



Consciousness: Exploring brain activity in coma & related states of consciousness

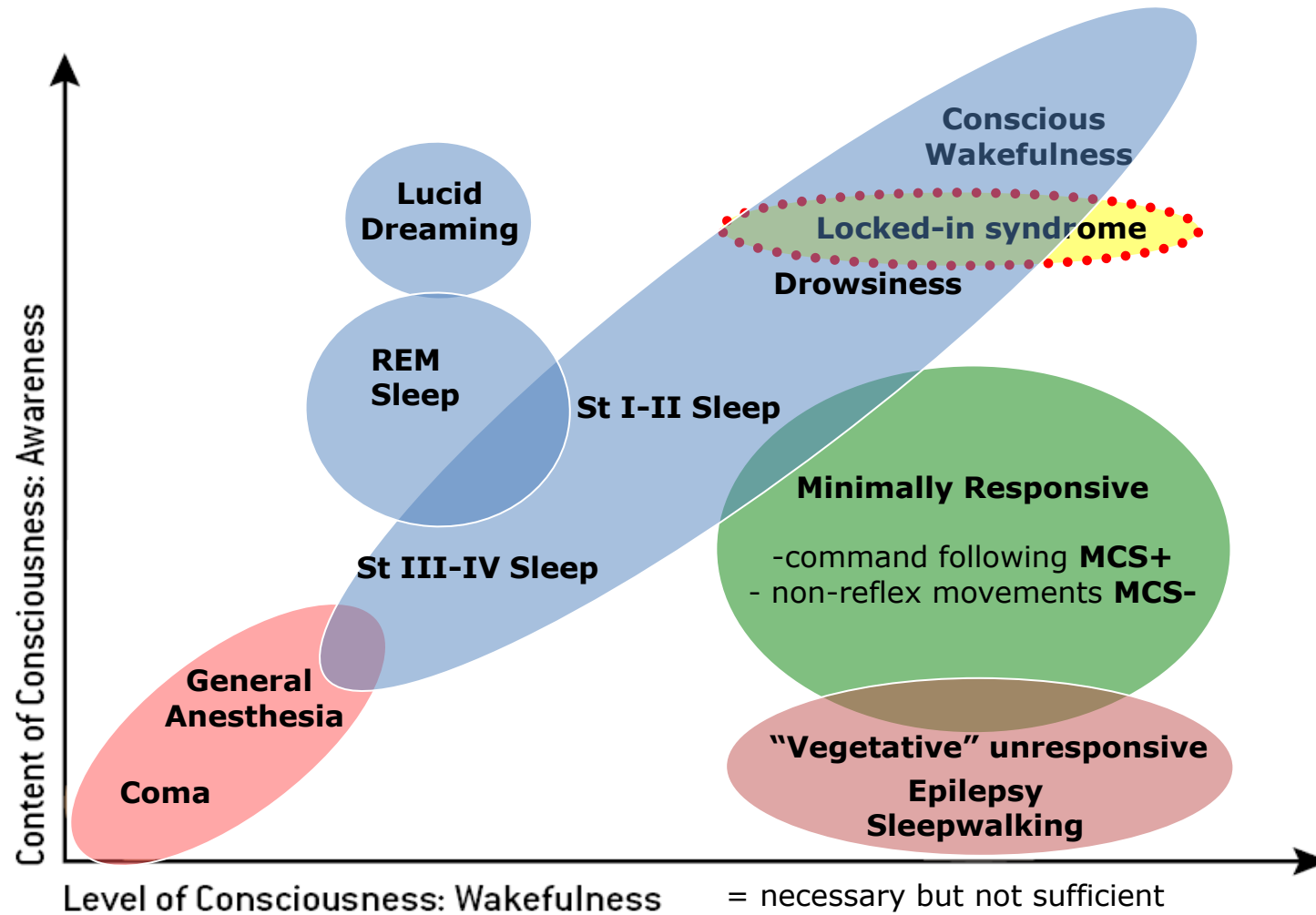
Helena CASSOL PhD student
Steven LAUREYS MD
University Hospital
& University of Liège
Belgium



coma@ulg.ac.be
www.comascience.org

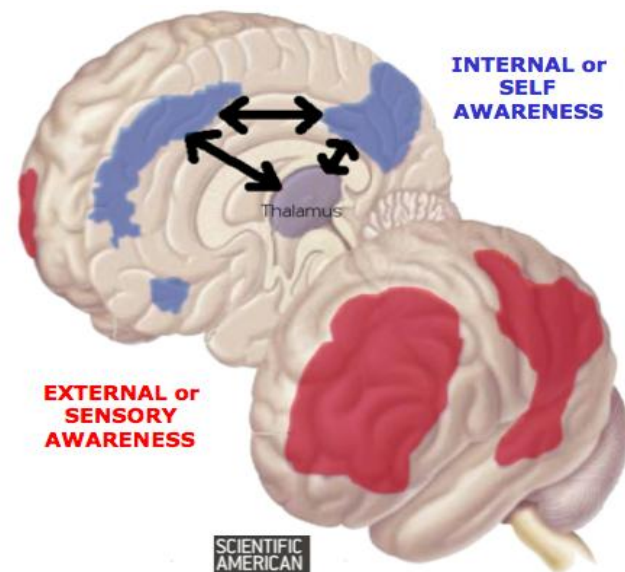
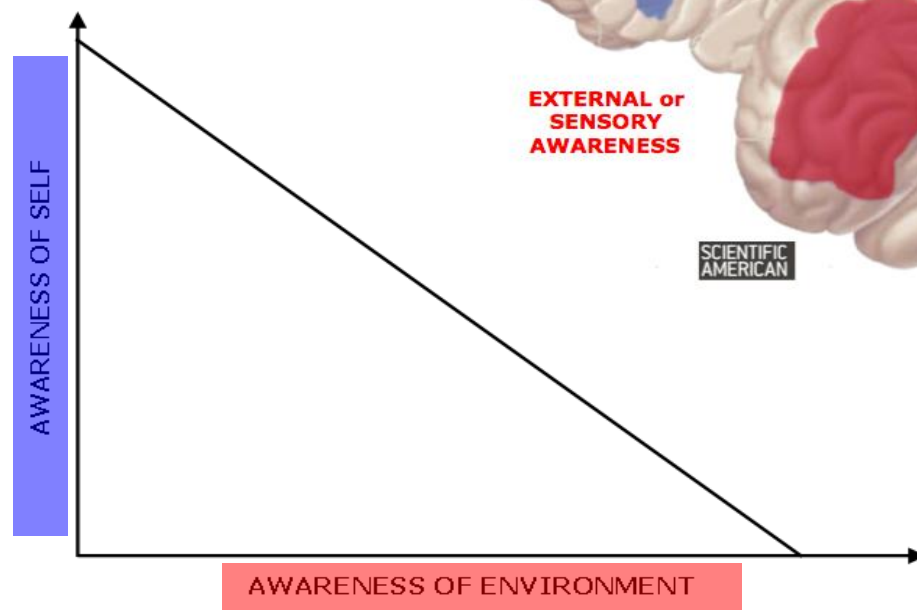


Arousal & awareness



TRENDSⁱⁿ
Cognitive
Sciences

Measuring awareness



Boly et al, *Ann NY Acad Sci*, 2009

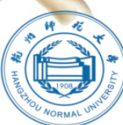
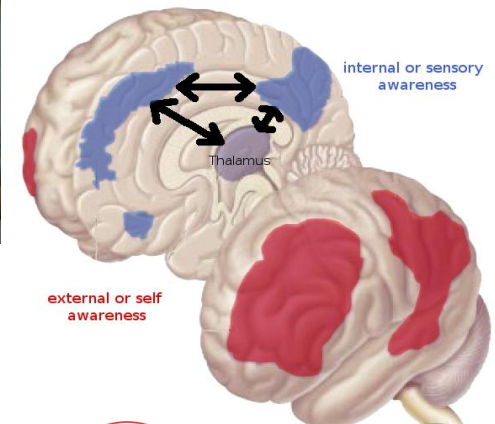
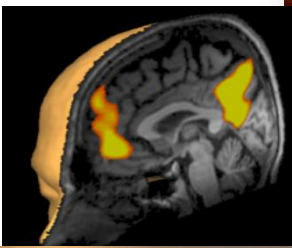
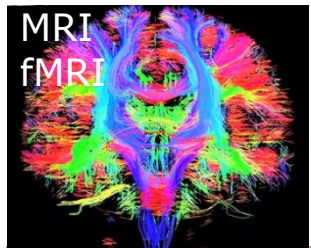
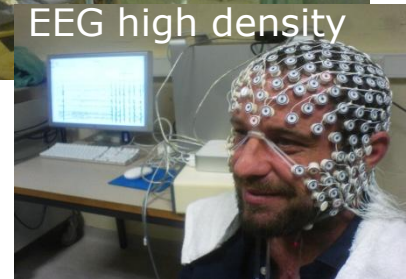
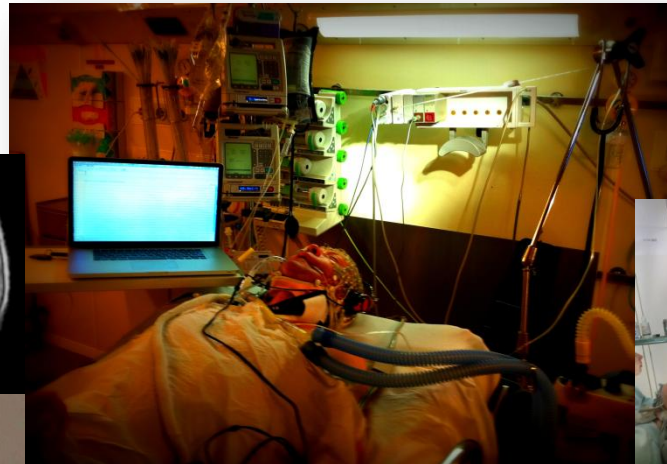
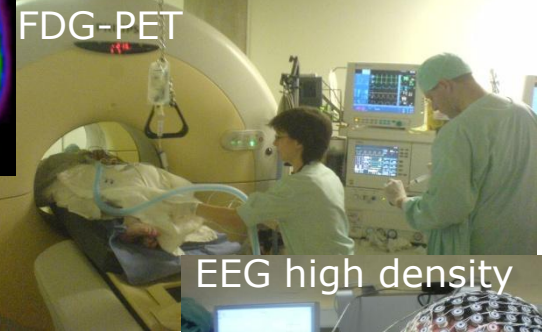
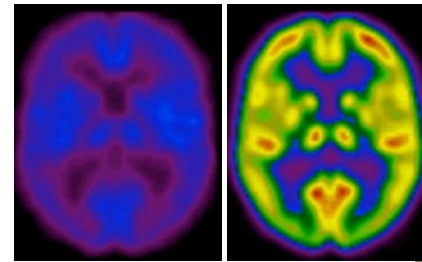
Vanhaudenhuyse & Demertzi et al, *J Cogn Neurosci*, 2011

Measuring brain activity

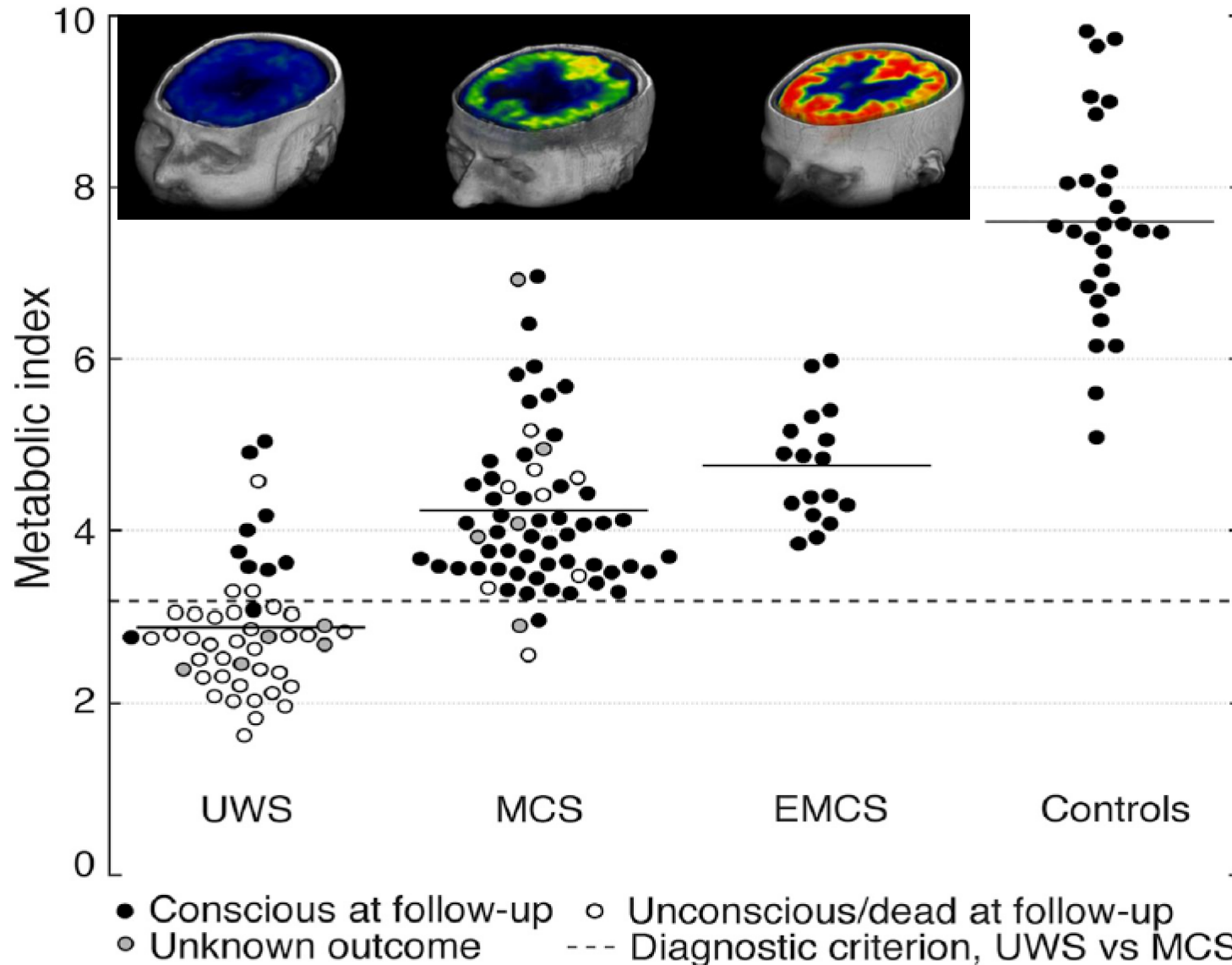


Altered states of consciousness

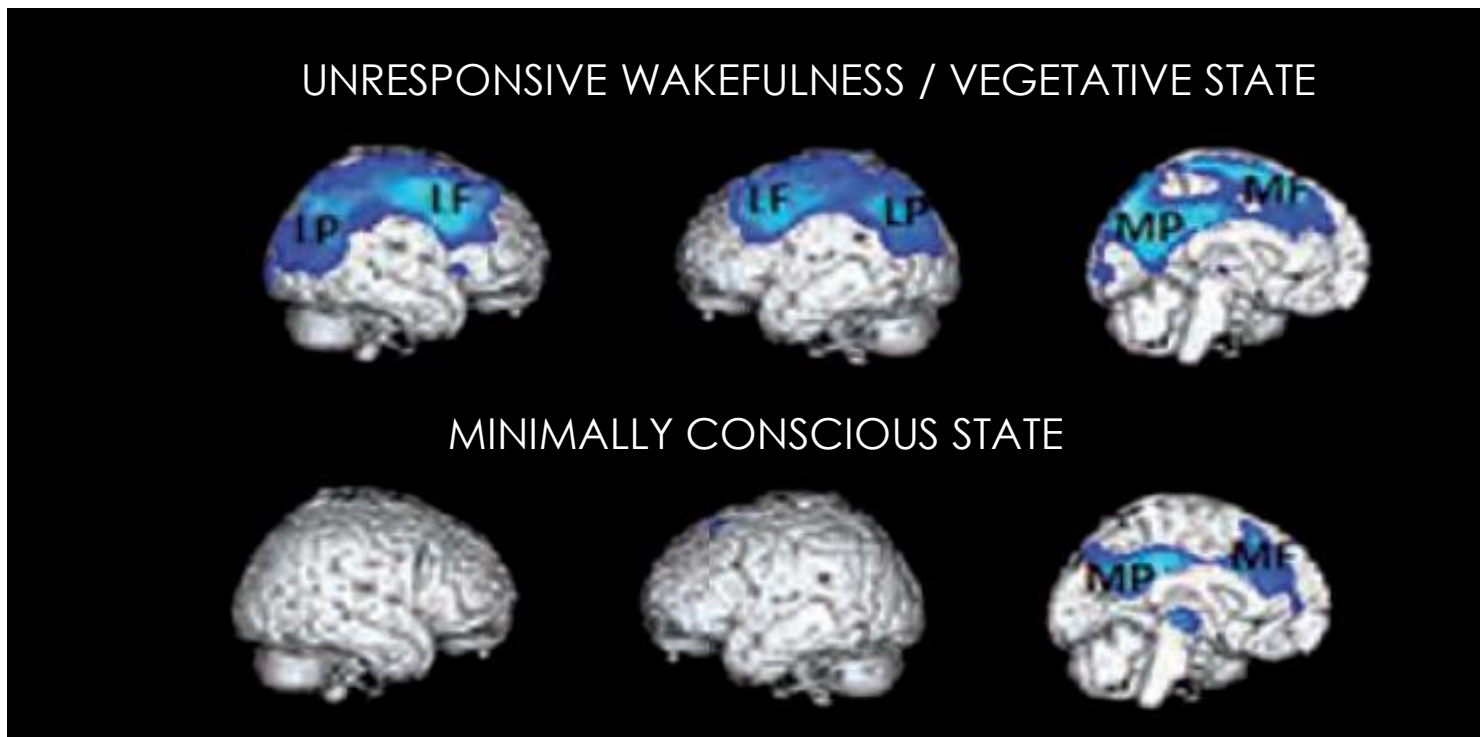
- Pathological : coma
- Pharmacological: anesthesia
- Physiological: hypnosis



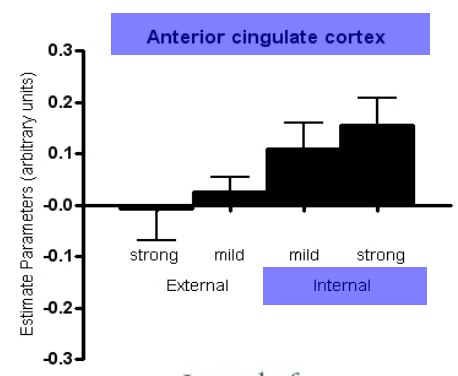
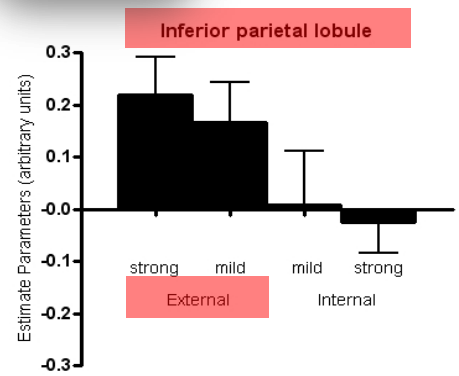
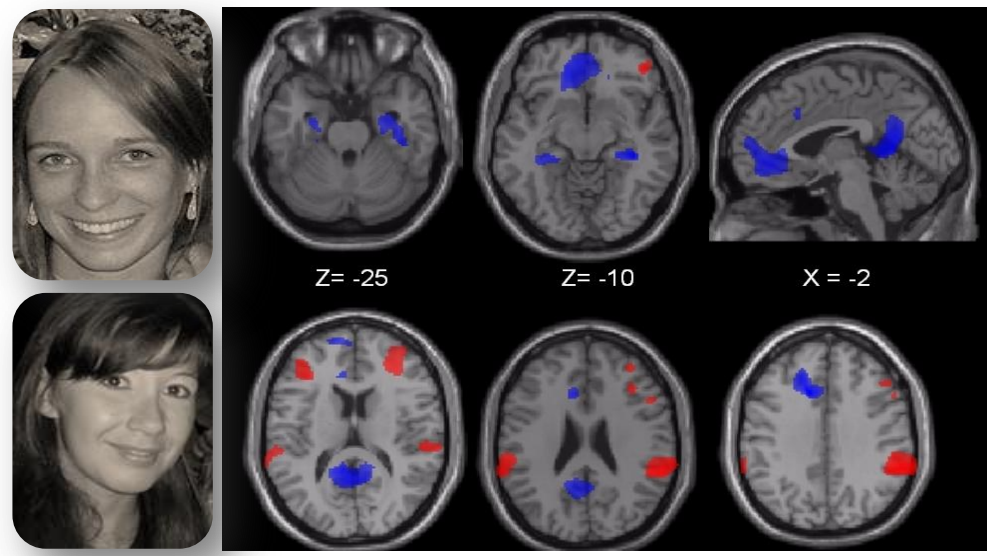
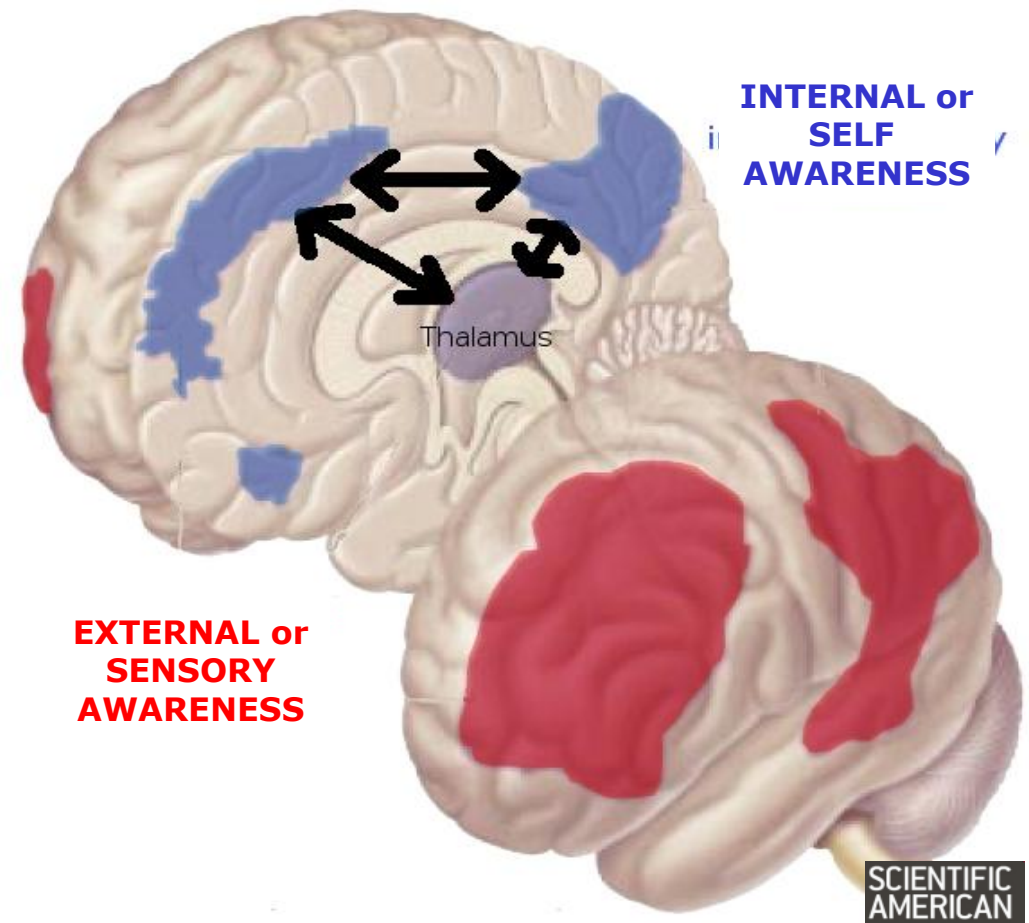
Consciousness and global brain function



“Global workspace” of consciousness

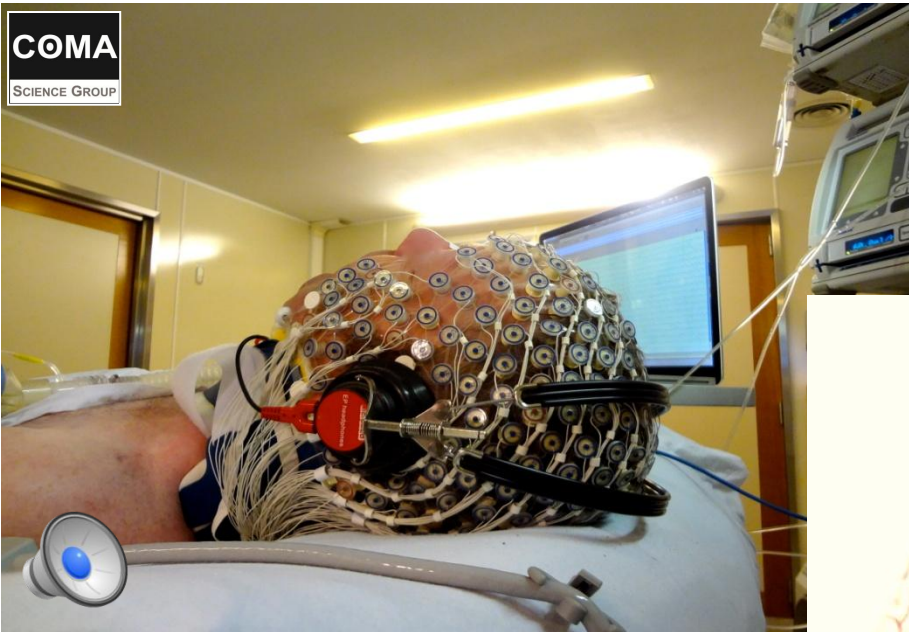


External & internal awareness

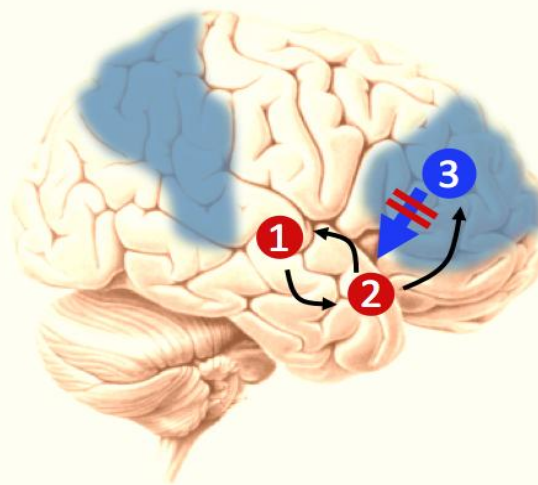


Journal of Cognitive Neuroscience

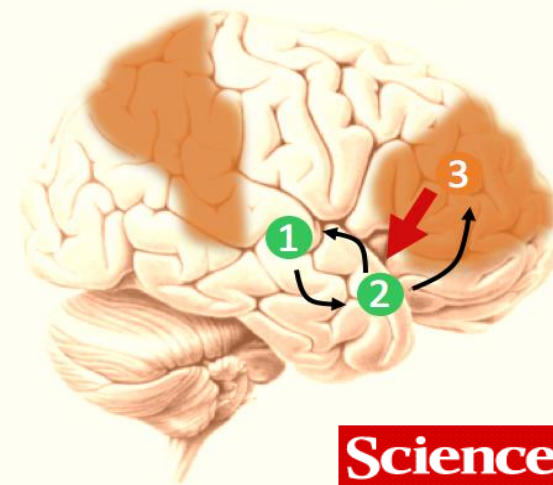
Consciousness \approx top-down



“VEGETATIVE”
UNRESPONSIVE



MINIMALLY
RESPONSIVE



Science

Boly, Garrido, Gosseries, Bruno, Schnakers, Massimini, Litvak, Laureys, Friston, *Science*, 2011

Temporal dynamics of EEG measures

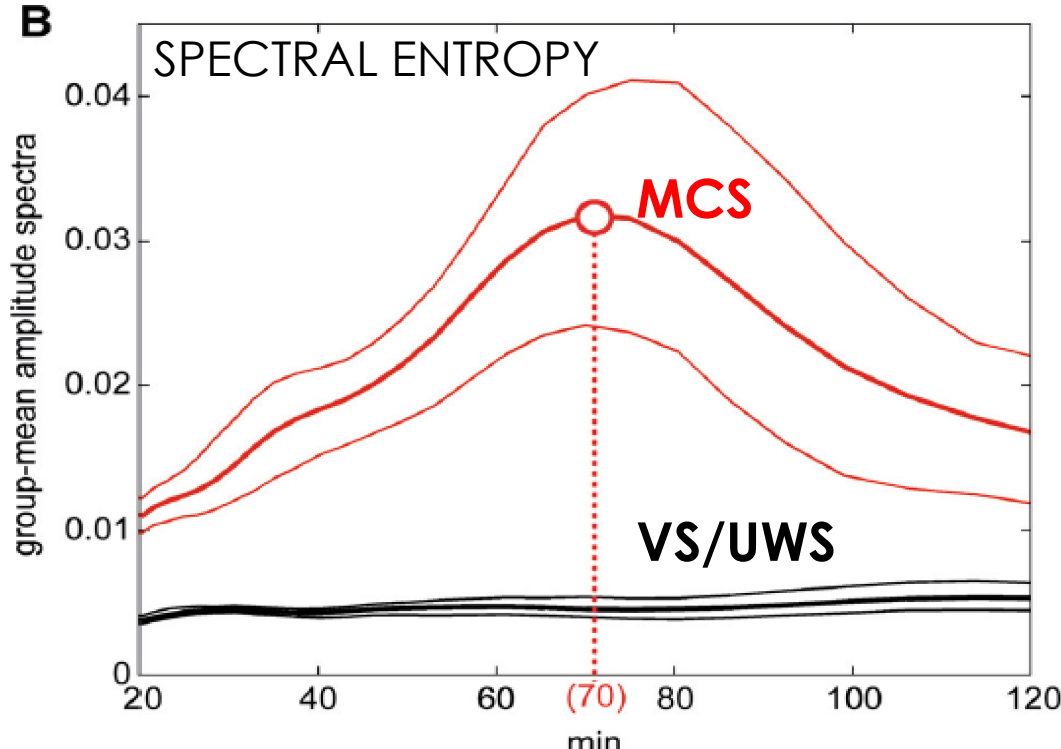
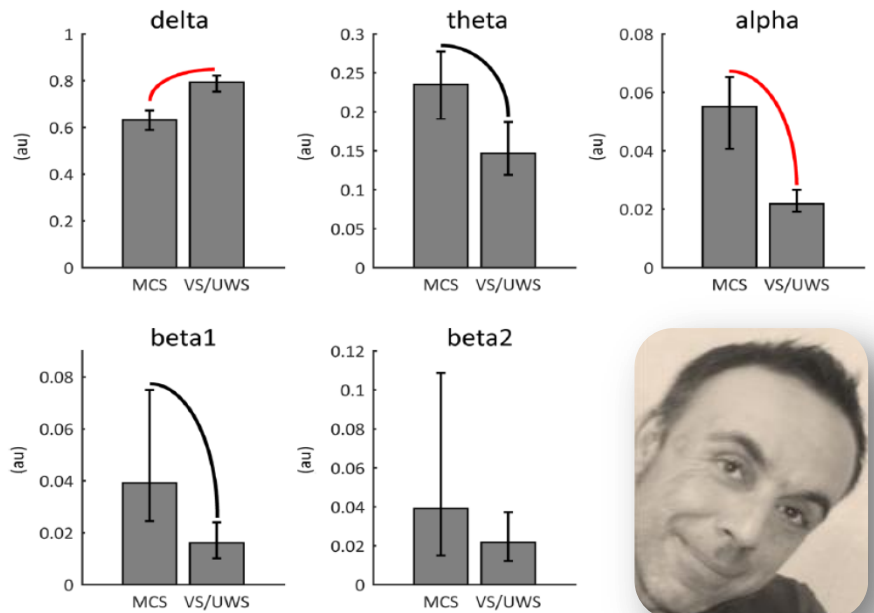
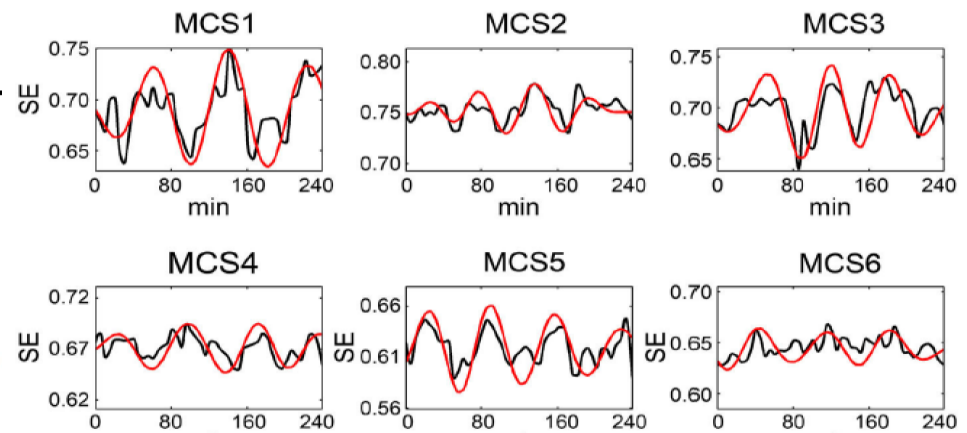


J Neurol
DOI 10.1007/s00415-016-8196-y

ORIGINAL COMMUNICATION

EEG ultradian rhythmicity differences in disorders of consciousness during wakefulness

Andrea Piarulli^{1,2} · Massimo Bergamasco² · Aurore Thibaut¹ · Victor Cologan³ · Olivia Gosseries^{1,4} · Steven Laureys¹



Diagnostic error after coma



n=103 post-comatose patients

- 45 clinical consensus diagnosis 'vegetative state'
- 18 signs of awareness (Coma Recovery Scale)



↪ 30-40% potential misdiagnosis

JFK COMA RECOVERY SCALE - REVISED ©2004			
Record Form			
Patient:	Date:		
AUDITORY FUNCTION SCALE			
4 - Consistent Movement to Command *			
3 - Reproducible Movement to Command *			
2 - Localization to Sound			
1 - Auditory Startle			
0 - None			
VISUAL FUNCTION SCALE			
5 - Object Recognition *			
4 - Object Localization: Reaching *			
3 - Visual Pursuit *			
2 - Fixation *			
1 - Visual Startle			
0 - None			
MOTOR FUNCTION SCALE			
6 - Functional Object Use †			
5 - Automatic Motor Response *			
4 - Object Manipulation *			
3 - Localization to Noxious Stimulation *			
2 - Flexion Withdrawal			
1 - Abnormal Posturing			
0 - None/Flaccid			
OROMOTOR/VERBAL FUNCTION SCALE			
3 - Intelligible Verbalization *			
2 - Vocalization/Oral Movement			
1 - Oral Reflexive Movement			
0 - None			
COMMUNICATION SCALE			
2 - Functional: Accurate †			
1 - Non-Functional: Intentional *			
0 - None			
AROUSAL SCALE			
3 - Attention			
2 - Eye Opening w/o Stimulation			
1 - Eye Opening with Stimulation			
0 - Unarousable			
TOTAL SCORE			

✳ **SELF-STUDY DVD OFFER** ✳

**COMA RECOVERY SCALE - REVISED:
GUIDELINES FOR ADMINISTRATION AND
SCORING**



coma@ulg.ac.be

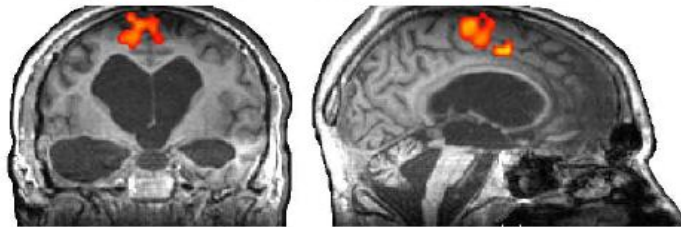


fMRI-based communication

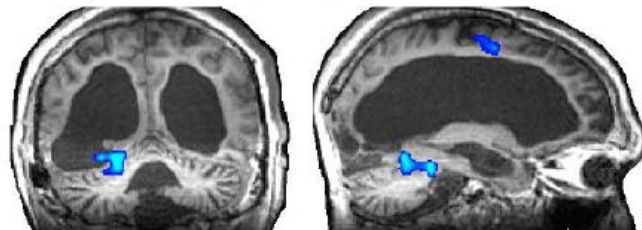


Imagine **Tennis** to answer 'YES'
 Imagine **Navigating** to answer 'NO'

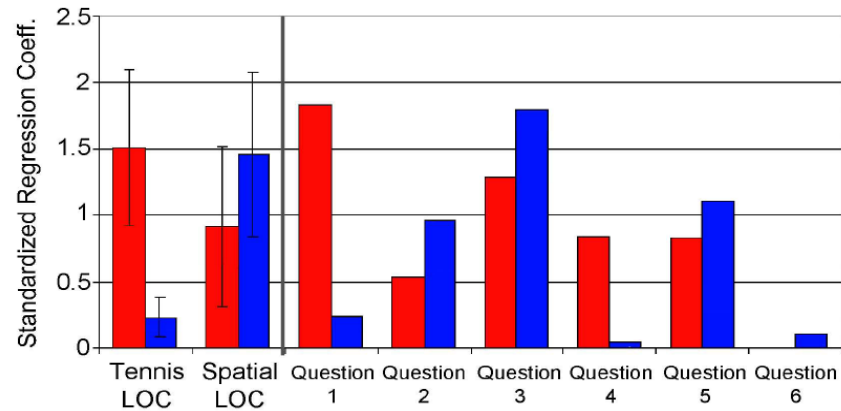
Is your father's name Alexander ?



Is your father's name Thomas ?



The NEW ENGLAND JOURNAL of MEDICINE



Brain Computer Interfaces



“MOVE YOUR FOOT”

“MOVE YOUR HAND”



CONTROL
SUBJECT



“VEGETATIVE”
UNRESPONSIVE
PATIENT

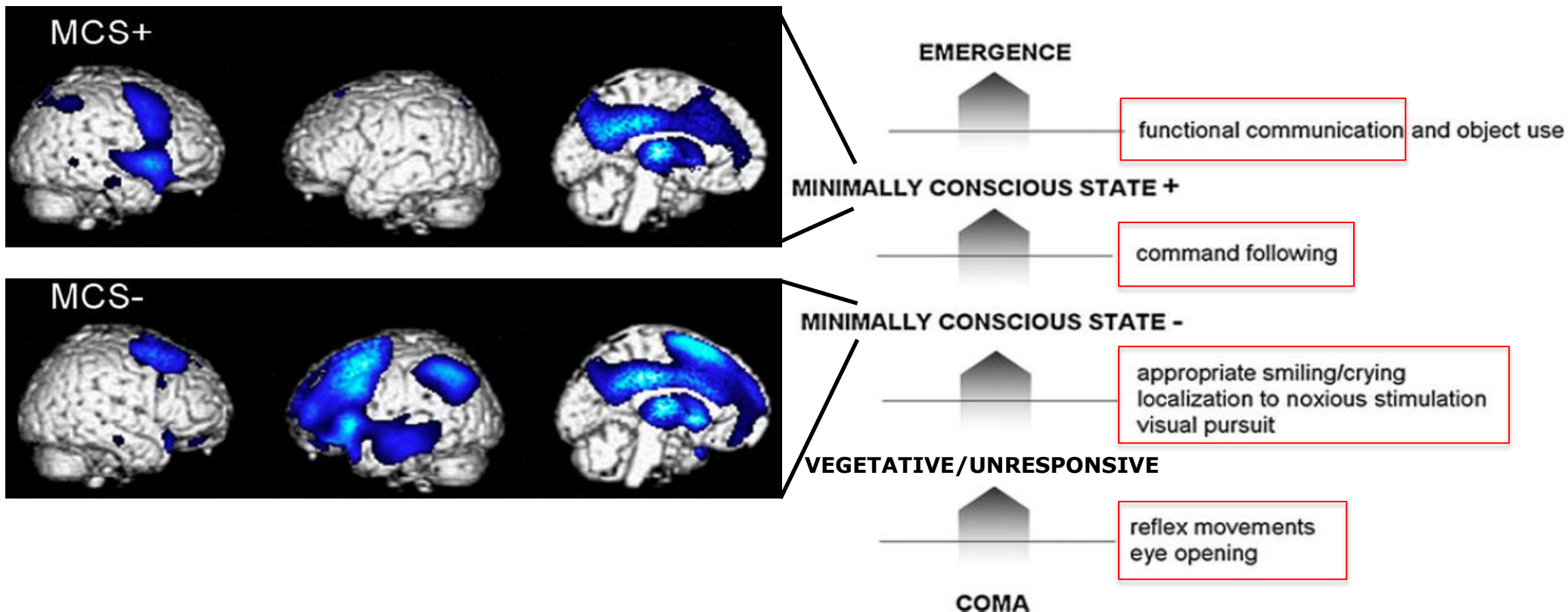


Noirhomme et al *NeuroImage* 2015

Lesenfants, Habbal et al *J Neural Engineering* 2014

Cruse et al *Lancet*, 2011, also see Goldfine et al, *Lancet*, 2013

Measuring consciousness



Classifying "resting" fMRI



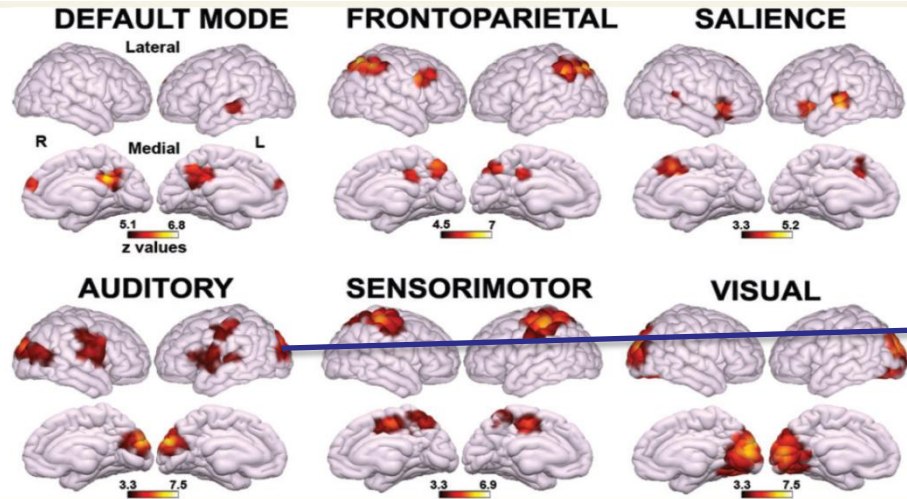
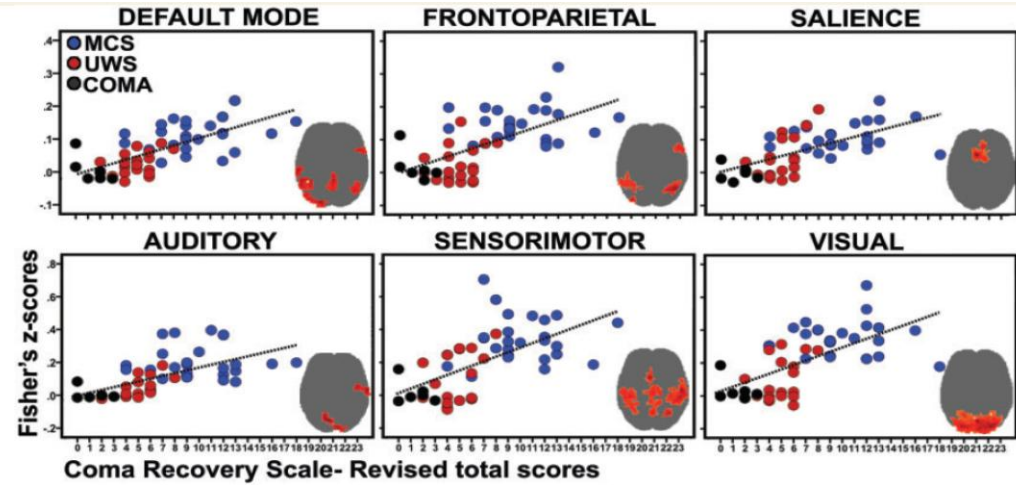
doi:10.1093/brain/aww169

BRAIN 2015; 138; 2619–2631 | 2619

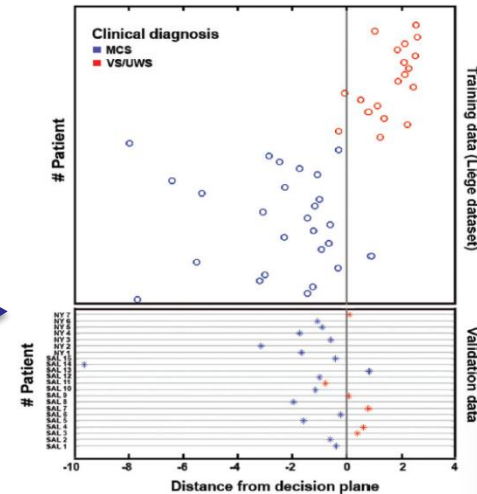
BRAIN
A JOURNAL OF NEUROLOGY

Intrinsic functional connectivity differentiates minimally conscious from unresponsive patients

Athena Demertzi,^{1,*} Georgios Antonopoulos,^{1,*} Lizette Heine,¹ Henning U. Voss,² Julia Sophia Crone,^{3,4,5} Carlo de Los Angeles,⁶ Mohamed Ali Bahri,⁷ Carol Di Perri,¹ Audrey Vanhauzenhuyse,⁸ Vanessa Charland-Verville,¹ Martin Kronbichler,^{3,4} Eugen Trinkla,⁵ Christophe Phillips,⁷ Francisco Gomez,⁹ Luaba Tshibanda,¹⁰ Andrea Soddu,¹¹ Nicholas D. Schiff,^{12,13} Susan Whitfield-Gabrieli^{6,*} and Steven Laureys^{1,*}

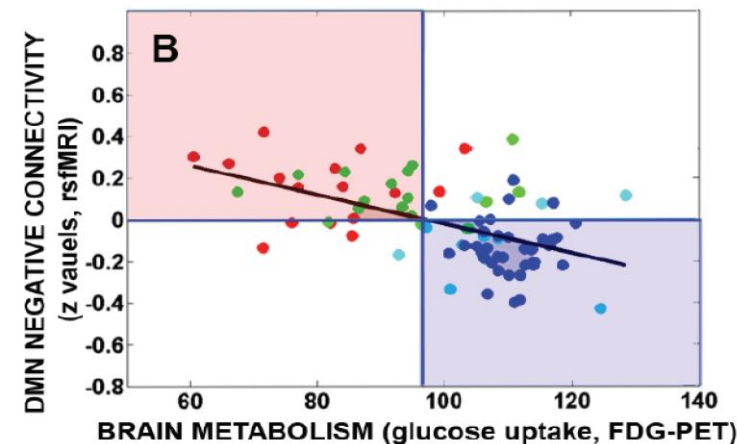
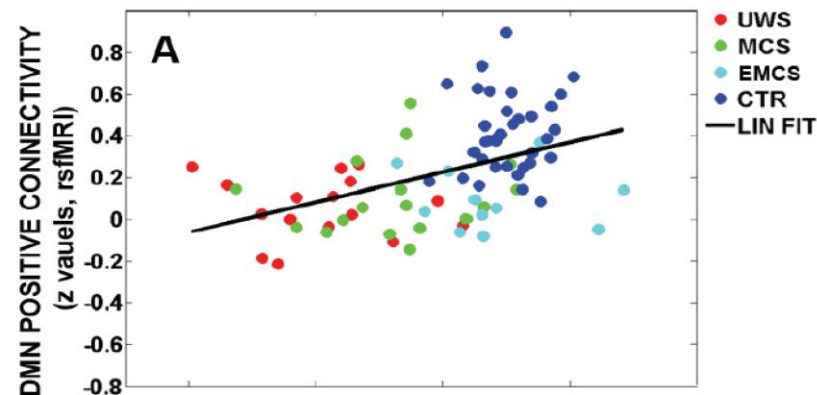
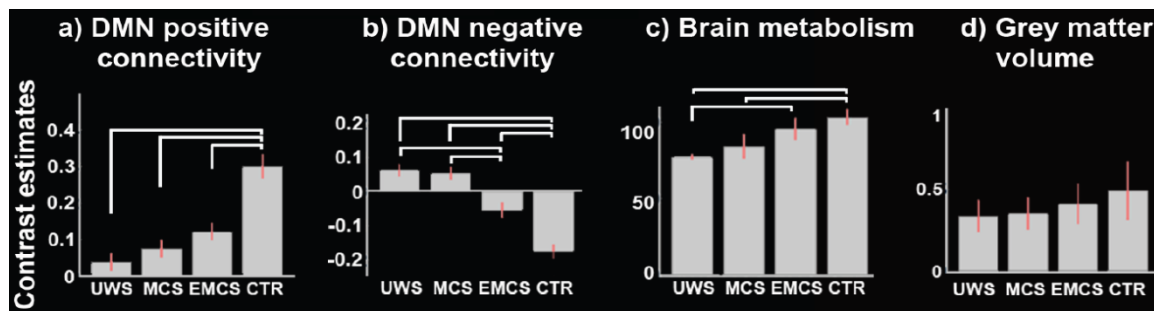
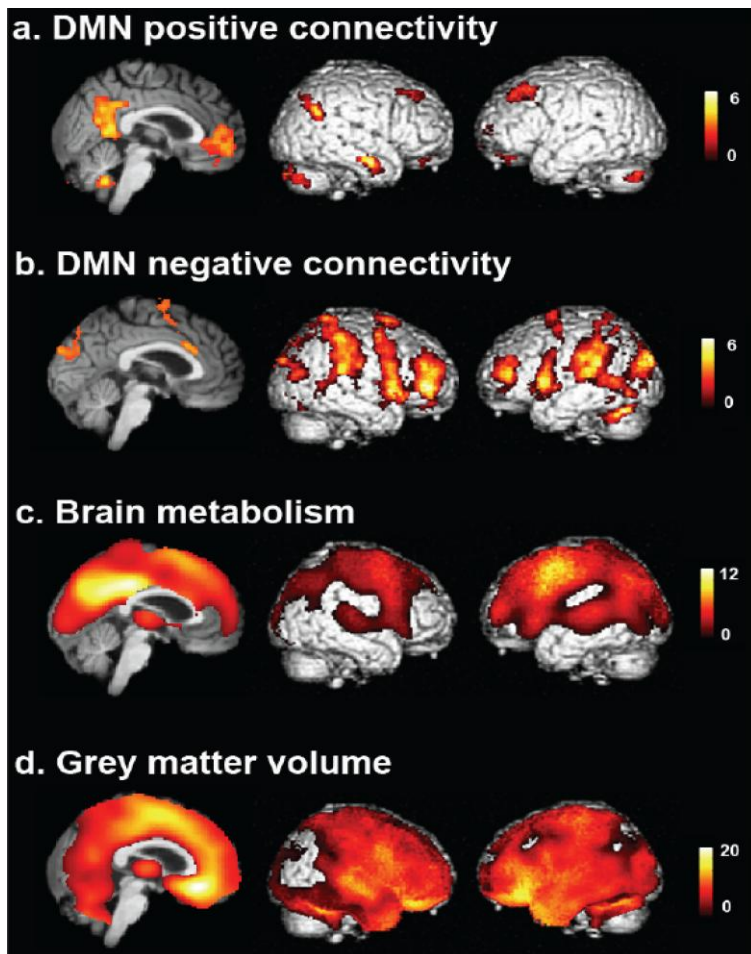


support
vector
machine
classifier

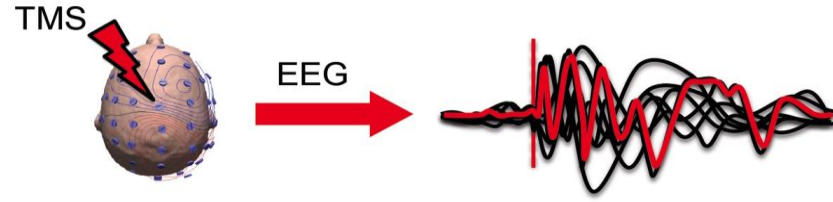


Vanhauzenhuyse et al, *Brain*, 2010
Demertzi et al, *Brain*, 2015

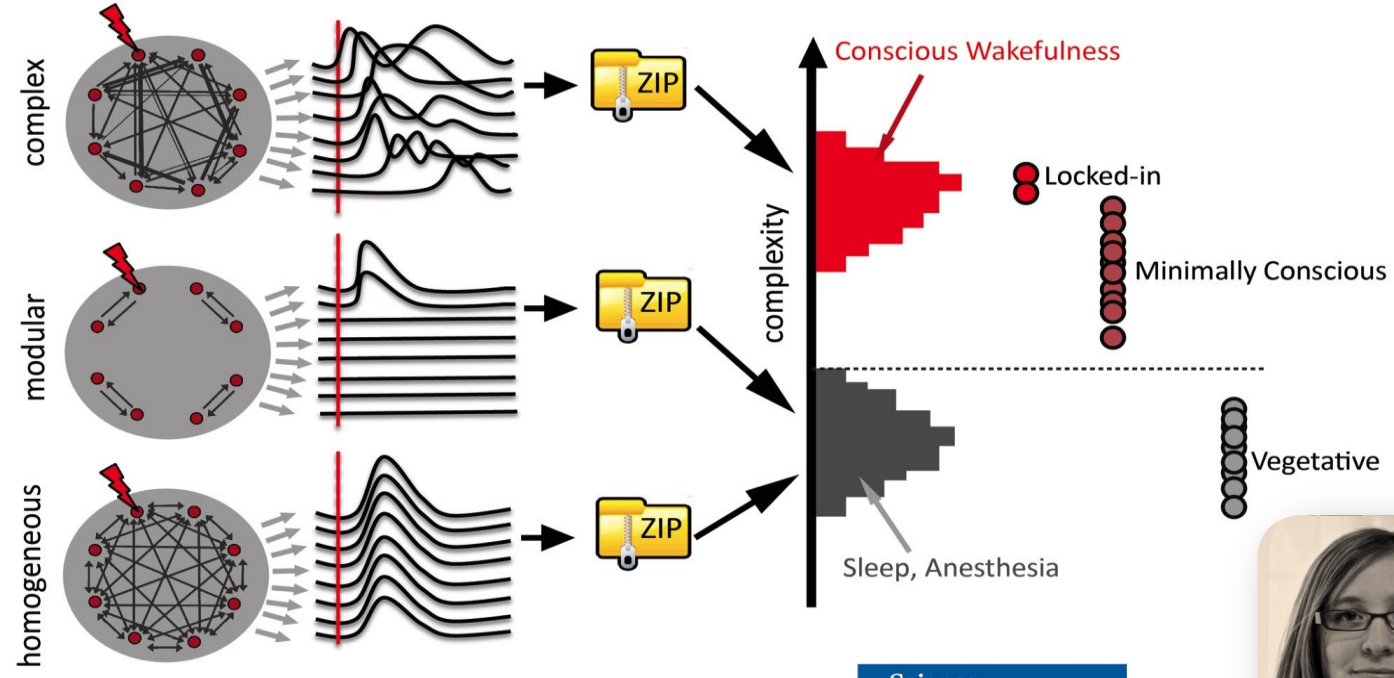
Pathological hyper-connectivity



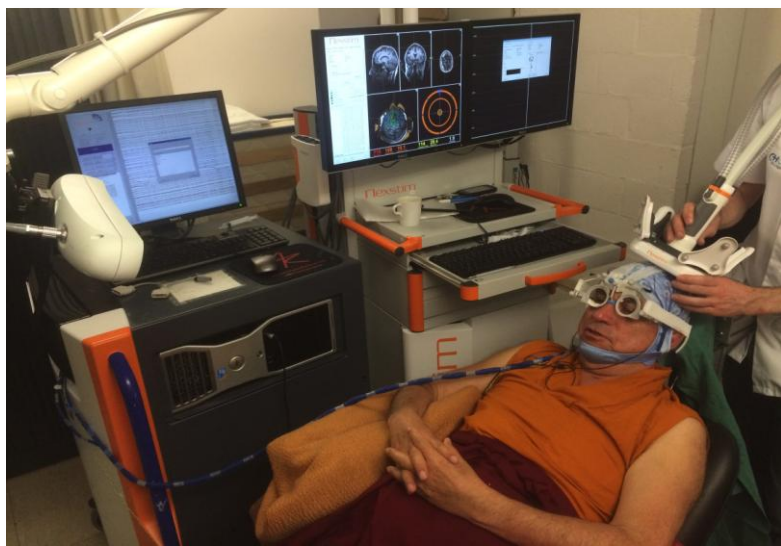
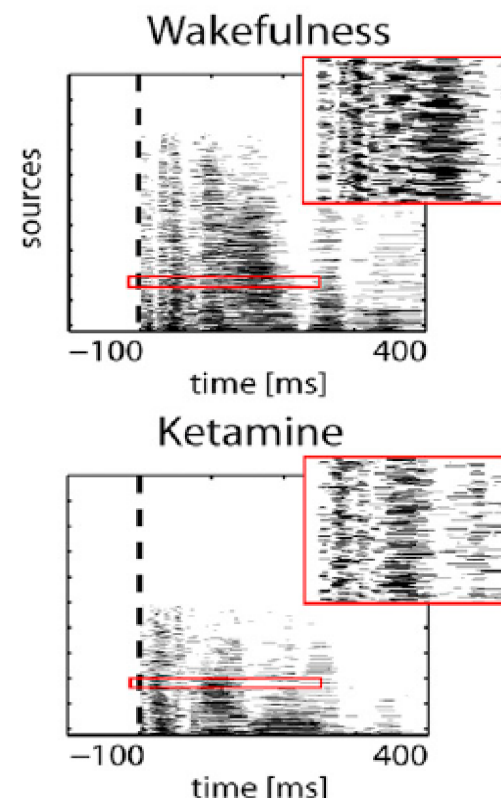
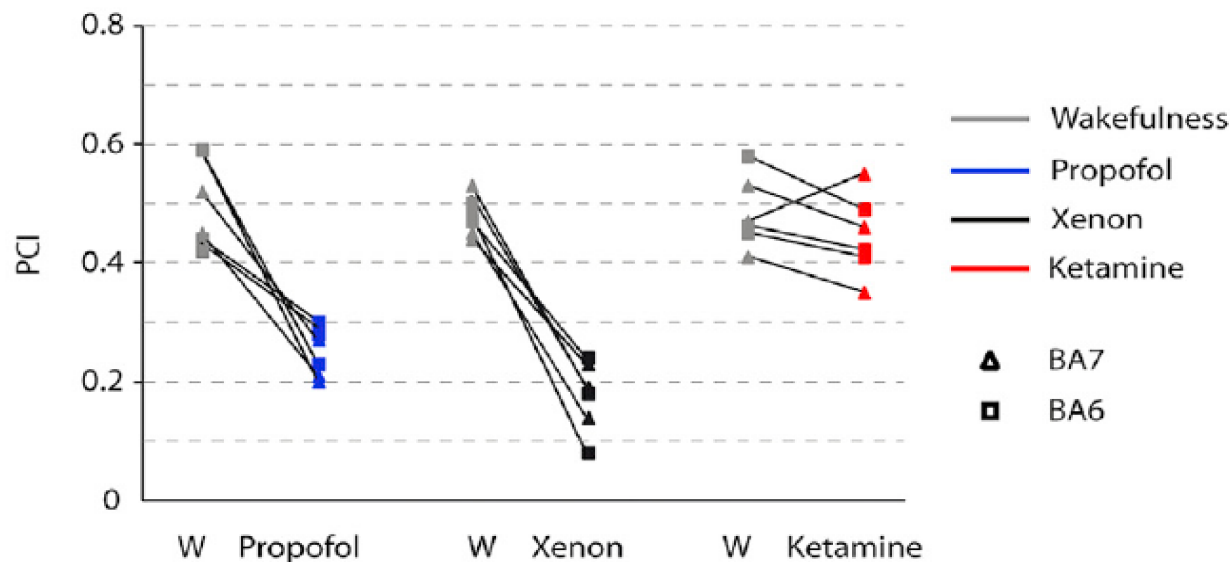
EEG-TMS Perturbational Complexity Index



perturbation → recording → compression → reference scale → patients



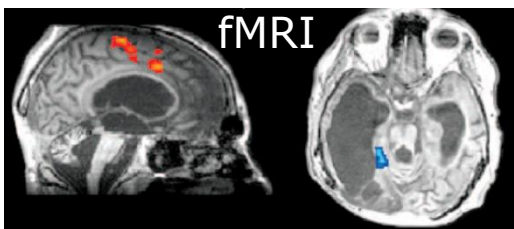
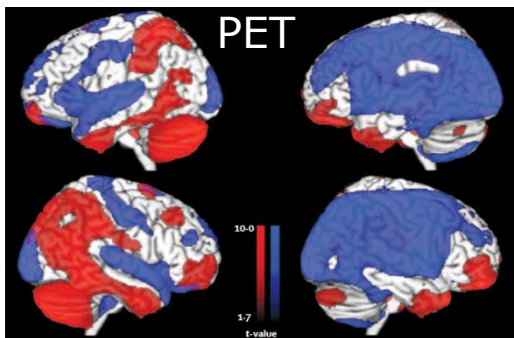
EEG-TMS Perturbational Complexity Index



Multi-modal imaging



130 patients (29/y)
 4 excluded (3%)
 81 MCS
 41 VS/UWS
 4 LIS
 110 chronic (87%)
 78 non-trauma (62%)



	Coma Recovery Scale-Revised results		
	UWS	MCS	Total
Clinical consensus diagnosis			
VS/UWS	33 (37%)	18 (20%)	51 (57%)
MCS	2 (2%)	36 (40%)	38 (43%)
Total	35 (39%)	54 (61%)	89 (100%)
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%)
Mental imagery fMRI			
VS/UWS	25 (36%)	23 (33%)	48 (69%)
MCS	3 (4%)	19 (27%)	22 (31%)
Total	28 (40%)	42 (60%)	70 (100%)

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

Table 2: Diagnostic results by modality

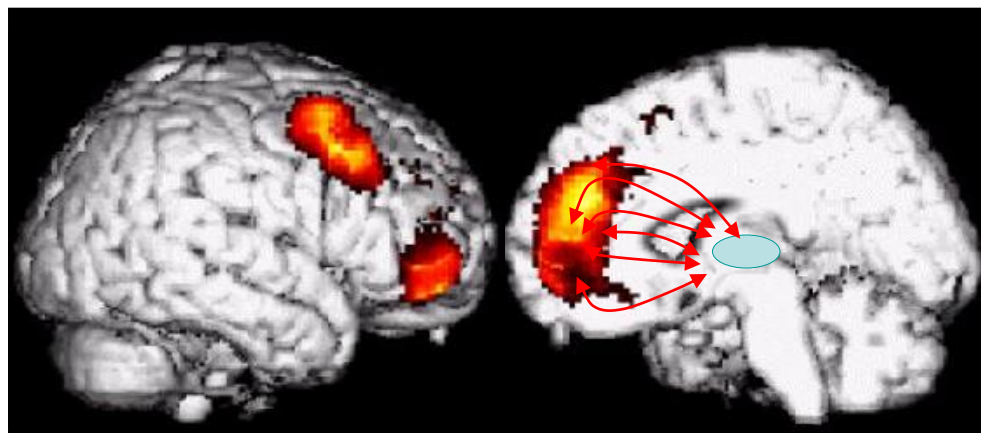
35% clinical misdiagnosis

32% CRS-R misdiagnosis

THE LANCET

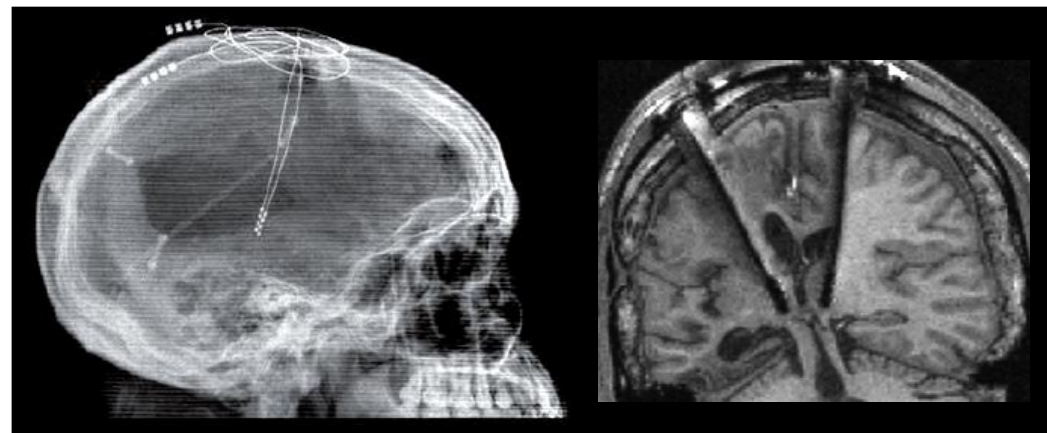
Consciousness \approx thalamo-cortical

Intralaminar nuclei “reconnections”
in spontaneous recovery from
“vegetative” unresponsive state



Laureys et al, *Lancet* 2000

Intralaminar nuclei stimulation
induces “recovery” from
minimally responsive state

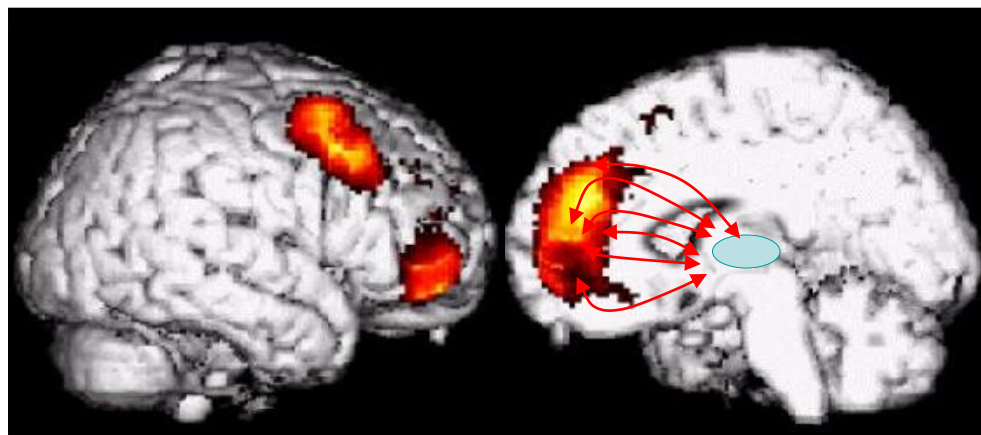


Schiff et al, *Nature* 2007

Consciousness \approx thalamo-cortical

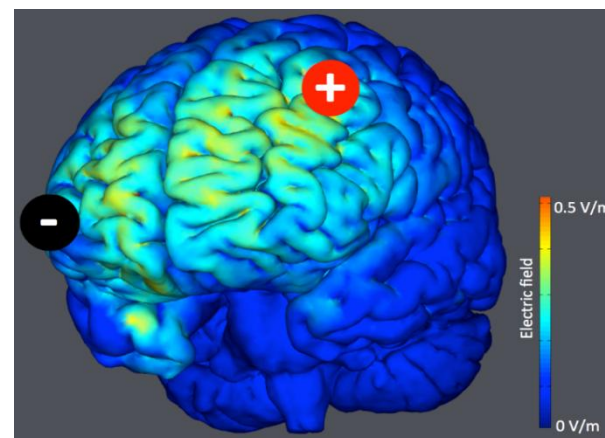


Intralaminar nuclei “reconnections”
in spontaneous recovery from
“vegetative” unresponsive state



Laureys et al, *Lancet* 2000

Transcranial direct current stimulation
(tDCS)



Thibaut et al, *Neurology* 2014



Ethical framework



The American Journal of
BIOETHICS
AJOB NEUROSCIENCE
September 2008, Volume 8, Number 9

NEUROIMAGING AND DISORDERS OF CONSCIOUSNESS:
Envisioning an Ethical Research Agenda

Target Article *The American Journal of Bioethics*, 8(9): 3–12, 2008

Neuroimaging and Disorders of Consciousness: Envisioning an Ethical Research Agenda

Joseph J. Fins, Weill Medical College of Cornell University*

Judy Illes, University of British Columbia*

James L. Bernat, Dartmouth Medical School**

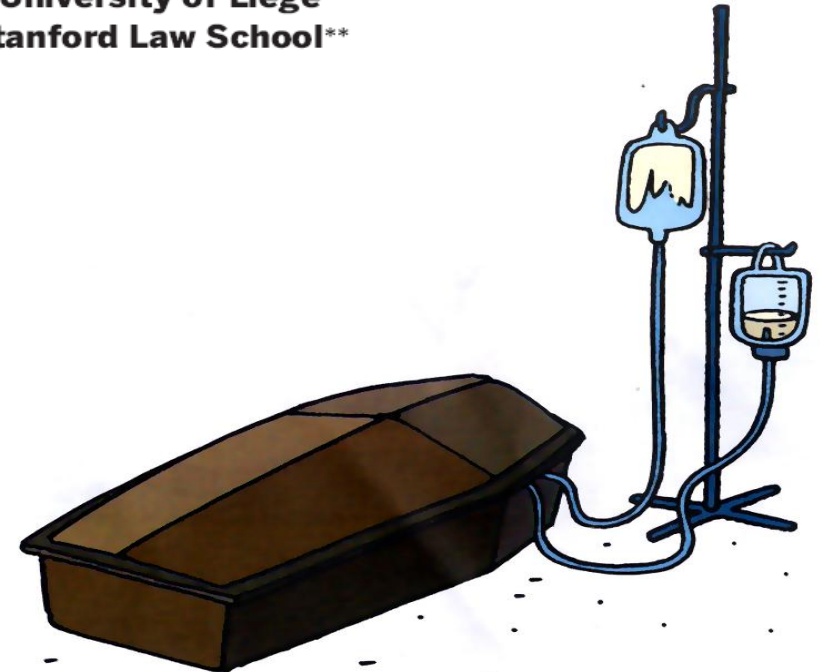
Joy Hirsch, Columbia University**

Steven Laureys, University of Liege**

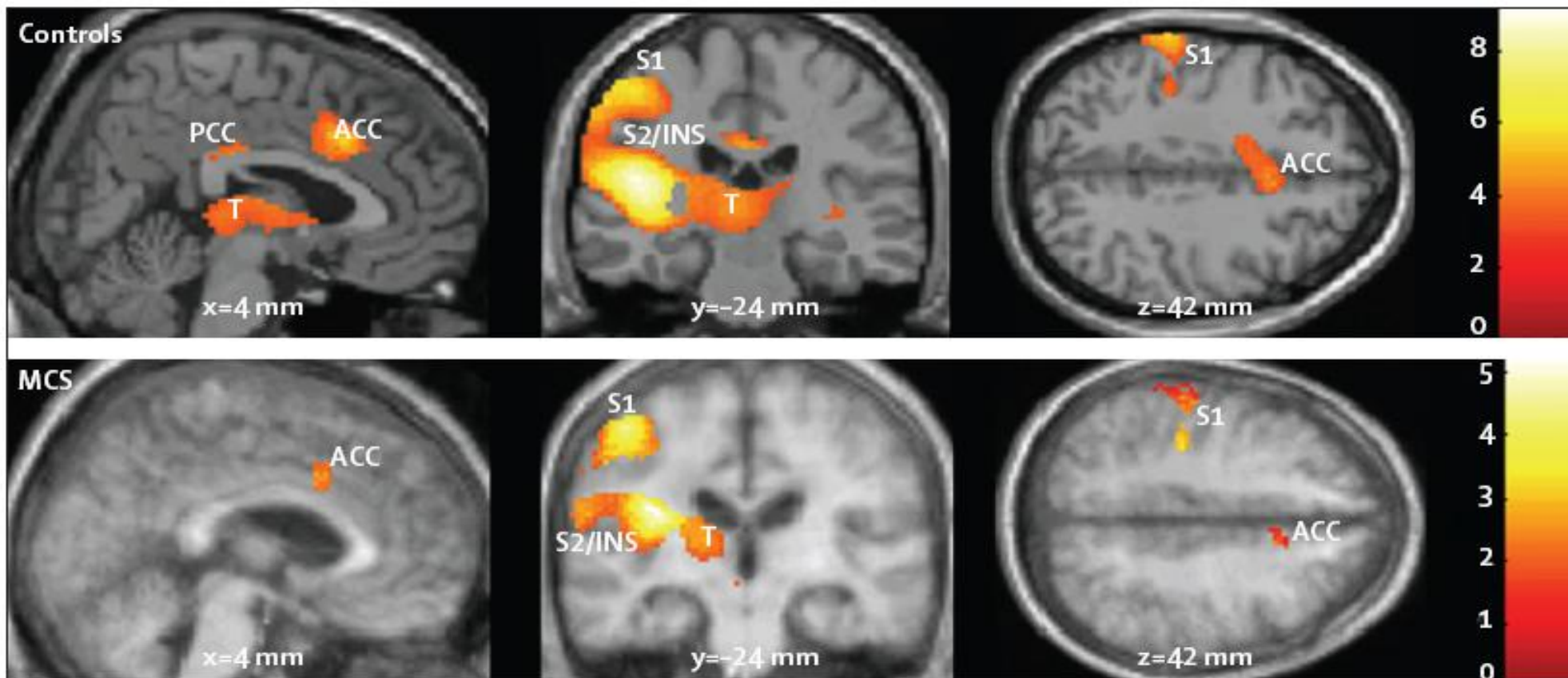
Emily Murphy, Stanford Law School**

*Co-lead authors.

**Equal authors in alphabetical order.



Pain in minimally conscious state



<http://neurology.thelancet.com>

Quality of life



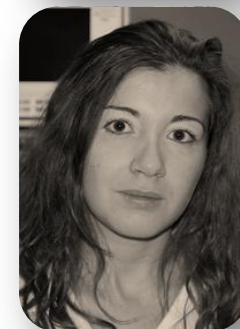
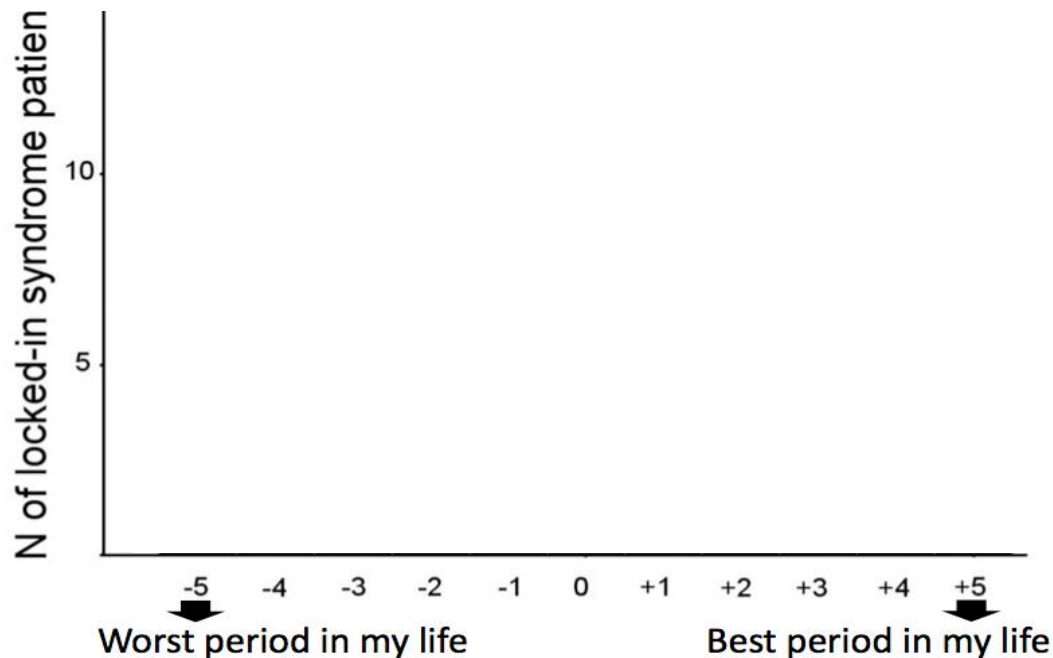
Open Access

Research

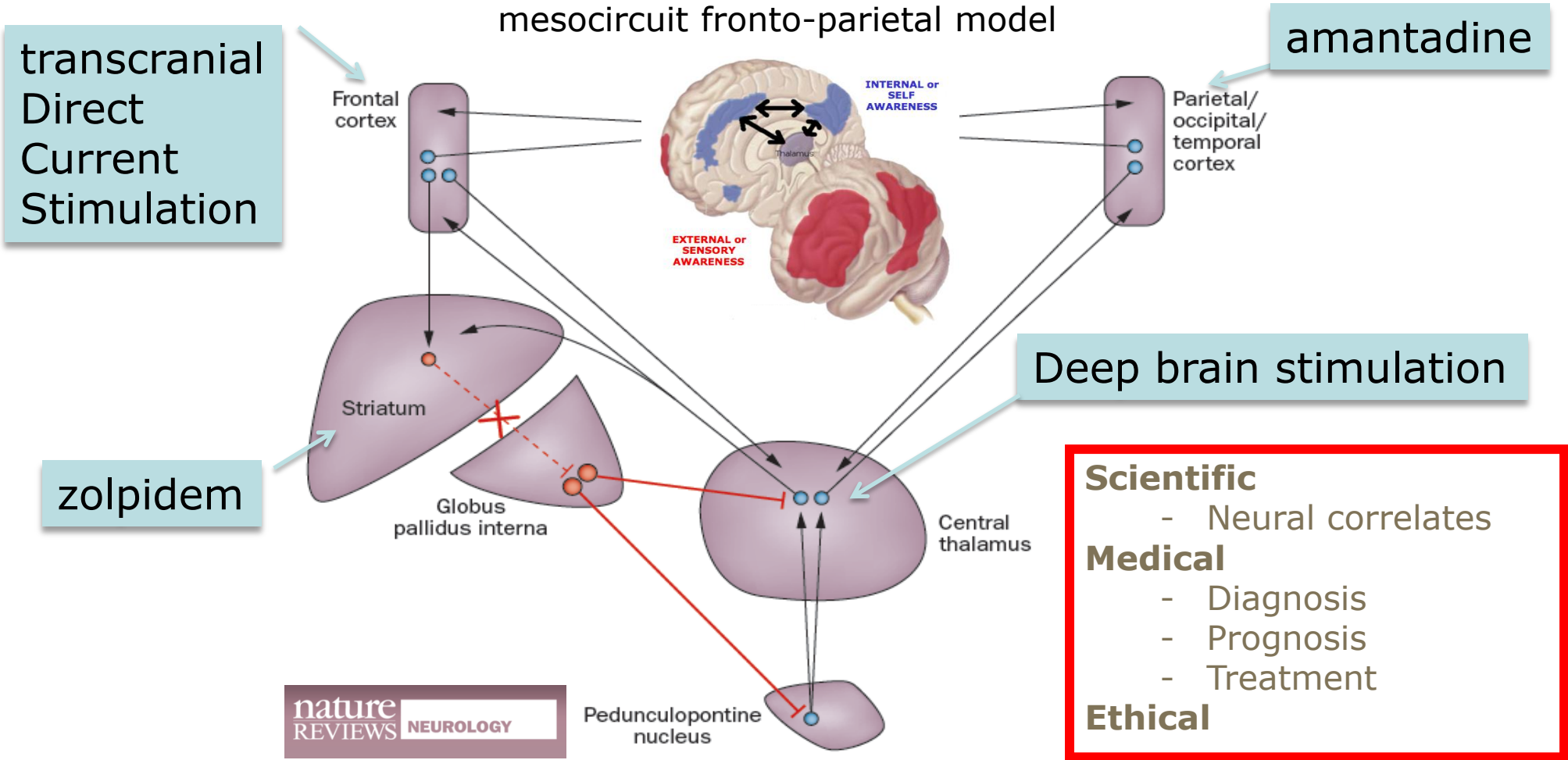


A survey on self-assessed well-being in a cohort of chronic locked-in syndrome patients: happy majority, miserable minority

Marie-Aur lie Bruno,¹ Jan L Bernheim,² Didier Ledoux,¹ Fr d ric Pellas,³ Athena Demertzi,¹ Steven Laureys¹

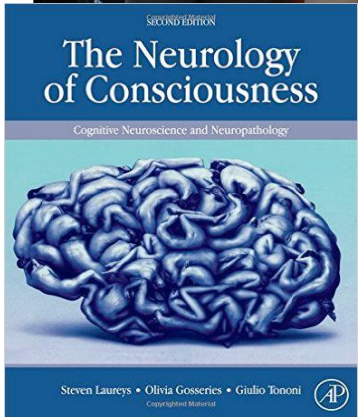


Paradigms (re)framed by neuroimaging



Laureys & Schiff, *NeuroImage*, 2012

Giacino, Fins, Laureys, Schiff, *Nature Rev Neurol*, 2014



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Human Brain Project

