Space Flight and Motion Sickness: A Historical perspective

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SPACE MOTION SICKNESS: AN OVERVIEW

- A Historical Summary.
- How Prevalent Is Motion Sickness?
- What Is Motion Sickness?
- Space Motion Sickness.
- Treatments and Alternatives.
- How Does Retinal Slip Factor Into The Space Motion Sickness Equation?
- What Is The Relationship Between Retinal Slip, Space Motion Sickness, Terrestrial Motion Sickness and Stroboscopic Vision?
EARLY HISTORY OF MOTION SICKNESS

- Earliest occurrence may have coincided with the first attempt to improve on natural mobility - probably a water craft.
- Greeks provide the first written account of motion sickness - Nausea derives from the Greek ‘naus’ meaning a ship.
- Then as now, motion sickness was a problem for the military.
  - Cicero claimed that he would rather be killed in battle than suffer the ‘tortures’ of nausea maris.
  - Admiral Lord Nelson never adapted to his seasickness.
  - General Carbuccia refused to use camels for the troops in Napoleon’s army.
- Motion sickness has even been used as a form of punishment.
- There are now well documented cases of sea sickness, car-sickness, airsickness, train-sickness, camel-sickness, elephant-sickness, and of course laboratory induced sickness initiated by riding on moving devices or watching moving scenes.

Source Material: Reason and Brand, Motion Sickness, Academic Press. 1975; Reschke, Statistical Prediction of Space Motion Sickness, In: Motion and Space Sickness, Crampton, CRC Press, 1990
EARLY THEORIES OF MOTION SICKNESS
1820 - 1900

• Most early theories agreed that motion sickness had as its root cause motion, but it took some time to discover what part of the anatomy was affected by the motion.

• Some of the earliest theories:
  – Blood and Guts - Typically divided into separate camps with the Gut theorists believing that motion disturbed the viscera, and the vascular theoretical proponents believing that symptoms were due to some form of cerebral blood flow change.
  – Respiratory factors
  – Shock to the central and autonomic nervous system
  – Infection similar to ‘marsh poisoning, cholera, yellow fever, etc.

• Vestibular and other sensory contributions to motion sickness were built upon the early work of Purkinje, Flourens, Meniere and others.

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MODERN THEORIES OF MOTION SICKNESS

Two theories developed in 1900’s established their roots at the Naval Aerospace Medical Research Laboratories (NAMRL), Pensacola Florida, and have been further refined by NASA and our Russian counterparts). The third theory was developed from space flight observations.

- Over stimulation of the semicircular canals:
  - Dominated the years between 1945 and 1960 as the primary cause of motion sickness. Lost favor when it became clear that very small motion (or even no direct vestibular stimulation) could be as provocative as excessive stimulation of the primary sensory organs.

- Fluid shift theory:
  - Derived from the observed headward shift of fluid induced by space flight. More-or-less discounted when testing did not support the concept

- Sensory-conflict theory:
  - More of a hypothetical construct than it is a theory or working hypothesis. Yet it remains the most viable alternative available today.

THE SENSORY CONFLICT THEORY OF MOTION SICKNESS

• Sensory Conflict Theory starts from the basic premise that situations which cause motion sickness are characterized by sensory rearrangement. That is, motion information signaled to the brain by the vestibular receptors, the eyes, and proprioceptors is at odds with the information that is expected on the basis of past experience.

• This theory has been revised, reformed and made more inclusive as it has evolved. Never-the-less, it remains a very limited theory...But the best we have...
  ✓ It lacks predictive power
  ✓ An inability to explain in situations where there is conflict but no sickness
  ✓ Failure to include sensorimotor conflict that induces motion sickness
  ✓ Inability to explain specific mechanisms by which conflict actually gives rise to vomiting
  ✓ Failure to address the observation that adaptation is not possible without conflict

The Susceptible: How Prevalent is the Problem

Motion sickness is a *wretched and often debilitating condition* that is linked with our technological efforts to improve and extend our means of transportation. As both the variety and availability of transport increase, so grows the magnitude of the motion sickness problem.

- Each year more than *2 million* people visit a doctor for dizziness, and an untold number suffer with motion sickness, which is the most common medical problem associated with travel.

- A quick rule of thumb (based on questionnaires and actual testing) is that only 10% of the population at large is free of all symptoms of motion sickness.

- In the U.S. alone this would suggest that nearly *300 million* people are prone to some degree of susceptibility.

- Other estimates suggest that between *9 and 75 million* people in the U.S. Suffer a debilitating response to motion.

Source Material: American Academy of Otolaryngology - Head and Neck Surgery, 2008; Original Art: Cathy Crowl (color pencil)
The Susceptible: How Prevalent is the Problem

- Only about 1 To 2% of general population experience problems on commercial aircraft.

- About 30 To 60% experience motion sickness in cars, buses, etc. at some point in their lives.

- Somewhere between 40 and 70% of the military personnel are susceptible.

- And about 70% are susceptible to some extent on the rides in amusement parks (perhaps something of a misnomer).

WHAT DEFINES MOTION SICKNESS

• Although we typically refer to the nausea associated with motion sickness as “feeling sick” and then as “being sick”, motion sickness, in the strictest sense of the word is not a sickness at all, but a functional disorder that occurs in normal healthy individuals without structural or pathological damage to the body or CNS.

• In fact, the reverse is true. It is the absence, rather than the presence of symptoms which is indicative of a real pathology.
Some consider Space motion sickness (SMS) to be the most clinically significant phenomenon occurring during the first few days of space flight, and immediately following flight.

Exposure to microgravity rearranges the relationships among signals from visual, skin, joint, muscle, and vestibular receptors. Congruence between vestibular signals and those from other receptors, as well as between the vestibular otolith and semicircular canal receptors, is disrupted by the absence of gravity. This lack of congruence between sensory
Space Motion Sickness: Symptoms

Exposure to provocative real or apparent motion leads to the progressive cardinal symptoms of terrestrial motion sickness which typically include: pallor, increased body warmth, cold sweating, dizziness, drowsiness, nausea and vomiting.

The symptoms experienced as part of SMS may differ slightly with: flushing more common than pallor, and nearly universal are stomach awareness, malaise, loss of appetite, lack of initiative and irritability. Vomiting is usually sudden, often without prodromal nausea.

Difference between terrestrial and space motion sickness originally led to the belief that space motion sickness did not require motion. Hence the birth of the term, Space Adaptation Syndrome.
EFFECTS OF PERFORMANCE ON MS and EFFECTS OF MS ON PERFORMANCE

There is plenty of anecdotal evidence and limited empirical data suggesting that acts required for survival (or difficult physical/mental tasks) can override even the most debilitating effects motion sickness. This can be considered peak efficiency or the effects of performance on motion sickness.

Call to battle
Maybe group endeavors (singing)

On the other hand, there are volumes of data supporting the concept that motion sickness can have a severe effect on performance, permitting the those affected to perform only the very basic tasks. This can be considered as maintenance efficiency.
Space Motion Sickness: First Occurrence

Most of the motion sickness problems aboard Apollo were not widely known or widely discussed until the first incidence aboard Skylab III.
Space Motion Sickness Incidence: U.S.

US SPACE PROGRAM: PERCENT EXHIBITING SYMPTOMS
Space Motion Sickness Incidence: Russian

USSR/ RUSSIAN: PERCENT EXHIBITING SYMPTOMS

PERCENT

0 10 20 30 40 50 60 70 80

VOSTOK VOSKHOD SOYUZ/SALUT (1&4) ASTP SALYUT 6 SALYUT 7
Frequency Of Crew Symptoms: Shuttle

Percentage

Malaise | Dry heaves | Stomach awareness | Sweating | Nausea | Vomiting

0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100
Treatment For Space Motion Sickness

Existing countermeasures for SMS include:

- Medications to control symptoms
- Preflight adaptation
Medication For Space Motion Sickness

The pharmacological management of motion sickness symptoms has several disadvantages:

- Drugs can only be used at specific times during a flight
- They typically cannot be used before the appearance of motion sickness symptoms
- Regardless of efficacy, all drugs have side effects
- With long duration flights there is a concern about the degeneration of drug quality
- Complication with oral administration is a reduction in gastric motility
- Transdermal application, suppository, and intramuscular (IM) injections have been used
Non-Pharmacological Management of Motion Sickness Symptoms

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Retinal Slip: VOR In Space Flight

VOR Gain Change Across Flight Day

Flight Day

VOR Gain Change Across Flight Day

Flight Day
Background

- Stroboscopic vestibular adaptation study (Jones & Mandl, 1981)
- Crew member observations (Reschke et al. 2004)
Stroboscopic Glasses

• Flicker at either 4 or 8 Hz
• Dwell times of 10 or 20 msec
• Frequency chosen to be below those known to induce susceptibility to photosensivity

QuickTime™ and a H.263 decompressor are needed to see this picture.
Stroboscopic Glasses And Saccades: Pilot

Visually Guided Saccades

- No goggles
- Goggles flash @ 4 Hz
- Regression (No goggles)
- Regression (Goggles)

Peal Velocity (deg/sec)

Duration (msec)

Amplitude (deg)
Stroboscopic Motion Sickness Experiments

• Initial Validation Study
  • Strobe Light vs.... Glasses
• Parabolic flight study
• Carsickness
  • With the outside view occluded
  • With the normal outside view
• Seasickness
• Helicopter
• Clinical pilot
Scoring Or Measuring Motion Sickness

- Subject Rates or Ranks his/her ‘feeling’ at the moment.
- Motion Experience Questioner developed by Robert Kennedy and others.
- Pensacola Diagnostic Index developed by Miller and Graybiel at the NAS.
- The PDI is a psychometric scale designed to remove and control for the nonlinear aspect of motion sickness.
- The PDI includes ranking the severity of most symptoms allowing a controlled termination of a test.
Strobe Vs. Glasses

• Left-right reversing prisms
• Reading *Treasure Island*
• Yaw head movements - 0.2 Hz
• Protocols
  • Phase I: Strobe (4 Hz @ 30 µsec) vs..... No Strobe
  • Phase II: Glasses flicker (4 Hz @ 10 msec) vs..... No Flicker
• 19 Subjects for each phase, 6 subject participated in both phases
Strobe Results: Reversing Prism
Glasses Results: Reversing Prism

![Bar chart showing PDI values for subjects with and without flash.](image)
Parabolic Flight Studies

- 9 Subjects
- 2 flights each - treatment and control
- Flights separated by 5 weeks
- Subjects made whole body pitch movements during microgravity portions of flight (Lackner & Graybiel, 1984)
- Subjects’ heads held still and eyes closed during 1.8g pull outs and transitions
- Flash: 4 Hz / 10 msec
Parabolic Flight Results

- 5 out of 9 Ss did not complete the 35 parabolas during no flicker condition.
- Of those 5 subjects, 4 were capable of completing more parabolas while wearing the flicker glasses (2 of 5 finished all 35 parabolas).
- 3 subjects completed all 35 parabolas regardless of the treatment afforded by the glasses.

Majority of Symptoms Developed During 2g Pull-ups
Car Sickness Methodology

- Phase I: Outside view occluded
- Phase II: Outside view normal
- Subjects read young reader adapted version of *Treasure Island*
- Glasses flicker vs...... Not flicker
- 10 subjects in each phase
- Flash: 8 Hz / 20 msec
Car Sickness Results

No Occlusion

Outside
Occluded

Subject

Tolerance Time

Flicker
No Flicker

Subject

Tolerance Time

Flicker
No Flicker
Sea Sickness Methods

- Three subjects participated in this study (2 males, 1 female).
- Subjects were taken by boat out to the Aquarius Underwater Laboratory off the coast of Florida to support NASA’s Extreme Environment Mission Operations (NEEMO) platform.
- This was a two-part experiment, consisting of an outbound and inbound portion.
- The subjects donned the goggles (8 Hz @ 10 msec dwell) immediately upon entering the boat.
Sea Sickness Results

It is worth noting that all three subjects experienced frank sickness without the glasses.

With the glasses, only one subject experienced frank sickness.
Helicopter Flight Methods

- Six subjects participated in this study: Three wearing 4 Hz strobe glasses and three wearing 8 Hz glasses.
- Both were set to a dwell duration of 10 msec.
- The subjects were required to read the text of an Army aircraft manual while seated in the cabin area of a USAARL JUH-60 Black Hawk helicopter during 20 min of a provocative flight pattern.
Helicopter Flight Results

- MS was scored using version of the Motion Sickness Questionnaire rather than the PDI.
- The MSQ consists of 28 items (symptoms) that are rated by the participant in terms of severity on a 4-point scale that included three primary factors (nausea, oculomotor disturbance, and disorientation) with yes/no answers.
- The total symptom severity score is an aggregate of all these symptoms.