# Motion sickness induced by g-transitions during spaceflight

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Motion Sickness: Theories, Models and Empirical Evidence

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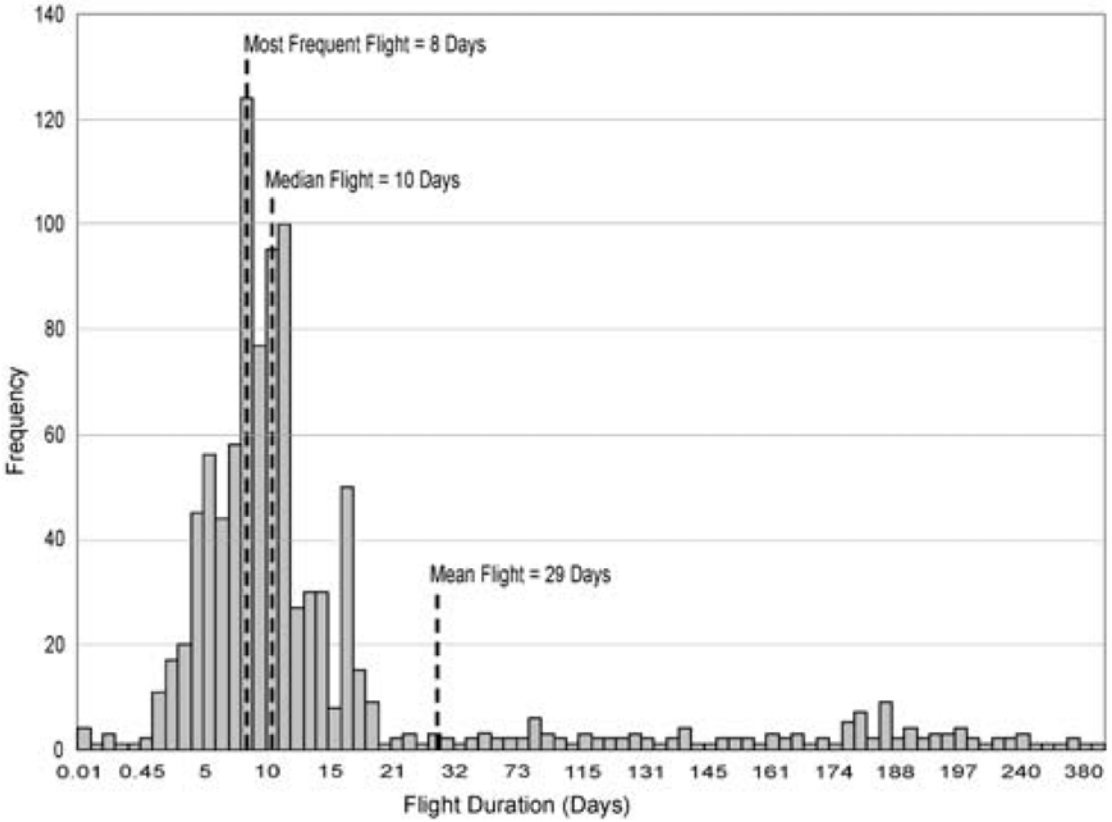
# General observations

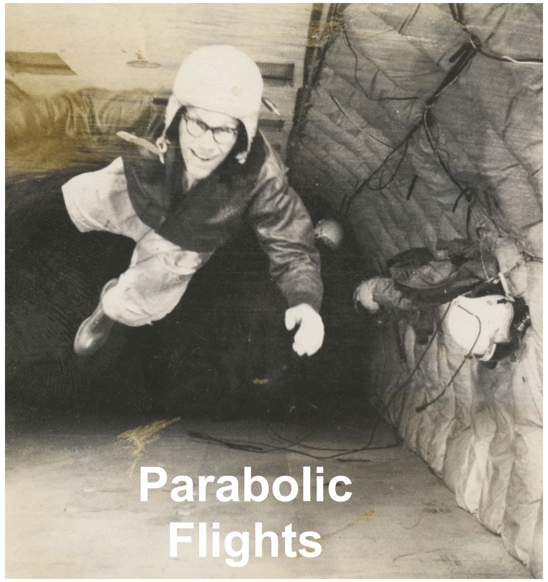
- Motion sickness represents one of the greatest clinical challenges impacting crew activities during g-transitions
- Given the high frequency of short duration missions (median 10 days), the major focus has been on early *in-flight* “Space Motion Sickness” (SMS)
- The incidence and severity of *re-entry* motion sickness symptoms during return to Earth increases with flight duration
- Given the operational nature of the environment, it has been difficult to characterize due to clinical interventions (medications) and variations in missions

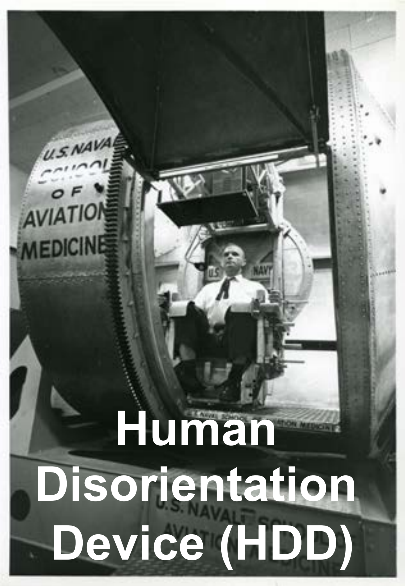


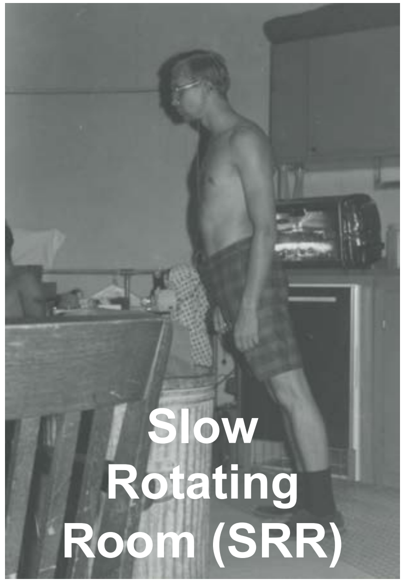

Reschke et al., SP–2007–560

# Gallaudet 11: The deaf *right stuff*

- Prior to human space flight, Graybiel and colleagues began to test bilateral vestibular loss subjects from Gallaudet University on various motion stressors
- Key findings from this research were that “labyrinthine defective” (LD) subjects showed no signs of motion sickness (e.g., Kellogg et al., Aerosp Med, 1965) and negligible change in performance associated with the slow rotating room (Clark & Graybiel, Aerosp Med, 1961).



# Inflight SMS symptoms

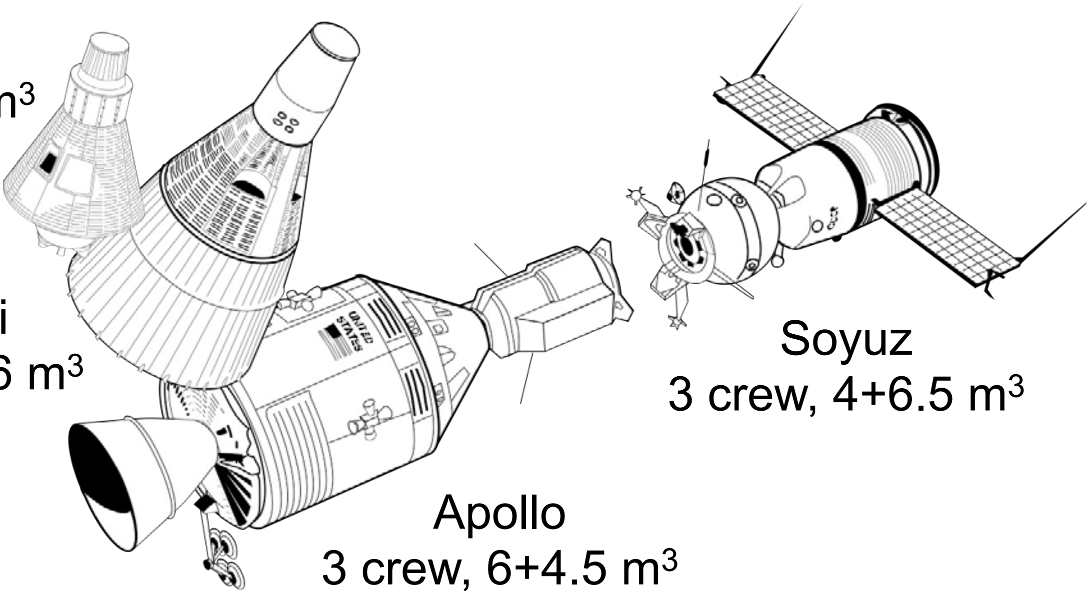
- SMS symptoms differ from acute terrestrial motion sickness likely due lack of normal air-current vection and gravitational force on stomach contents, e.g., sweating is less common, and flushing is more common than pallor.
- SMS typically is more often associated with stomach awareness, vomiting, headache (due perhaps to headward fluid shifts), impaired concentration (Davis et al. 1988).
- Vomiting is usually sudden, infrequent, and is often not marked by prodromal nausea. Bowel sounds, obtained by auscultation, are decreased or absent in crewmembers experiencing SMS (Thornton et al. 1987).
- Despite these differences, nearly universal symptoms are malaise, anorexia or loss of appetite, lack of initiative, and (for some) increased irritability.
- Fluctuating waves of drowsiness or "sopite syndrome" can mask other symptoms

# Inflight SMS incidence

- Incidence has varied with spacecraft volume:
  - No SMS reported in Mercury or Gemini programs
  - 33% incidence in Apollo (Homick 1975), 54% in Soyuz (Bryanov et al. 1986)
  - 73% in Shuttle (Jennings 1998)
- Decreased incidence and severity in repeat flyers (Davis et al, 1988)


Mercury
1 crew, 1 $m^3$

Gemini
2 crew, 1.6 $m^3$



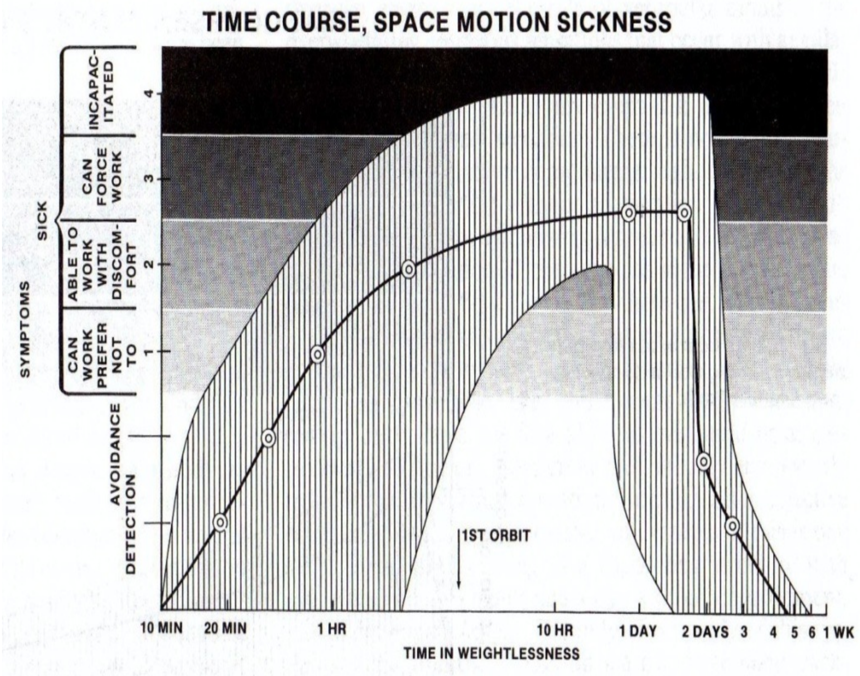
Apollo
3 crew, 6+4.5 $m^3$

Soyuz
3 crew, 4+6.5 $m^3$

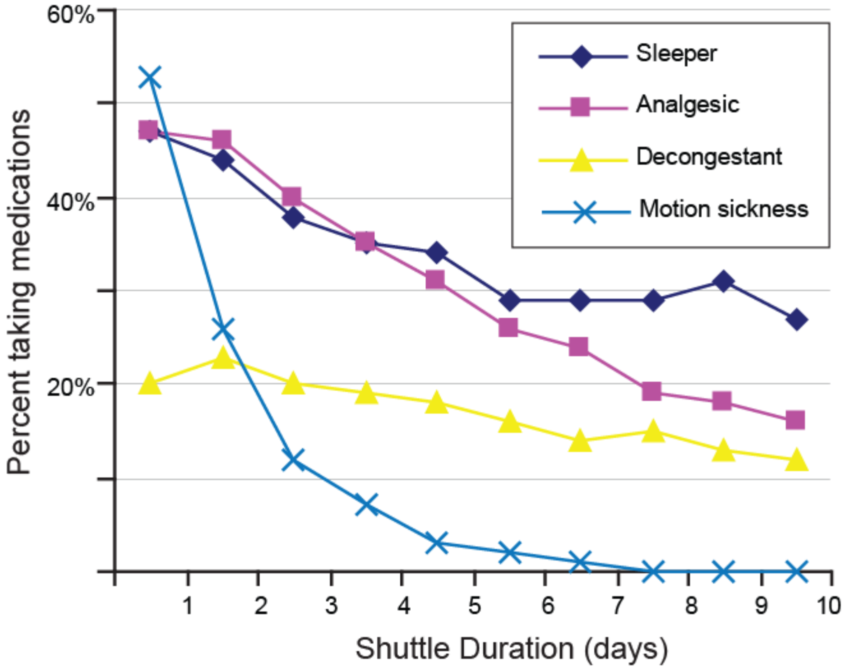
Shuttle
6 crew, 71.5 $m^3$

# Inflight SMS severity & time course

- Symptom severity is variable, with over half categorized as moderate to severe (Jennings 1998)
- Symptoms generally last 2-3 days inflight, although may persist more than 1 week (Reschke et al 2018)
- Critical performance-related procedures such as extra-vehicular activity (EVA) are restricted during the first three days of missions



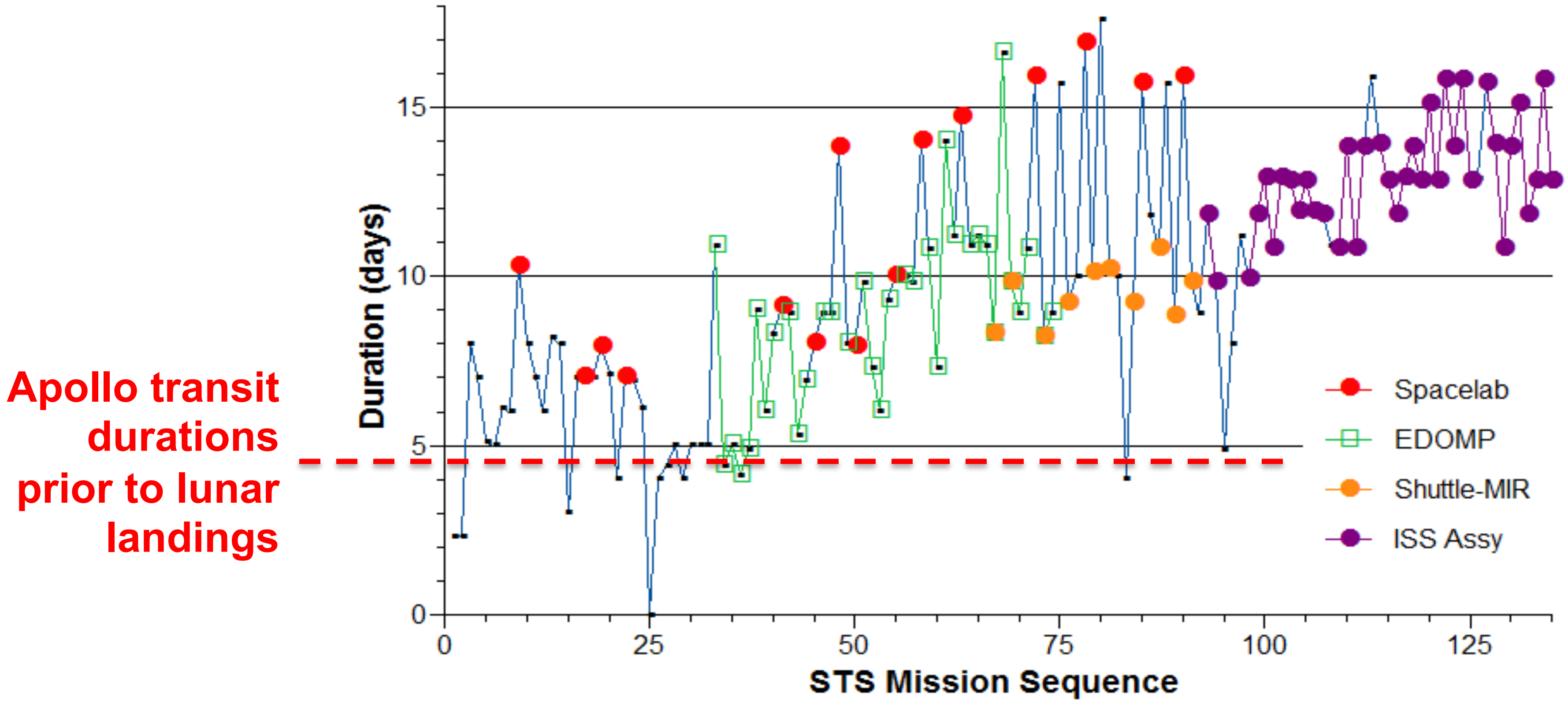

**Thornton et al., 1987**




**Putcha et al, 1999**

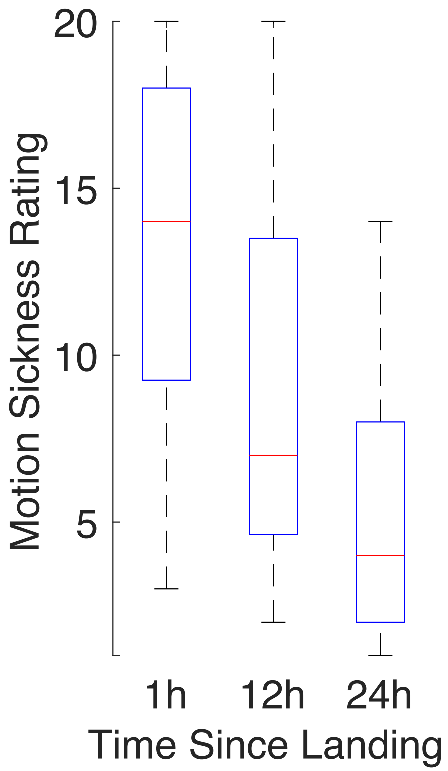
# STS re-entry motion sickness

- Incidence of re-entry nausea was ~15% after Shuttle with majority of crewmembers experiencing clumsiness in movements, difficulty walking and persisting sensation after-effects (Bacal et al. 2003)
- Since post-flight impairment was greater with longer flights only CDRs with prior landing experience were considered for flights of extended duration




# ISS re-entry motion sickness

- Re-entry motion sickness remained highly variable after long-duration ISS missions with majority experiencing nausea and vomiting (Reschke et al 2017)
- 15% of crew did not attempt test at landing site and 32% attempted tests in the medical tent but could not complete all testing




(Field Tests, Reschke & Kozlovskaya, n=38)

# In-flight versus re-entry motion sickness

- Both have a similar onset with symptoms appearing within minutes of g-transition with head movement sensitivity persisting for several days (more pronounced following longer duration spaceflight)
- In-flight provocative head movements and/or visual reorientation illusions (e.g., seeing inverted crewmember or unexpected cabin orientation) can trigger sudden vomiting
- In-flight susceptibility does not necessarily predict re-entry susceptibility. Heat stress, dehydration, orthostasis (fainting on standing), sleep deprivation and exhaustion are commonly observed post-flight and may increase susceptibility.
- In contrast to in-flight motion sickness, the incidence or severity of re-entry sickness does not appear consistently lower with repeat flights.
- Post-flight there have been reports of “relapse” phenomenon, e.g., when turning a corner in a car, eliciting ‘mild’ to ‘severe’ symptoms

# Interventions

- Intramuscular promethazine has been the most effective in-flight with a 90% initial response rate and reduction in residual symptoms the next flight day. When possible, treatment is offered in the pre-sleep period to mask potential treatment-related drowsiness. (Jennings 1998)
- Meclizine is the more common post-flight treatment, often administered prophylactically prior to landing (Lee 2020)
- Preflight training techniques, including desensitization to provocative stimuli in the Russian program (Clément 2001) or preflight adaptation (Harm et al. 1994), have not been validated to reduce motion sickness with spaceflight.
- In-flight symptoms can be alleviated by restricting early activities, maintaining familiar orientation with respect to the visual environment, and maintaining contact cues
- Immediately following landing, the earlier introduction of head movements and other motor activity, as long as they are self-paced and within one’s threshold for motion tolerance, has been used to facilitate adaptation (Wood 2011)

# Predicting susceptibility

- Part of the difficulty in predicting motion sickness is the lack of a terrestrial vestibular analog. Another challenge is the operational nature of the environment wherein pharmaceutical countermeasures or other interventions confound any systematic investigation.
- Inversion immersion in the Weightless Environment Training Facility (WETF) pool was proposed during Shuttle due to anecdotal evidence that EVA training may be beneficial, resulted in similar incidence of 78% (Norfleet et al. 1995)
- Other promising terrestrial predictors include:
  - Reversing prisms (Oman et al. 1986)
  - Torsional disconjugacy (Markham and Diamond 1993)
  - Sickness induced by centrifugation (SIC, Nooij et al. 2007)
- **The only reliable predictor of susceptibility is motion sickness experienced during a previous spaceflight**

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