Intrinsic functional architecture reflects the level of consciousness and differentiates non-communicating patients.
An operational definition of C

Awareness = command following

Conscious Wakefulness

Drowsiness

Sleep St I-II

Deep sleep

Minimally Conscious State
- MCS+ (command following)
- MCS− (non-reflex movements)

“Vegetative”/unresponsive wakefulness syndrome

= eyes opening

General Anesthesia

Coma

Wakefulness

Laureys et al, Trends Cogn Sci 2005
Demertzi et al, ANYAS 2009
The brain’s default mode at rest

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
Default mode anticorrelations

DMN anticorrelated network

Default mode network
The cognitive counterpart of resting state

Anticorrelated activity is modified in hypnosis.

Demertzi, Soddu, Faymonville et al, Progress in Brain Research 2011
Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, J Physiol Paris in press
Less anticorrelated activity after exposure to microgravity

Parabolic flight

Parabolic flight trajectory
Less anticorrelated activity after exposure to microgravity.
Anticorrelated activity is absent in DOC
Systems-level intrinsic connectivity

Demertzì & Gómez et al, Cortex 2014
Heine et al, Front Psychol 2012; Smith et al, PNAS 2009; Beckmann et al, Phil. Trans. R. Soc. B 2005; Damoiseaux PNAS 2006
Fewer “neuronal” networks in DOC

Demertzi & Gómez et al, Cortex 2014
Seed-based connectivity networks
Intrinsic connectivity reflects the level of C

Demertzis & Antonopoulos… Whitfield-Gabrieli & Laureys, Brain 2015
Which network discriminates best?

### Table: Feature selection criterion (t-test)

<table>
<thead>
<tr>
<th>Network</th>
<th>t value</th>
<th>Rank</th>
<th>p value</th>
<th>TP</th>
<th>TN</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory</td>
<td>8.32</td>
<td>1</td>
<td>&lt;.001</td>
<td>25</td>
<td>18</td>
<td>43/45</td>
</tr>
<tr>
<td>Visual</td>
<td>7.79</td>
<td>2</td>
<td>&lt;.001</td>
<td>23</td>
<td>15</td>
<td>38/45</td>
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<tr>
<td>Default mode</td>
<td>6.95</td>
<td>3</td>
<td>&lt;.001</td>
<td>23</td>
<td>15</td>
<td>38/45</td>
</tr>
<tr>
<td>Frontoparietal</td>
<td>6.82</td>
<td>4</td>
<td>&lt;.001</td>
<td>23</td>
<td>15</td>
<td>38/45</td>
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<tr>
<td>Salience</td>
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<td>5</td>
<td>&lt;.001</td>
<td>24</td>
<td>15</td>
<td>39/45</td>
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<tr>
<td>Sensorimotor</td>
<td>5.87</td>
<td>6</td>
<td>&lt;.001</td>
<td>24</td>
<td>13</td>
<td>37/45</td>
</tr>
</tbody>
</table>

**FWE p<0.05 (cluster-level)**

Demertzi & Antonopoulos… Whitfield-Gabrieli & Laureys, Brain 2015
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

Demertzi & Antonopoulos et al, Brain 2015

Classification MCS
Classification VS/UWS

Distance from decision plane
Conclusions

• DMN anticorrelations have a cognitive counterpart, which can be modulated under psychological and physiological conditions

• Clinical objective: to separate unconscious from (minimally) conscious patients

• The most discriminative feature is the connectivity between occipital, parietal, insular and superior temporal regions
  - Anesthetized patients?
  - Prognostic value?
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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Denoising (Chai et al, NeuroImage 2012):
1. Motion artifact detection (ART)
2. Regressing out the realignment parameters, their derivatives and the ART-detected outliers
3. Anatomical component-based noise correction method (aCompCor) which models the influence of noise as a voxel-specific linear combination of multiple empirically estimated noise sources (WM, GM and CSF)
4. Temporal band-pass filtering [0.008-0.09Hz]
Classifier generalizes to healthy
 Detecting awareness with fMRI

Active paradigms

"Imagine playing tennis"

"Imagine visiting the rooms of your house"

Owen et al, Science 2006
Monti & Vanhaudenhuyse et al, NEJM 2010

Passive paradigms

median nerve

Boly et al, Lancet Neurol 2008

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
Propofol-induced anesthesia

Cross-modal interaction

Wakefulness vs. Anesthesia

Visual network

Auditory network

DMN anticorrelations
Awareness is modified in hypnosis

Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, J Physiol Paris in press
Consciousness

- Functionalism
- Materialism
- Dualism

![Cartoon illustration of a brain with multiple signs pointing in different directions, labeled "Consciousness", "Materialism", "Dualism", "Functionalism"].

<table>
<thead>
<tr>
<th>Agreement (%)</th>
<th>Edinburgh survey (n=250)</th>
<th>Liège survey (n=1858)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mind and brain are two separate things</td>
<td>67</td>
<td>42</td>
</tr>
<tr>
<td>Mind is fundamentally physical</td>
<td>41</td>
<td>36</td>
</tr>
</tbody>
</table>

**ns**

**Edinburgh survey (n=250)**

**Liège survey (n=1858)**