Sensorimotor Functional Task Performance Measures Following G-Transitions

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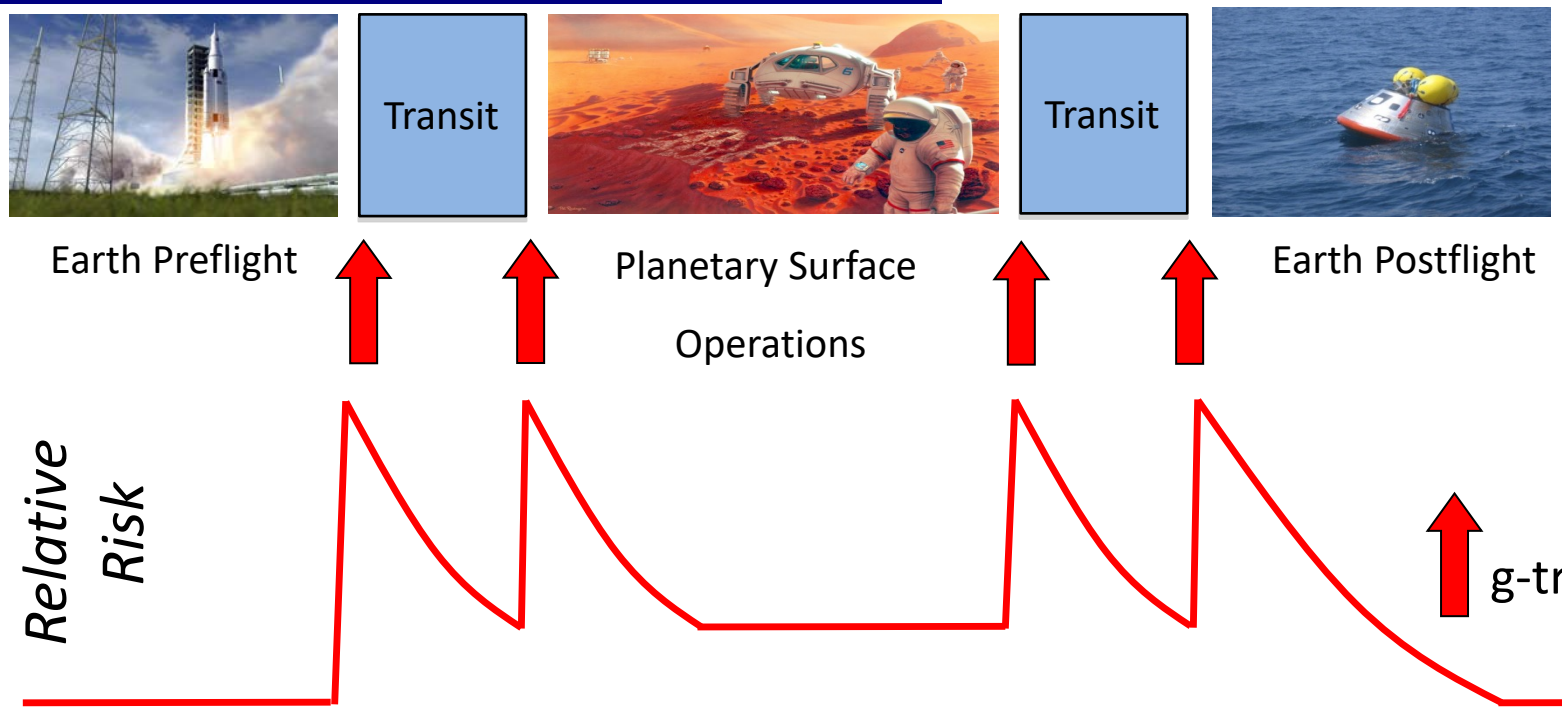
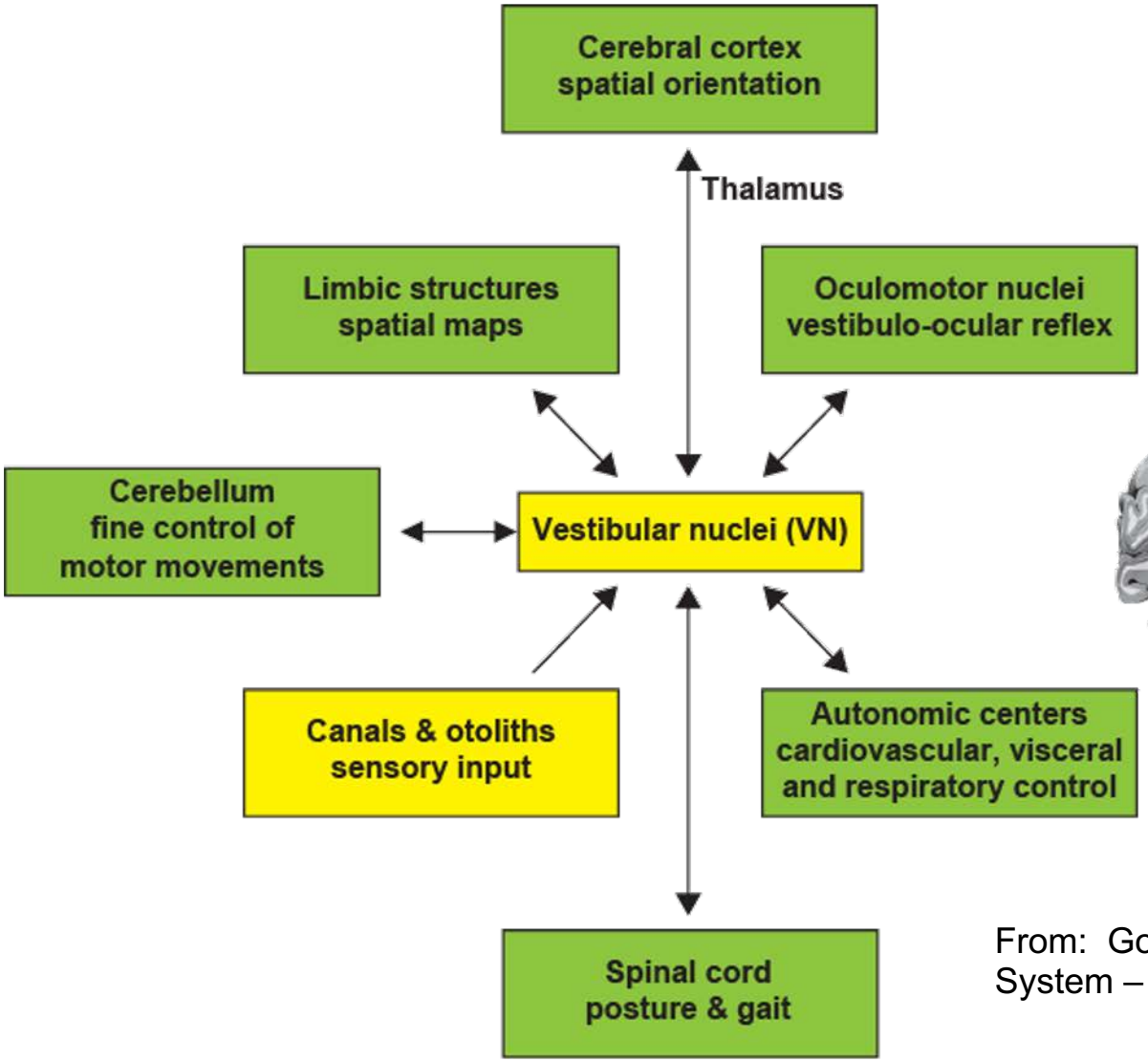
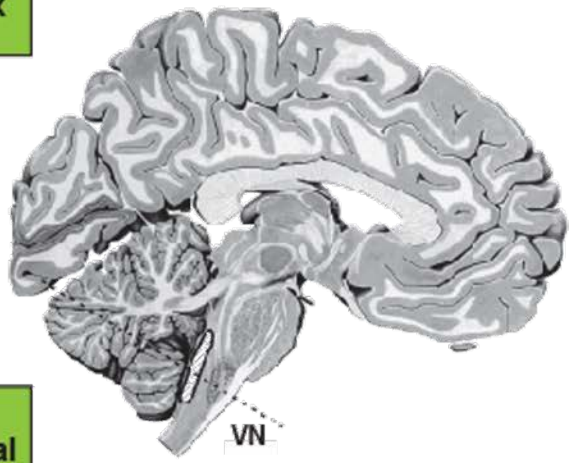
SM Risk greatest at G-transitions



- Adaptive changes that optimize sensorimotor function in one gravity environment are maladaptive for transitions to other gravity states
- High degree of intersubject variability, and level of functional decrements and time of recovery vary as a function of flight duration

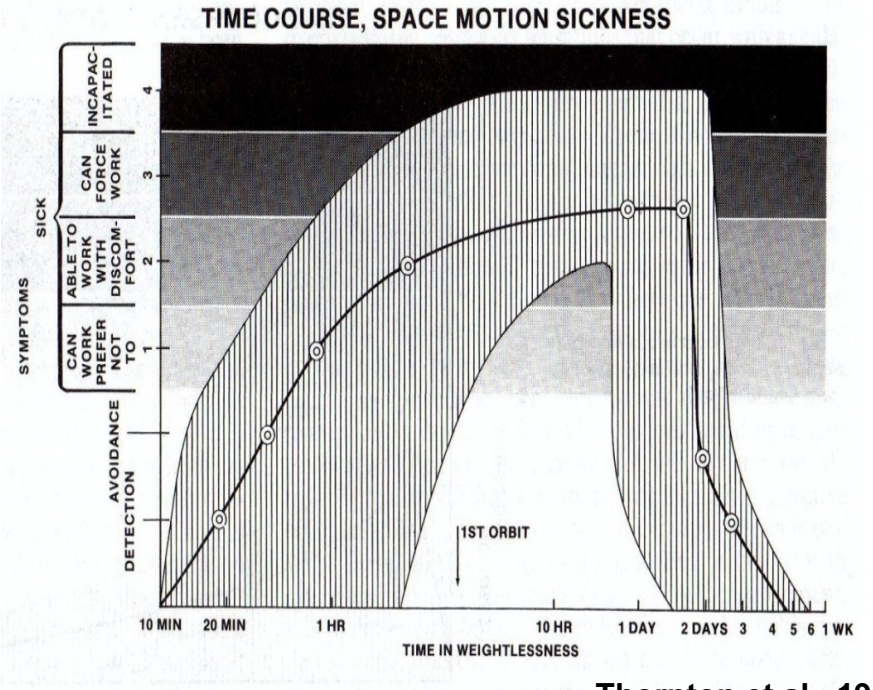
Major functional pathways





From: Goldberg et al., The Vestibular System – A Sixth Sense, 2012 (fig 6-1)

Motion Sickness

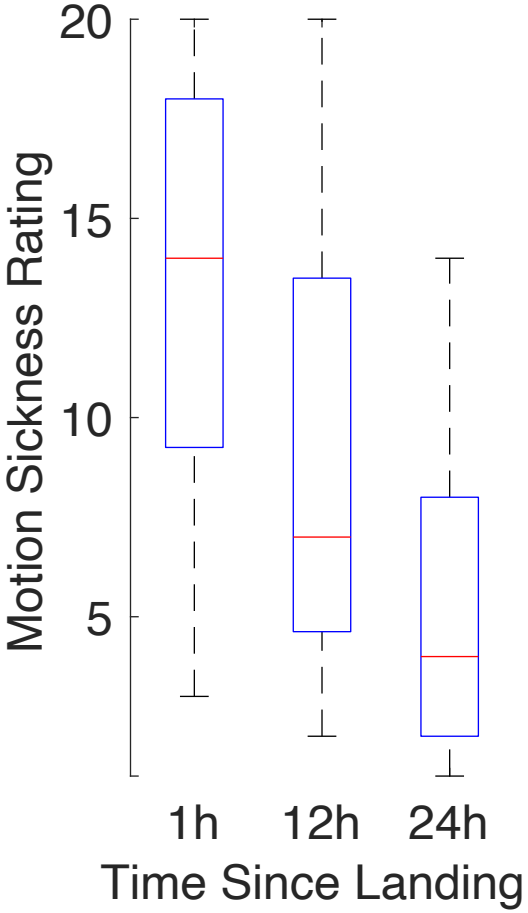


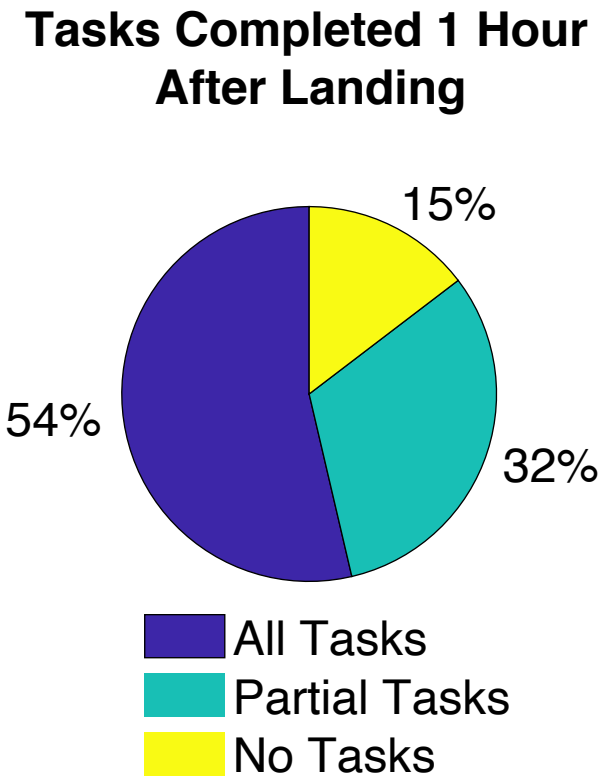
Thornton et al., 1987

- Inflight space motion sickness (SMS) incidence ~70%, developing within hours and resolving within 2-3 days but may persist in a few (Jennings, 1998, Reschke et al, 2018)
- SMS severity highly variable across crews, with decreased incidence in repeat flyers (Davis et al, 1988)

- Re-entry motion sickness ~30% after 1-2 week Shuttle missions
- Results from recent Field Tests (Reschke & Kozlovskaya) suggest re-entry re-entry MS incidence is much higher following longer duration 6-mo ISS flights (100%, n=38)

Re-entry motion sickness





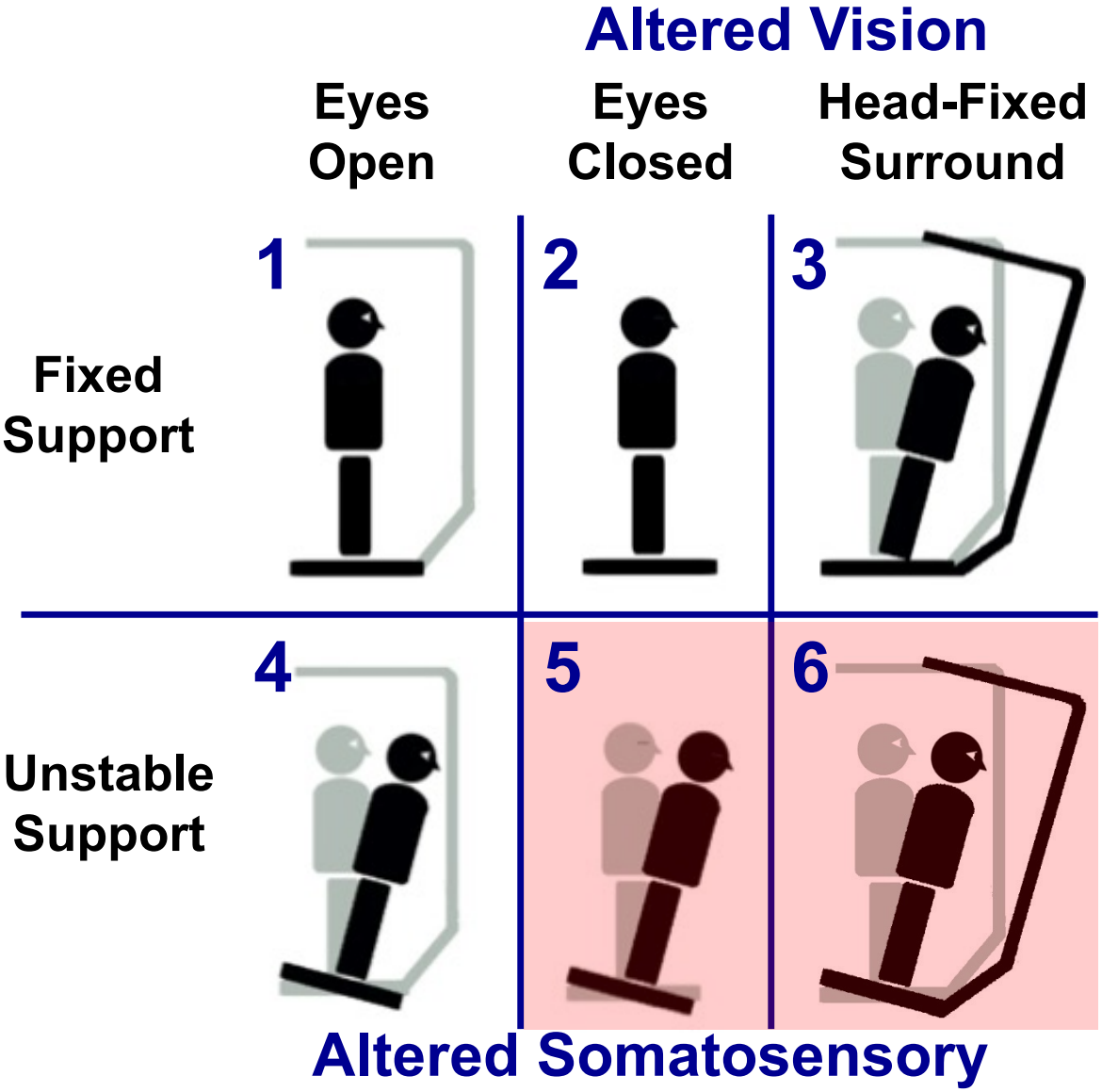
(Pilot and Full Field Tests, Reschke & Kozlovskaya, n=38)

Post-flight STS neuro exam

Rank Order	Neurological Function Test	% with positive signs on Landing Day
1	Tandem/Heel to Toe Walk (eyes open)	57.0%
2	Gaze/Ocular Movements	55.0%
3	Dynamic Equilibrium	47.2%
4	Leg lift-Hop	39.6%
5	Standing/ Romberg	22.2%
6	Finger to Nose	19.4%
7	Dizziness/Faintness	16.5%
8	Rising from Chair	13.8%
9	Vertigo/Spinning	11.9%
10	Drift	10.2%
11	Headache	7.5%

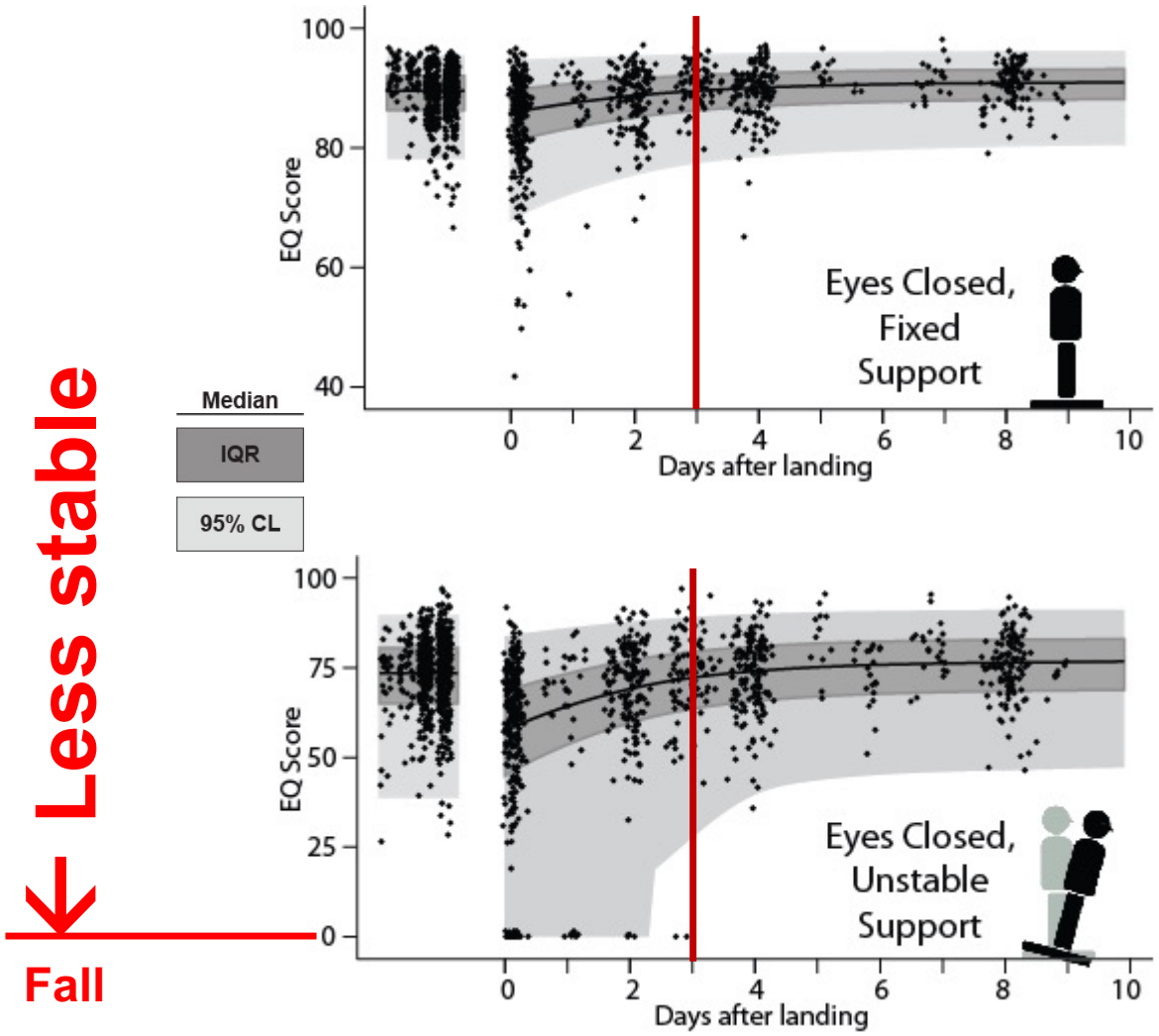
Clark JB. J Vestib Res (2002) 11:321-322

Sensory Organization Tests



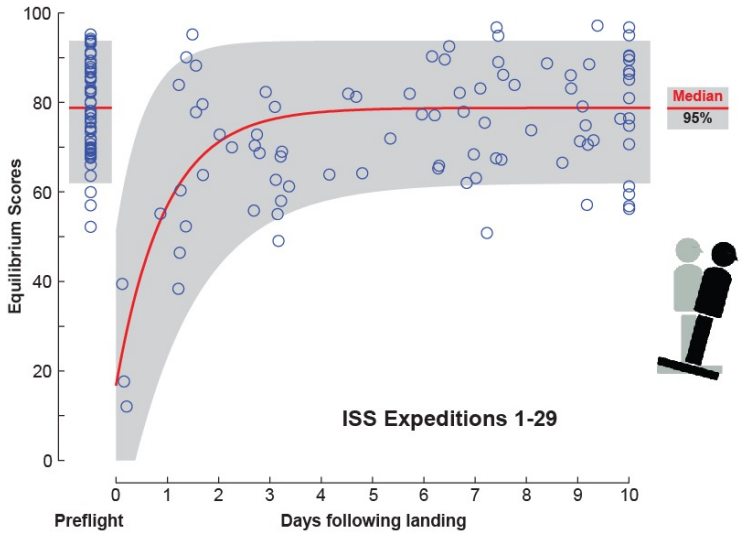
(Nashner et al., 1982)

Supplement to Post-Shuttle Neuro Exam



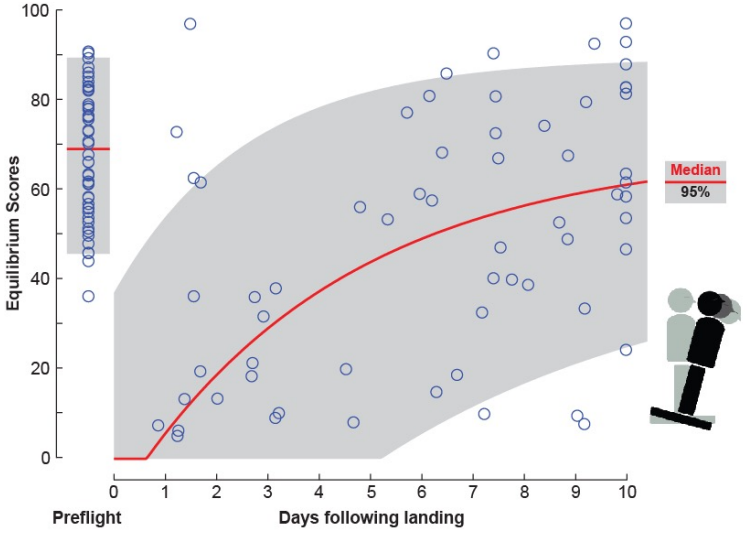
Sharpen tests with head tilts

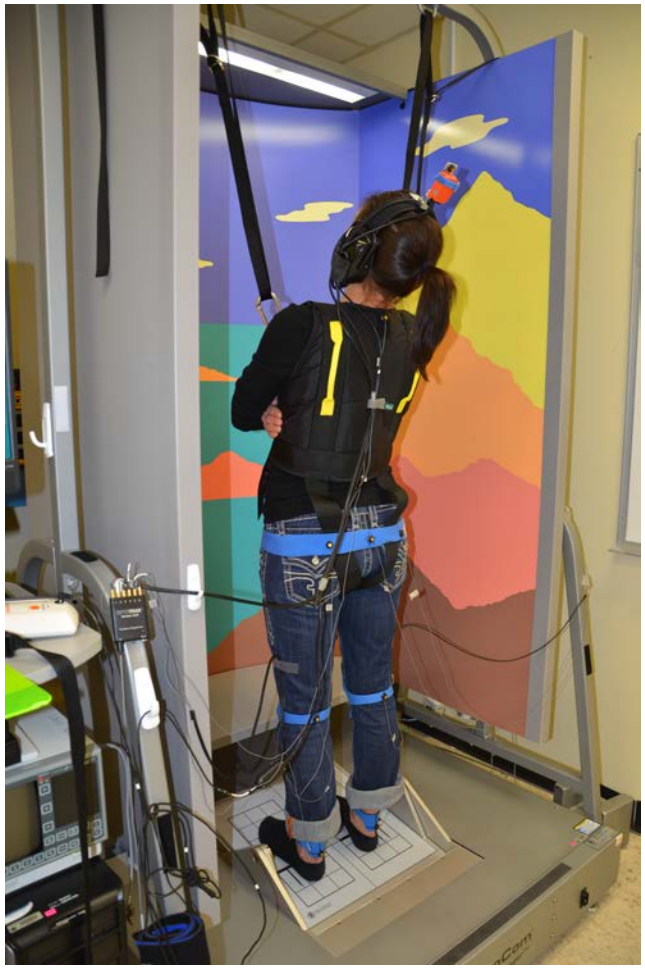
Head Erect



Head Moving

Pitch 0.33 Hz ±20°



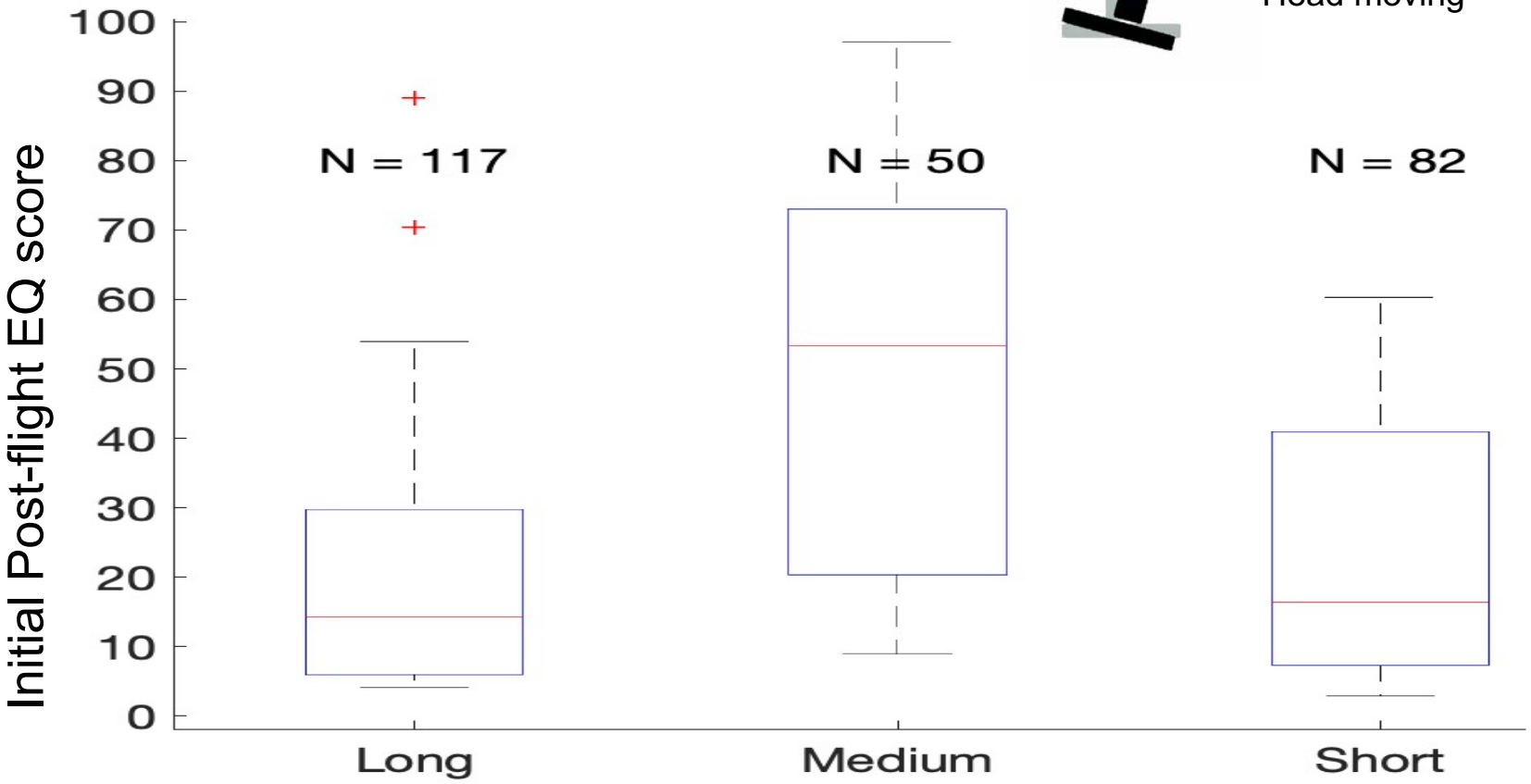


SOT5: Eyes closed, Unstable support

Wood et al., Aviat Space Environ Med (2013)

Effect of duration

SOT-5M
Eyes Closed,
Unstable support,
Head moving



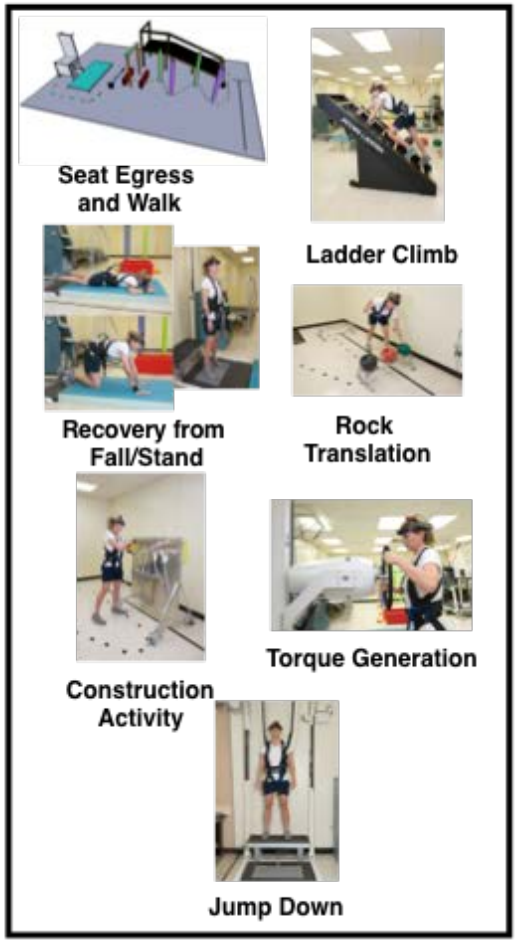
>180d,
R+22-36h

30-180d ,
R+22-36h

<18d,
R+2-6h

Functional Task Test

Functional Performance



Map

Physiological Measures

Muscle
- Strength
- Power
- Control
- Neuromuscular Drive

Sensorimotor
- Balance
- Gait
- Dynamic Visual Acuity
- Fine Motor Control

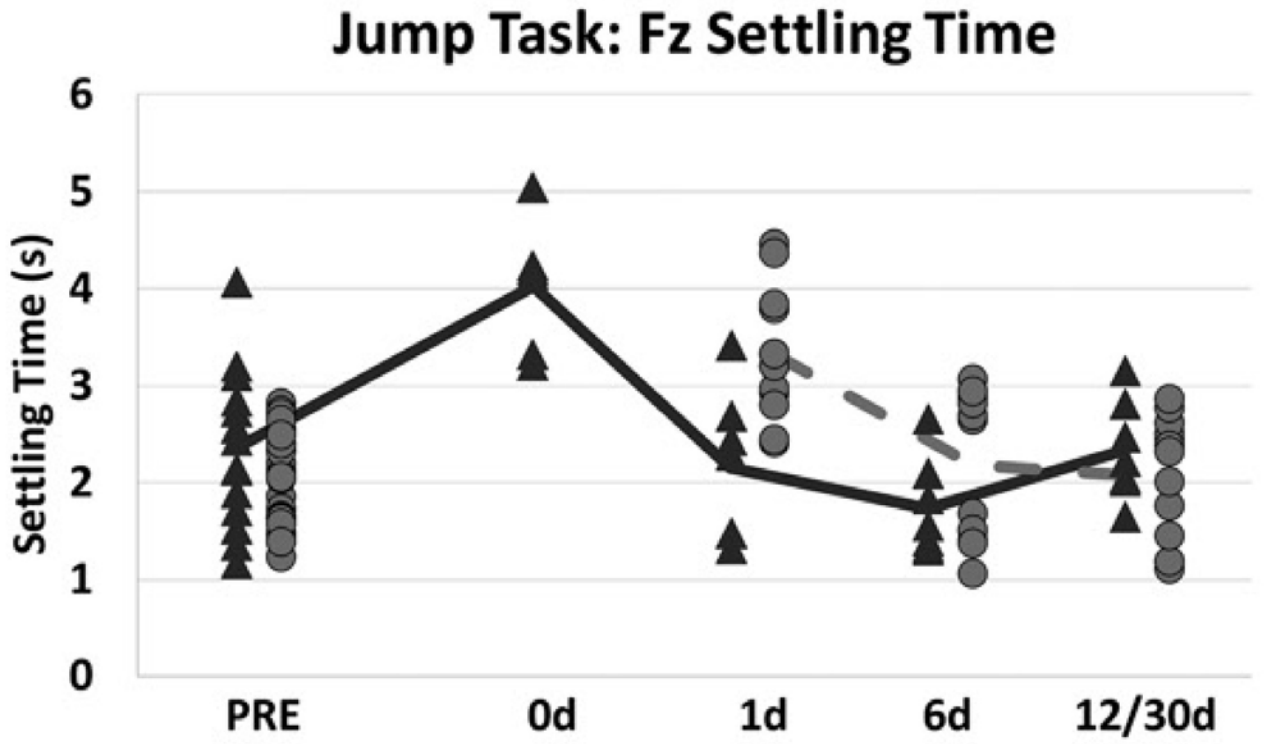
Cardiovascular
- Plasma Volume
- Heart Rate
- Blood Pressure

Interdisciplinary testing regimen maps postflight functional performance to related physiological changes.

PI: J. Bloomberg

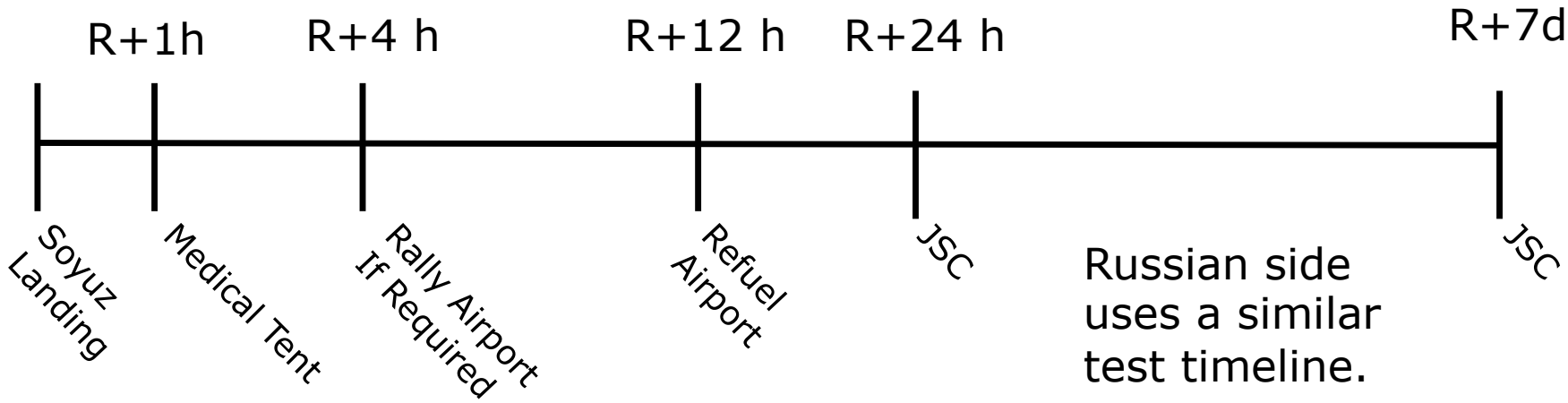
Functional task tests

Jump Down



- Functional tasks with a postural equilibrium challenge show the greatest change shortly after Shuttle landings (Mulavara et al, 2018)
- Performance more impaired following longer duration ISS missions on R+1 compared to short-duration STS missions (Miller et al, 2018)

Field Test: Early Postflight Testing

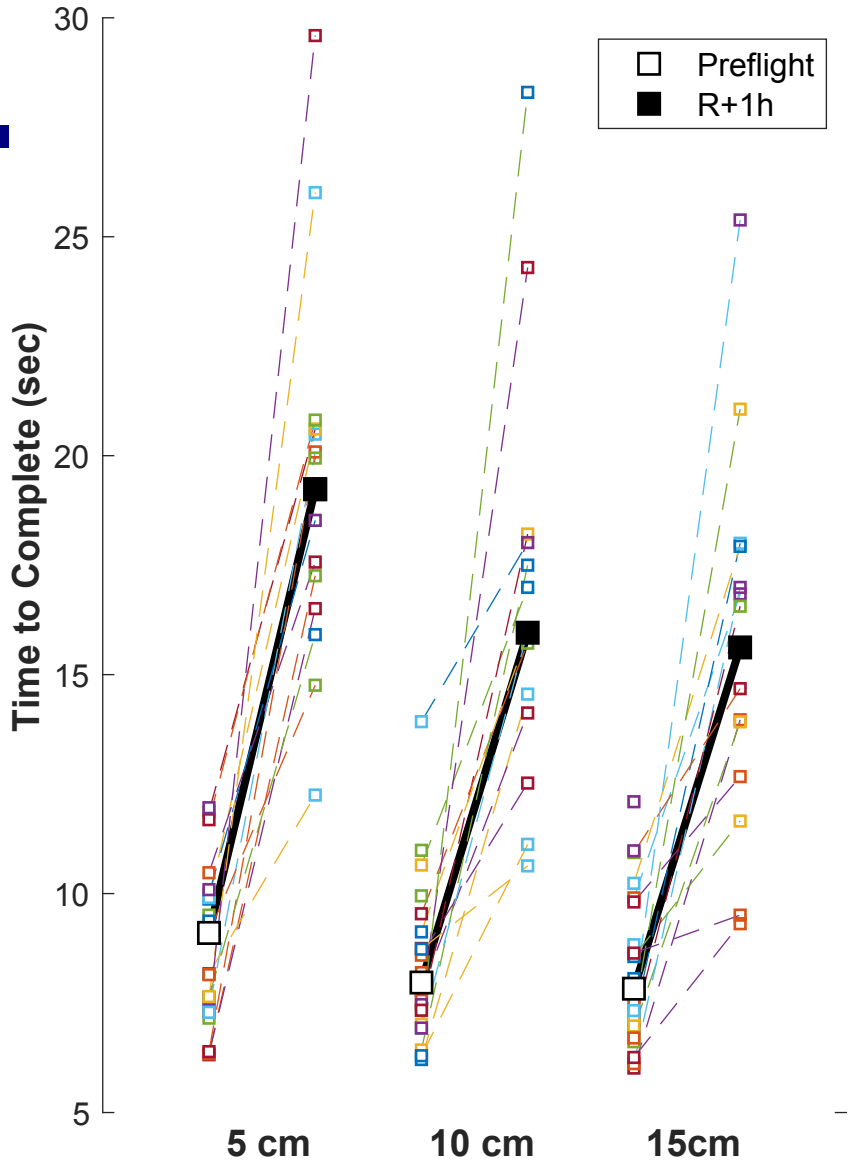


Russian side uses a similar test timeline.

PIs: M. Reschke, I. Kozlovskaya

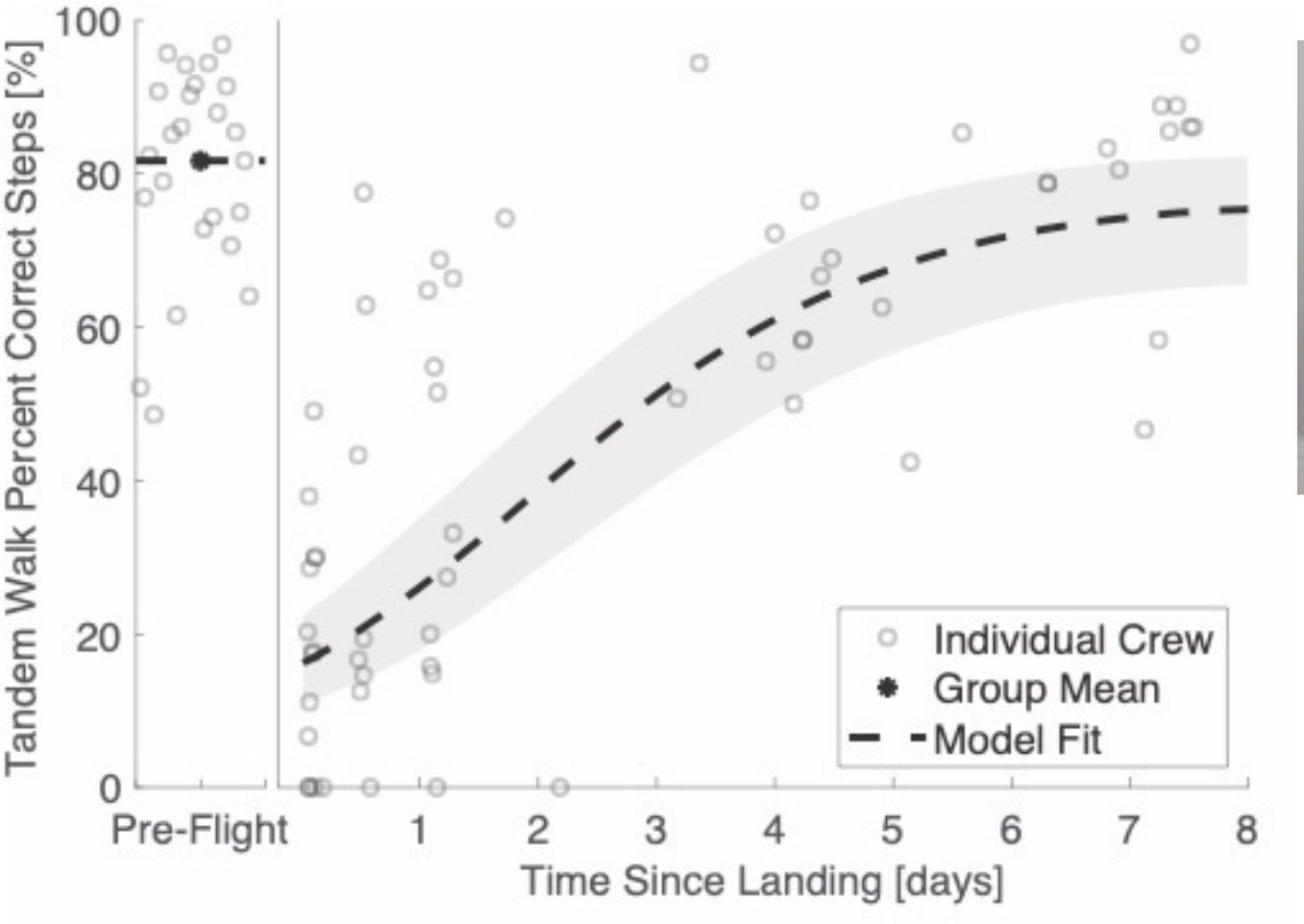
Recovery from fall

Obstacle Walk

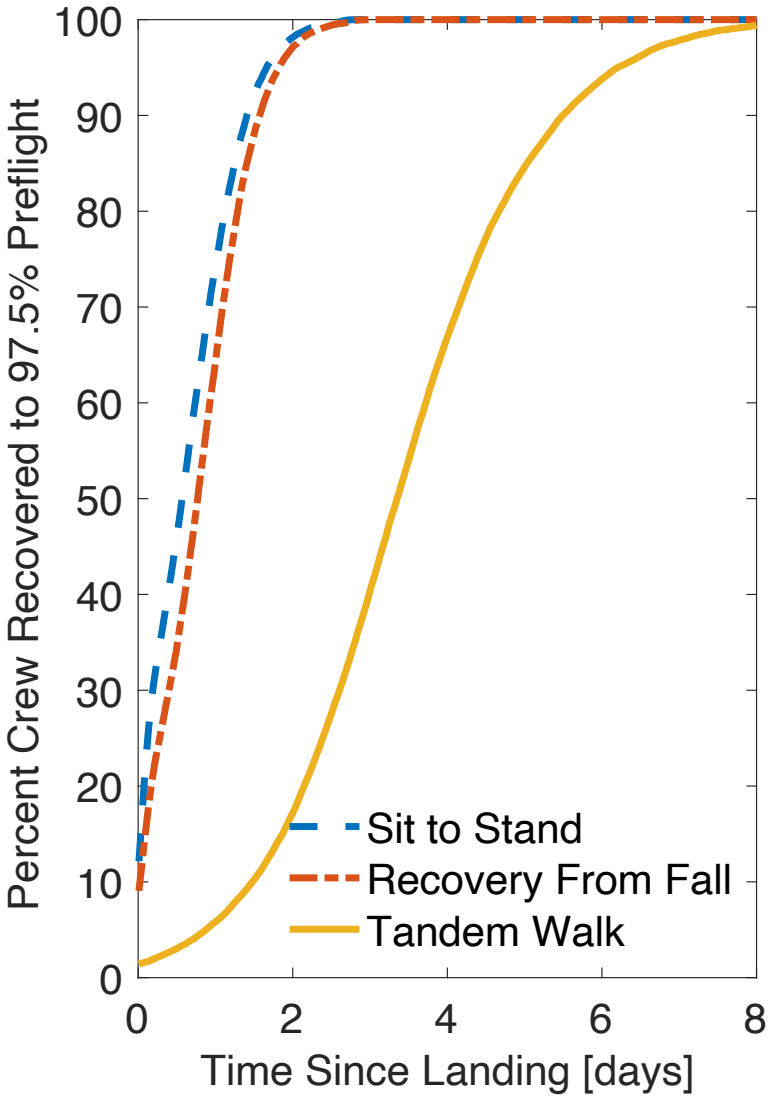


(Reschke et al., 2020 in review)

Tandem walk


Tandem Walk Percent Correct Steps [%]
100
80
60
40
20
0
Pre-Flight
1
2
3
4
5
6
7
8
Time Since Landing [days]
Individual Crew
Group Mean
Model Fit

Recovery curves

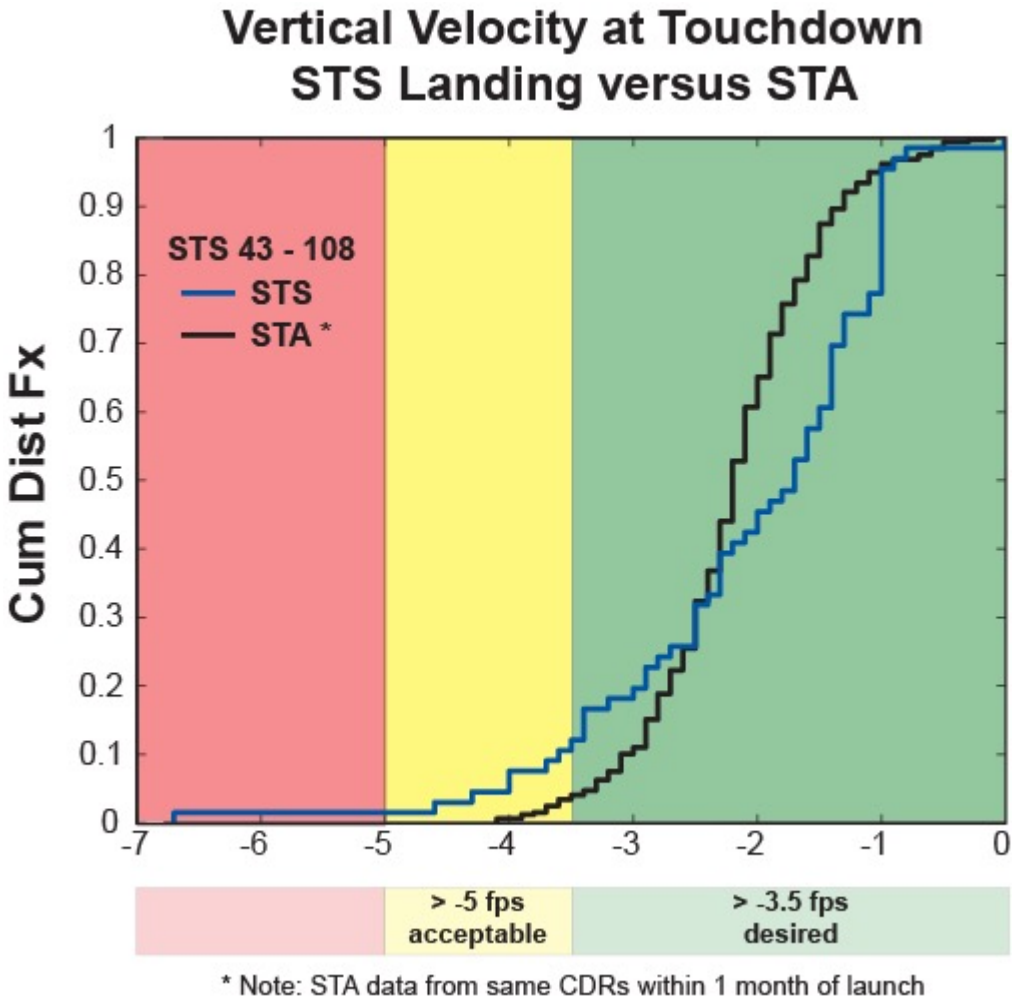


Sit-to-stand

Recovery from Fall

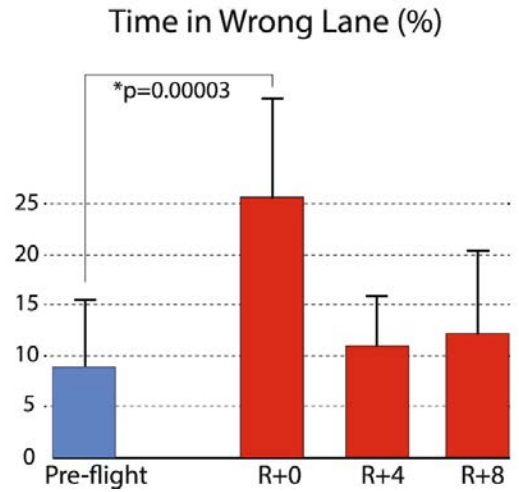
Tandem Walk

Manual control



Paloski et al., J Gravit Physiol (2008) 15:1-29

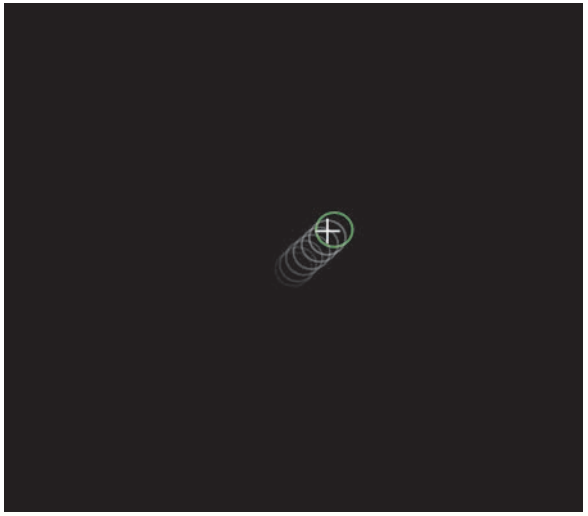
Manual Control

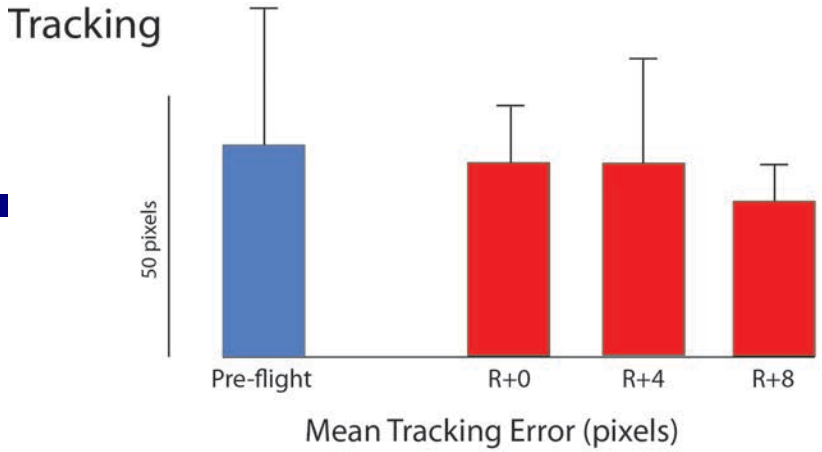


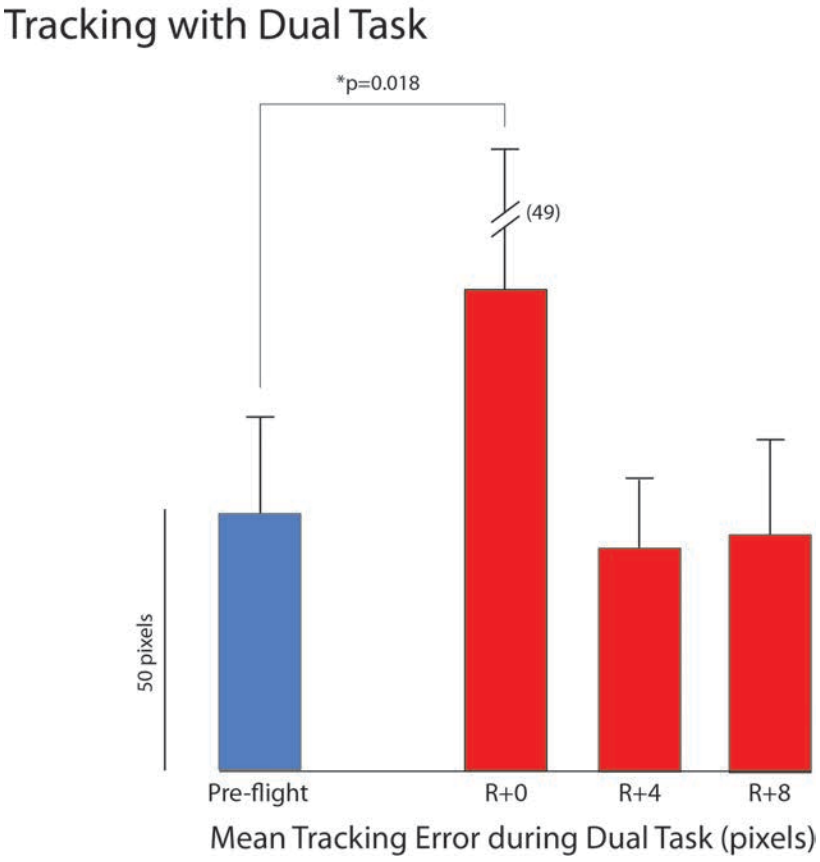
Moore et al., 2019, Sci Rep 9:2677

- ISS crewmembers (n=8) exhibited significant deficits on R+1d in manual dexterity (Pegboard), dual-tasking and tilt motion perception, and a striking degradation in the ability to operate a vehicle
- Similar deficits were not seen in control groups for schedule recency or following 30h sleep restriction
- Limitation: Testing conducted following return to JSC (>R+24 hrs)

Dual task





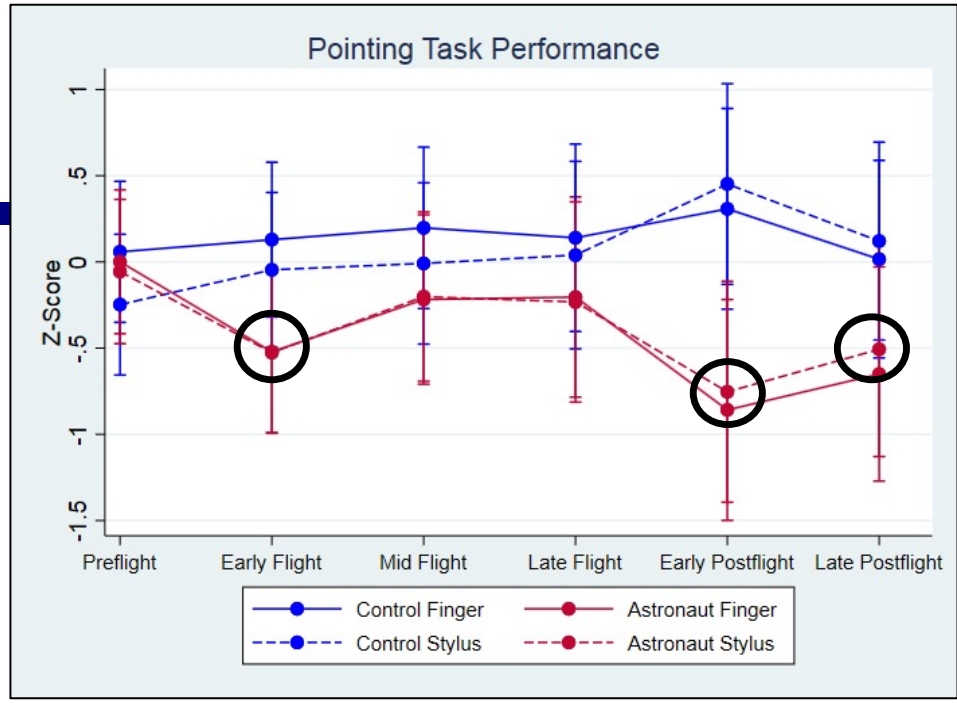


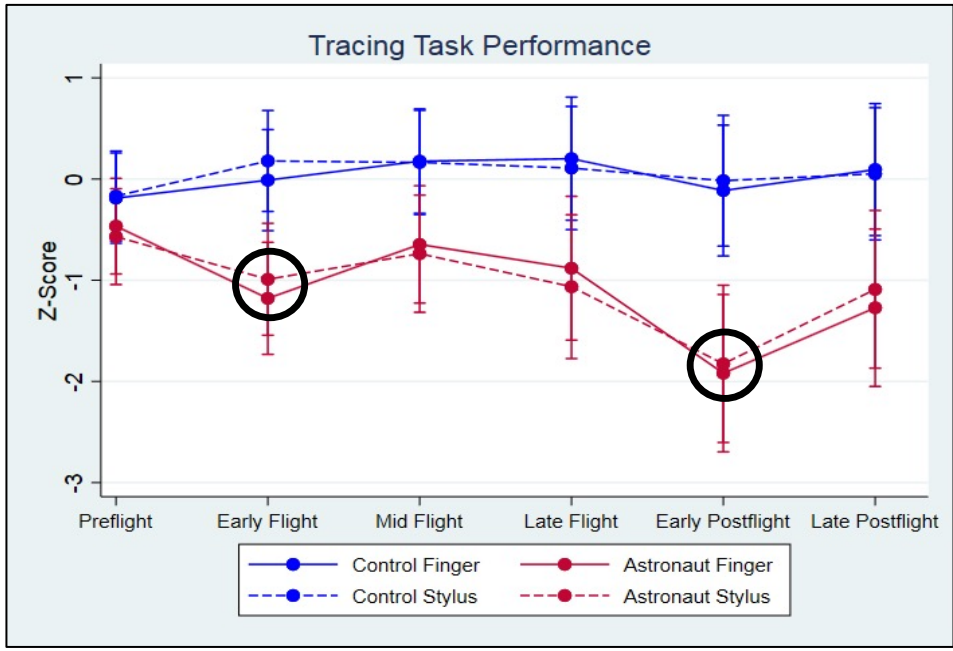
Moore et al., 2019, Sci Rep 9:2677

Fine motor control

Small but reliable decrements in fine motor control observed during g-transitions (PI: Holden)

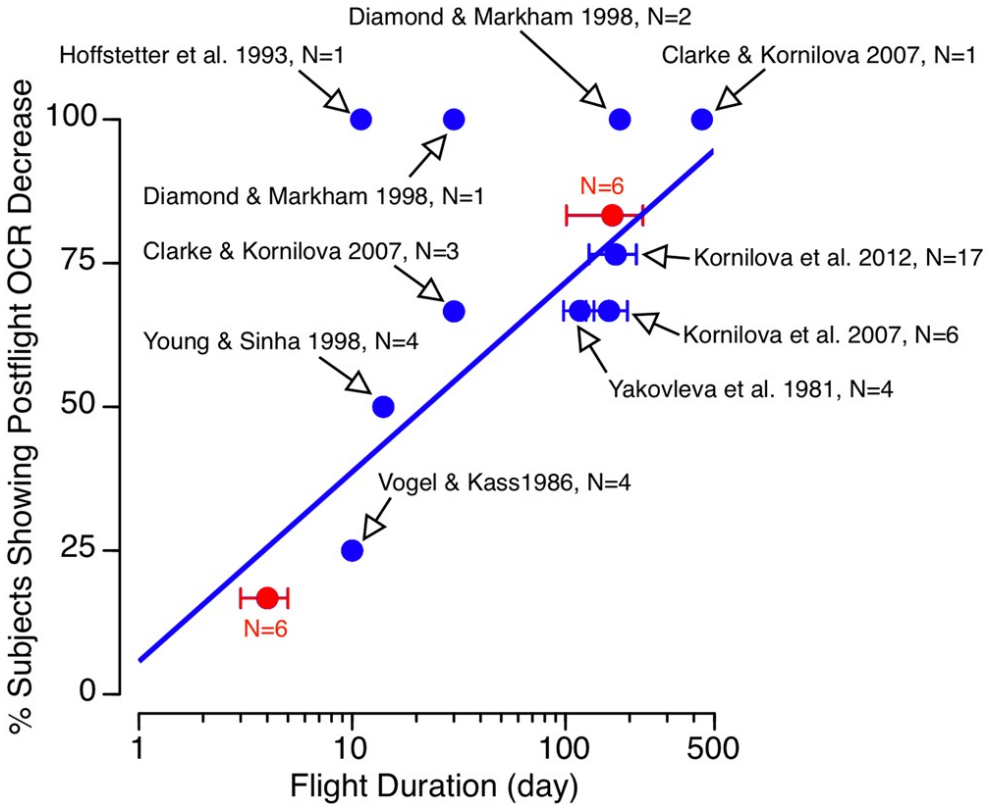
- Specifically seen in pointing tasks, dragging tasks, and shape tracing tasks.
- Decrements were observed while transitioning from 1G to microgravity as well as upon return to Earth





Vestibulo-ocular reflex

- Clark et al. (2000) reported changes in up/down asymmetry of vertical VOR gain and reductions in torsional VOR gain during active head movements on ISS flights, with some recovery in the later phase
- Reschke et al (2019) reported decreases in post-flight ocular-counterrolling that were dependent on mission duration

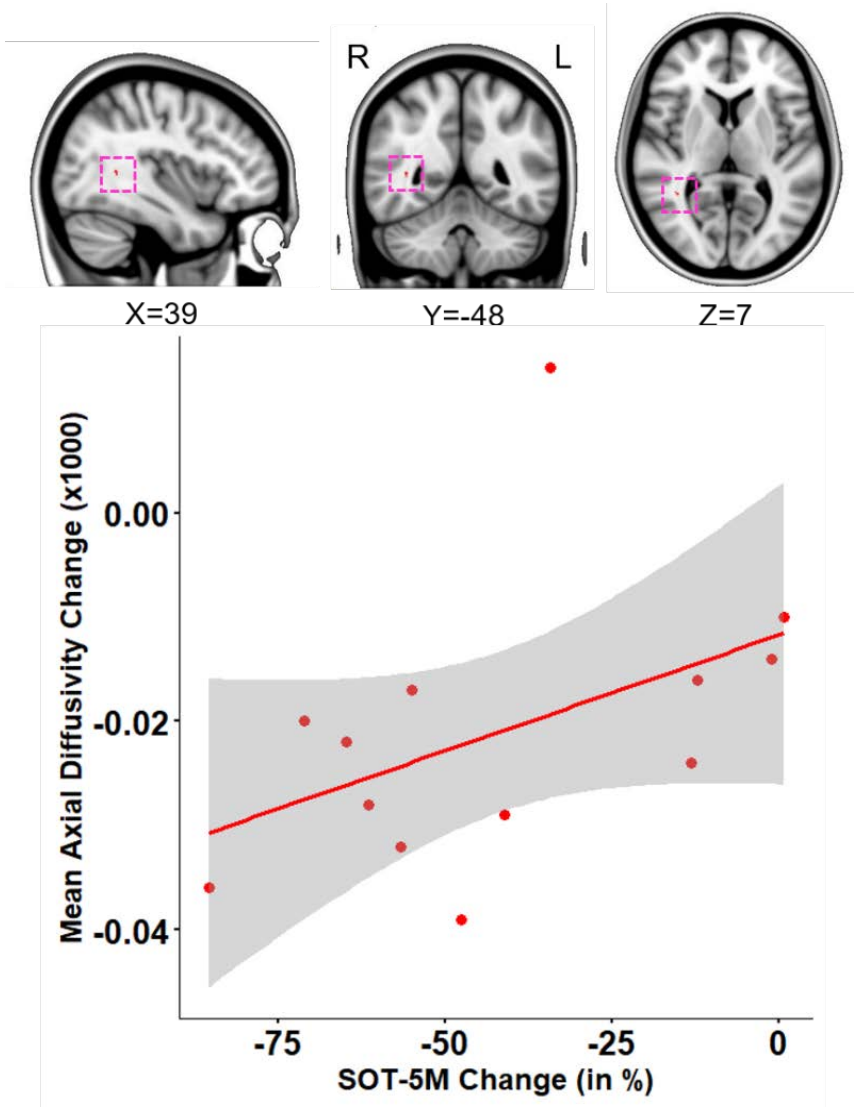


(Reschke et al. 2018, *Sci Report)*

Neuroimaging

- Spaceflight is associated with redistribution of brain extracellular fluids; white matter changes occur throughout the brain and, in some cases, are significantly associated with mission duration and post-flight declines in balance.
- Greater declines in the white matter underlying the vestibular cortex from pre to post flight are associated with larger declines in balance.

PI R. Seidler, Neuromapping



(Lee et al. 2019, *JAMA Neurology)*

Summary

- Returning crewmembers exhibit vestibular/cerebellar and sensorimotor decrements following G-transitions that reflect adaptive responses in central neural pathways
- Large inter-subject variability, also influenced by current countermeasures and amount of active movement
- There is a greater incidence and severity of sensorimotor deficits with increasing flight duration
- Time course of recovery for a given metric depends on flight duration and task complexity
- Ongoing work to map changes in neuroimaging studies with behavioral consequences