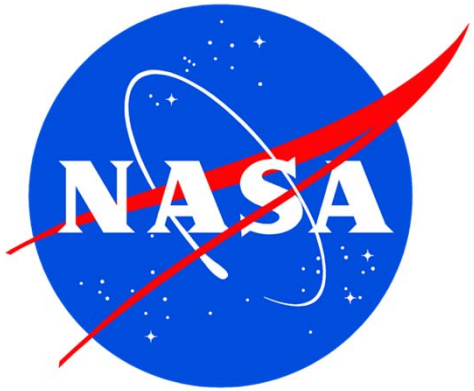
Assessing changes in postural and manual control following spaceflight: Implications for managing clinical status evaluations

Scott Wood

[1] NASA Johnson Space Center

[2] Azusa Pacific University

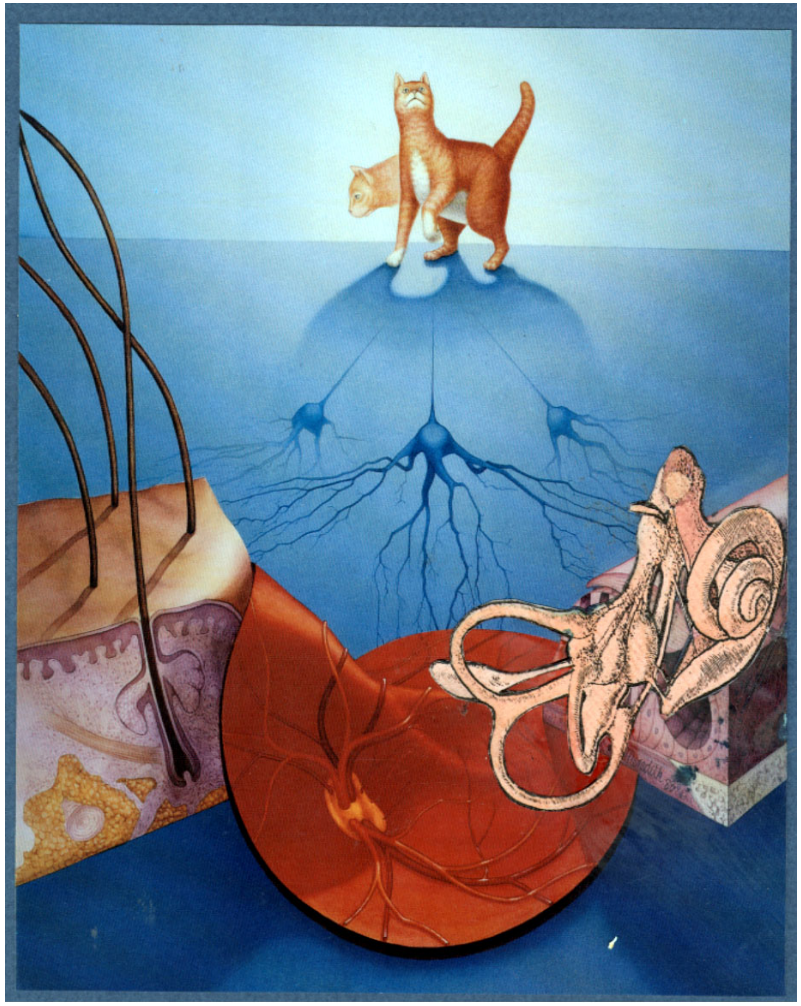


Towards Integrated Countermeasures
August 28, 2013

Objectives

- Postural recovery after space flight
  - Multisensory aspects
  - ISS countermeasures
- Evidence gap for manual control risk
  - Shuttle ZAG experiment – Clément
  - ISS Manual Control – Moore
- I ni ions

Resolving sensory ambiguity



- Our ability to sense motion and orientation depends on a learned ability to interpret the continuous input of multiple sensory signals
- Redundancy means that one system can compensate for limitations in another
- Redundancy also sets up potential for sensory conflict through aging, pathology or environmental change

Mechanisms of Adaptation

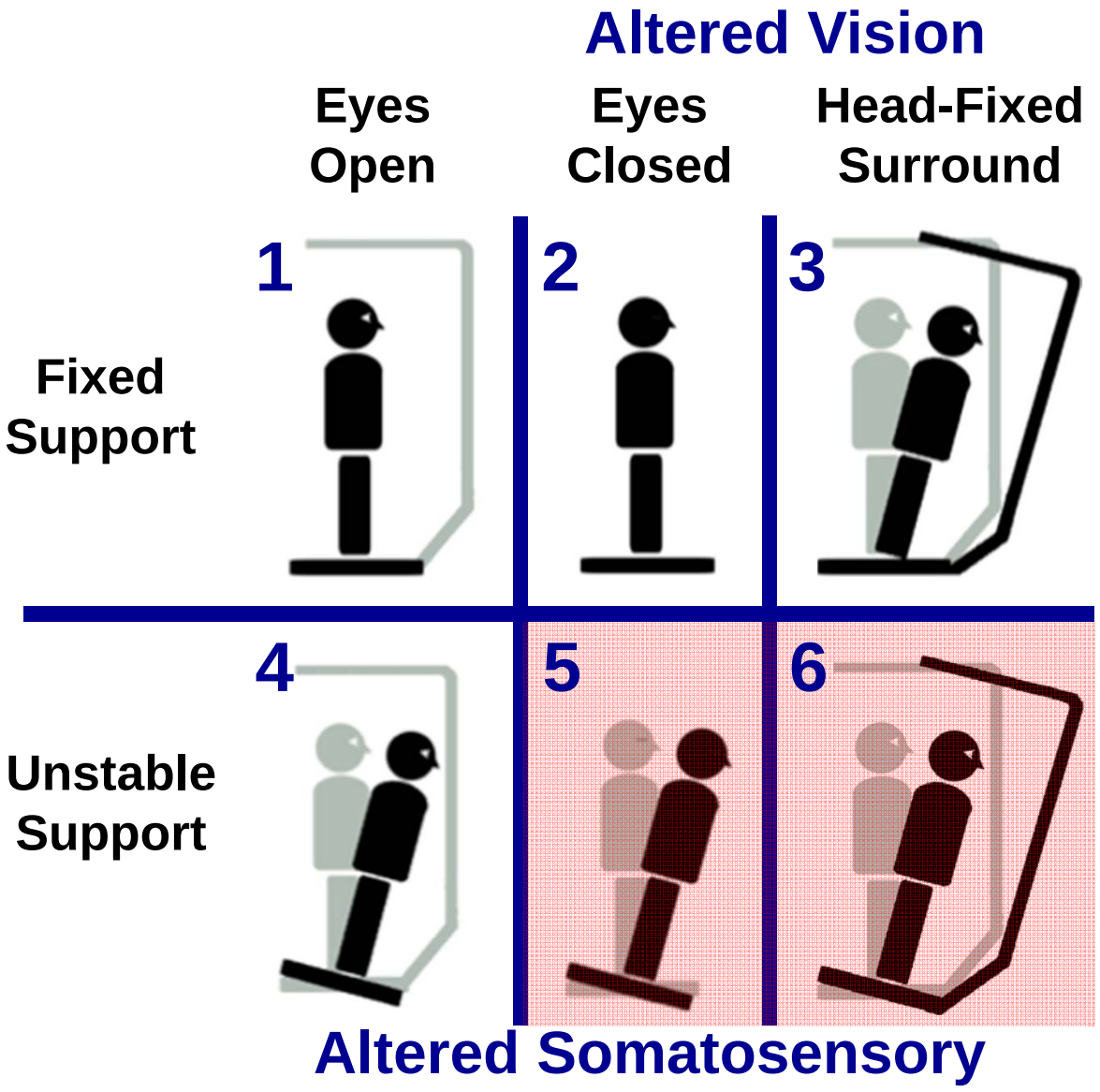
- Multisensory integration
  - Different patterns of sensory cues, e.g., otolith cues during head tilt
  - Interaction with support surfaces for locomotion and orientation
- Gravitational unloading
  - Altered proprioception for mass discrimination and force control
  - Fluid shifts, deconditioning
- Adaptive for microgravity … maladaptive for transition to new gravitoinertial state

Post-flight neurological 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%

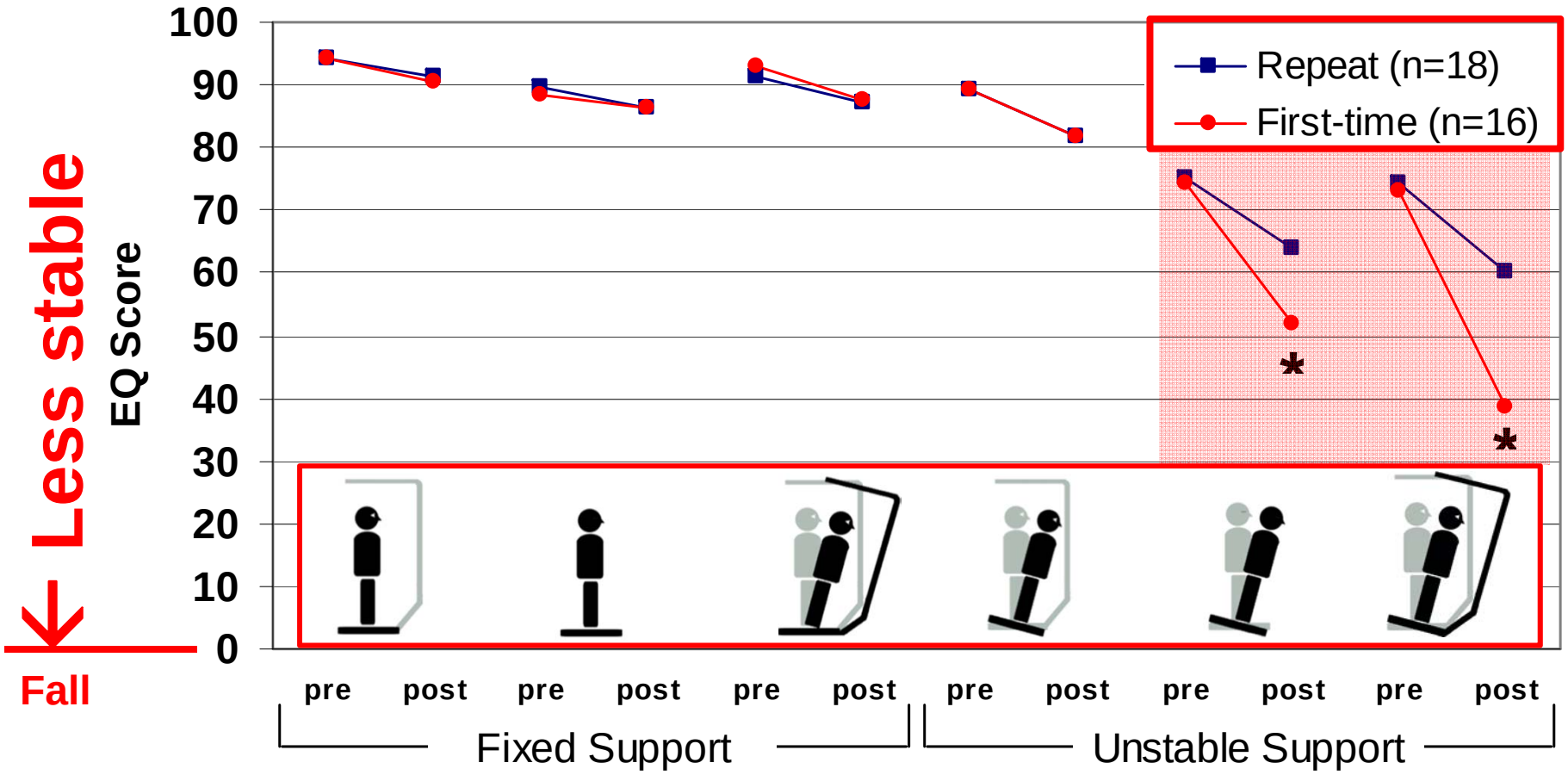
Clark JB. J Vestib Res (2002) 11:321-322

Sensory Organization Tests



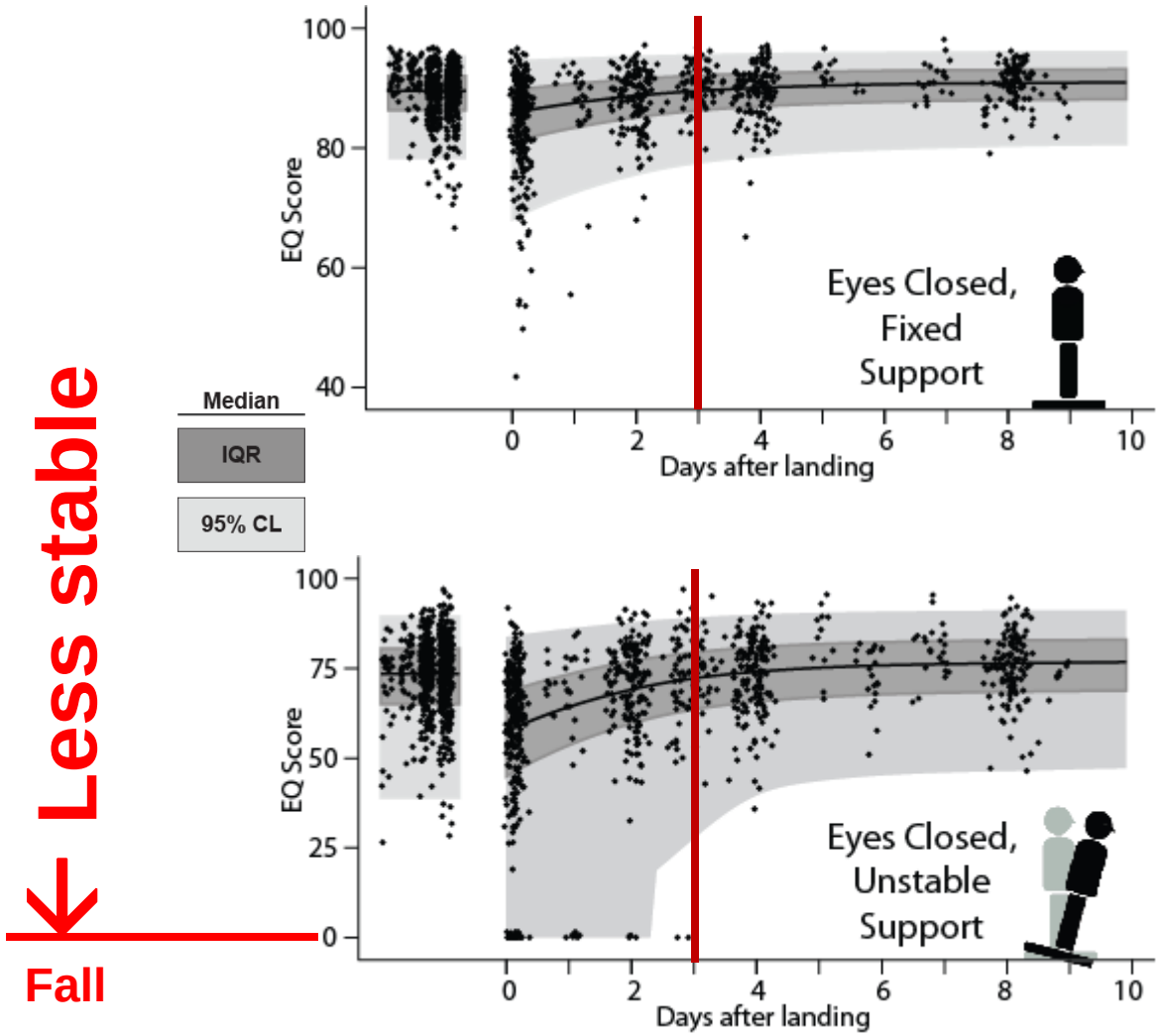
Nashner et al., J Neuroci (1982) 2:536-544

Post Shuttle (EDOMP)

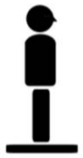


Adapted from Paloski et.al. 1995

Supplement to Post-Shuttle Neuro Exam



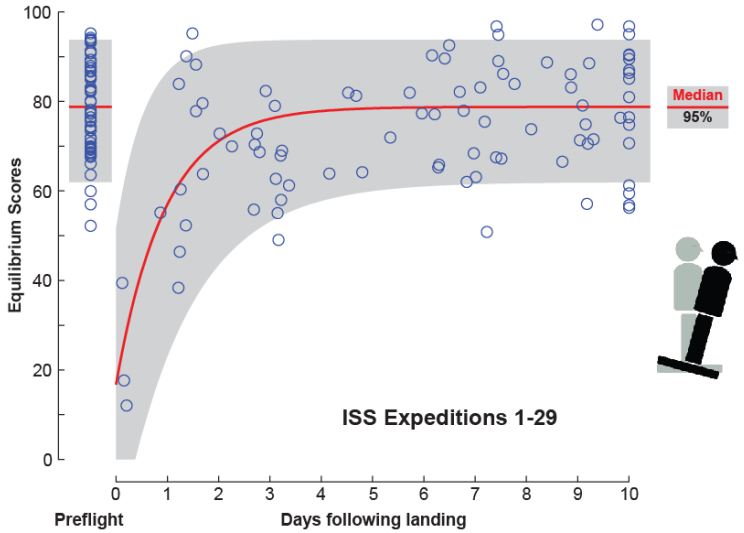
% Change R+0 Post-ISS (Exp 1-29)

	Eyes Open	Eyes Closed	Head-Fixed Surround
Fixed Support	1 -4.6% 	2 -8.1% 	3 -7.0% 
Unstable Support	4 -22.3% 	5 -82.4% 	

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

Sharpen tests with head tilts

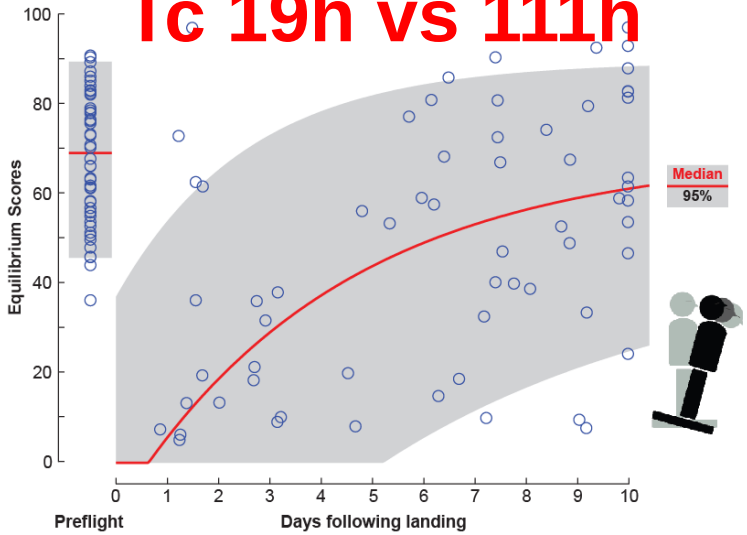
Head Erect

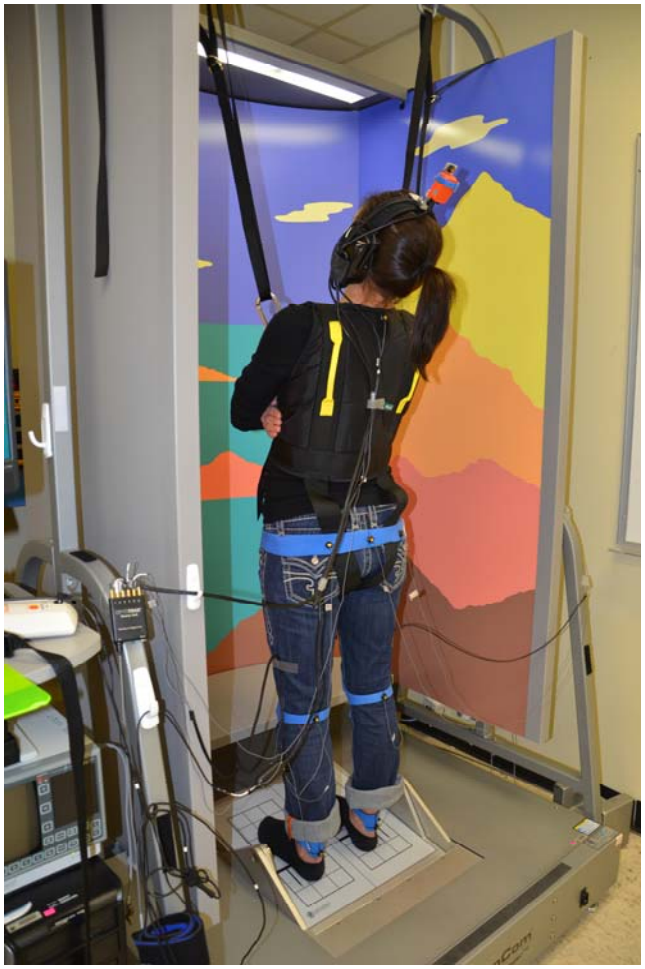


Head Moving

Pitch 0.33 Hz ±20°

Tc 19h vs 111h

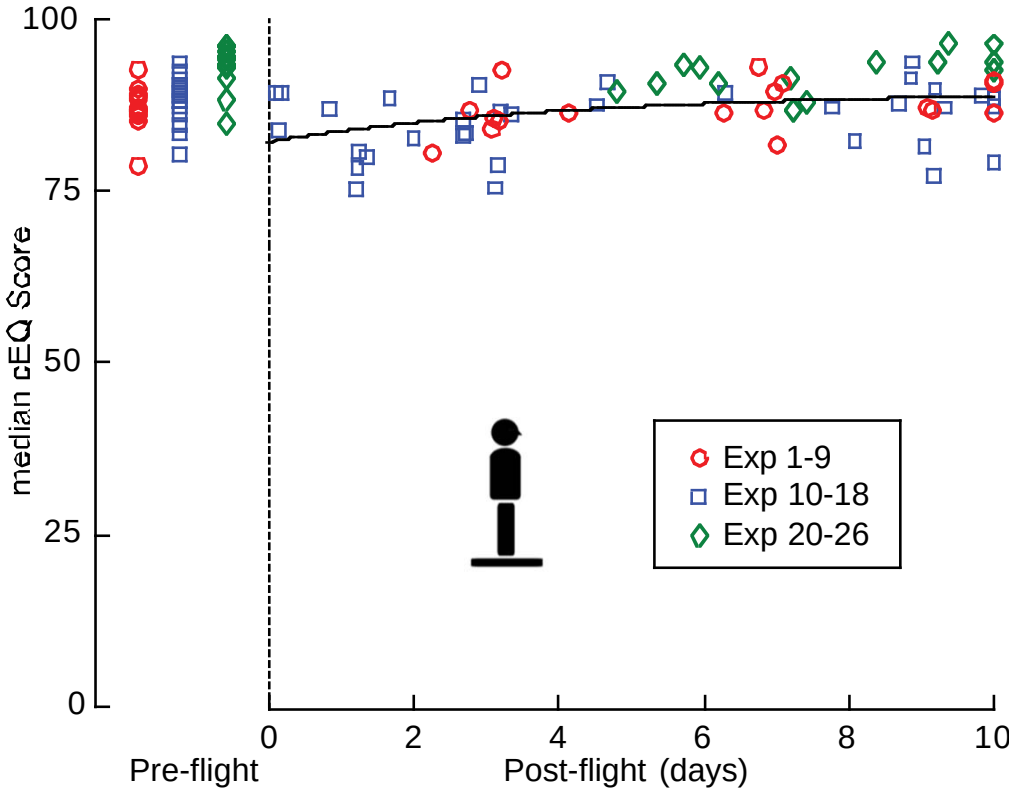




Wood et al., Aviat Space Environ Med (2013)

ISS Countermeasures

Head Erect, Eyes Closed, Fixed Support



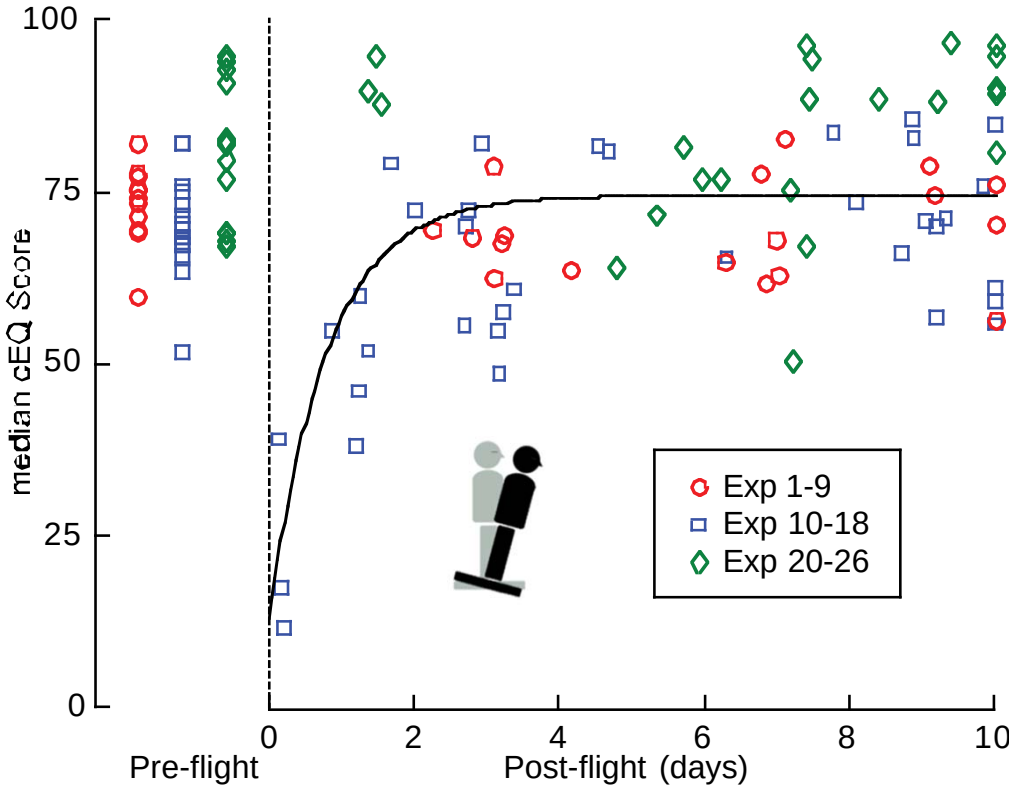
Interim Resistive Exercise Device

Advanced Resistive Exercise Device

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

ISS Countermeasures

Head Erect, Eyes Closed, Unstable Support



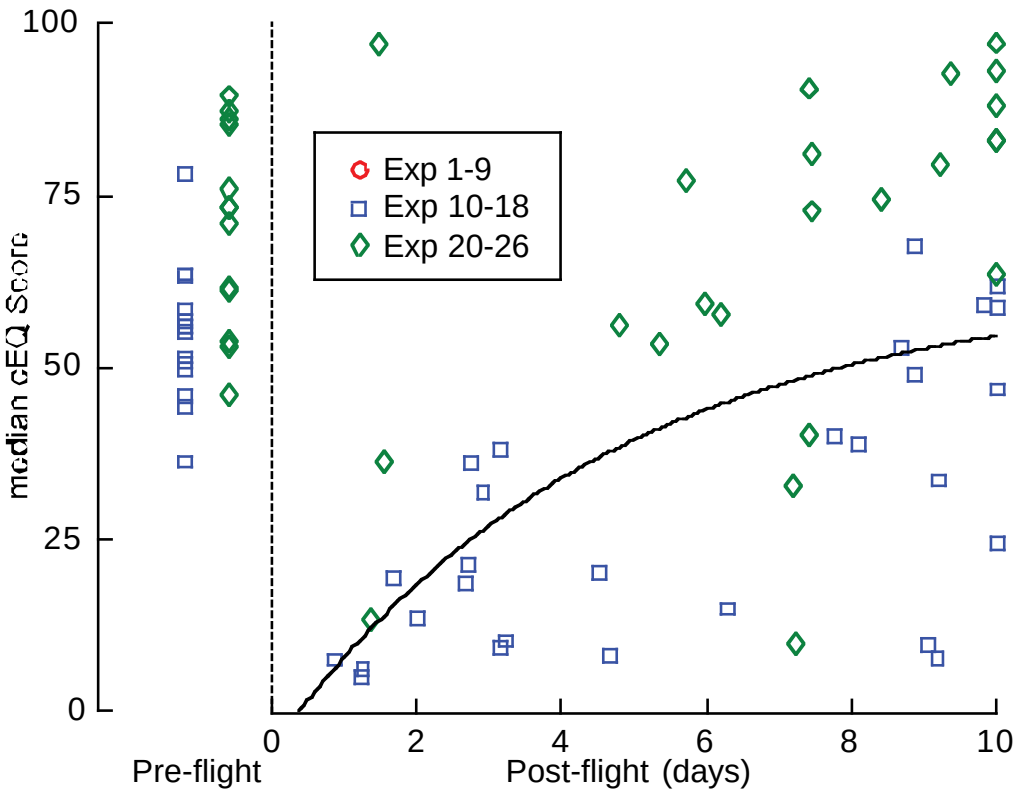
Interim Resistive Exercise Device

Advanced Resistive Exercise Device

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

ISS Countermeasures

Head Moving, Eyes Closed, Unstable Support



Interim Resistive Exercise Device

Advanced Resistive Exercise Device

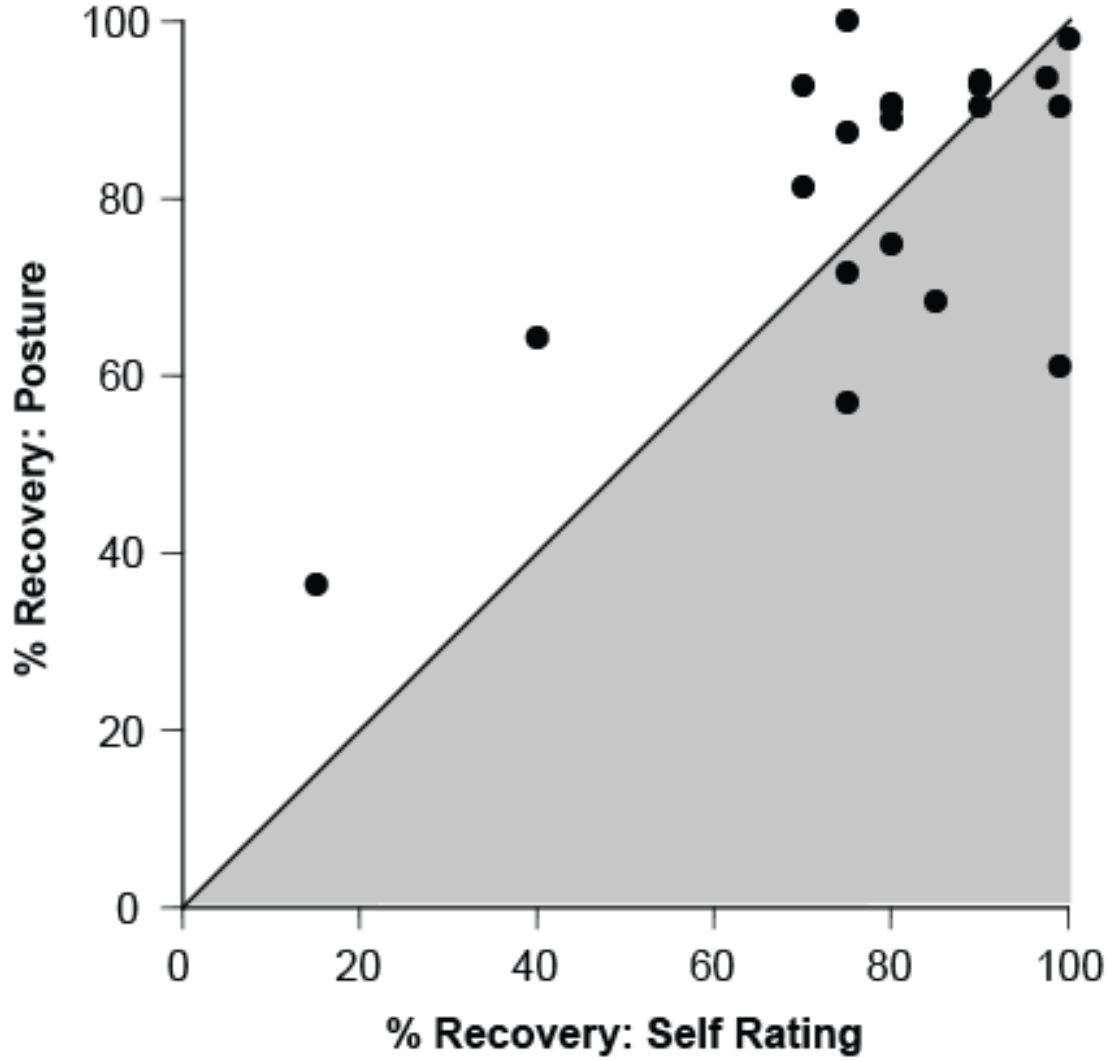
Wood et al., Aviat Space Environ Med (2013)

Post-flight Reconditioning Program

Exercise	Schedule
1 Dynamic Stretch & Warm-up	Every day: R+1-45
2 Aerobic Conditioning	Every day: R+1-45
3 Resistance Exercise	Every other day: R+1-45
4 Mobility, Balance & Proprioception Drills	Every other day: R+1–45
5 Medicine Ball Drills	Every other day, R+1-45
6 Cone and Agility Ladder Drills	Every other day: R+6-45
7 Jumping Drills	Every other day: R+21-45
8 Core Exercise	Every day: R+1-45
9 Static Stretching	Every day: R+1-45

Wood Loehr & Guilliams, NeuroRehab (2011) 29:185-95

Posturography vs Self-Rating

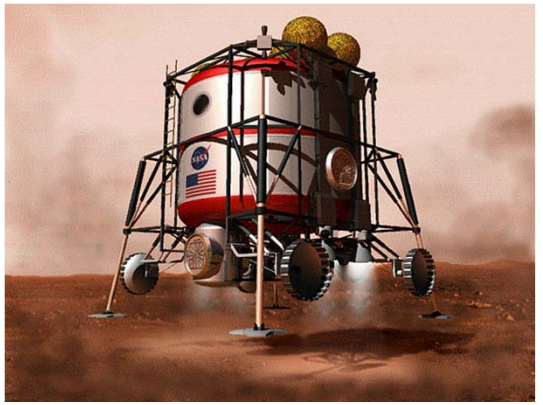


Wood et al. NeuroRehab (2011) 29:185-95

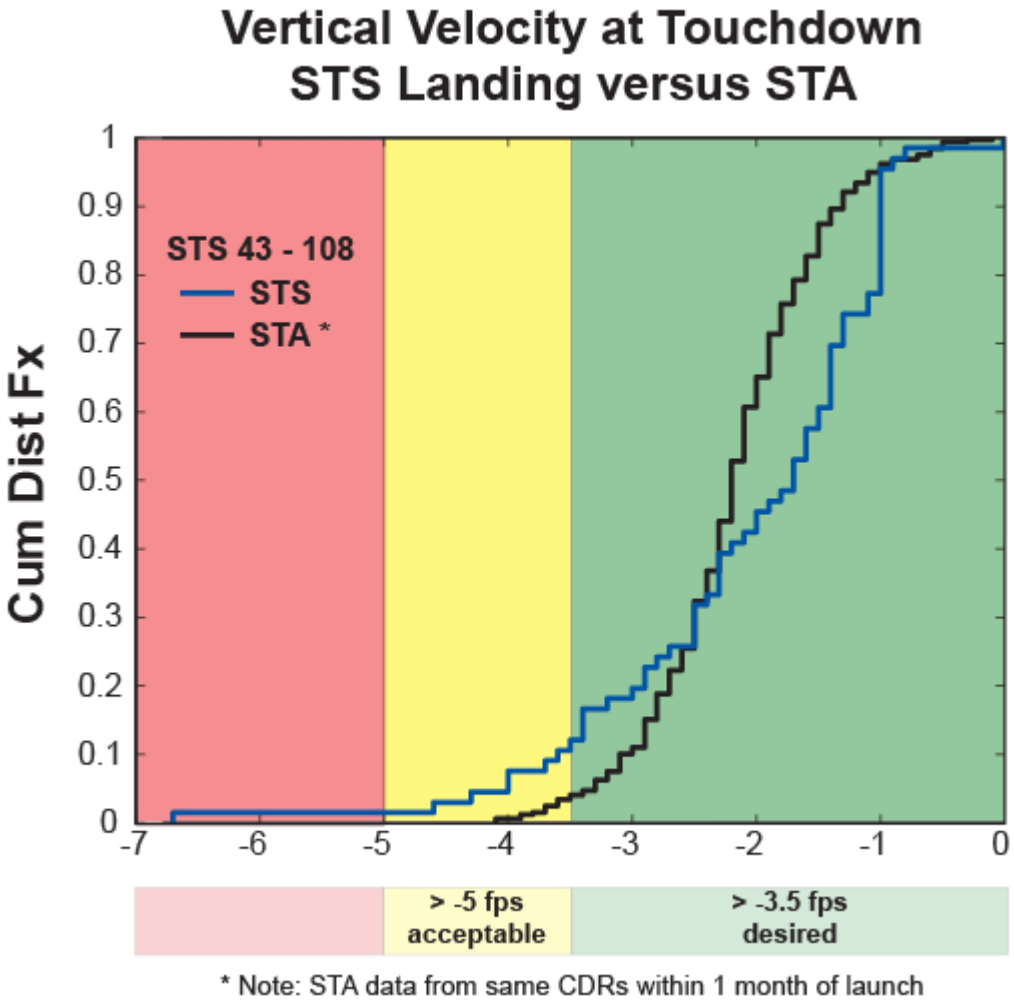
Manual control risk?

Risk of impaired control of spacecraft, associated systems and immediate vehicle egress due to vestibular/sensorimotor alterations associated with space flight

SM6: Addresses vehicular control after six months in microgravity

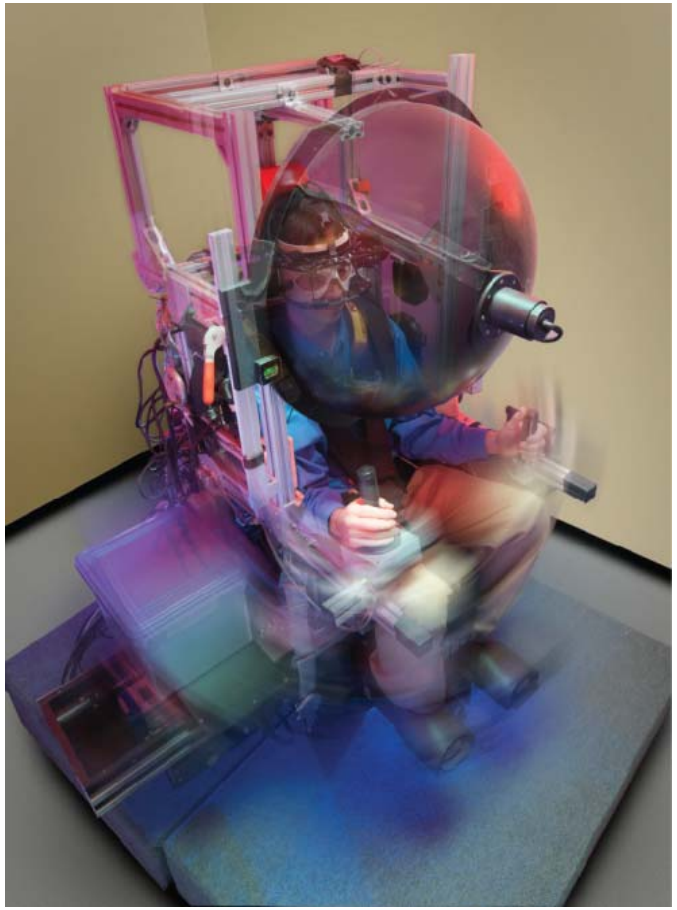


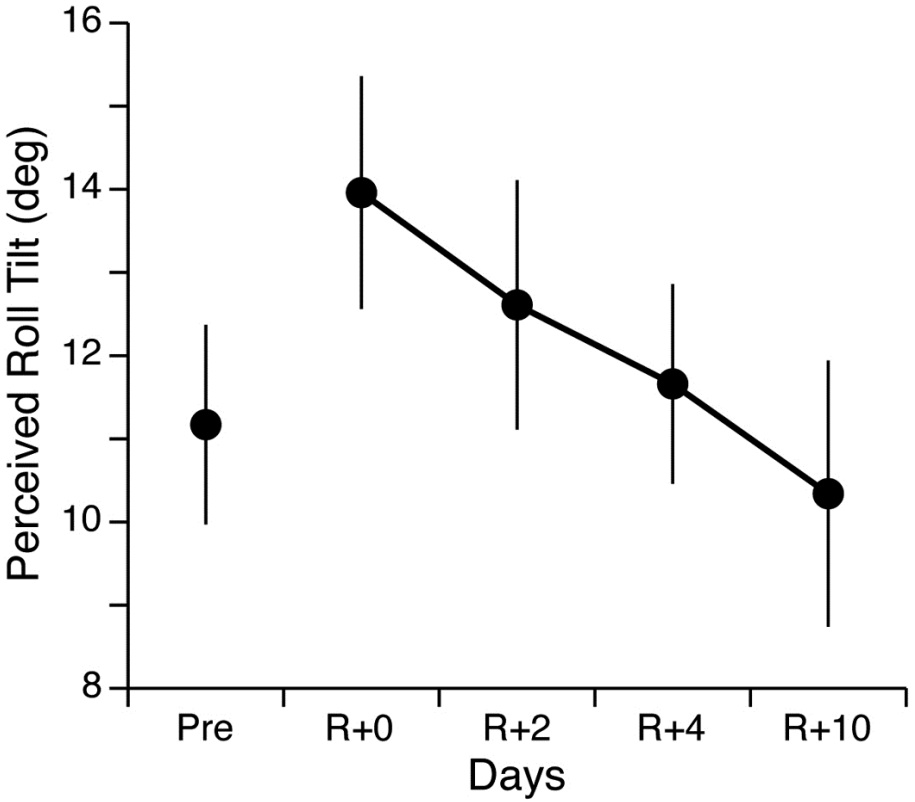
Shuttle data mining



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

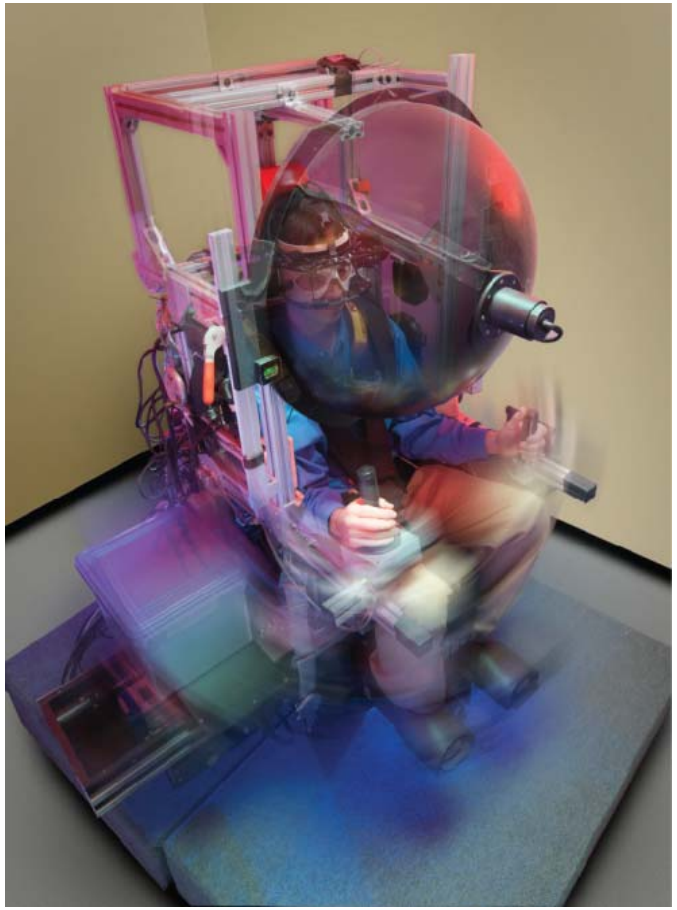
Shuttle ZAG experiment – Clément

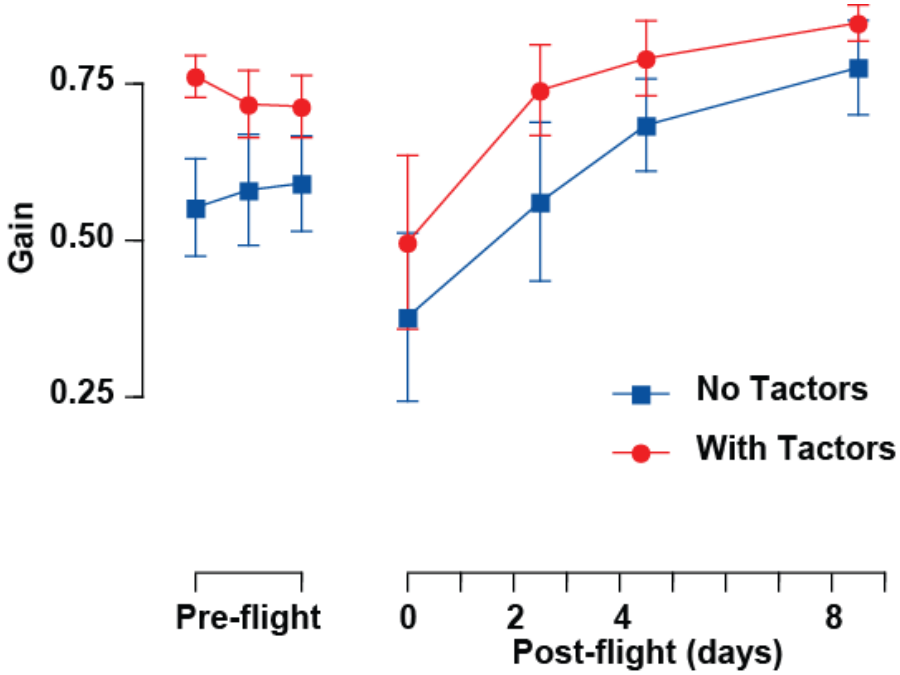




Clément & Wood, Acta Astronautica (2013) 92:48–52

Shuttle ZAG experiment – Clément





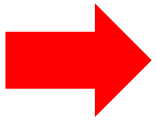
- **On R+0 nulling gain reduced by >30%**
- **Recovery within 2 days after return**

Clément & Wood, Acta Astronautica (2013) 92:48–52

ISS Manual Control – Moore

Operator proficiency tests (motion simulations)

- driving a car
- landing an aircraft
- operating a Mars rover



Sensorimotor Test Battery

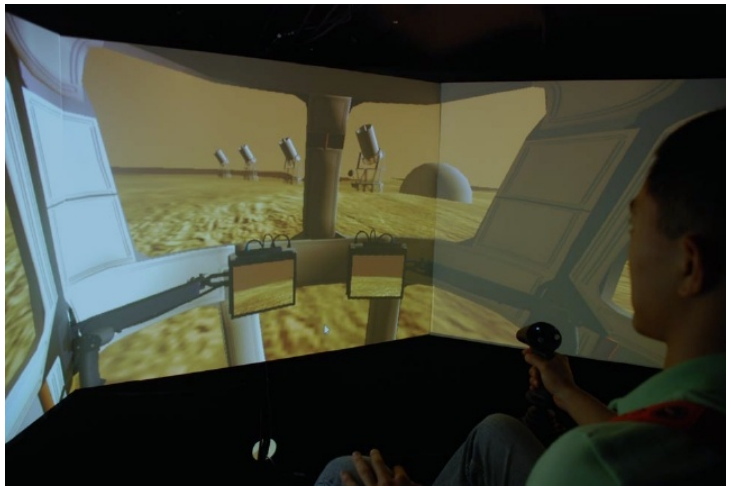
- Reaction time
- Perspective taking
- Manual tracking
- Dual tasking and manual tracking
- Manual dexterity
- Visual acuity
- Sleepiness rating
- Motion perception

ISS Manual Control – Moore

Operator Proficiency Tests

Driving

Flight



Mars Rover

Implications: Clinical Status Eval

- Large inter-subject variability! Self-assessment will be important during more autonomous missions
- Functional tests requiring more complex tasks sharpen diagnostic performance
- Both inflight countermeasures and post-flight reconditioning (e.g., systematically increasing crew activities) can enhance adaptation and reduce risk
- Post-ISS reconditioning may represent “better case” scenario – some self-administered reconditioning capability should be expected