The Effects of Spaceflight & Head Down Tilt Bed Rest on Neurocognitive Performance: Extent, Longevity, & Neural Bases

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Background & Justification

- Spaceflight effects on gait, balance, & manual motor control have been well studied; some evidence for cognitive deficits
- Rodent cortical motor & sensory systems show neural structural alterations with spaceflight

Specific Aims

- Aim 1- Identify changes in brain structure, function, and network integrity as a function of head down tilt bed rest and spaceflight, and characterize their time course.

- Aim 2- Specify relationships between structural and functional brain changes and performance and characterize their time course.

Evaluating neurocognitive changes occurring with bedrest

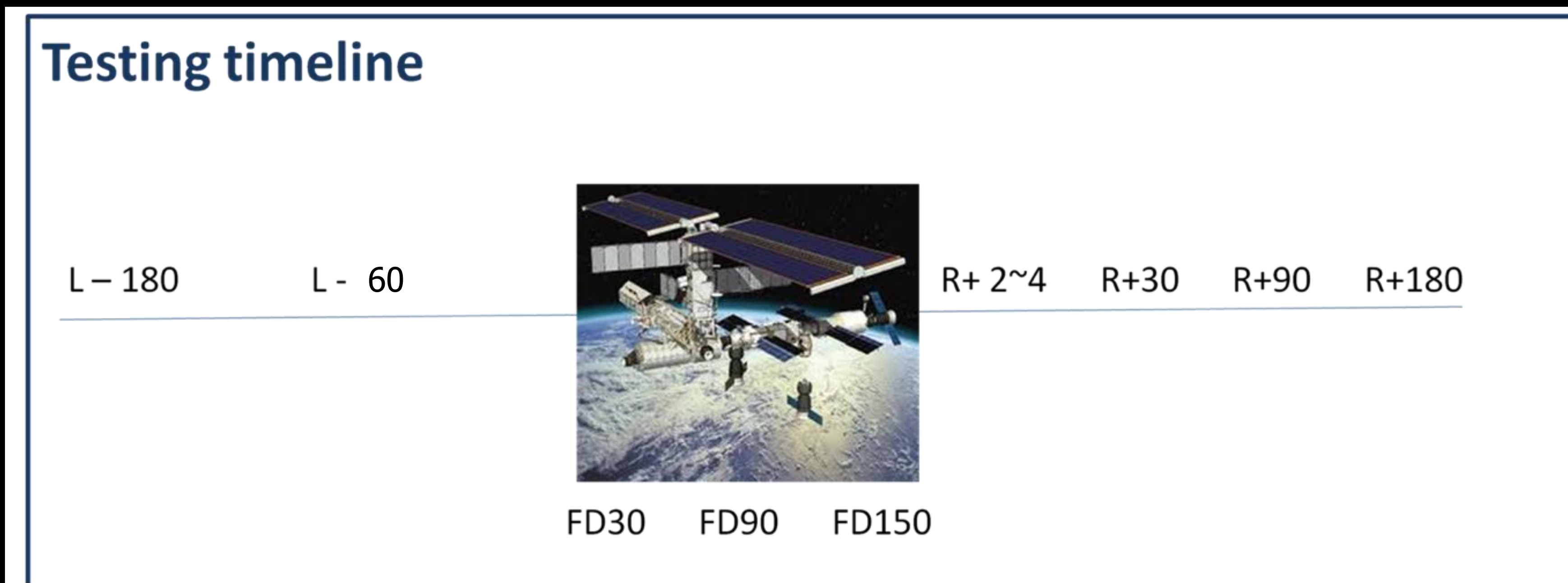
~BR- 12 ~BR-7

BR+0 or +1 ~BR+6 ~BR+13

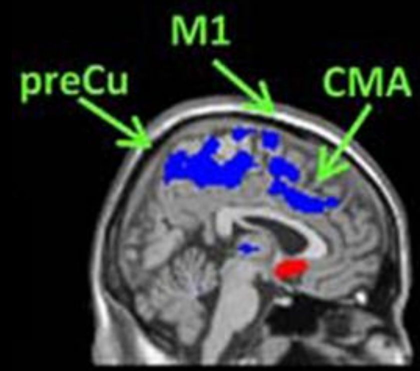
~BR7 ~BR50

Conduct most behavioral & MRI assessments in ~last 5 days of BR, first session post BR = postural assessments only (SOT, FMT)

Evaluating neurocognitive changes occurring with spaceflight



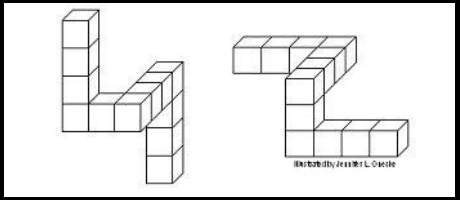
Assessments

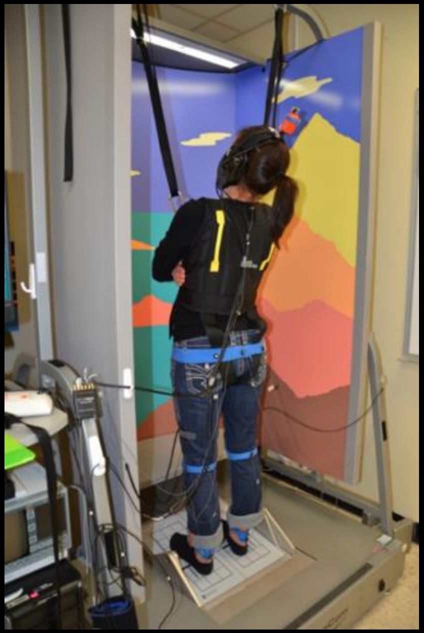


Structural MRI:
- Volumetric gray matter changes
- Diffusion weighted images

Functional MRI:
- Resting state functional connectivity of cognitive & motor networks
- Task based fMRI of motor, cognitive & sensory processing

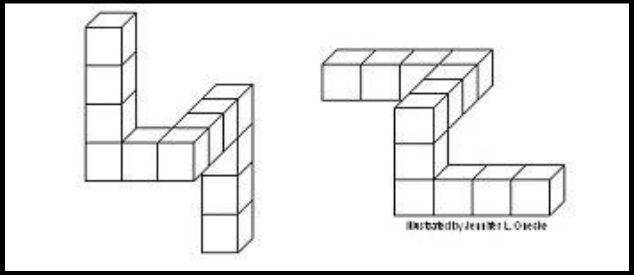
Additional Behavioral Metrics:
- Spatial cognition / working memory
- Manual motor control
- Vestibular evoked myogenic potentials
- Gait & balance (FMT, SOT)
- Sensory bias (rod & frame test)

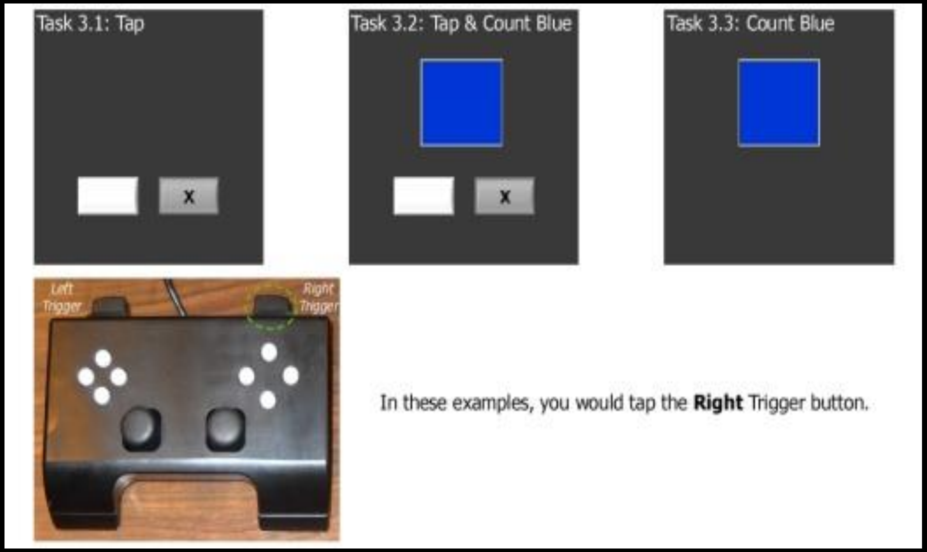




Inflight tests: behavior

- Sensorimotor adaptation
- Spatial cognition
- Cognitive-motor dual tasking

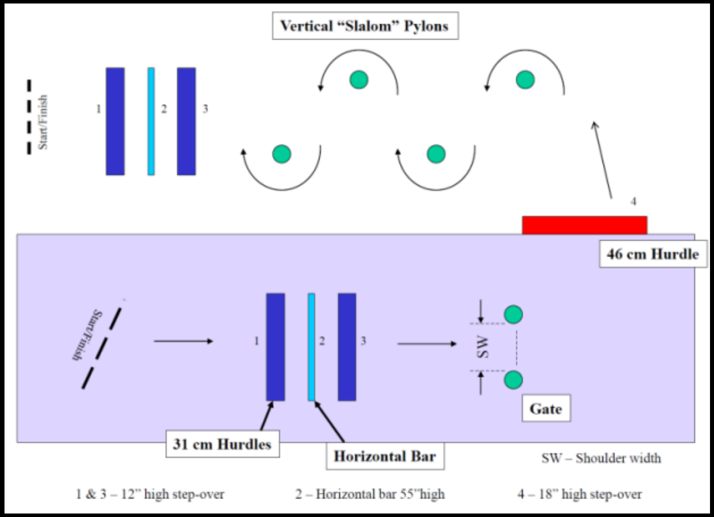


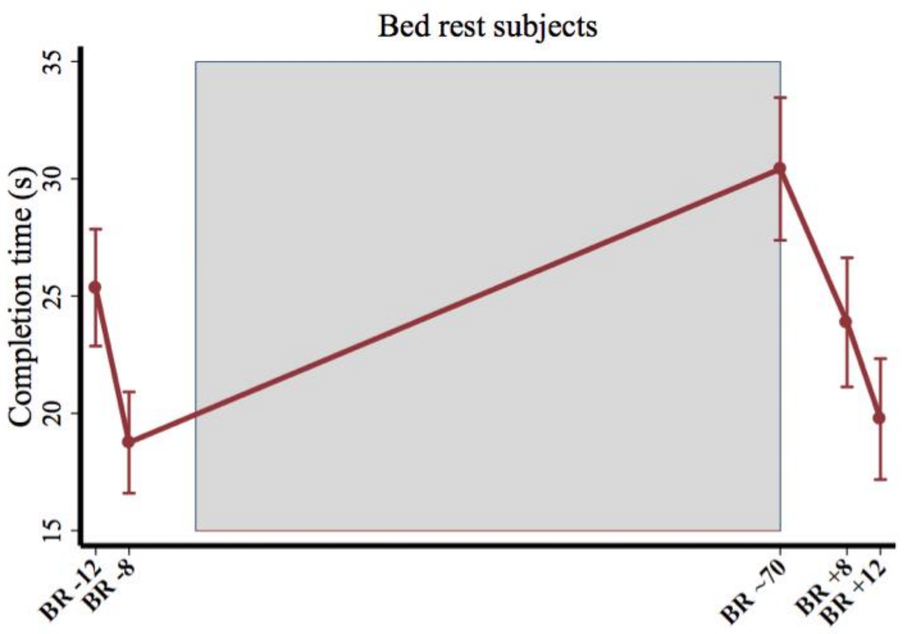


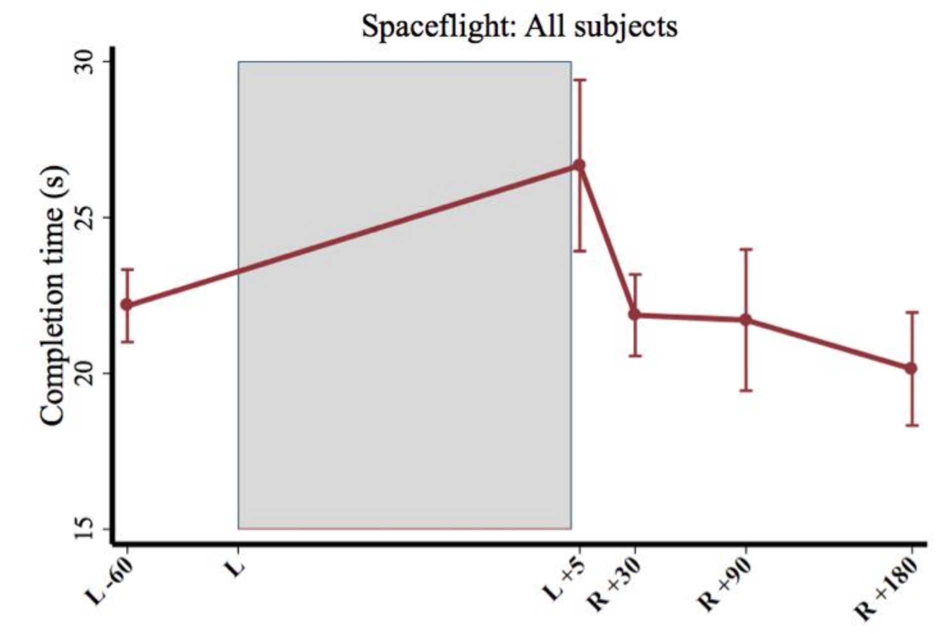
Progress Report

- 5, 6-month crew members have completed at least 1 post flight scan, 1, 1 YRM crew member
- CO2 and AG bed rest versions kicking off soon
- Bed rest version of the study is complete, several papers published:
  - Yuan et al. (2016) *Frontiers in Systems Neuroscience*
  - Cassady et al. (2016) *Neuroimage*
  - Koppelmans et al. (2015) *Frontiers in Systems Neuroscience*
  - Four others under review
- Retrospective paper has been published:
  - Koppelmans V, Bloomberg J, Mulavara AP, & Seidler RD (in press). Brain structural plasticity with spaceflight. *npj Microgravity*.

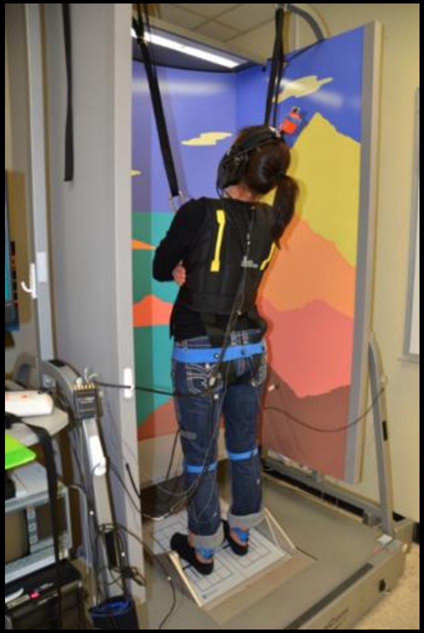
Functional mobility declines with bed rest, flight

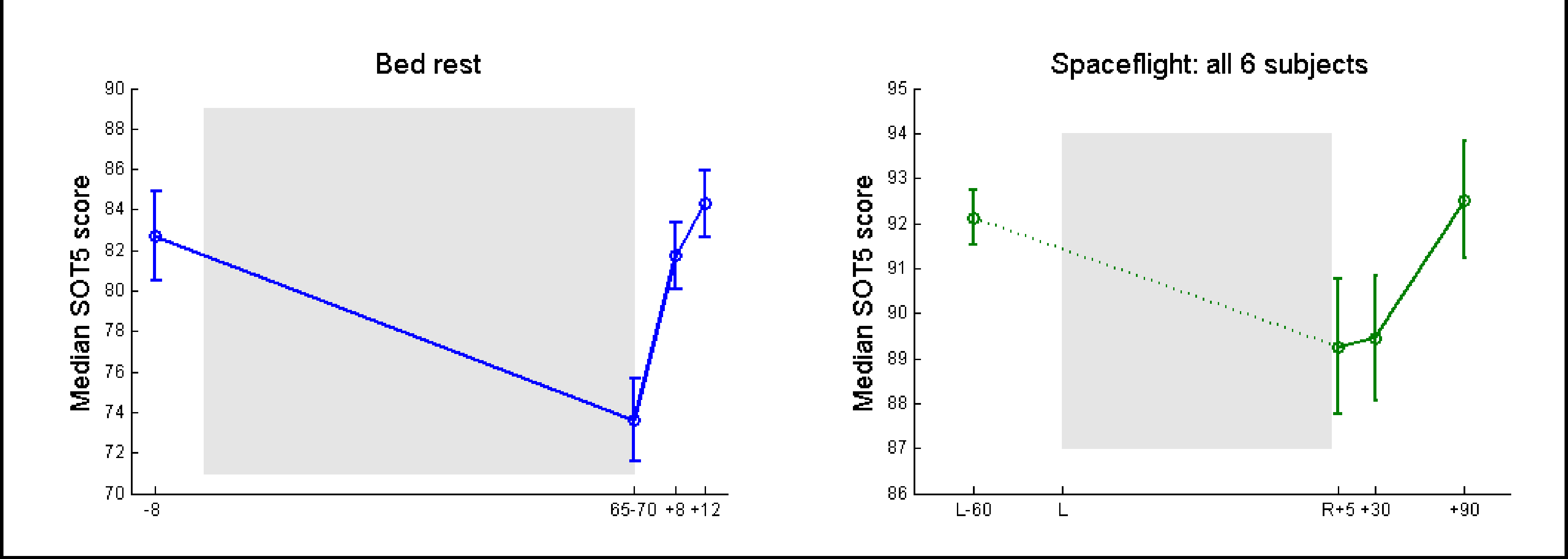




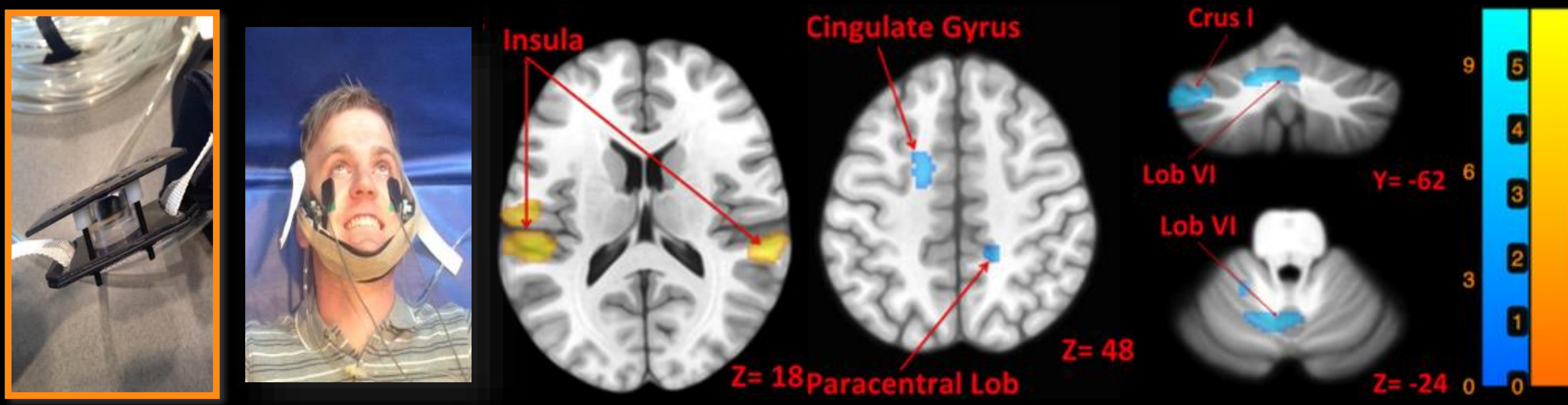


Balance declines with bed rest, flight



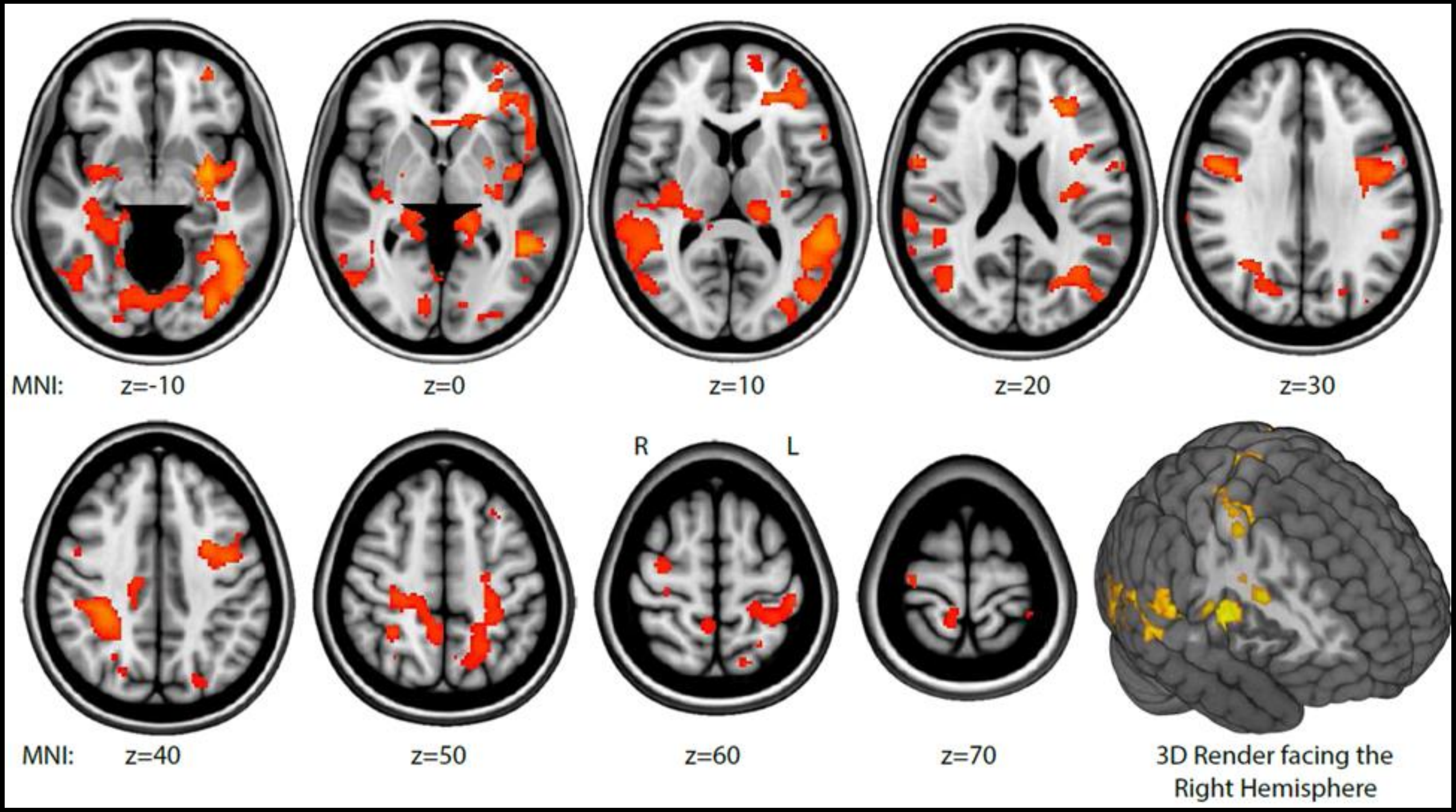


Functional imaging of human vestibular cortex



Noohi et al. under review

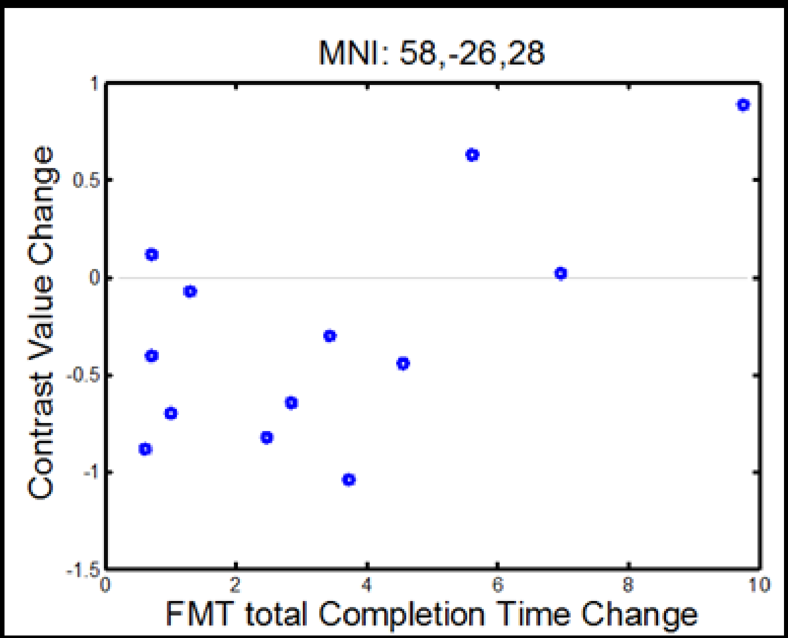
Activity increases in somatosensory, visual and frontal cortices in response to vestibular stimulation with bed rest

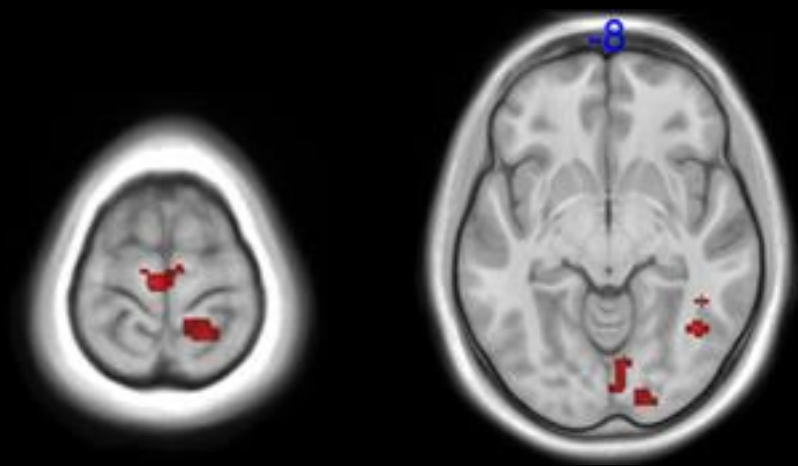


Peng et al. under review

Please note that activation results are overlaid onto a standard template brain for

Greater increases in activation are associated with more mobility slowing

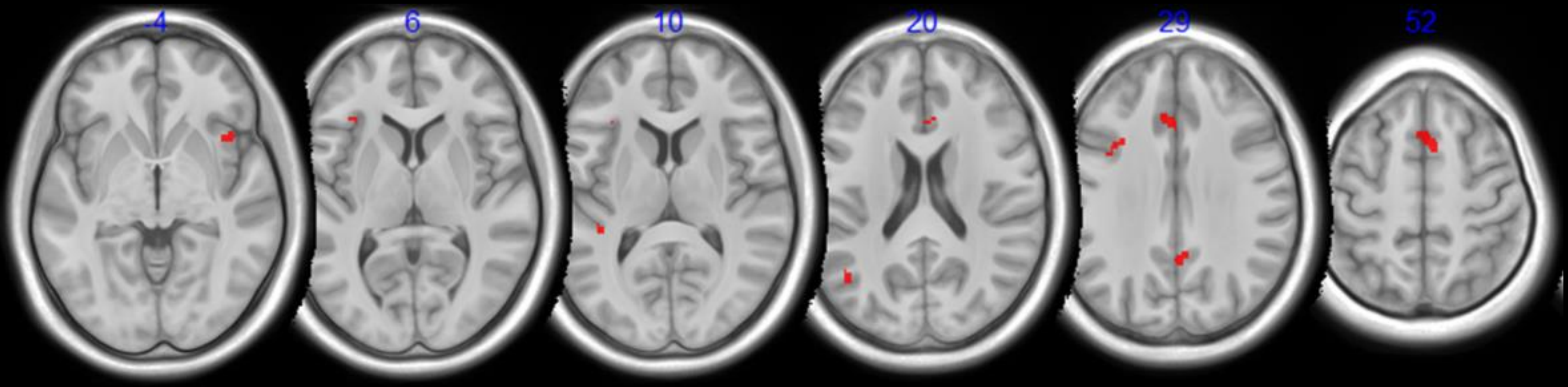




Peng et al. under review

Please note that activation results are overlaid onto a standard template brain for

Brain responses to vestibular stimulation increase with flight, more so with increasing flight duration (n=6)



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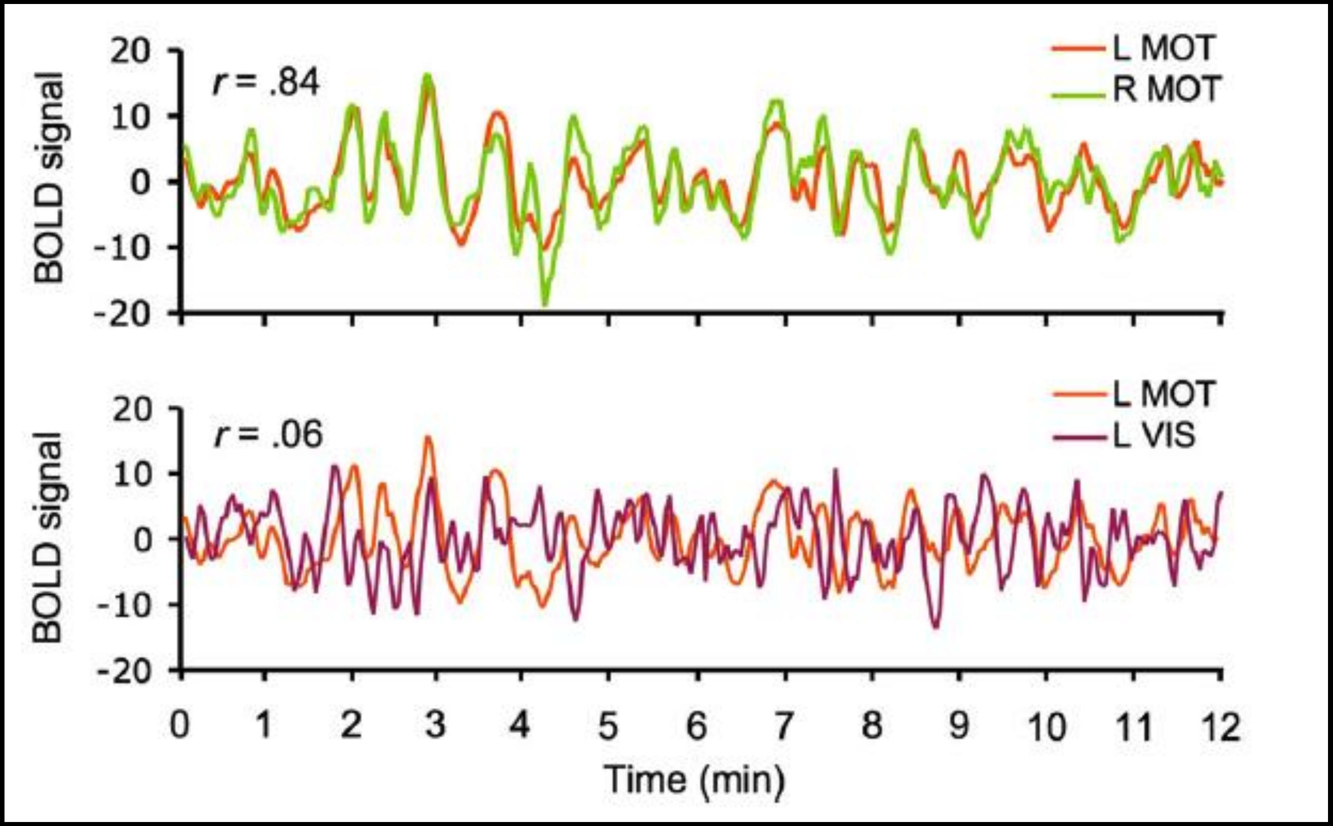
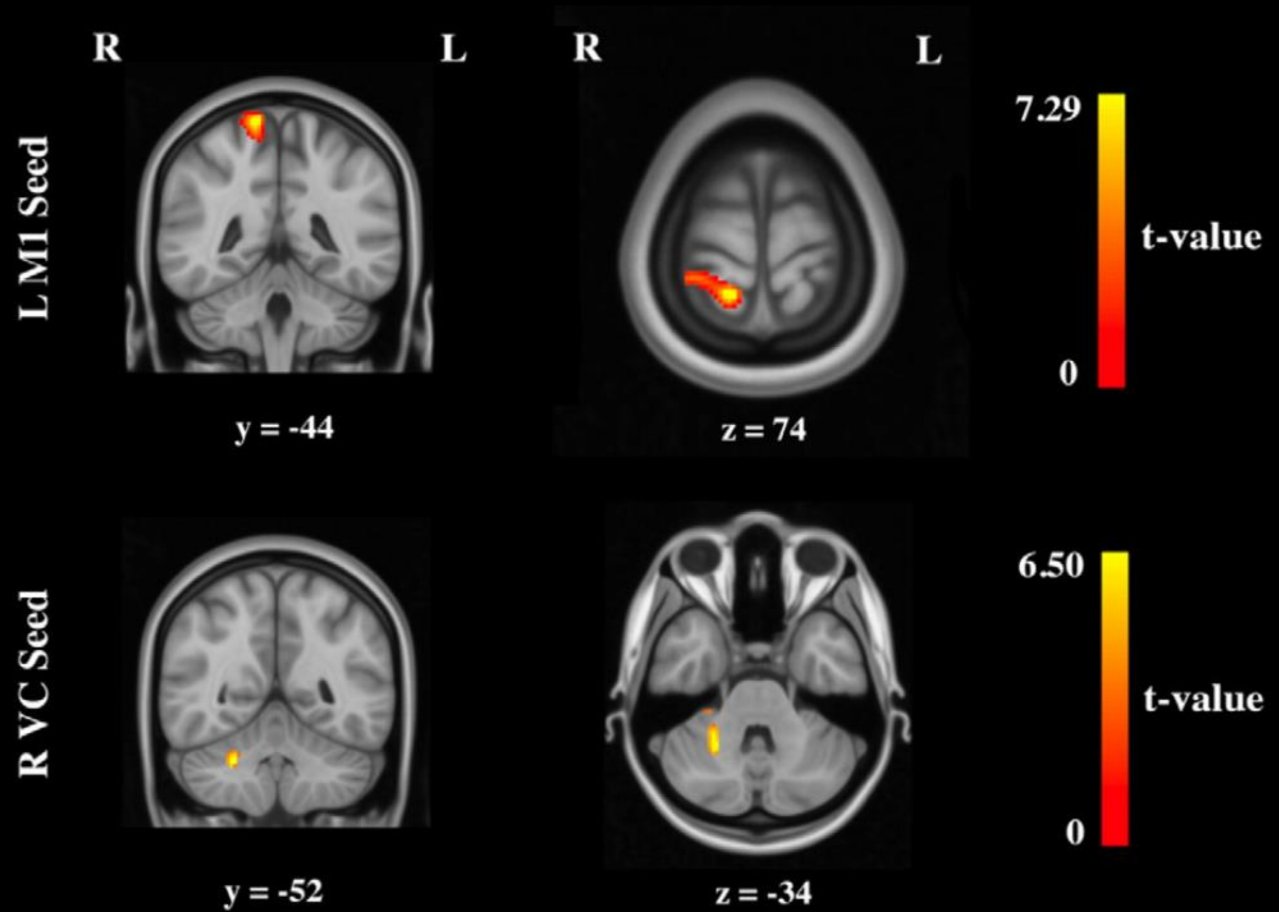
Resting state functional connectivity MRI (fcMRI)



Buckner et al. (2013)

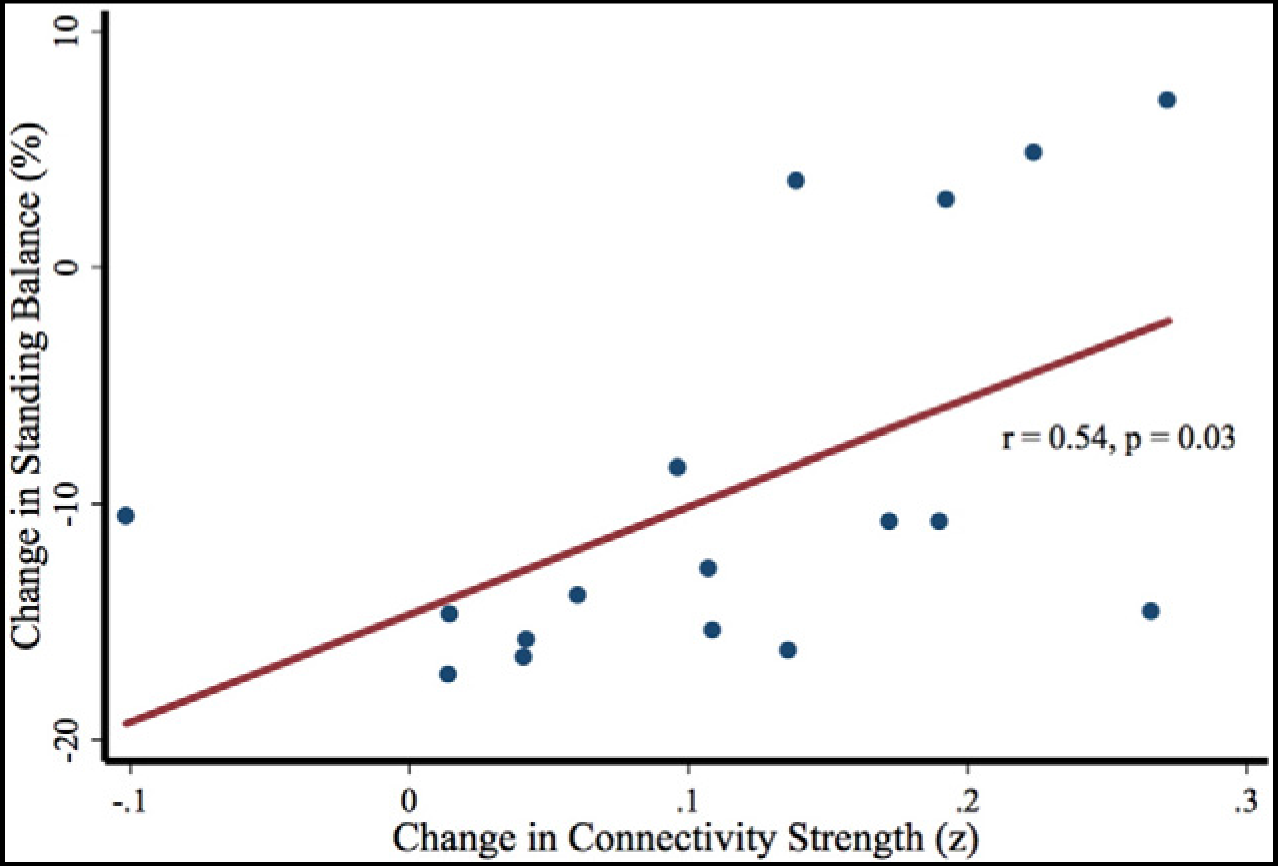
Motor-somatosensory and vestibular-cerebellar connectivity increase with bed rest



Cassady et al. (2016). *Neuroimage*

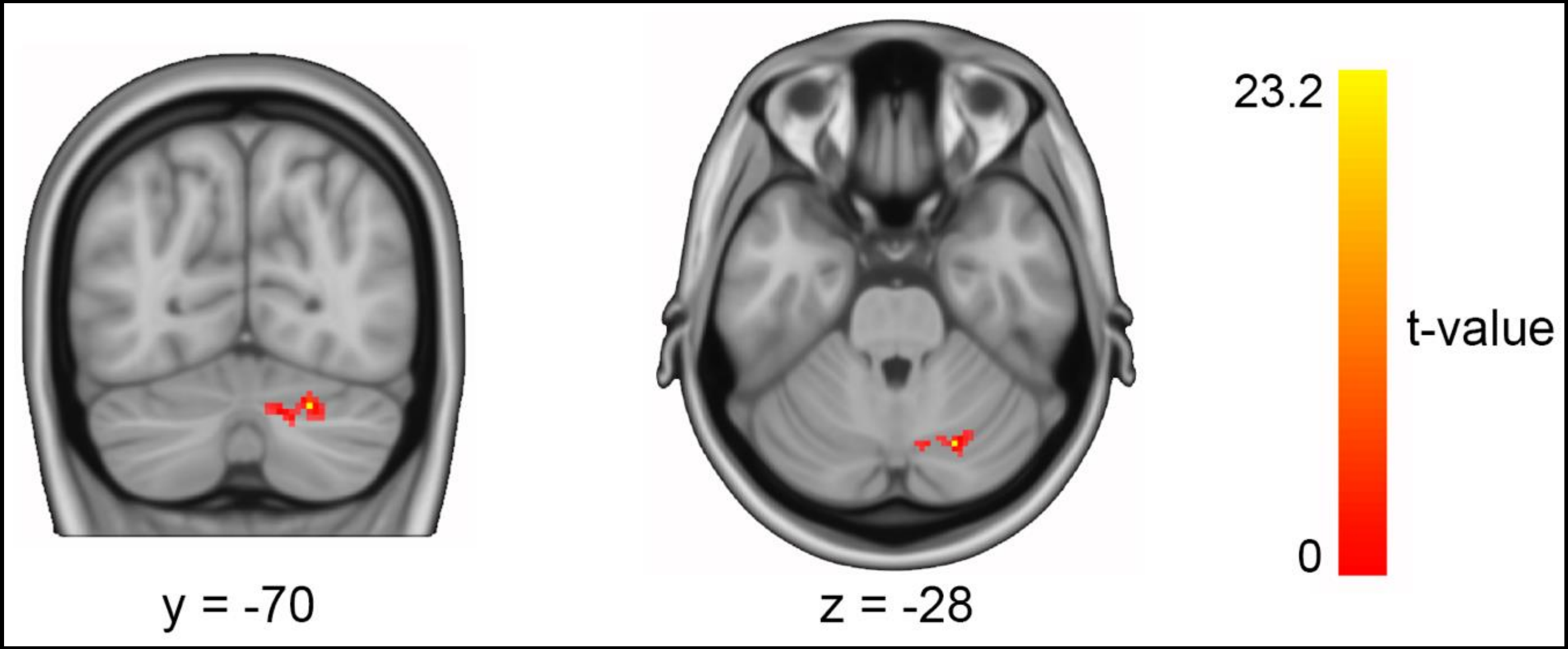
Please note that activation results are overlaid onto a standard template brain for

Larger motor-somatosensory connectivity increases with bed rest were associated with smaller balance decrements



Cassady et al. (2016). *Neuroimage*

Intracerebellar connectivity increases with spaceflight (n=6)



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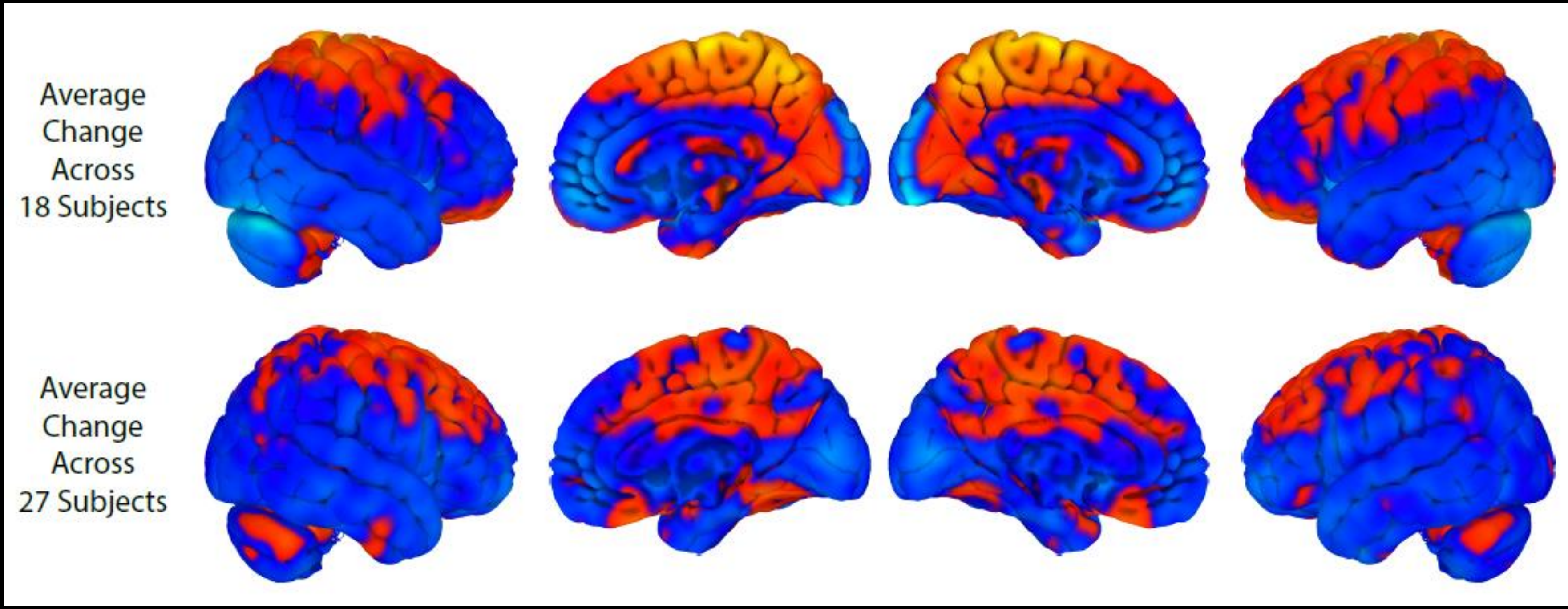
Bed rest and flight brain structural changes

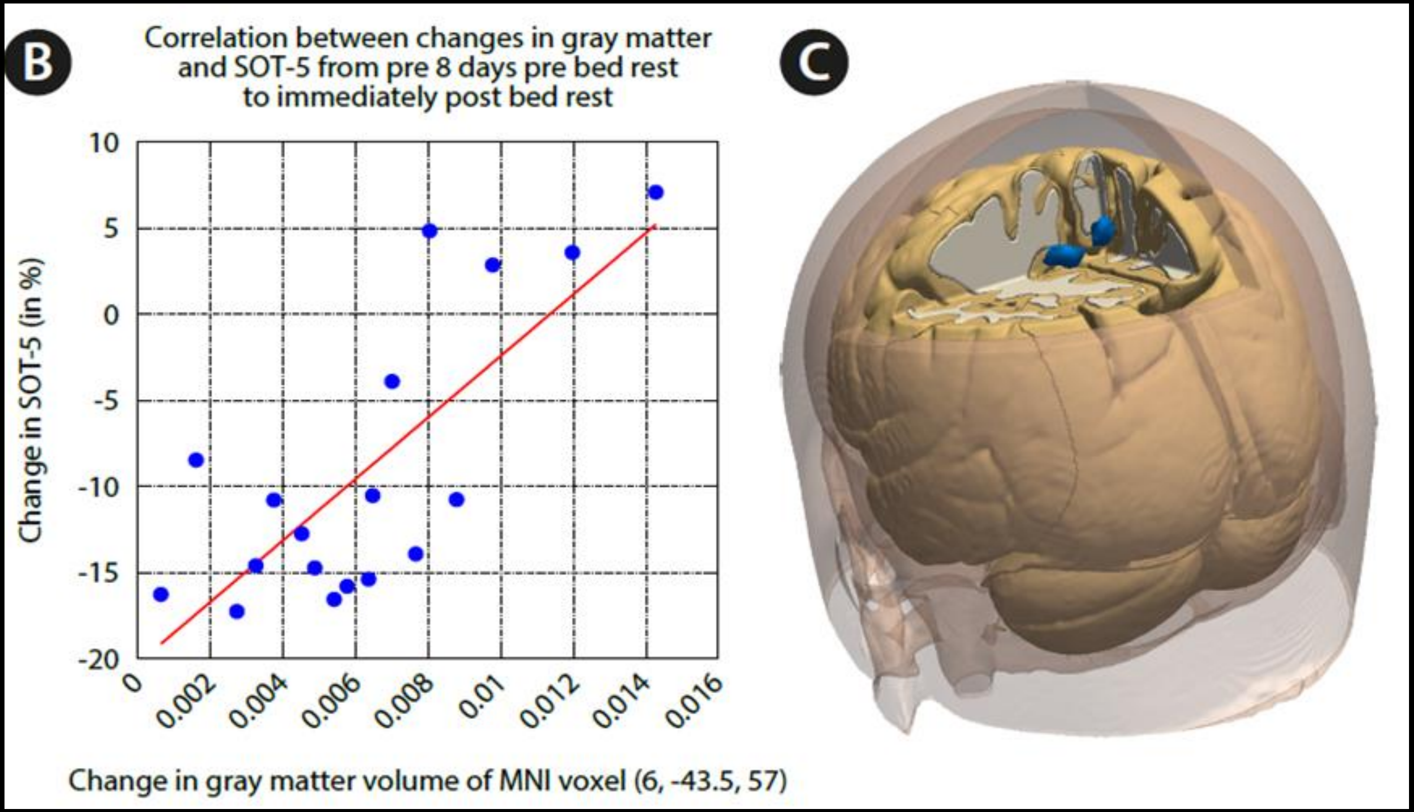
Bed rest

Flight



Koppelmans et al. (in press) *npj Microgravity*

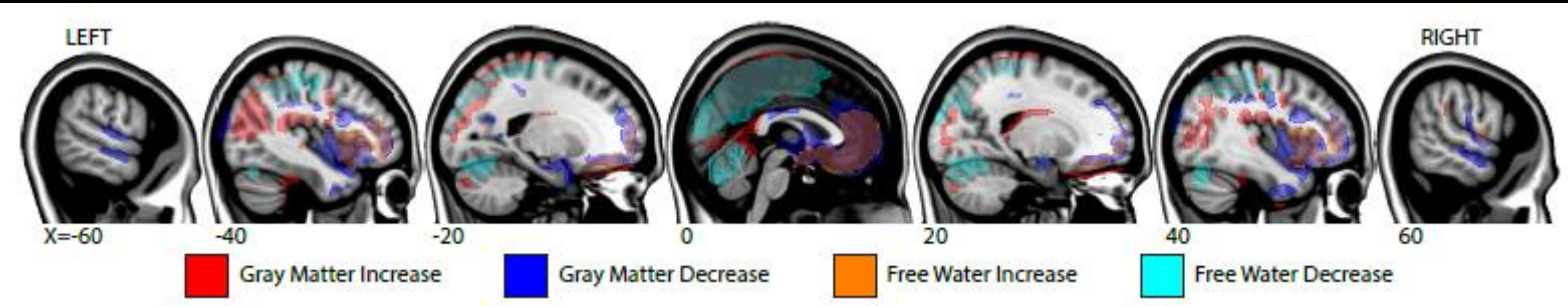
Larger bed rest increases in GM volume correlate with smaller balance decrements



Koppelmans et al. (under review a)

Please note that activation results are overlaid onto a standard template brain for

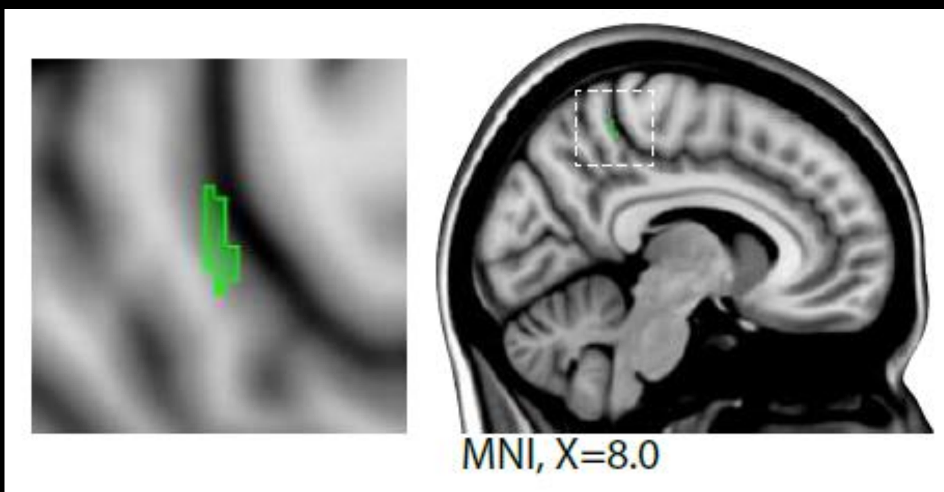
Bed rest GM changes largely overlap with interstitial fluid shifts measured with dMRI

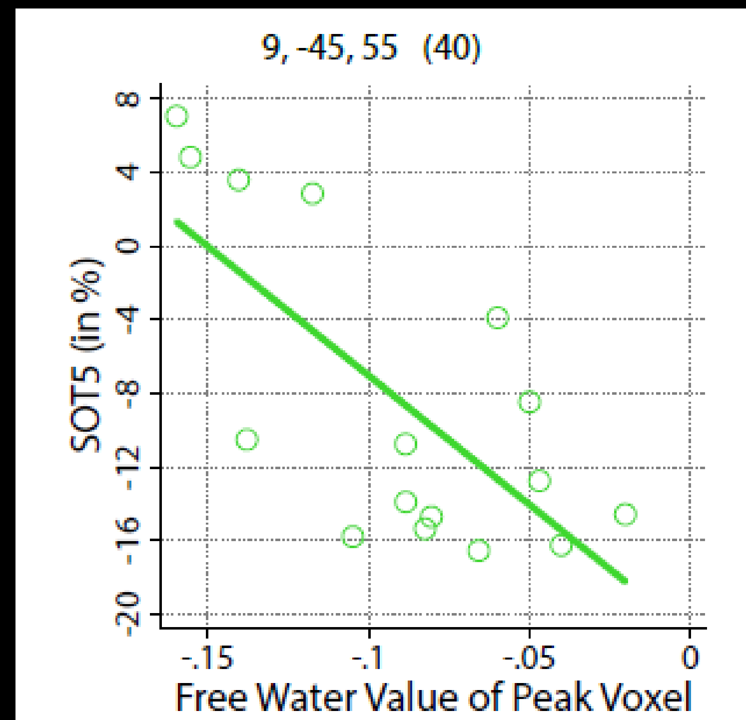


Koppelmans et al. (under review b)

Please note that activation results are overlaid onto a standard template brain for

Decreasing free water in somatosensory cortex is associated with smaller balance decrements with bed rest





Koppelmans et al. (under review b)

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Summary

- Numerous brain & behavioral changes with bed rest; suggest adaptation, sensory reweighting, and fluid shifts
- Retrospective flight data show some parallels to bed rest, but also large regions of qualitative differences (cerebellum)
- Data collection & analyses for prospective spaceflight study are ongoing

Acknowledgements

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