoms also occur during exposure to some types of visual displays. Even with no actual motion, symptoms may result from visually perceived motion, which are often classified as effects of visually induced motion sickness (VIMS). This paper includes a brief discussion on general motion sickness and then focuses primarily on three lines of recent VIMS investigation that we have conducted.

Introduction

Historical chronicles of the human experience with motion sickness-like symptoms date back at least to Hippocrates, and while Julius Caesar, Lawrence of Arabia, and Admiral Nelson suffered bouts of sickness (Money, 1972), adaptation and repeated exposure minimized these adverse effects. More recent human encounters with motion environments, including simulators, virtual environments and even some commercially available video games that create the illusion of motion, demonstrate the general rule that motion sickness adversely affects operational efficiency among susceptible individuals (Benson, 1978). For example, the U.S. Navy has long been concerned with the influence of various ship motions on seasickness and performance. Ernie Pyle, who witnessed first-hand the World War II D-Day invasion in Normandy, described his impression of the enormously reduced fighting efficiency of soldiers and sailors due to sea sickness and seasickness drugs, and it was observed that the landing occasioned"... the greatest mass vomiting ever known in the history of mankind..." (p. 18, Reason & Brand, 1975).

Human experience with motion sickness symptoms may be traced to the wide use of various means of passive conveyance (including camels, carts, carriages, etc.) The pathognomonic sign is vomiting (and at times, retching), but other signs of the syndrome are many and disparate, including overt manifestations such as pallor, sweating, and salivation (Colehour & Graybiel, 1966; Stern, Koch, Stewart, & Lindblad, 1987), lassitude and a reluctance to communicate. Motion sickness symptoms can also occur during exposure to certain dynamic and static visual displays (Hettinger & Riccio, 1992). In such cases, even with no actual motion, symptoms may result from visually perceived motion, which are often classified as effects of visually induced motion sickness (VIMS). This paper will include a brief discussion on general motion sickness and will then focus primarily on three lines of VIMS investigation we have followed in recent years.

The most commonly reported motion sickness symptoms (i.e. nausea, drowsiness, general discomfort, apathy, headache, stomach awareness, disorientation, fatigue, and incapacitation) implicate the vagus nerve complex related to the autonomic nervous system (Kennedy & Frank, 1986). Postural and eye/hand incoordinations (Kennedy, Stanney, Compton, Drexler, & Jones, 1999) and the sopite syndrome (Graybiel & Knepton, 1976) are less well-known problems which may occur as sole manifestation of sickness or may be present with other symptoms. As a result, the subtlety of the latter two can result in conditions leading to accidents following exposures. Other physiological signs of motion sickness include changes in cardiovascular, respiratory, gastrointestinal, biochemical, and temperature regulation functions.

Traditional motion induced symptoms (viz. vomit, salivation, drowsiness) appear in humans as well as other non-human species, such as dogs and monkeys. Rats, which do not have a characteristic vomit mechanism, have showed disordered operant response after prolonged rotation (Eskin & Riccio, 1966). There have been reports of seals and even fish regurgitating their food while being transported in trucks and aboard ships (Chinn & Smith, 1955).

Nausea is likely to be the most prevalent form of sickness and it appears to occur when environmental motion exists within frequencies ranges near 0.2 HZ (McCauley & Kennedy, 1976). The word *nausea* originates from the Greek word for sailor [*nautes*] or boat [*naus*], and dominant motion frequencies in sea-going vessels are generally considered to be less than one Hz. The severity of motion induced nausea is strongly influenced by both the rate at which one is accelerated through the 0.2 Hz range, as well as the time spent at the frequency.

Other vehicles operating at similar low frequency ranges have shown a prevalence of comparable sickness symptoms (e.g. automobiles, buses, aircraft, and moving based simulators). In addition to transportation or simulated environments, other environments operating in the 0.2 Hz range have demonstrated their own forms of motion sickness. Carnival and attraction rides that are rotational can produce rotation induced sickness, especially those with Coriolis-type stimulations (Kennedy & Graybiel, 1965).Microgravity environments such as with space travel can produce space sickness, particularly with longer duration missions.

Motion sickness symptoms often ensue as a result of exposure to dynamic and static visual displays (Hettinger & Riccio, 1992) absent of significant physical motion. Currently there are many research centers studying VIMS, several of which will be presenting at this conference. What I would like to review in the remainder of this paper are three lines of investigation we have followed in the recent past and which we believe hold promise for control and management of VIMS symptoms.

Visually Induced Motion Sickness (VIMS)

It has been argued that physiological responses to visual stimuli should be distinguished from those experienced from motion stimuli (Tyler & Bard, 1949). Early research reported visually induced disturbances (viz., dizziness and nausea) using devices such as the Haunted Swing Illusion (Wood, 1895) and eyeglasses with inverting prisms (Stratton, 1897). In later studies, Dichgans and Brandt (e.g., 1972, 1973, 1978) examined perceived ego-motion (called “vection”) resulting from stimulation of the visual system. Their work formed the basis of research done by current authors on the psychophysical determinants of vection (Hettinger, 2002; Howard & Howard, 1994; Kennedy, Hettinger, Harm, Ordy & Dunlap, 1996). Our plan is to review our work following these themes: vection studies, sopite studies, and SSQ studies.

Vection Studies. Visually induced motion sickness (VIMS) resulting from flight simulator exposure often presents with symptoms typical to motion sickness (Hettinger & Riccio, 1992). The connection between vection and VIMS is elucidated by the fact that those that are resistant to vection are also resistant to VIMS (Hettinger, Berbaum, Kennedy, Dunlap, & Nolan, 1990). Relatedly, those with bilateral labyrinthine deficits are immune to motion effects in several environments (Kellogg, Kennedy, & Graybiel, 1965; Kennedy, Graybiel, McDonough & Beckwith, 1968) and though they can perceive vection (Cheung, Howard, Nedzelski, & Landolt, 1989), they are also immune to sickness caused by vection (Cheung, Howard, & Money, 1991). Becaue of the similarities, we and others have worked with vection becaue of its relative ease of calibration and control (Kennedy, Hettinger, Harm, Ordy & Dunlap, 1996). Initially we used patterns consisting of dots and stripes and more recently we have moved toward more ecologically valid patterns. We will present some of this research which demonstrated differing levels of sickness (incidence, severity) resulting from various vection patterns.

Sopite Studies. One common manifestation of motion sickness is drowsiness or sleepiness, often referred to as the "sopite" syndrome. This response can occur prior to the onset of other symptoms or may be a sole manifestation (Graybiel & Knepton, 1976; Kennedy, 1994; Lawson, Mead, & Clarke, 1997). Sopite effects such as drowsiness, sleepiness and fatigue have been reported in connection with motion sickness from rotation (Graybiel & Knepton, 1976), space sickness (Lawson et al., 1997), and cybersickness (Kennedy, Massey, & Lilienthal, 1995), the implications of which on performance and operational safety are significant, possibly even more so than with the more traditional symptoms of motion sickness (sweating, nausea, etc.).

Because of the relationship between Sopite Syndrome and motion sickness in general, we were interested in exploring whether hormonal and biochemical concomitants of motion sickness also occurred in connection with VIMS. We will present results in which we found elevated levels of cortisol and melatonin during and after exposure to circular vection inducing stimuli (Kennedy, French, Ordy & Clark, 2003).

VIMS Profiles. Just as individuals vary in their responses to motion environments, we believe that differences in virtual reality and other visually provocative environments result in unique symptomological profiles (Kennedy, Dunlap, and Fowlkes, 1990). For example, motion induced sickness commonly includes emesis as a prevalent symptom. However, visually induced stimuli, more typically dominant in virtual and simulated environments, rarely includes such symptoms ((Kennedy, Graybiel, McDonough, & Beckwith, 1968; Kennedy, Lilienthal, Berbaum, Baltzley, & McCauley, 1989; Kingdon, Stanney, & Kennedy, 2001; Reason & Brand, 1975). The most logical factor associated with variations in response symptoms is that which varies the stimuli to its participants: the visual displays responsible for providing the simulated environment. Research has supported equipment features as a primary factor in VE sickness (Kennedy, Drexler, & Compton, 1997). The extent to which equipment features differentially influence sickness symptoms necessitates unique, equipment specific technological interventions or modifications directed at alleviating the associated symptoms.

We have recently employed data-mining methods to compile data from over 5000 simulator sickness questionnaires (SSQ) across several different VIMS producing environments resulting in a motion sickness profile. The SSQ is the self-report form which we have used for over 40 years for all forms of motion sickness. I plan to discuss how symptom profiles are reliably emblematic of individuals in a particular environment or device and at the same time realiably different from device to device. A proposed future line of investigation will be suggested that we think holds promise for control and allieviation of VIMS through "getting control of the stimulus." By that I mean we believe that using the profile of the three sub-elements of simulator sickness (i.e. Nausea, Oculormotor & Disorientation; NOD) and if they can be manipulated experimentally (where higher or lower levels of symptom clusters can be produced systematically) a psycho-physical approach to VIMS can be applied. We think that having control of the stimulus in that manner will have high pay-off from the standpoint of determining the elements that are conducive to, or can be used to prevent, VIMS.

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