EVALUATION OF MOTION SICKNESS COUNTERMEASURES

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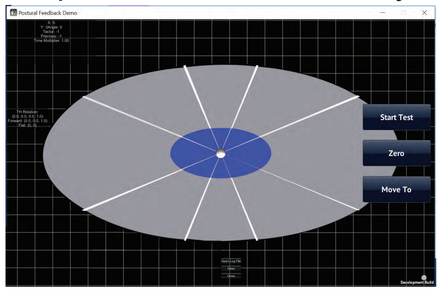
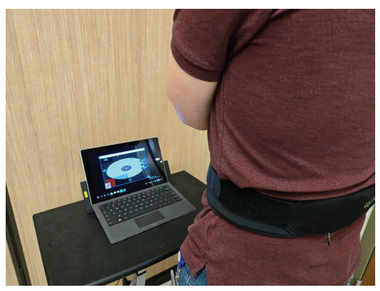
Background

Motion sickness induced during and following g-transitions can pose operational concerns and requires mitigation to optimize crew performance. Our overall goal is to characterize the effectiveness of motion sickness countermeasures to improve inflight and postflight recovery for future space travelers across various vehicles. This involves implementing motion sickness questionnaires during Spaceflight Standard Measures as well as retrospective data mining of medical records. We are also conducting controlled laboratory experiments of sensory augmentation as a potential non-pharmaceutical countermeasure for sensorimotor alterations.

Sensory Augmentation

Sensory augmentation, e.g., vibrotactile feedback of gravitational vertical, has been effective as a spatial awareness and balance aid with vestibular impairment. We are evaluating a wearable vibrotactile belt (Engineering Acoustics, Inc; Orlando, FL) to provide feedback of attitude and heading for spatial orientation. The system uses an onboard inertial measurement unit to detect motion and tablet software interface to provide a portable user interface. An array of eight tactors placed around an adjustable belt with adjustable firing can provide sufficient resolution of tilt direction and amplitude for both capsule and/or ambulatory conditions.

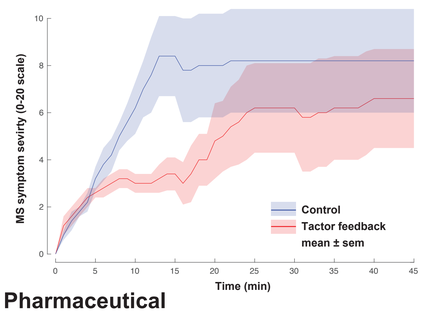




Credit: Engineering Acoustics, Inc.

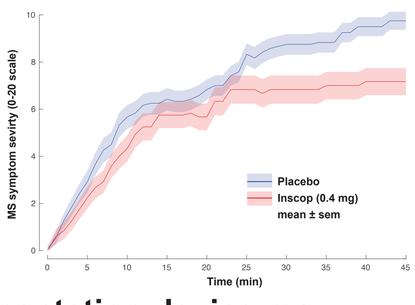
Sensory Augmentation

We previously demonstrated that Sensory Augmentation delayed motion sickness onset during simulated capsule wave motion (Bollinger et al, 2023).



Pharmaceutical

Pharmacueticals can have a delayed efficacy until therapeutic plasma levels are obtained due to bioavailability following adminstration (Wood et al, 2024).

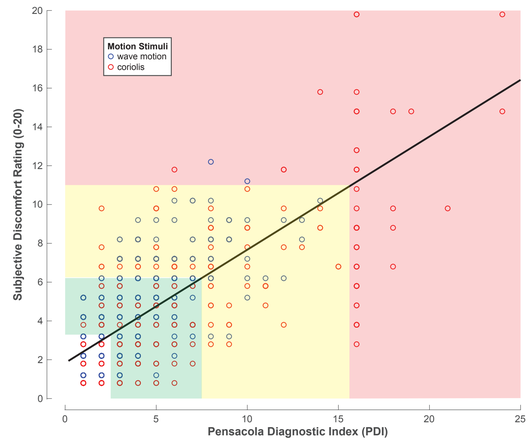


A wearable Sensory Augmentation device may improve the efficacy of treating motion sickness during capsule operations by delaying symptom onset until therapeutic drug levels are obtained.

Motion Sickness Reporting

Countermeasure efficacy can be evaluated from motion sickness symptom severity ratings using both medical and research data sets. The graph below demonstrates the relationship between a single Subjective Discomfort Rating score (0-20 range, often used with research studies such as Spaceflight Standard Measures, Oman et al., 1986) with the Pensacola Diagnostic Index (PDI, Guedry et. al., 1968) which is similar to the multisymptom scales used in medical operations (Gleed et al., 2025). These data were obtained across two laboratory studies where both scores were obtained concurrently. The Spearman rho was 0.70 ($p < 0.001$).

Provocative coriolis stimuli were used during Pradhan et al. (2024) and simulated capsule wave motion during Wood et al. (2023). For PDI scoring see Table below.



A questionnaire has been implemented in Standard Measures to standardize and holistically capture motion sickness experienced by crew members in the 72 hours following g-transitions. The survey asks crew members to report on mulitple symptoms, an overall 0-20 score, rate the efficacy of medications and has questions regarding activities that hindered or improved their adaptation. Scan the QR code if you would like to see our survey and provide feedback.

Symptoms included in the survey as well as prior medical operations records can be grouped in four categories: **gastrointestinal & nausea**, **peripheral thermoregulation**, **sopite-related alterations in arousal** and **central**. The table below highlights how these symptoms have been used with PDI to quantify an overall malaise score (italics indicate symptoms used in prior space flight medicine records).

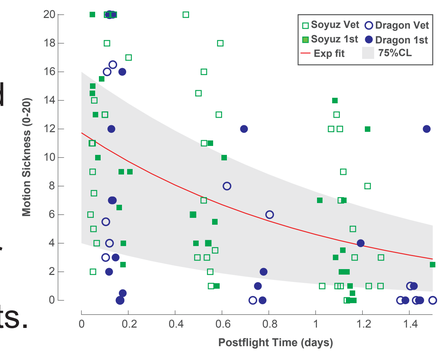
Category	Slight	Moderate	Severe
Nausea syndrome *Decreased appetite*	Epigastric *awareness* or discomfort (1-2)	*Nausea* (4-8)	*Vomiting* or retching (16)
Salivation (need to swallow)	First noticeable (2)	Pronounced (4)	Excessive (8)
Skin color	*Flushing* (1)	Pallor (2-4)	Ashen (8)
Sweating	Clammy, cool (2)	Visible sweating (4)	Profuse (8)
Drowsiness *Impaired concentration* *Irritability*	Less responsive (2)	*Sluggish* (4)	*Lethargic* (8)
Central nervous system *Disorientation*	*Dizziness* (1)		
Pain	*Headache* (1)		
PDI malaise from sum of individual symptom scores	1-2 points	3-7 points	8-15 points severe, ≥16 frank sickness

Retrospective Data Mining

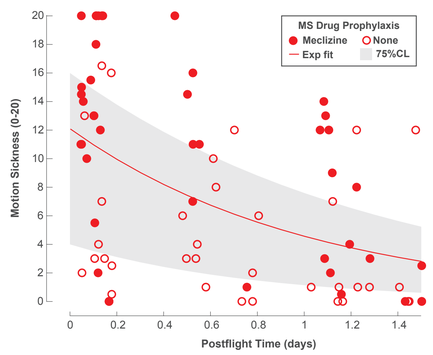
We have been summarizing medical reports of both inflight space motion sickness and postflight terrestrial readaptation motion sickness (TRMS) following landing using data from both Shuttle and ISS missions. Based on our initial analysis from data obtained from the Longitudinal Study of Astronaut Health (LSAH) data archive, there was a significant increase in TRMS following longer Shuttle flights (>10 days) compared to shorter flights. This finding is relevant for upcoming Artemis missions which will have longer microgravity transits to the lunar surface (>10 days) than encountered during Apollo (average 4.5 days).

Terrestrial Readaptation Motion Sickness (TRMS)

Symptoms scores from prior Field Tests and Spaceflight Standard Measures have provided insight into postflight symptom recovery and allowed comparisons across factors such as landing vehicle and prior experience following long-duration spaceflights.



These same TRMS scores have provided insight into the efficacy of various medication strategies, e.g. prophylatic use of meclizine illustrated here.



Forward Work

(1) We plan to deliver a wearable tactor belt that can provide attitude and heading feedback for both capsule operations to mitigate motion sickness and balance exercises to enhance recovery following g-transitions.
(2) The motion sickness questionnaire has also been incorporated into Spaceflight Standard Measures and CIPHER Vestibular Health experiments for use on the International Space Station and early Artemis missions.
(3) Summarizing medical reports of both inflight space motion sickness and postflight terrestrial readaptation motion sickness (TRMS) following landing will be used to evaluate the efficacy of the medications used and develop clinical practise guidelines.

References: [1] Oman CM et al. (1986) Exp Brain Res 64:316-334. [2] Graybiel A. et al. (1968) Aerosp Med 39:453-455. [3] Pradhan GN et al. (2024) Acta Astronaut 222:647-654. [4] Bollinger AM et al. (2023) HRP IWS. [5] Wood SJ et al. (2024) HRP IWS. [6] Gleed S, Omengan K, Wood SJ (2025) in prep.

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