

Functional connectivity and neuroimaging after exposure to short-term microgravity – implications for long-duration spaceflight

Symposium: Bio-Neuroscientific Approaches of life in space and extreme environments

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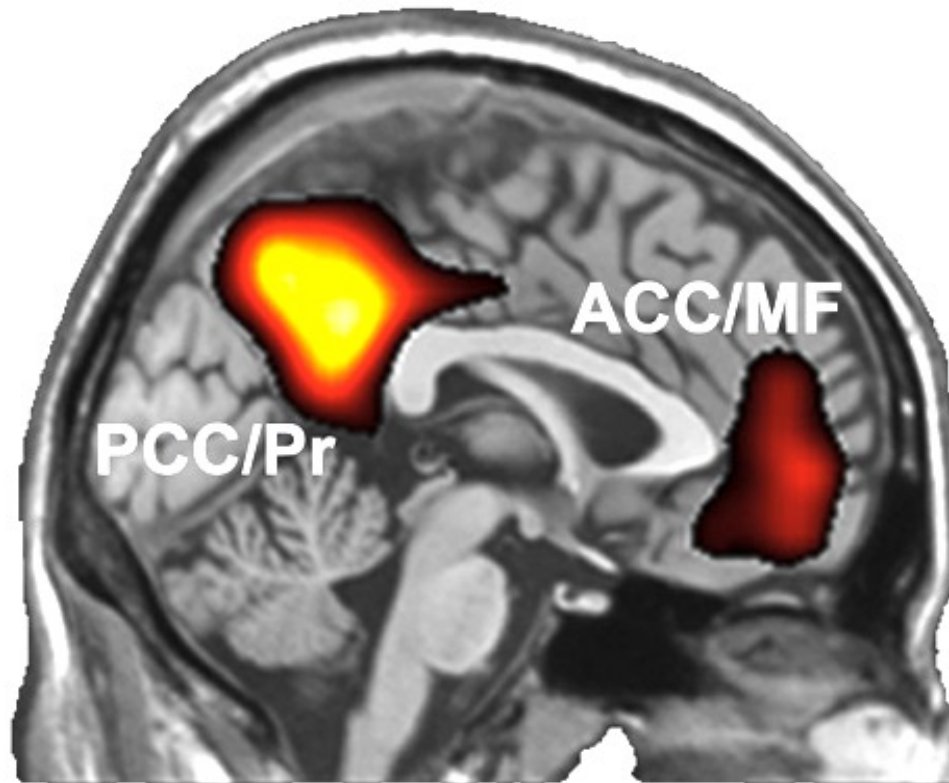


James S. McDonnell Foundation



CHERCHER, TROUVER, GUÉRIR, POUR VOUS & AVEC VOUS.

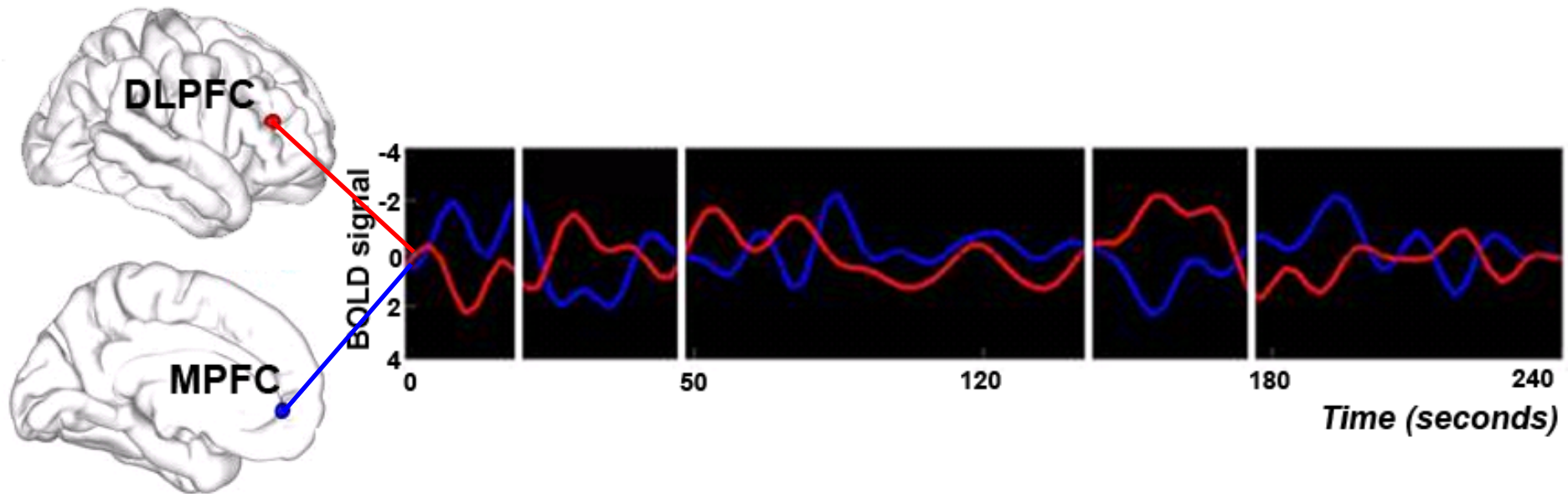
The brain's default mode of function



The brain's default mode of function

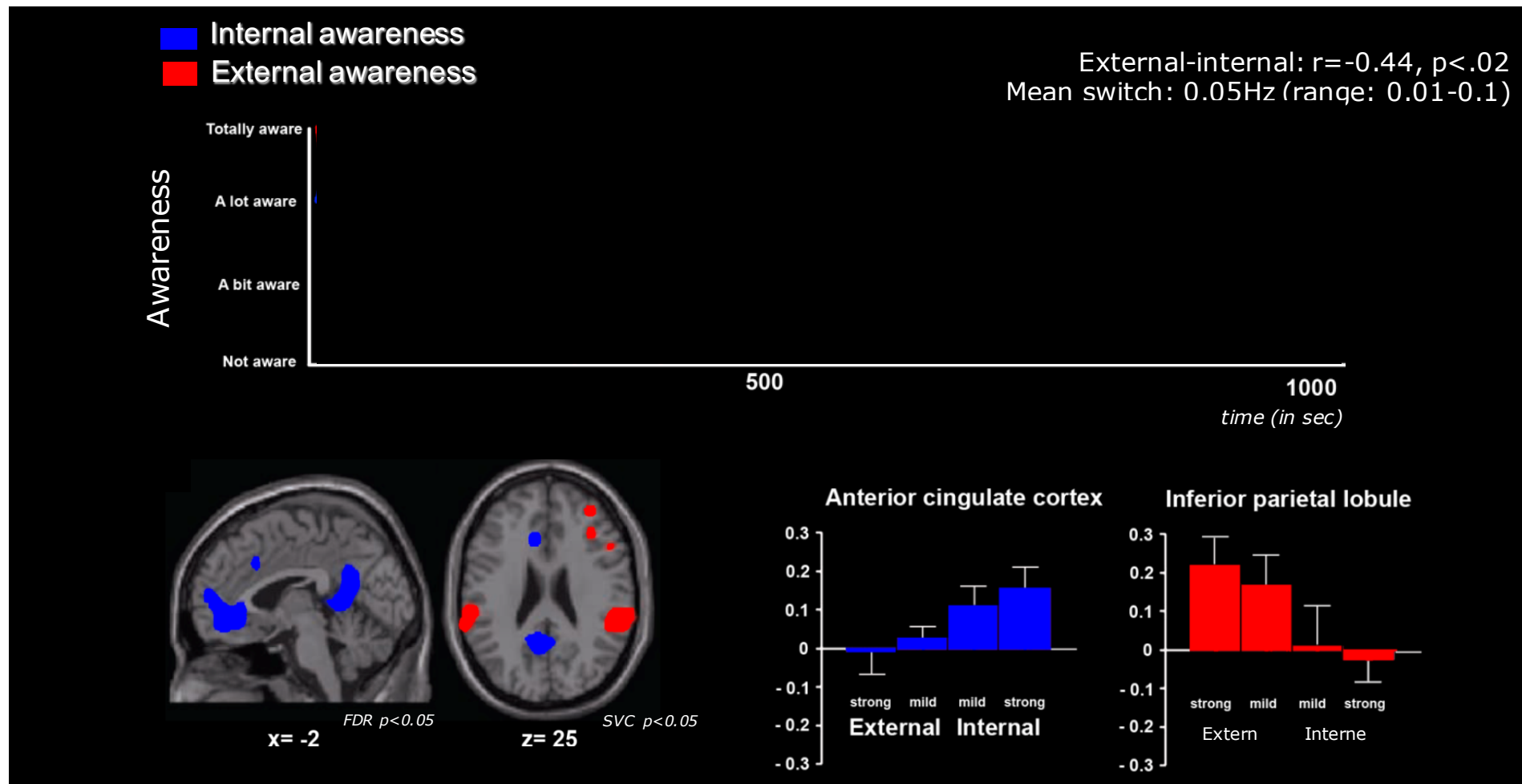


External awareness
or anticorrelated network



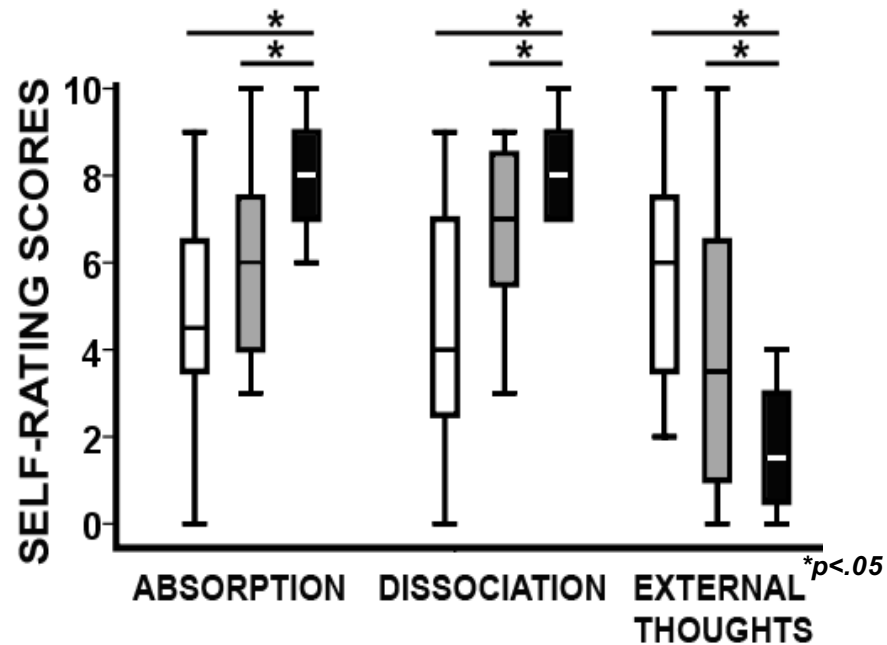
Internal awareness
or Default mode network

The cognitive counterpart of resting state



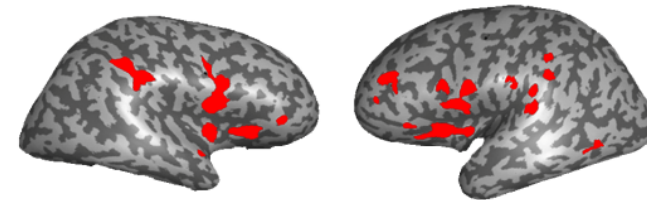
Anticorrelated activity is modified in hypnosis

- Normal consciousness
- Autobiographical mental imagery
- Hypnosis

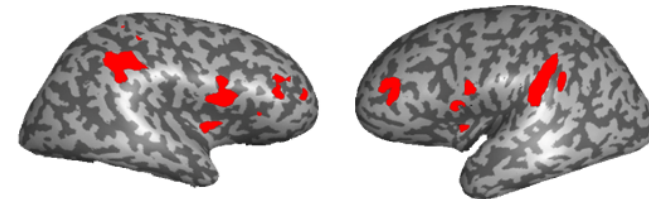


EXTRINSIC SYSTEM

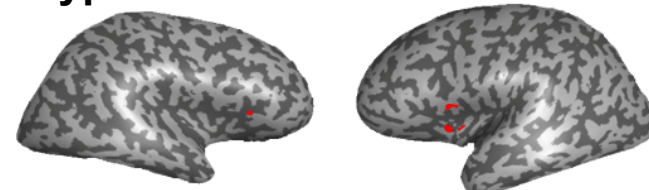
Normal consciousness



Autobiographical mental imagery

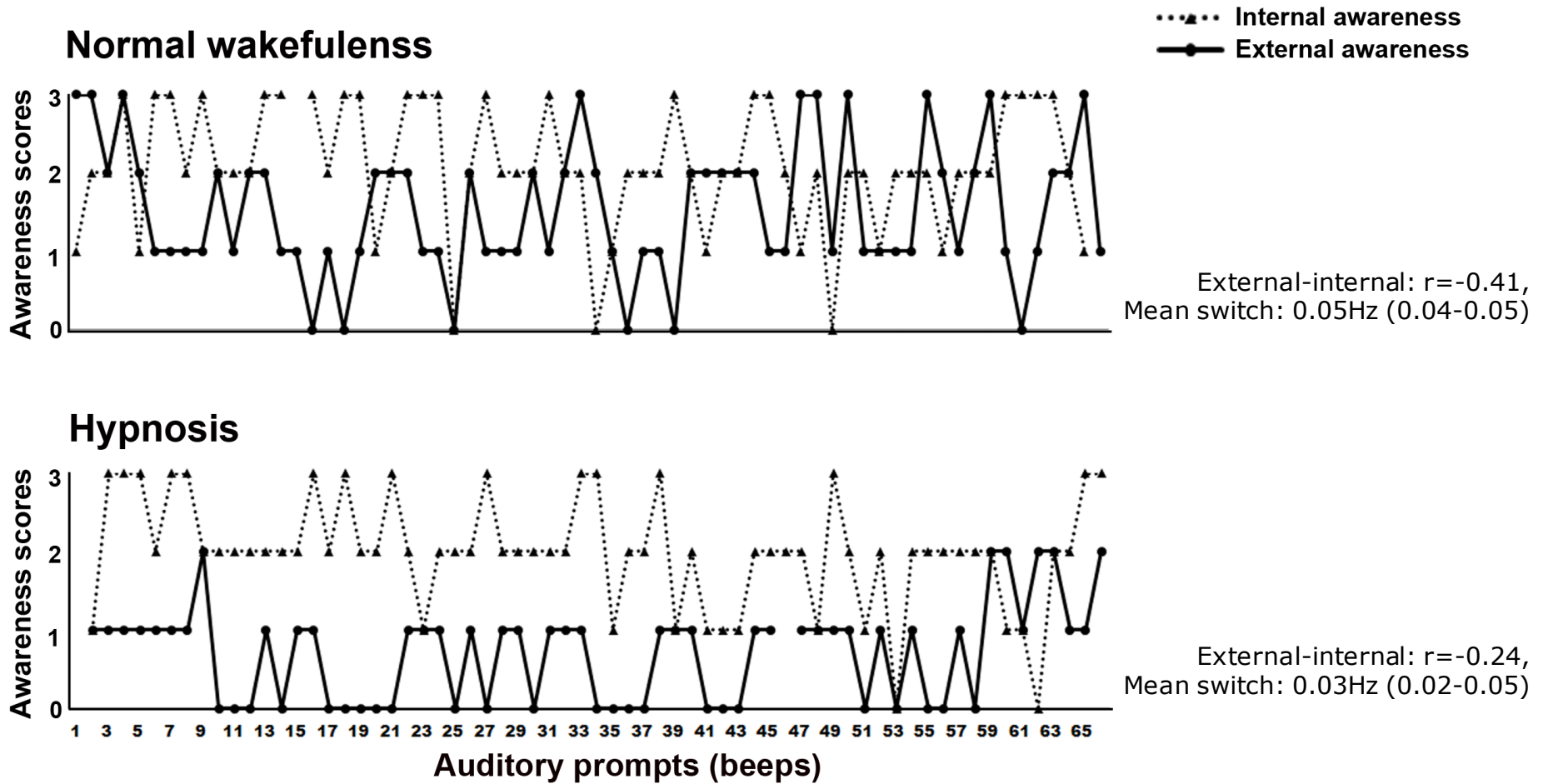


Hypnosis

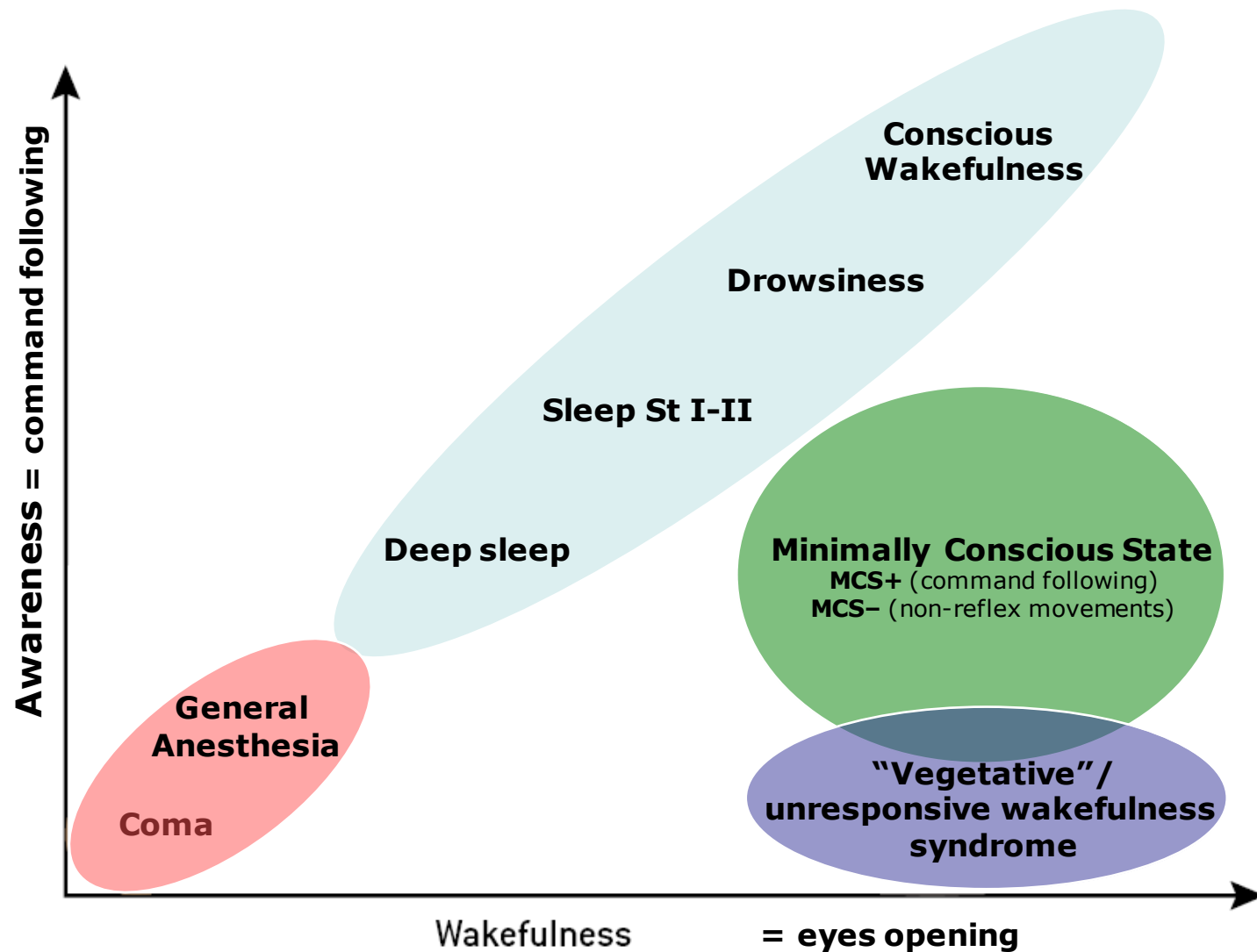


p < 0.05 corrected for multiple comparisons

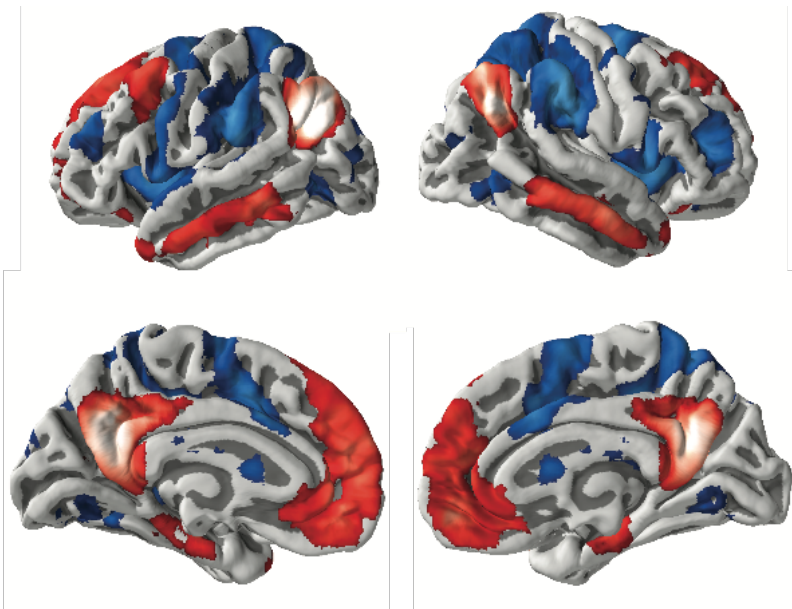
Awareness is modified in hypnosis



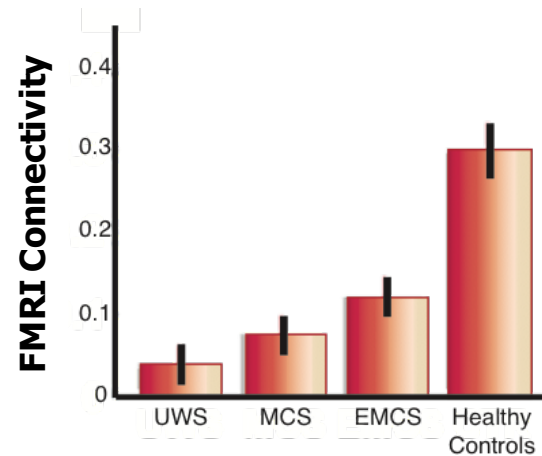
A clinical definition of consciousness



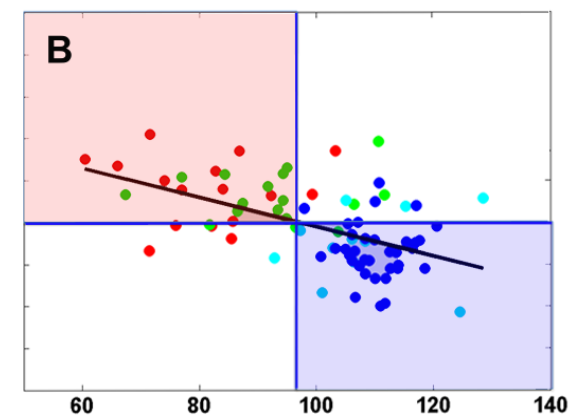
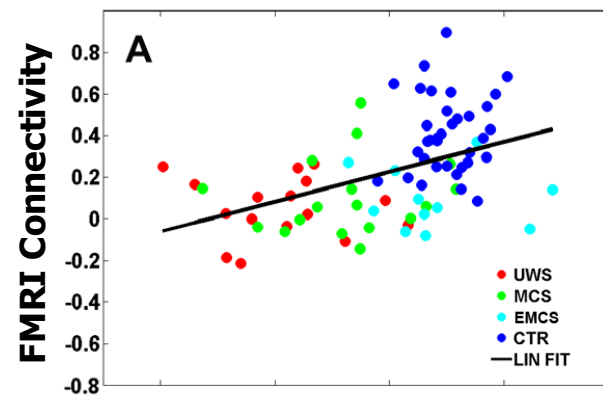
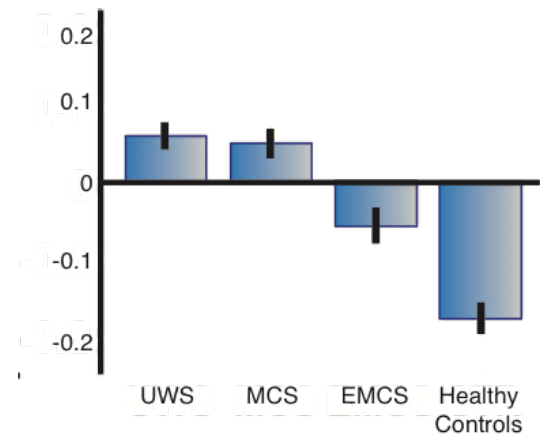
Anticorrelated activity is absent in DOC



DMN CORRELATIONS

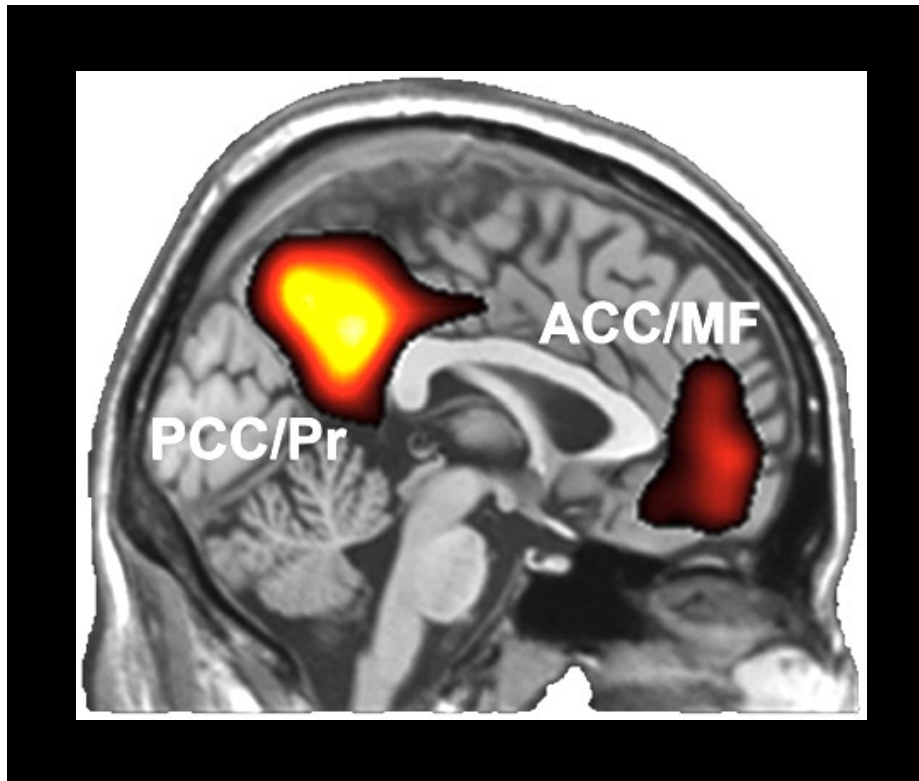


DMN ANTICORRELATIONS



Brain metabolism

The brain's default mode in DOC

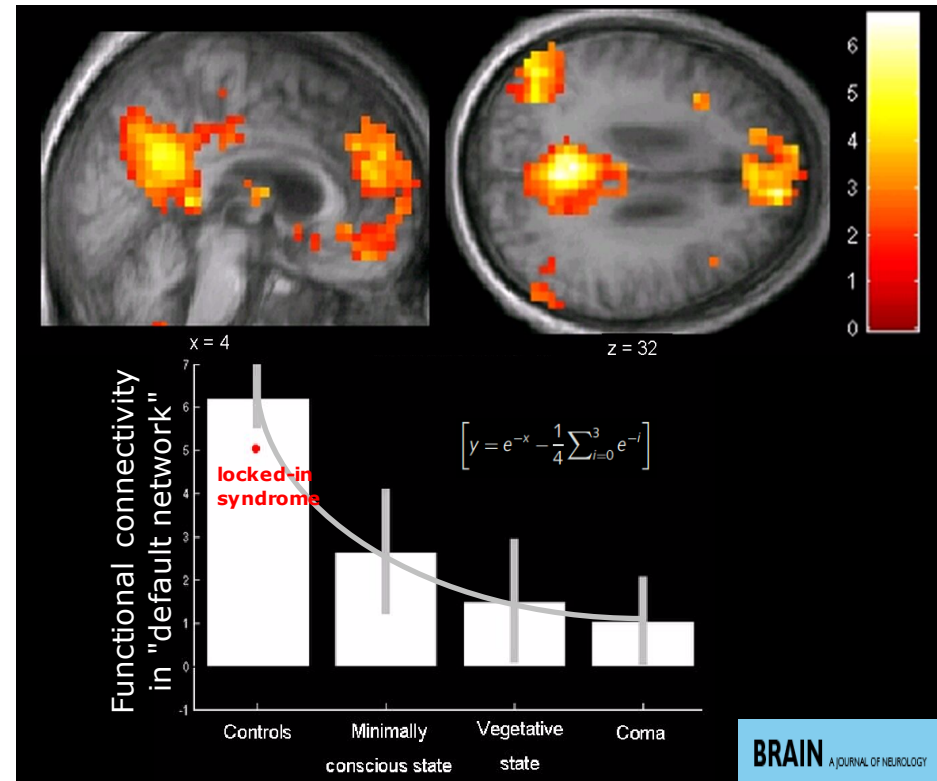


Demertzi & Whitfield-Gabrieli, in: *Neurology of Consciousness* 2nd ed. 2015

Demertzi, Soddu, Laureys, *Curr Opin Neurobiology* 2013

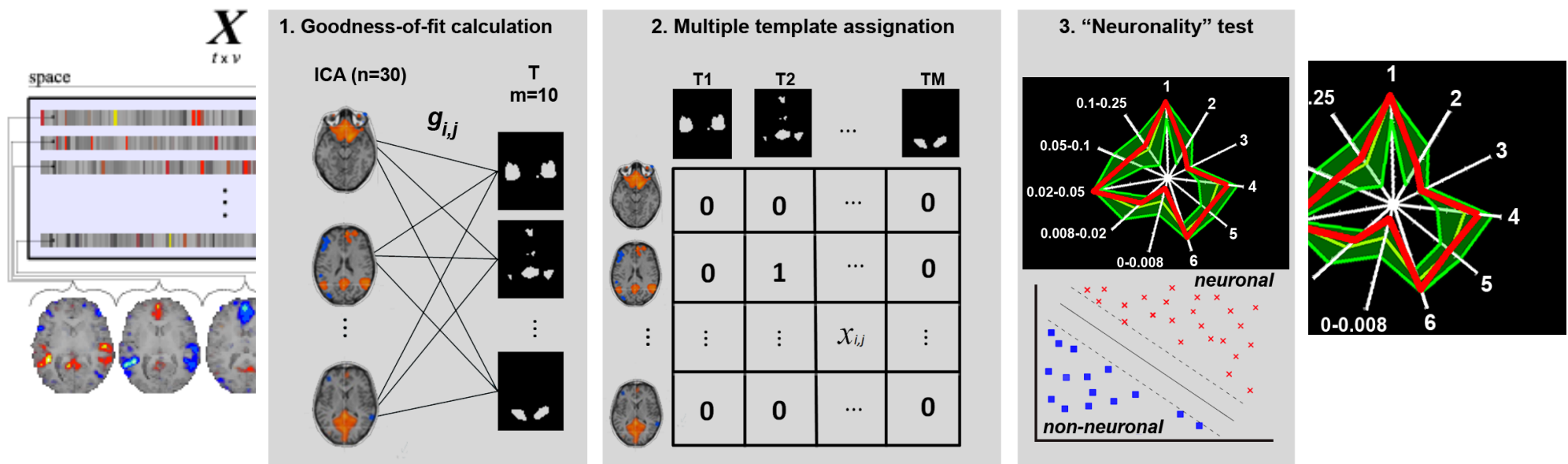
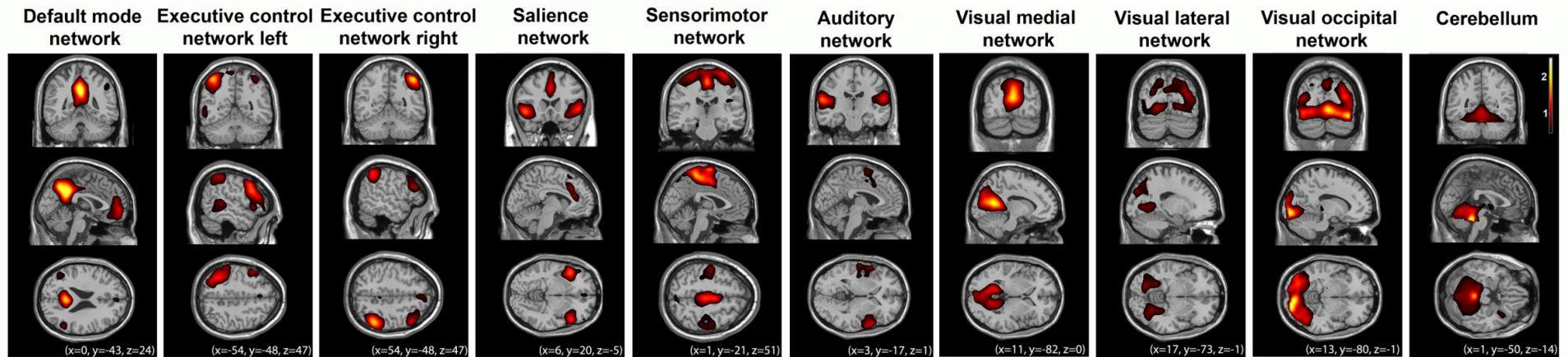
Demertzi et al, *Front Hum Neurosci* 2013

Raichle et al, *PNAS* 2001

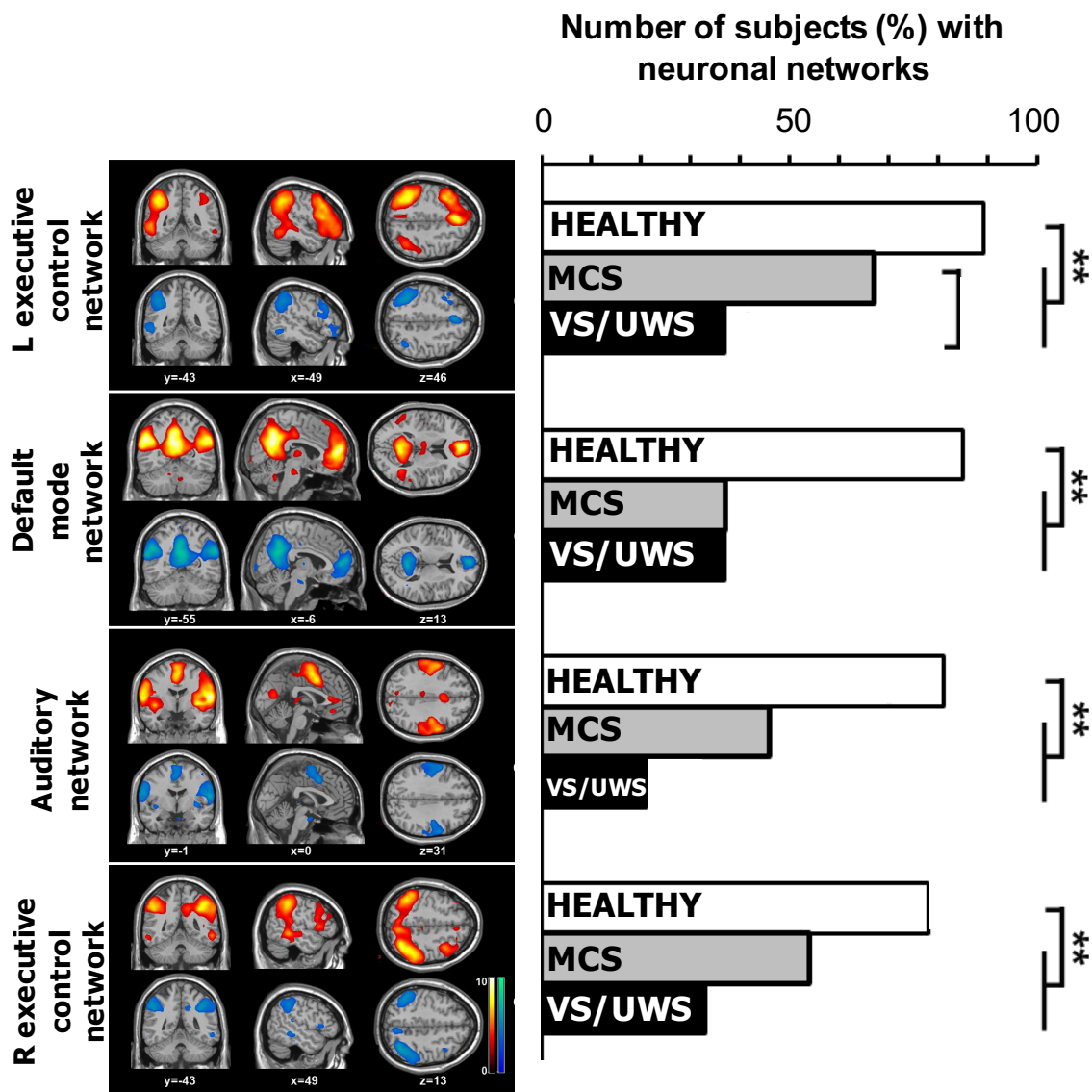


Vanhaudenhuyse & Noirhomme et al, *Brain* 2010

Systems-level intrinsic connectivity



Fewer "neuronal" networks in DOC

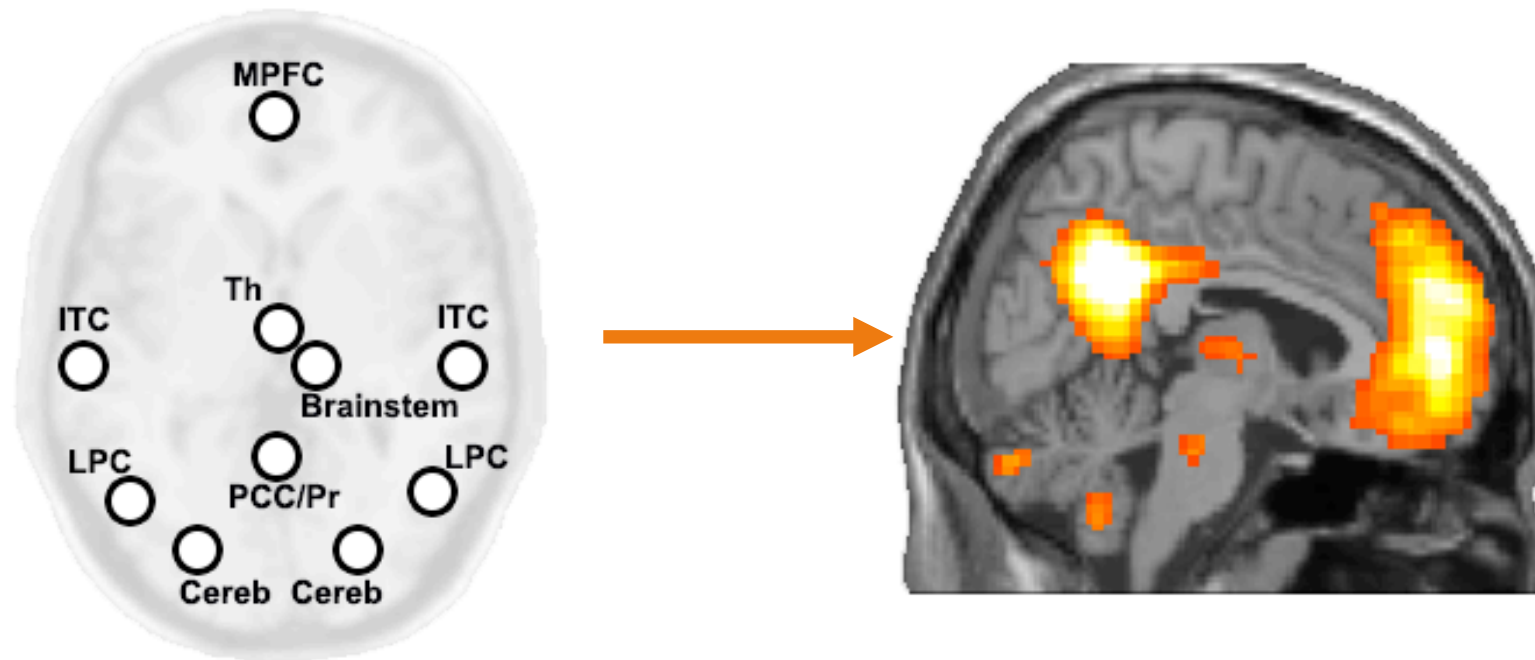


Single-patient classification

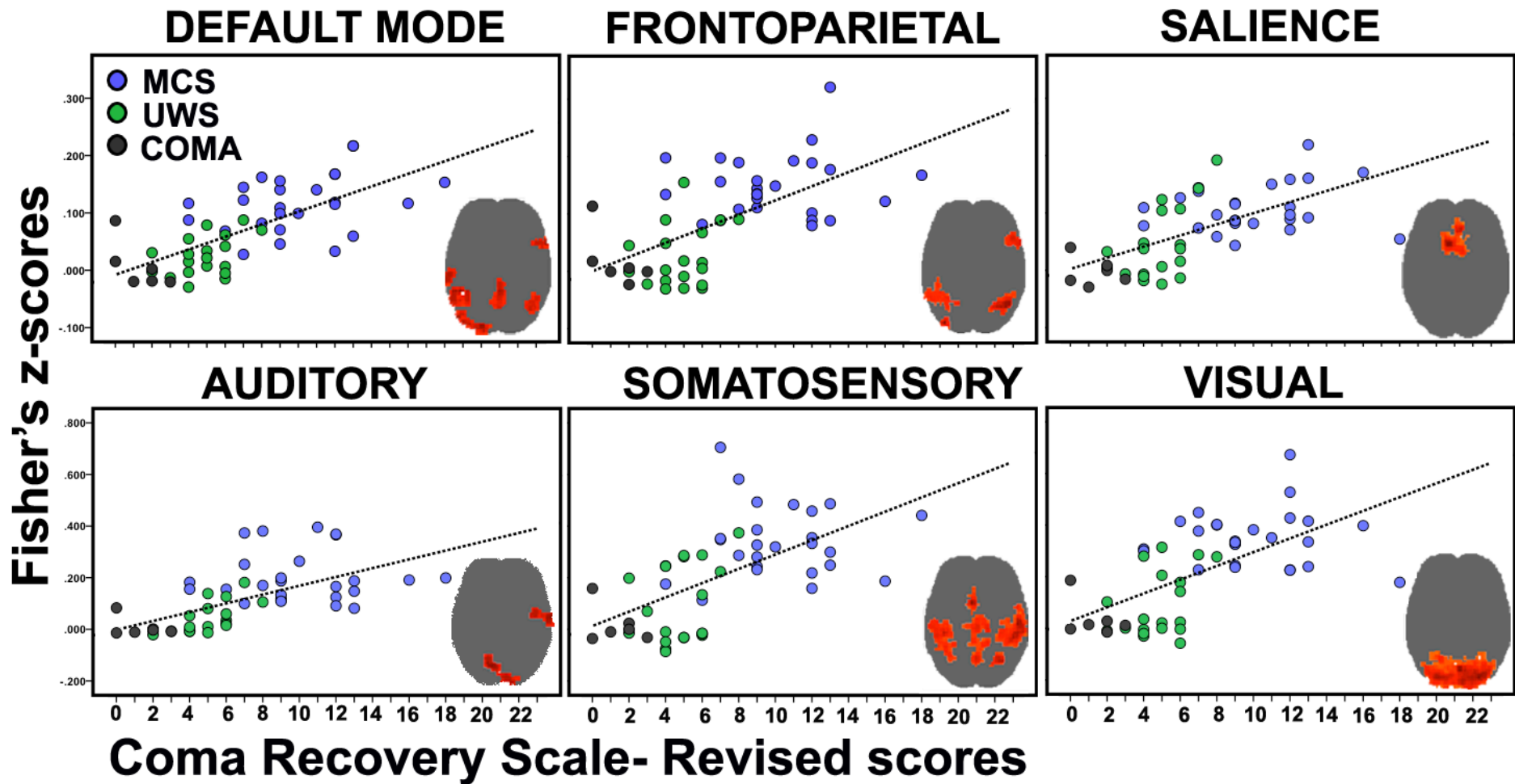
Performance measures	Accuracy	TPR healthy	TPR patients	Selected RSNs
Healthy vs. all patients				
Neuronal	85.3	.82	.87	Auditory, DMN

Intrinsic connectivity networks

Default mode network

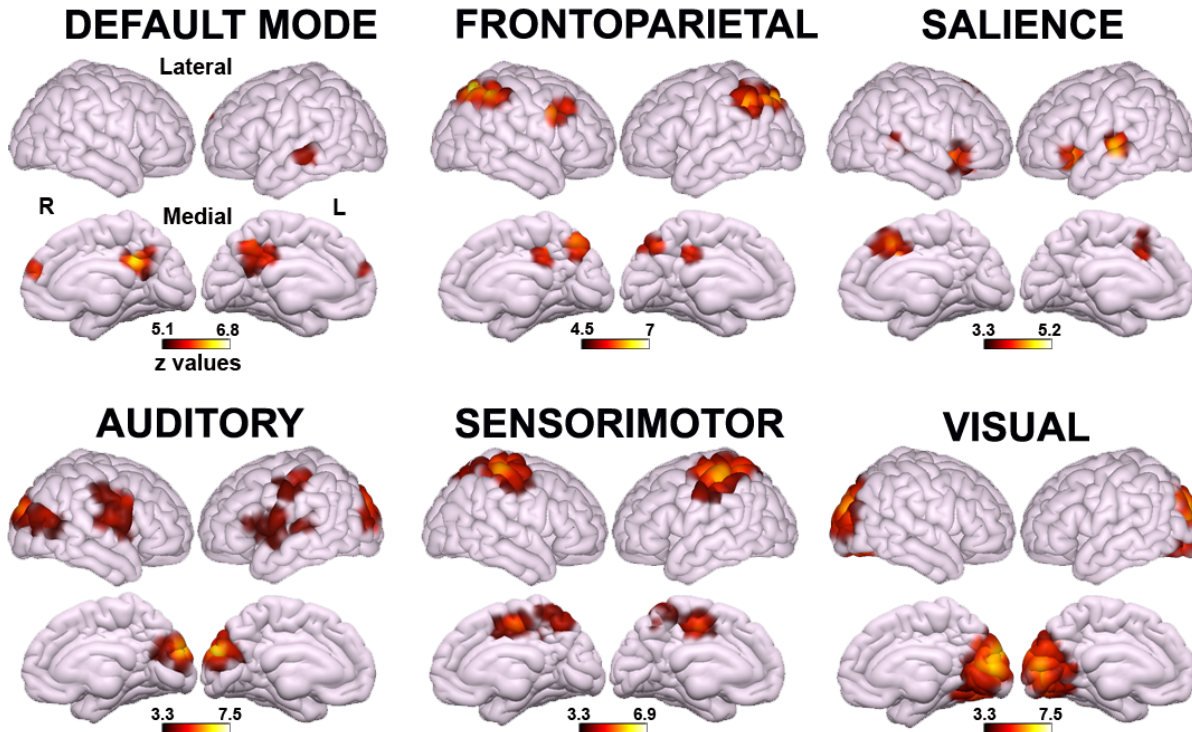


Intrinsic connectivity reflects the level of C



Which network discriminates best?

MCS > VS/UWS

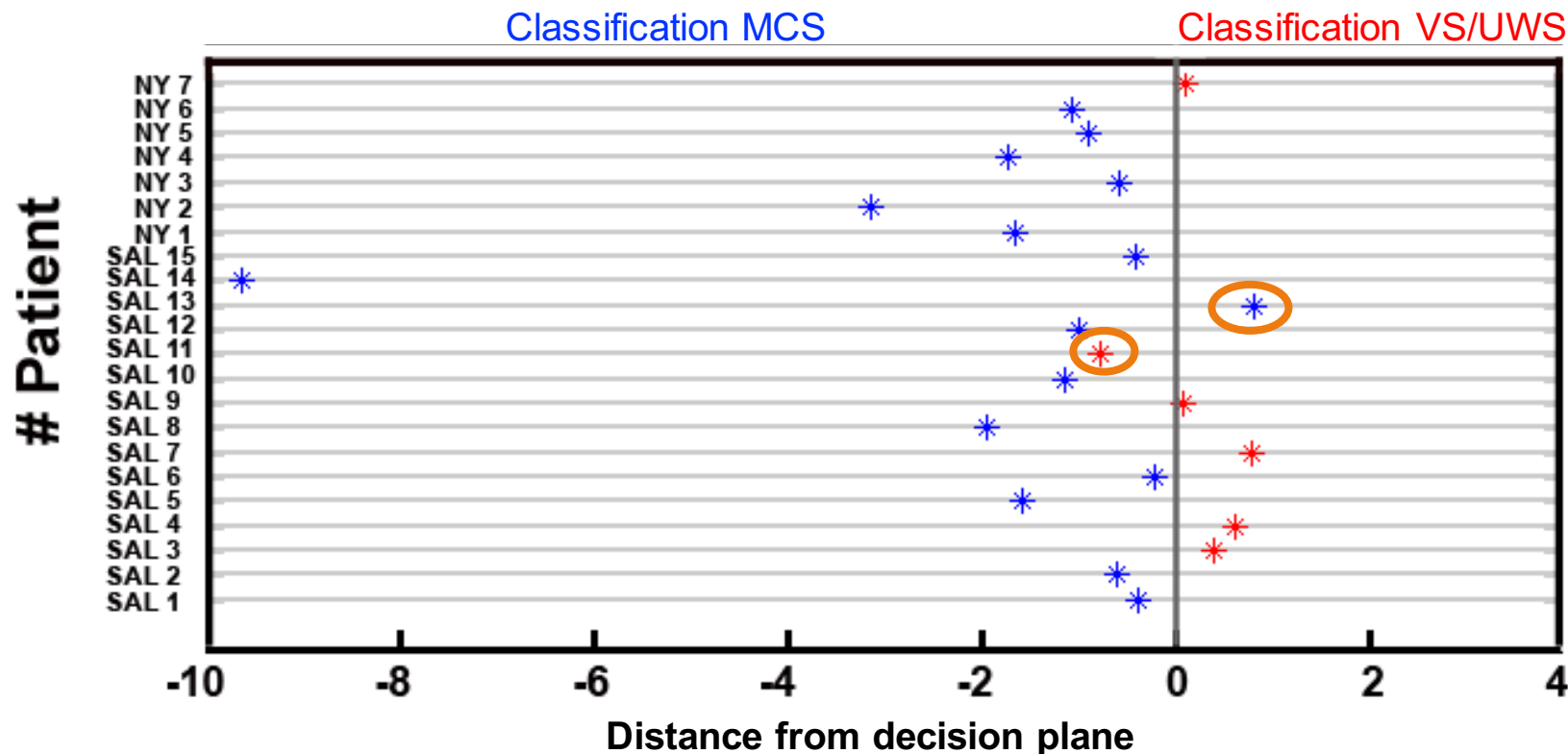
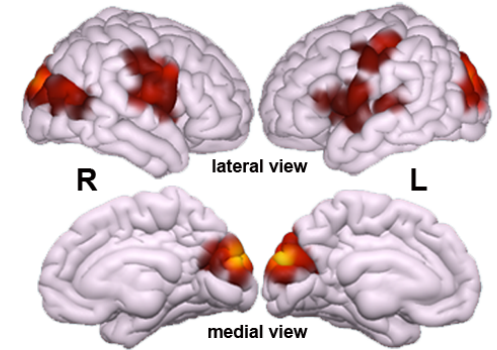


FWE $p < 0.05$ (cluster-level)

Network	Feature selection criterion (t-test)			Single-feature classification		
	t value	Rank	p value	TP MCS	TN VS/UWS	Accuracy
Auditory	8.32	1	<.001	25	18	43/45
Visual	7.79	2	<.001	23	15	38/45
Default mode	6.95	3	<.001	23	15	38/45
Frontoparietal	6.82	4	<.001	23	15	38/45
Salience	6.21	5	<.001	24	15	39/45
Sensorimotor	5.87	6	<.001	24	13	37/45

Crossmodal connectivity classifies independently assessed patients

- Training set: 45 DOC (26 MCS, 19 VS/UWS)
 - 14 trauma, 28 non-trauma, 3 mixed
 - 34 patients assessed >1m post-insult
- Test set:
 - **16 MCS**, **6 VS/UWS** (M_{age} : 43y, 15 non-trauma; all chronic)
 - From 2 different centers



Resting connectivity in weightlessness?

CHERCHER, TROUVER, GUÉRIR, POUR VOUS & AVEC VOUS.



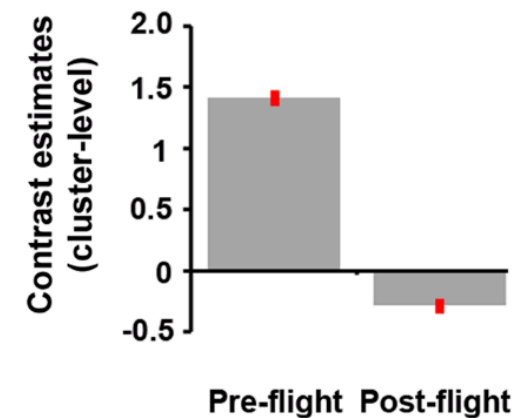
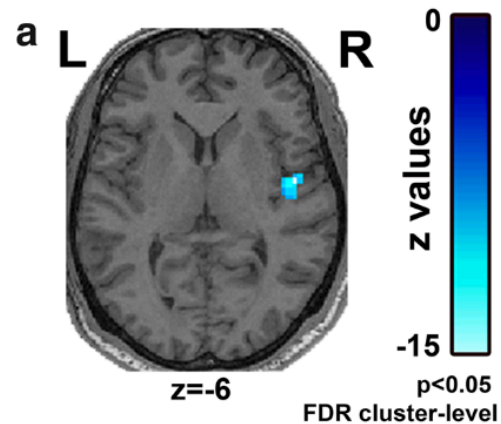
Cortical reorganization in an astronaut's brain after long-duration spaceflight

44-year-old male cosmonaut

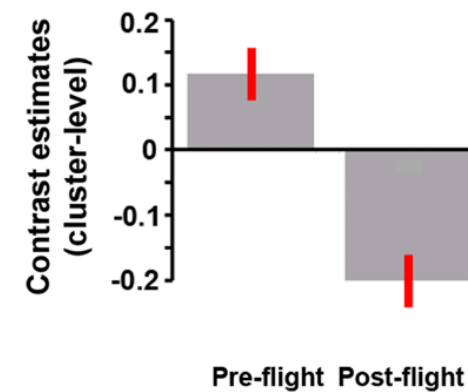
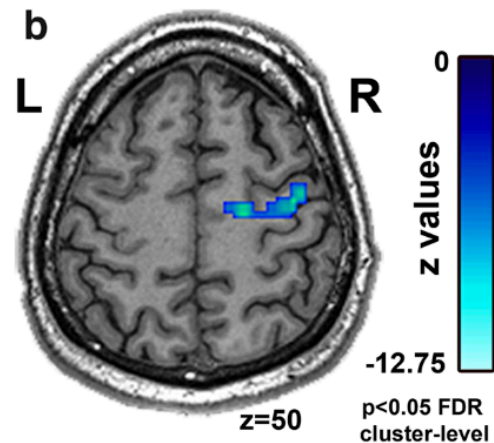
First long-duration mission (169 days) to the ISS in 2014

fMRI protocol pre-flight: 30 days, post-flight: 9 days after Earth re-entry

Hypothesis-free



Hypothesis-driven

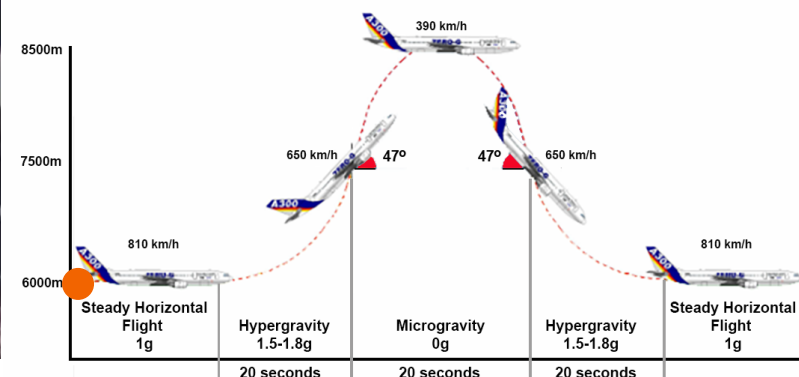


Less anticorrelated activity after exposure to microgravity

Parabolic flight

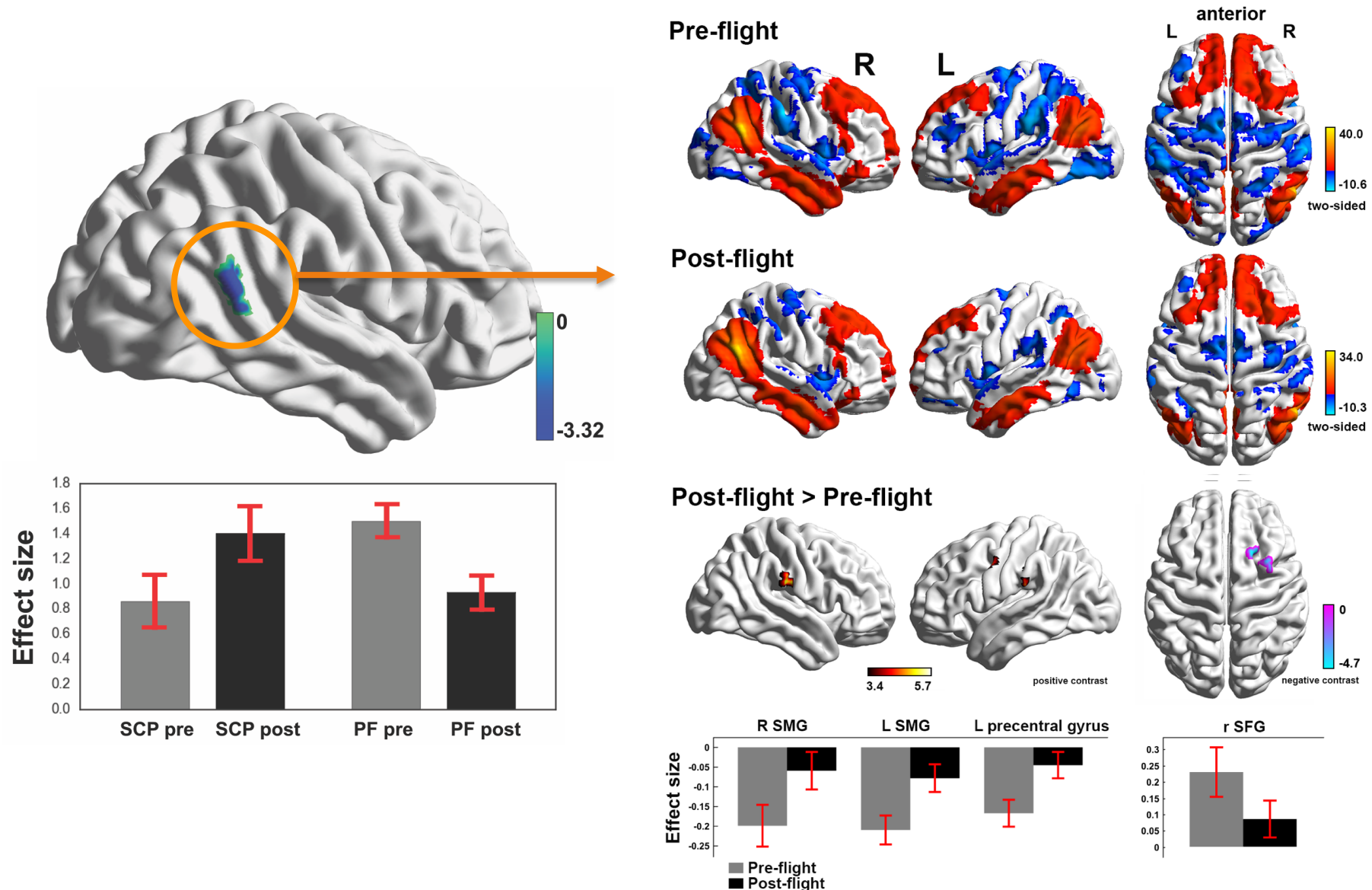


European Space Agency



Parabolic flight trajectory

Less anticorrelated activity after exposure to microgravity



Conclusions

- fMRI resting state connectivity can be utilized to assess consciousness by proxy
- The fMRI resting paradigm differentiates between conscious and unconscious subjects
- DMN anticorrelations have a cognitive counterpart, which can be modulated under both psychological and physiological conditions
- Implications for aerospace and for patients with vestibular disorders



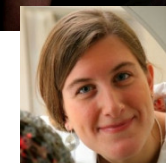
Thank you!



Coma Science Group & PICNIC Lab

The departments of Neurology and Radiology in Liège and Paris

...and mostly patients and their families!



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CHERCHER, TROUVER, GUÉRIR, POUR VOUS & AVEC VOUS.

