Can science explain consciousness?
Lessons from coma & related states

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Arousal & awareness

Laureys, 2005
Laureys et al, 2008
Measuring brain activity

Altered states of consciousness
- Pathological: coma
- Pharmacological: anesthesia
- Physiological: hypnosis
Measuring awareness

Boly et al, 2009
Vanhaudenhuyse & Demertzi et al, 2011
Consciousness ≠ global brain function

Laureys et al., Lancet Neurology, 2004
PET = diagnostic & prognostic markers

- 42% of normal activity represents the minimal energetic requirement for the presence of conscious awareness
Classifying “resting” fMRI

Intrinsic functional connectivity differentiates minimally conscious from unresponsive patients

Athena Demertzi,1,2* Georgios Antonopoulos,1* Lizette Heine,1 Henning U. Voss,2 Julia Sophia Crona,3,4,5 Carlo de Los Angeles,6 Mohamed Ali Bahri,7 Carol Di Perri,1 Audrey Vanhaudenhuyse,8 Vanessa Charland-Verville,1 Martin Kronbichler,3,4 Eugen Trinka,5 Christophe Phillips,7 Francisco Gomez,9 Luaba Tshibanda,10 Andrea Soddu,11 Nicholas D. Schiff,12,13 Susan Whitfield-Gabrieli15,16 and Steven Laureys1,16

Vanhaudenhuyse et al, Brain, 2010
Demertzi et al, Brain, 2015

support vector machine classifier
Diagnosis & prognosis
MCS patients activate the same areas as healthy controls, meaning that the stimulus can be integrated and processed

Laureys et al., Neuroimage, 2002
Boly et al., 2008
### 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**

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<th>Patient:</th>
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**AUDITORY FUNCTION SCALE**

- 4 - Consistent Movement to Command *
- 3 - Reproduction 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**

- 5 - Automatic Motor Response *
- 4 - Object Manipulation *
- 3 - Localization to Noxious Stimulation *
- 2 - Flexion Withdrawal
- 1 - Abnormal Posturing
- 0 - None/Record

**GROMOTOR/VERBAL FUNCTION SCALE**

- 3 - Intelligible Verbalization *
- 2 - Vocalization/Oral Movement
- 1 - Oral Reflective Movement
- 0 - None

**COMMUNICATION SCALE**

- 2 - Functional: Open Eye
- 1 - Non-Functional: Intentional *
- 0 - None

**AROUSAL SCALE**

- 5 - Attention
- 3 - Eye Opening with Stimulation
- 2 - Eye Opening without Stimulation
- 1 - Unresponsive
- 0 - Unmeasurable
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?*

Monti & Vanhaudenhuyse et al, 2010
EEG-based communication

“MOVE YOUR FOOT”

HEATHY CONTROL SUBJECT

“MOVE YOUR HAND”

“VEGETATIVE” UNRESPONSIVE PATIENT

Noirhomme et al, 2015
Lesenfants, Habbal et al, 2014
Quality of life

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

Marie-Aurélie Bruno,1 Jan L Bernheim,2 Didier Ledoux,1 Frédéric Pelat,3 Athena Demertzi,1 Steven Laureys1

Bruno et al, BMJ Open, 2011
99% positive
1% negative

140 coma
- anoxic (45)
- traumatic (30)
- other (65)
50 non-coma

Temporality of features

Charland-Verville et al., 2014
Martial et al., submitted
Near-death experiences memories

Thonnard et al, 2013
Near-death experiences

Brain function in syncope-induced near death experiences in normal healthy volunteers

43% reported a NDE as defined by the Greyson NDE scale

Charland-Verville* & Piuralli*, Martial, et al., in preparation
“Clinical” death VERSUS brain death

Sometimes confusion!

! Remember that not a single patient who showed clinical criteria of brain death has ever recovered consciousness!
Conclusion

**Human conscious awareness**
- ≈ emergent property of collective critical neural network dynamics,
  - involving a frontoparietal global workspace
- ≈ still not fully explained

**Diagnostic use**
- ≈ 40% misdiagnosis

**Prognostic use**
- ≈ multimodal imaging