



Tracking Consciousness in noncommunicating states

New Scientist Instant Expert: Consciousness
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Human Brain Project



Patients cannot express themselves



Hable con ella 2002, Pedro Almodóvar



The mechanical ventilator (1950s)



Bjørn Ibsen
(Copenhagen)

The resuscitation greets
Resuscitation. 2003



We need a brain

Typical brain



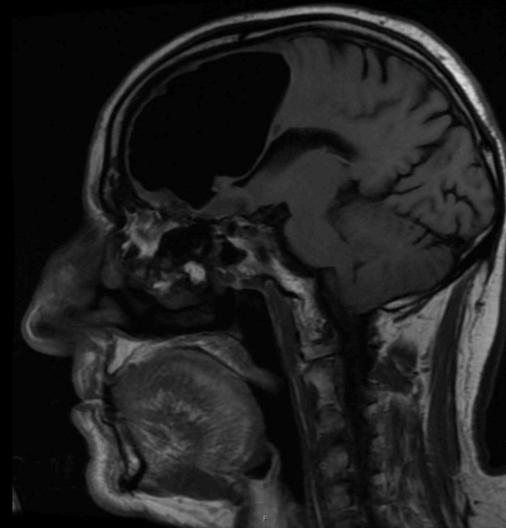
Primary cerebellar agenesis



24y female

Yu et al, Brain. 2014

Frontal air-filled cavity

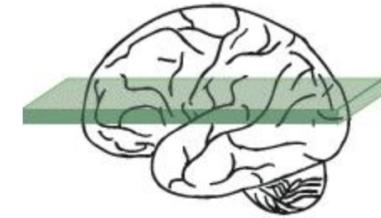
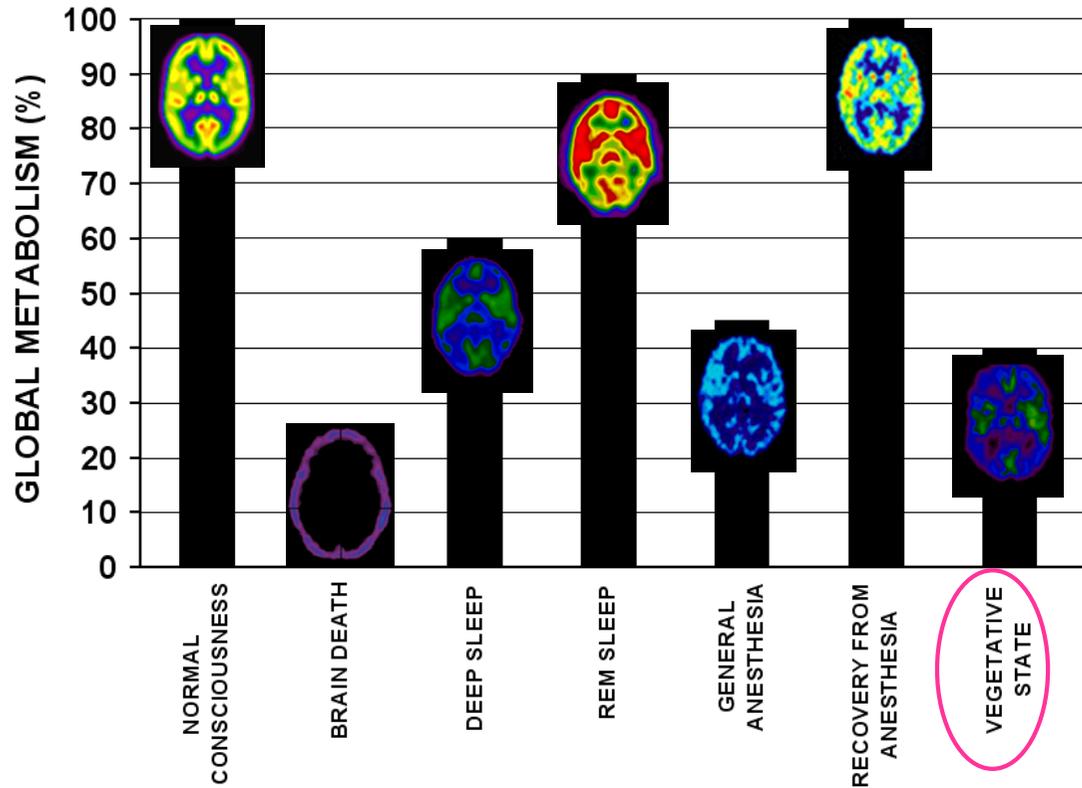


84y male

Brown & Vahidassr, BMJ Case Reports 2018



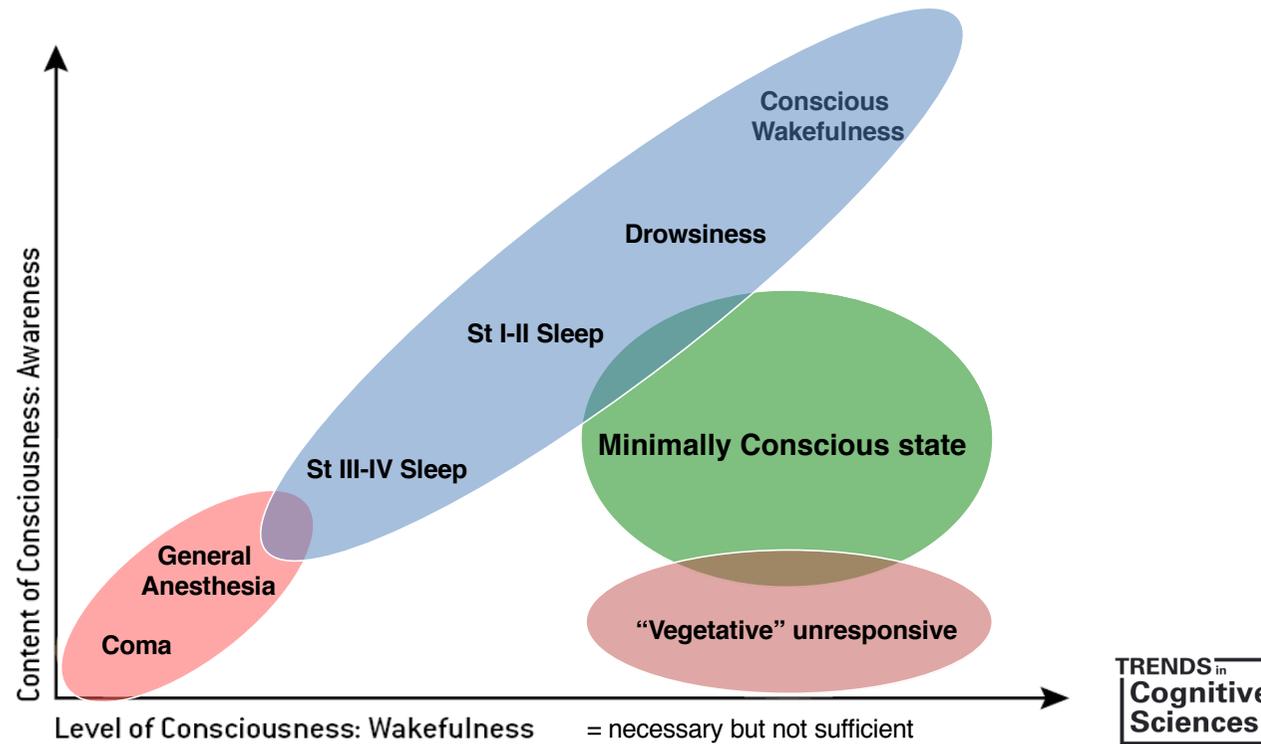
We need a functional brain



Laureys et al., Lancet Neurology, 2004
(sleep data from Pierre Maquet; anesthesia data from Mike Alkire)



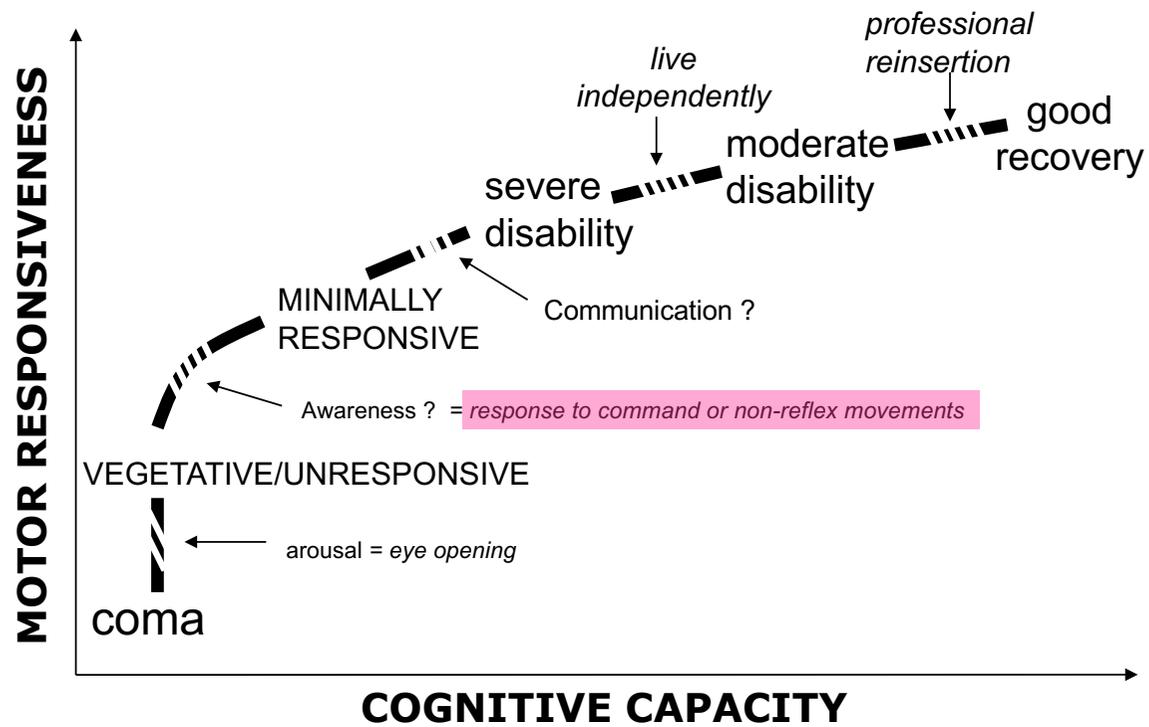
Disorders of Consciousness



Demertzi, Boly, Laureys. *Encyclopedia of Consciousness* 2009
Laureys. *Trends Cogn Sci* 2005; Laureys et al, *Nat Clin Med* 2008



Behavioural signs of Consciousness





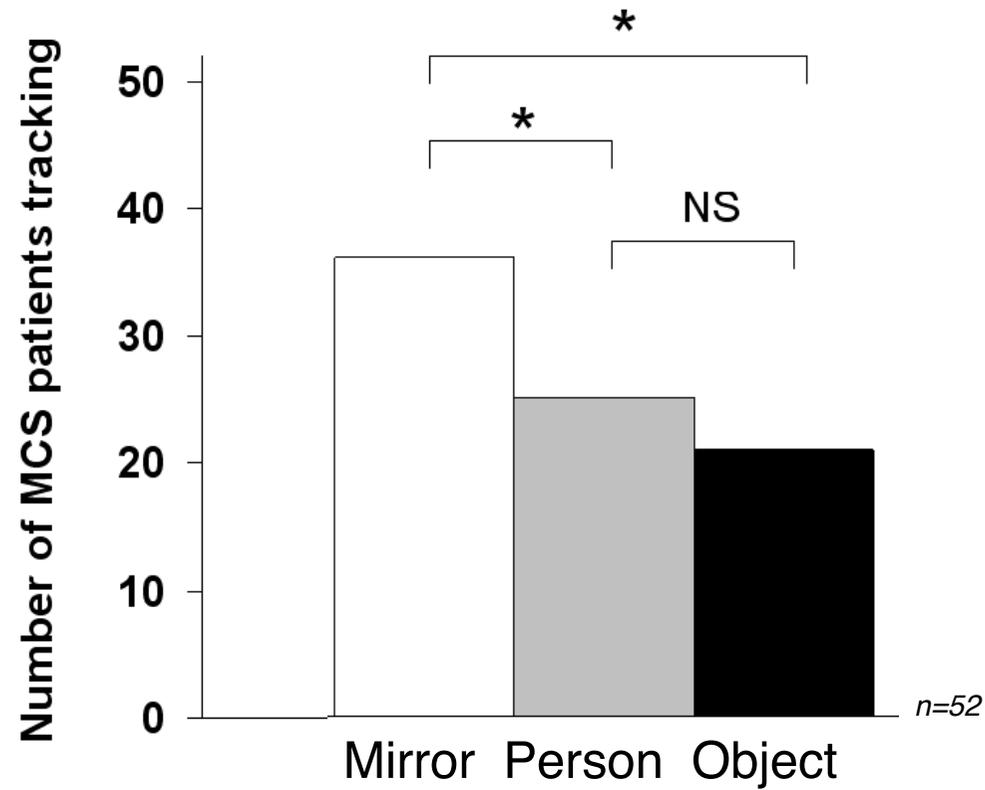
Response to command: behaviour



Terry Schiavo °1963,
vegetative 1990, † 2005 USA



Non-reflex movements: eye tracking



But: Is behaviour the gold standard?

Standardized assessment

n=103 post-comatose patients

45 Clinical diagnosis of VS

18 Coma Recovery Scale MCS

↳ 40% misdiagnosed

Schnakers et al, *Ann Neurol* 2006; *BMC Neurol* 2009

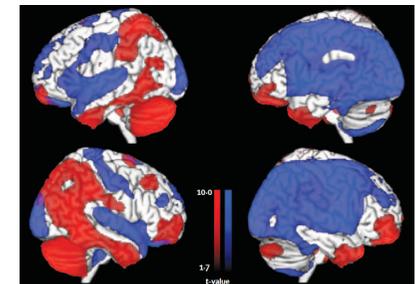
PET Neuroimaging

	Coma Recovery Scale-Revised results		
	UWS	MCS	Total
Clinical consensus diagnosis			
¹⁸F-FDG PET			
VS/UWS	24 (21%)	5 (4%)	29 (26%)
MCS	12 (11%)	71 (63%)	83 (74%)
Total	36 (32%)	76 (68%)	112 (100%)

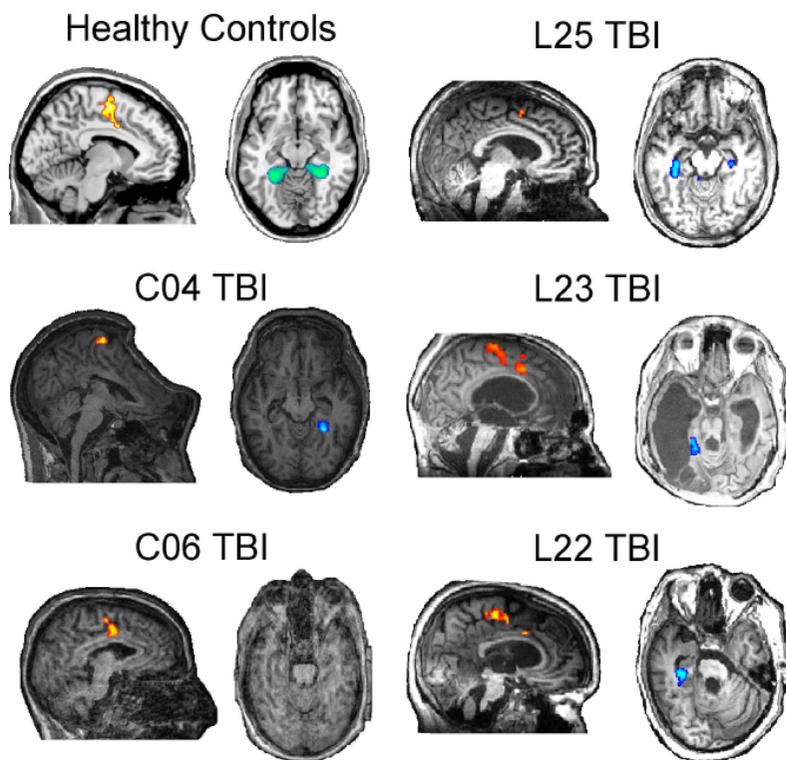
UWS=unresponsive wakefulness syndrome. MCS=minimally conscious state.

Table 2: Diagnostic results by modality

Stender & Gosseries et al, *Lancet* 2014

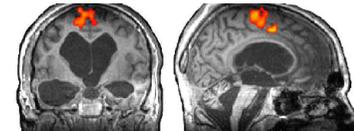


Response to command: brain activity

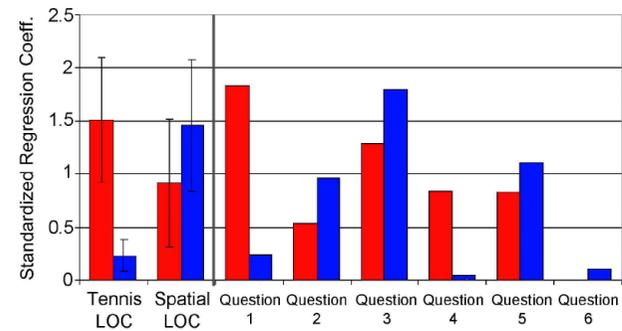
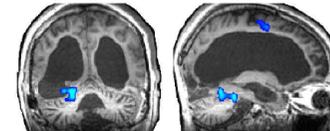


Imagine **Tennis** to answer 'YES'
 Imagine **Navigating** to answer 'NO'

Is your father's name Alexander ?

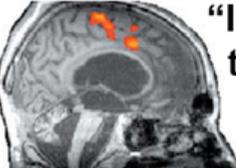
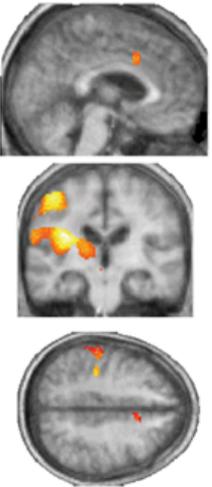
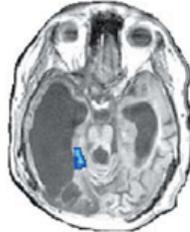


Is your father's name Thomas ?





But: what when not possible?

Active paradigms	Passive paradigms
 <p>“Imagine playing tennis”</p>	 <p>median nerve</p> 
 <p>“Imagine visiting the rooms of your house”</p>	

Heine, Di Perri, Soddu, Laureys, Demertzi
In: *Clinical Neurophysiology in Disorders of Consciousness*
Springer-Verlag 2015

Demertzi & Laureys, In: *I know what you are thinking: brain imaging and mental privacy*
Oxford University Press 2012

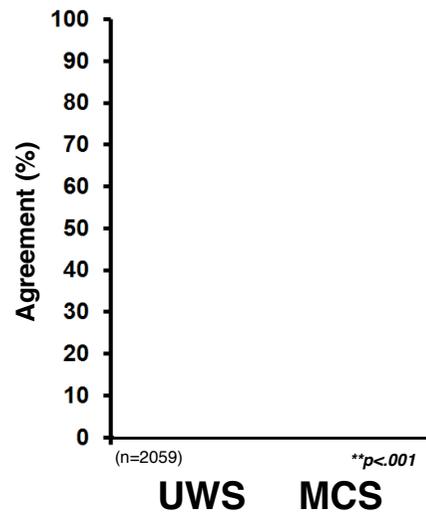


What is awareness?

Nociception, pain, suffering?

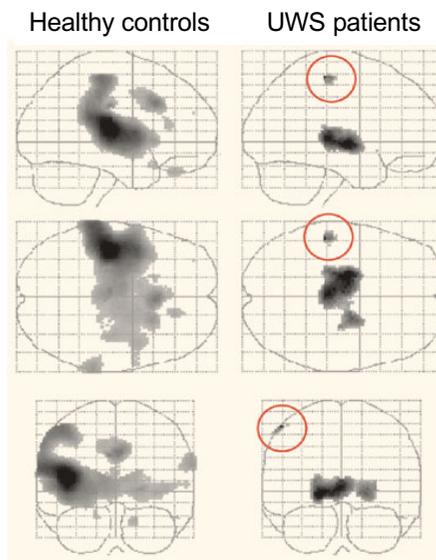


Do you think patients in a ...
can feel pain?



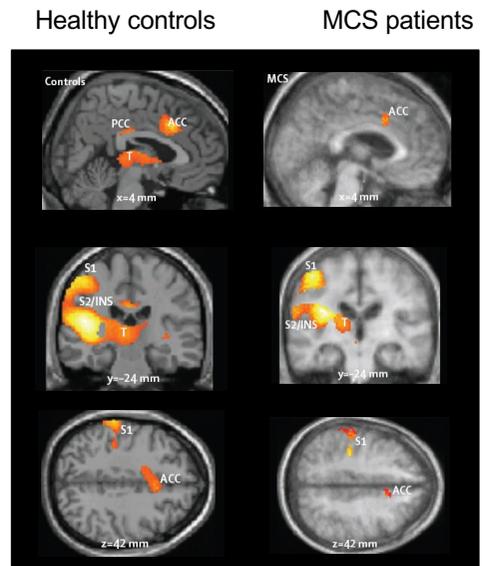
Demertzi et al, *Prog Brain Res* 2009
Demertzi & Racine et al, *Neuroethics* 2012

Unresponsive wakefulness syndrome



Laureys et al., *Neuroimage* 2002

Minimally conscious state



Boly et al, *Lancet Neurol* 2008



Some numbers

- The brain is ~2% of the weight of the body
- 80% of energy consumption supports neuronal signaling
- Performance-evoked changes in energy consumption <5%

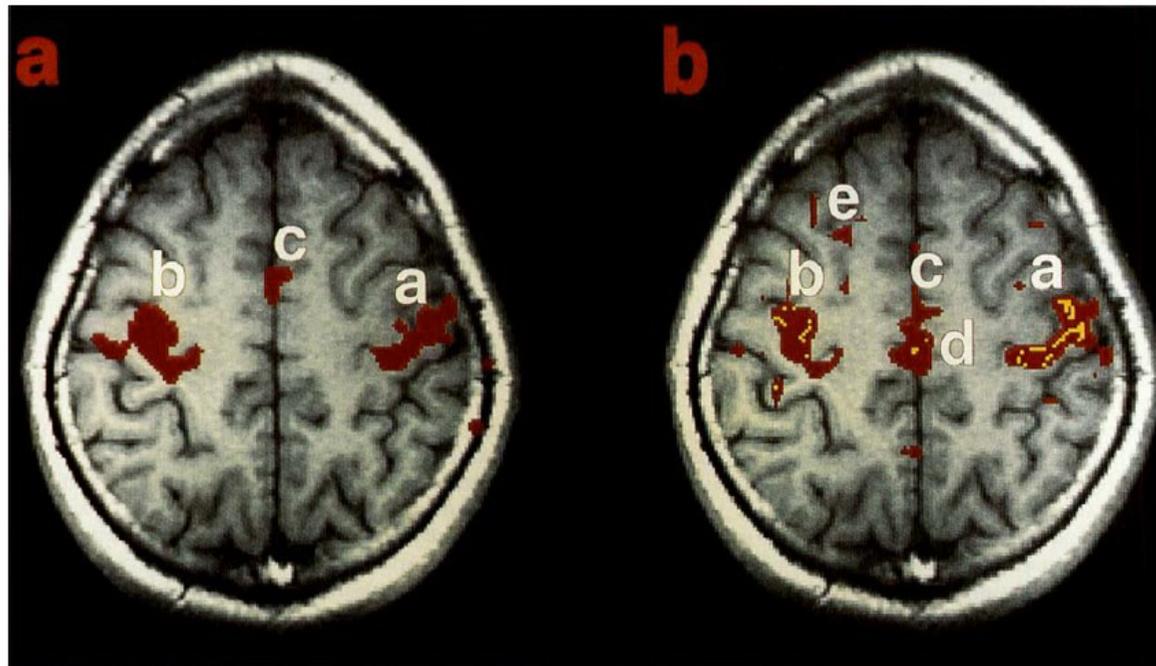


While conscious awareness is energetically inexpensive, it depends on a very complex, dynamically organized, non-conscious state of the brain that is achieved at great expense

The brain self-organizes

Task

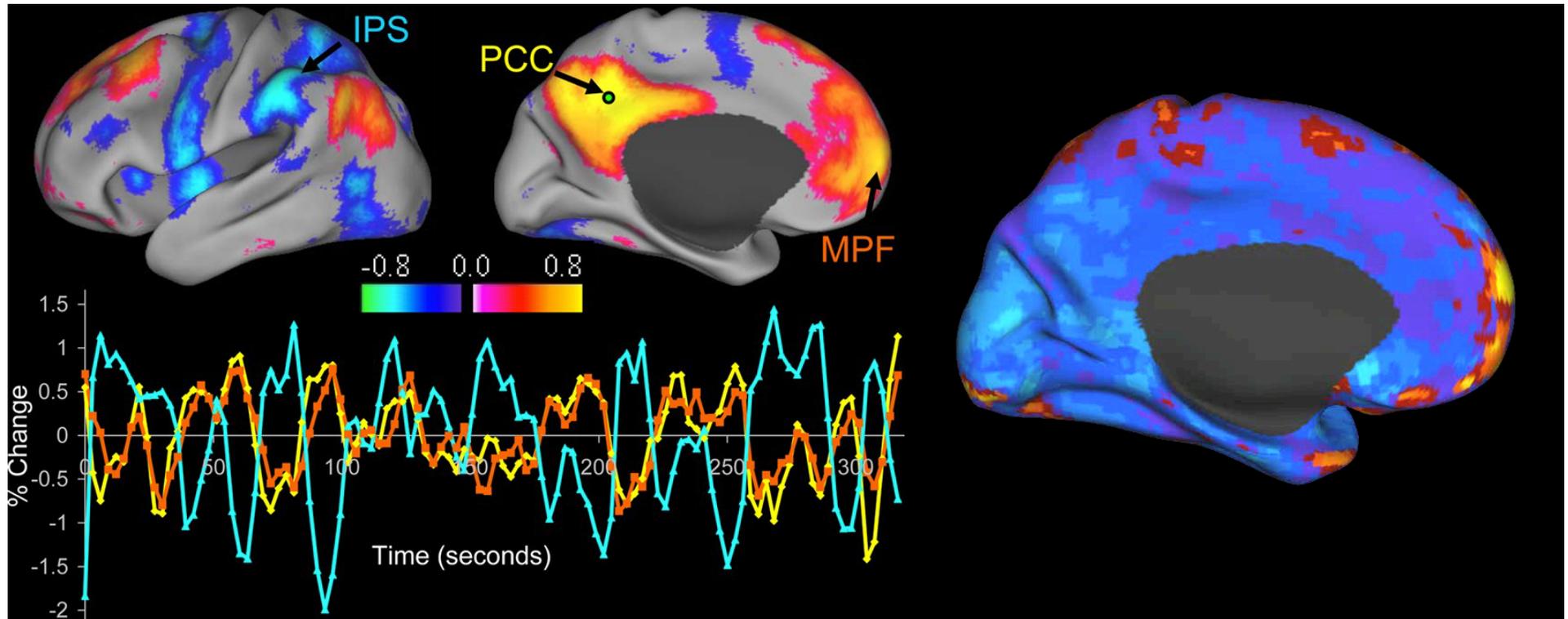
Rest



Biswal et al., *Magn Reson Med* 1995



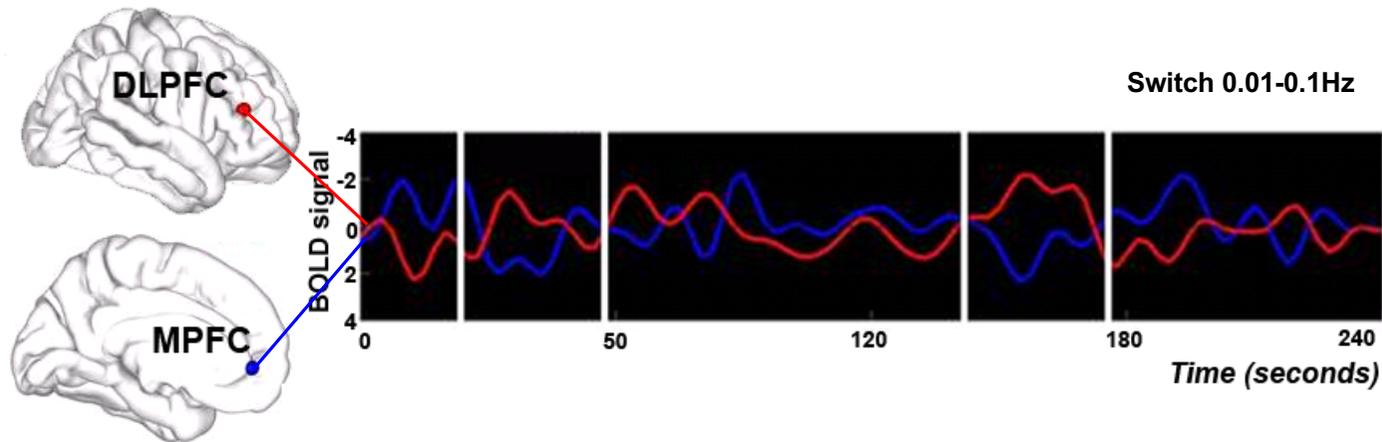
Default mode function



Fox et al, *Proc N Acad Sci* 2005

Default mode function: cognition?

External awareness
or anticorrelated network

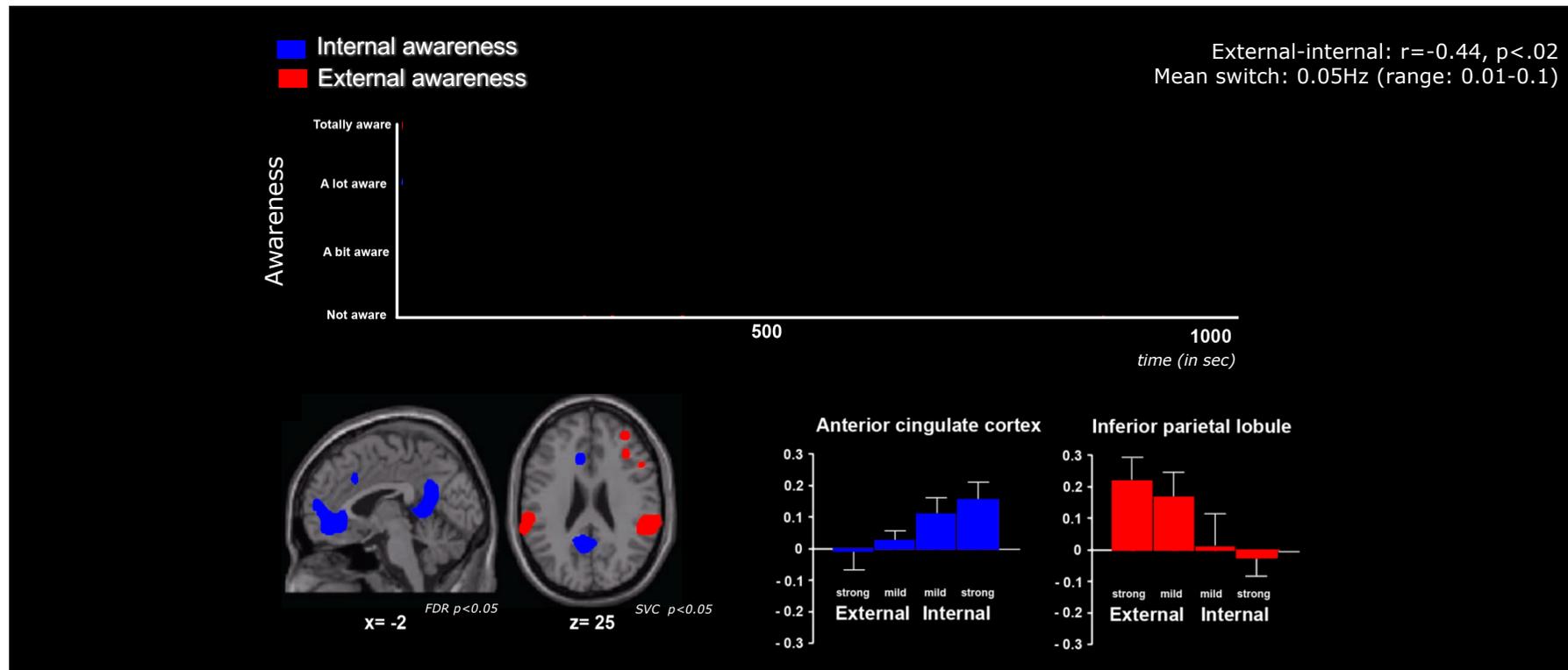


Internal awareness
or Default mode network

Demertzi & Whitfield-Gabrieli. in: *Neurology of Consciousness* 2nd ed. 2015
Demertzi et al, *Front Hum Neurosci* 2013
Demertzi, Soddu, Laureys. *Curr Opin Neurobiology* 2013



Cognitive-behavioral relevance

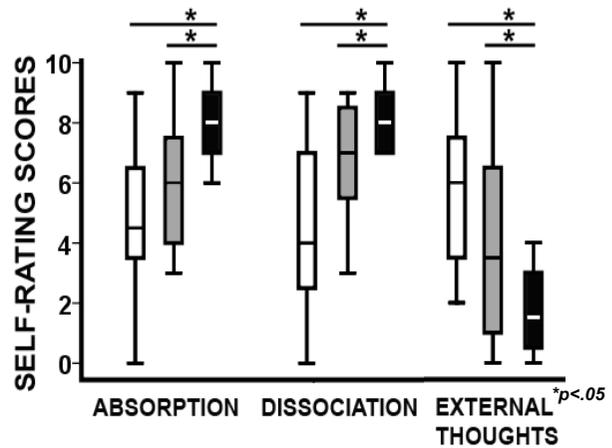


Vanhaudenhuyse*, Demertzi* et al, *J Cogn Neurosci* 2011

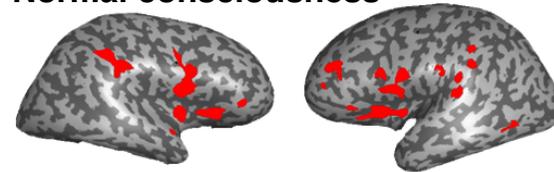


Effect of awareness

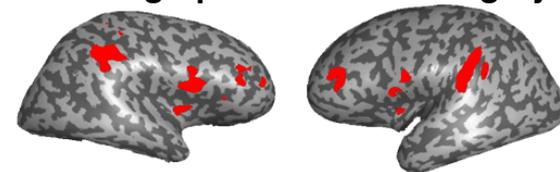
- Normal consciousness
- ▒ Autobiographical mental imagery
- Hypnosis



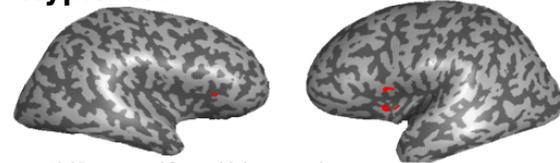
Normal consciousness



Autobiographical mental imagery



Hypnosis



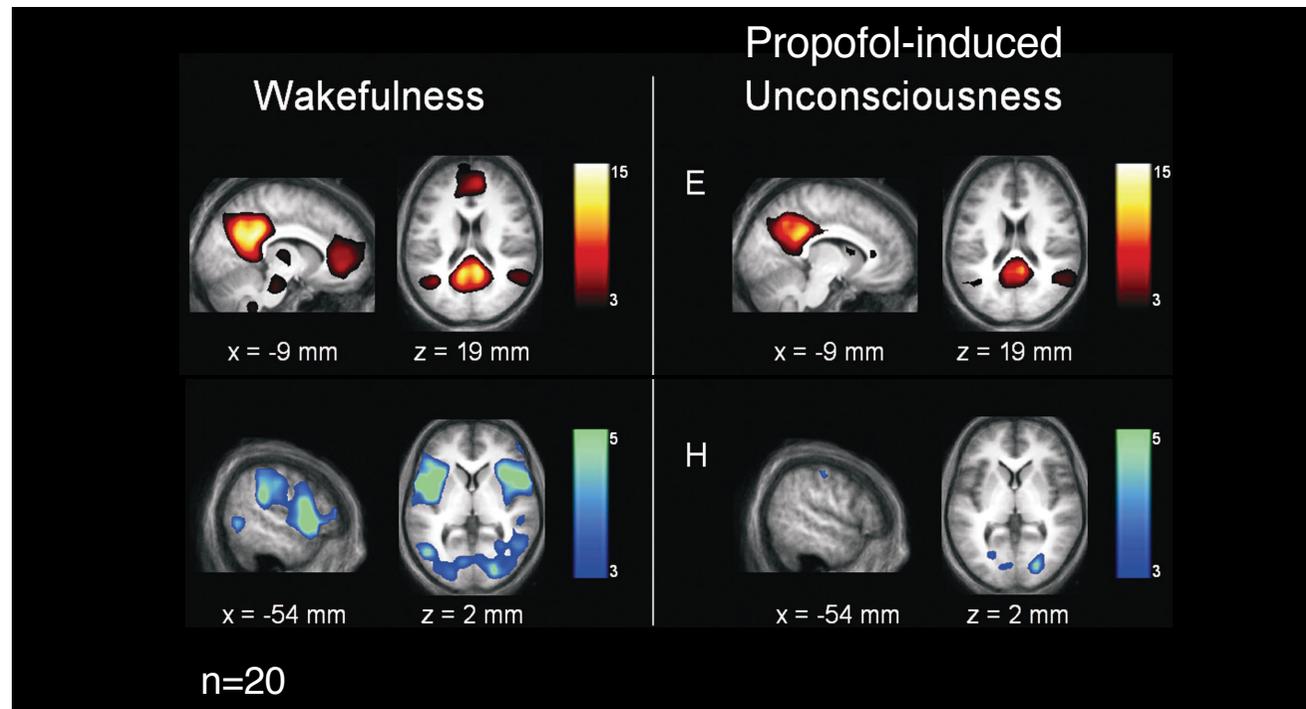
p<0.05 corrected for multiple comparisons

Demertzi, Soddu, Faymonville et al, *Prog Brain Res* 2011

Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, *J Physiol Paris* 2015



Effect of arousal



Boveroux et al, *Anesthesiology* 2010



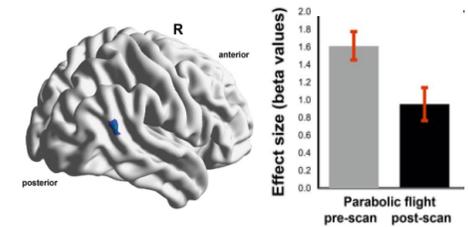
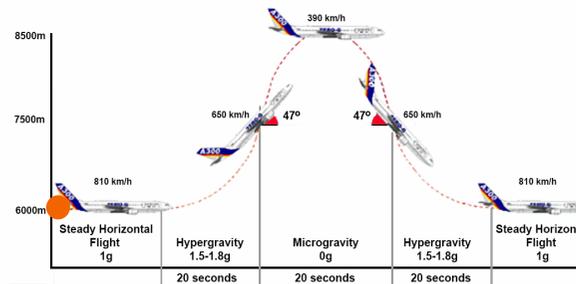
Effect of environment

SCIENTIFIC REPORTS

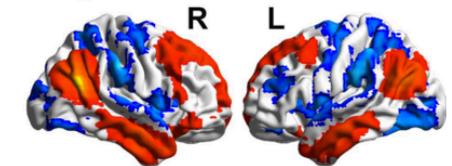
Parabolic trajectory



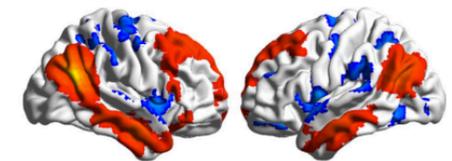
European Space Agency



Pre-flight



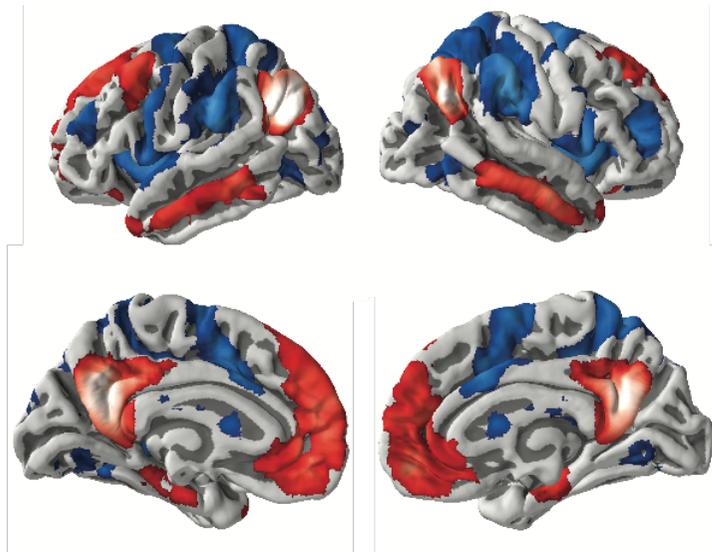
Post-flight



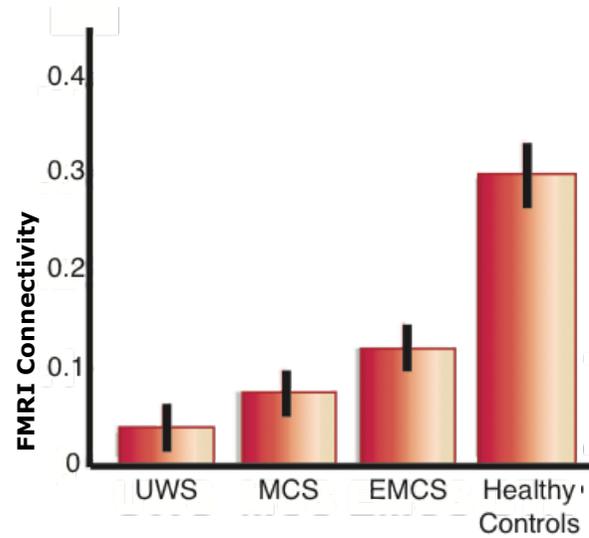
Angelique Van Ombergen¹, Floris L. Wuyts¹, Ben Jeurissen², Jan Sijbers², Floris Vanhevel³, Steven Jillings³, Paul M. Parizel³, Stefan Sunaert⁴, Paul H. Van de Heyning¹, Vincent Dousset⁵, Steven Laureys⁶ & Athena Demertzi^{6,7}



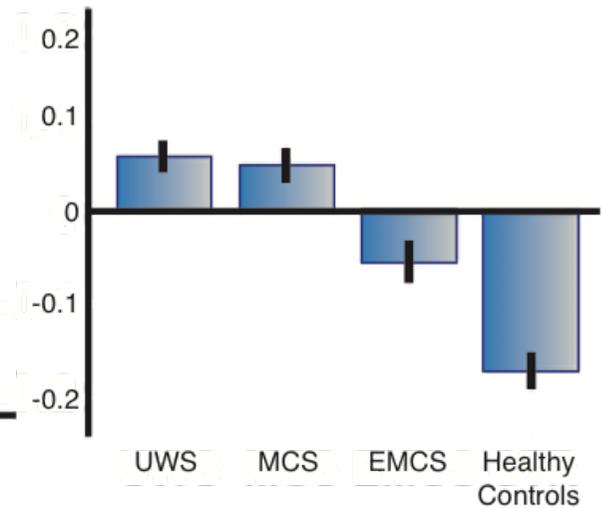
Effect of pathology



DMN CORRELATIONS

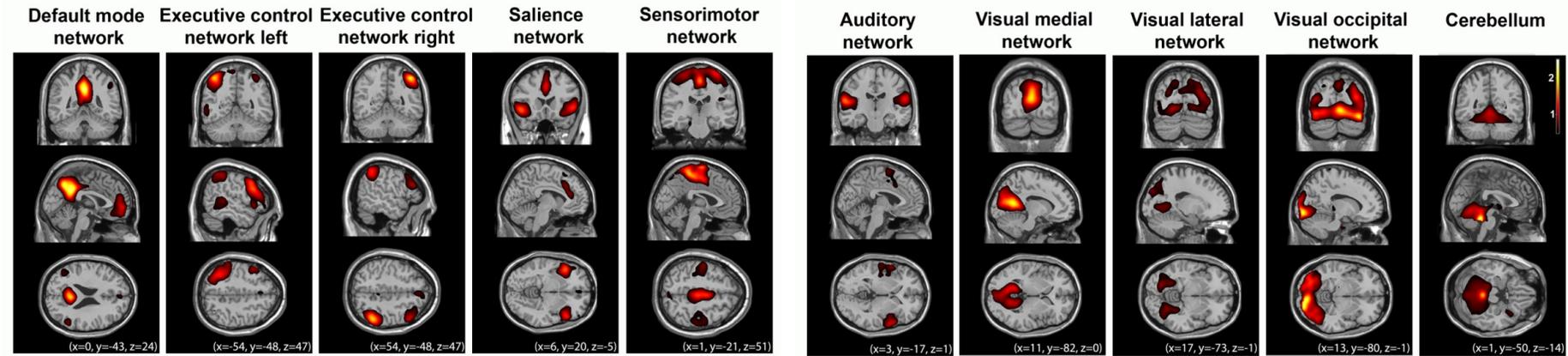


DMN ANTICORRELATIONS





Brain networks

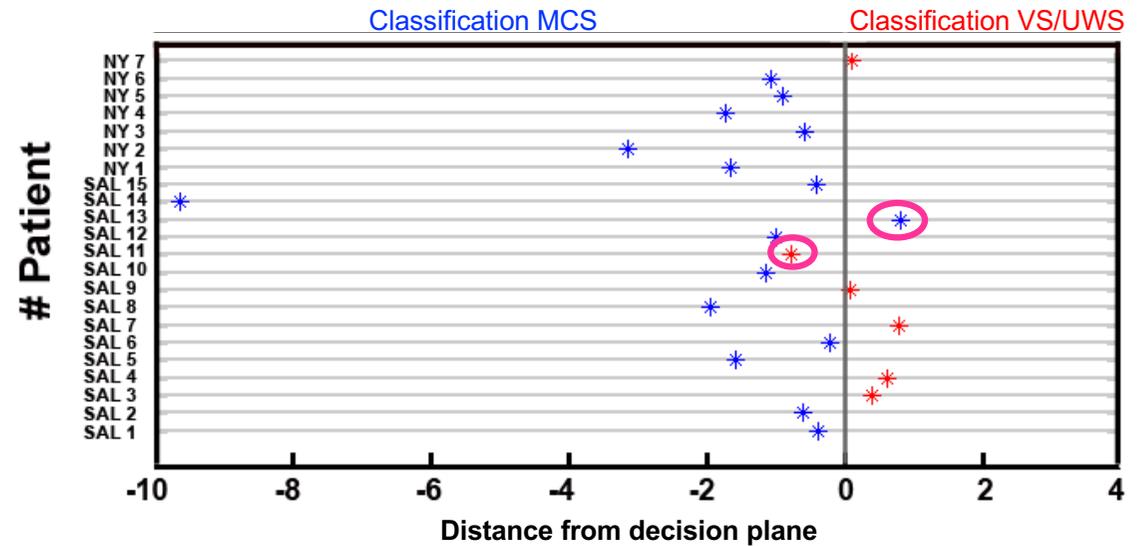
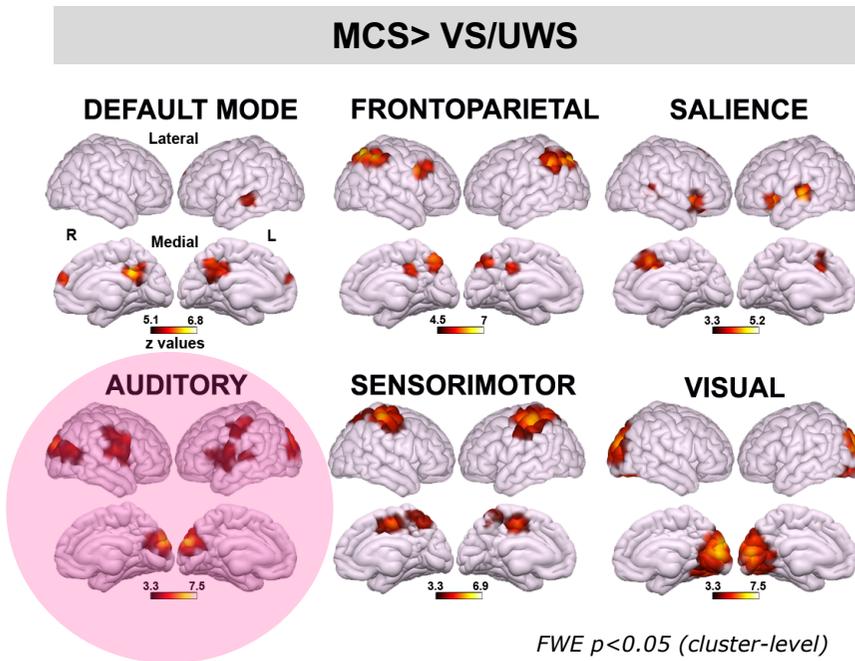




Which network discriminates best?

Single-patient classification

Training set: 45 DOC (26 MCS, 19 VS/UWS)
 Test set: **16 MCS**, **6 VS/UWS** 2 different centers

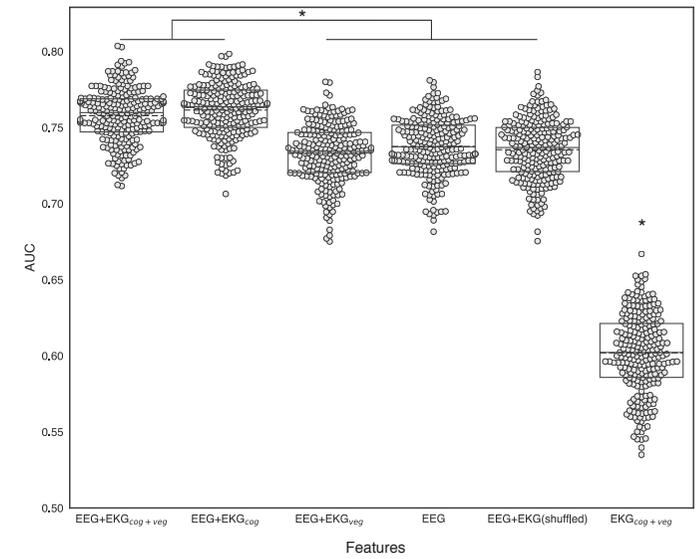
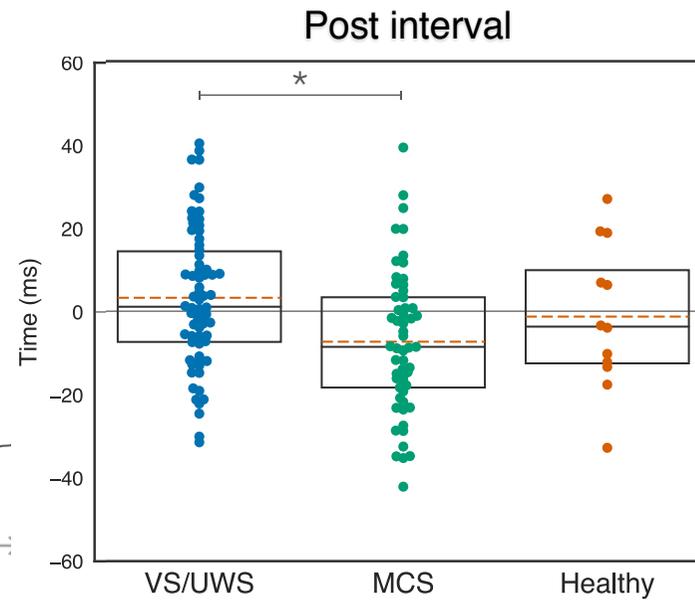
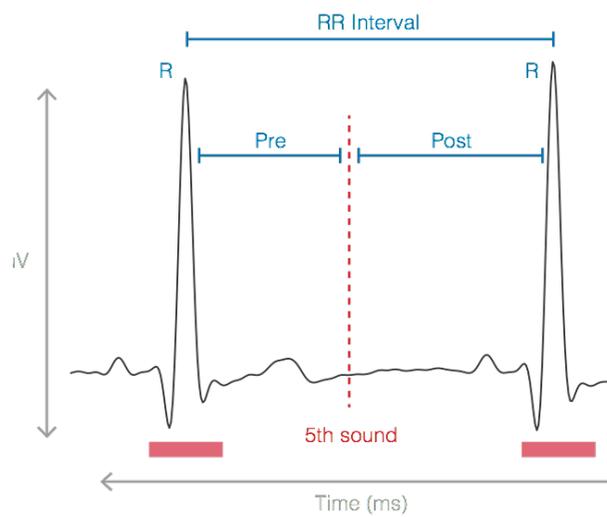


Demertzi & Antonopoulos et al, *Brain* 2015
 Demertzi et al, *Neurosci Consciousness* 2017



Listen to the heart

Auditory oddball paradigm



Raimondo, Rohaut, Demertzi et al, *Annals Neurol* 2017

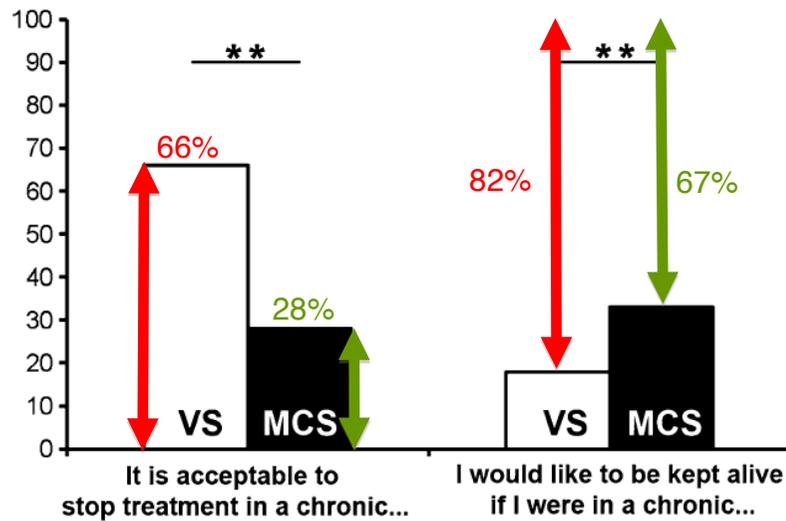


Why does it matter?



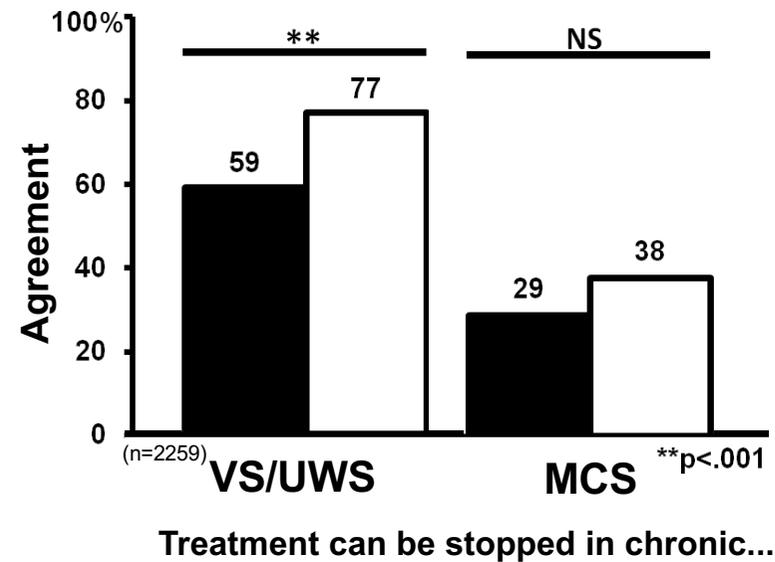
Consciousness has a moral significance

2,475 medical professionals



Demertzi et al, *J Neurol* 2011

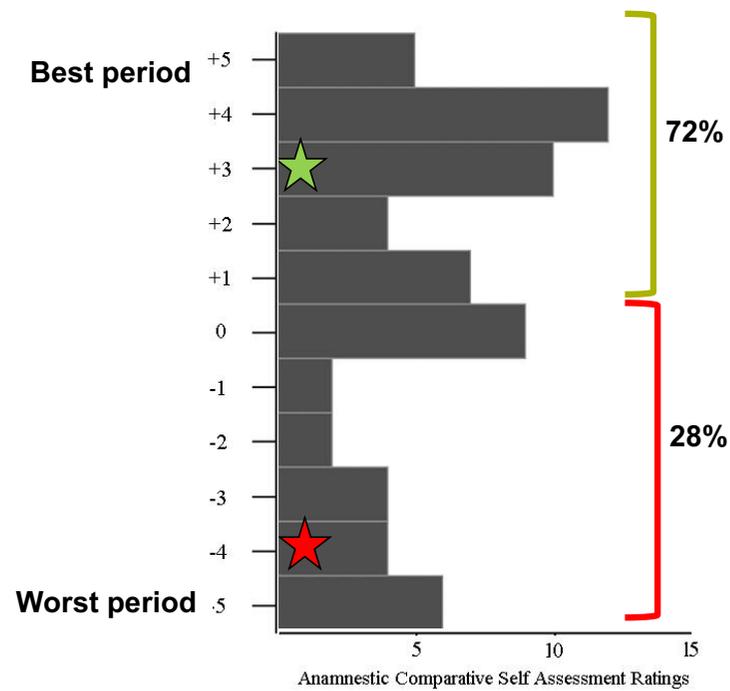
■ Feel pain
□ Do not feel pain



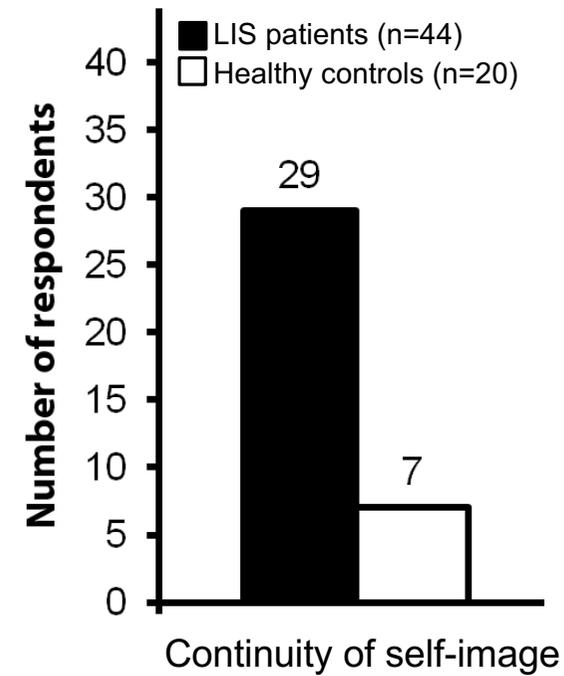
Demertzi & Racine et al, *Neuroethics* 2012



Quality of life



Bruno et al, *Br Med J Open* 2011



Nizzi & Demertzi et al, *Conscious & Cogn* 2012



What remains unsolved?

Patients cannot express *themselves*



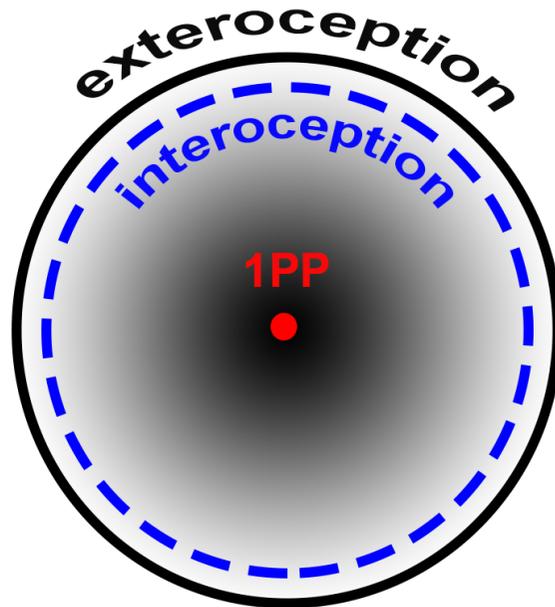
Hable con ella 2002, Pedro Almodóvar





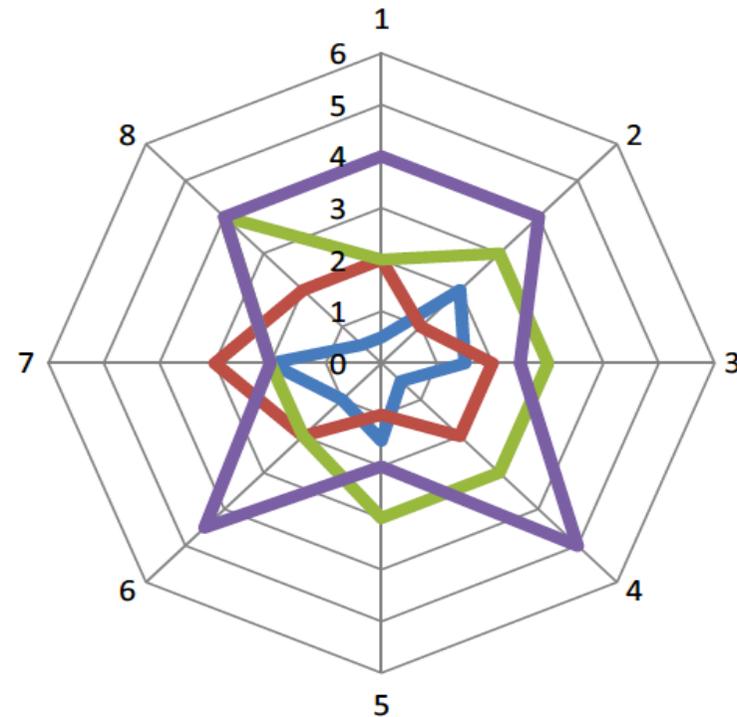
Self = Consciousness?

The minimal self



Blanke & Metzinger *Trends Cogn Sci* 2008

States of Consciousness



Bayne, Hohwy, Owen. *Trends Cogn Sci* 2016

Conclusions

- Consciousness in non-communicating states needs to be inferred: need of a framework for used technologies (Demertzi et al, *Neurosci Consciousness* 2017)
- Consciousness carries a moral significance
- Consciousness is not out there to capture

Consciousness concerns us all



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Coma Science Group & PICNIC Lab

The departments of Neurology and Radiology in Liège and Paris

...and mostly patients and their families!



James S. McDonnell Foundation



Human Brain Project



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de la santé et de la recherche médicale

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de Liège



fnr's
FREEDOM TO RESEARCH