Intrinsic functional connectivity changes along the spectrum of consciousness

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Consciousness

- Materialism
- Functionalism
- Dualism

A clinical definition of consciousness

Awareness = command following

Demertzi et al, Encyclopedia of Consciousness 2009
Laureys, Trends in Cognitive Sciences 2005
Attitudes towards end-of-life issues in disorders of consciousness: a European survey

A. Demertzi · D. Ledoux · M.-A. Bruno ·
A. Vanhaudenhuyse · O. Gossers · A. Soddu ·
C. Schnakers · G. Moonen · S. Laureys

2,475 medical professionals

It is acceptable to stop treatment in a chronic...

- 66% vs MCS
- 28%

I would like to be kept alive if I were in a chronic...

- 82% vs MCS
- 67%

Demertzi et al, J Neurol 2011; Prog Brain Res 2009; Neuroethics 2013; Br Injury 2014
Neuroimaging paradigms

Active paradigms

“Imagine playing tennis”

“Imagine visiting the rooms of your house”

Passive paradigms

median nerve

Owen et al, Science 2006
Monti & Vanhaudenhuise et al, NEJM 2010
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
Intrinsic brain activity & awareness

External awareness
or anticorrelated network

Internal awareness
or Default mode network

Demertzi & Whitfield-Gabrieli, in: Neurology of Consciousness 2nd ed. 2015
Demertzi, Soddu, Laureys, Curr Opin Neurobiology 2013
Demertzi et al, Front Hum Neurosci 2013
Laureys, Scientific American 2007
Cognitive counterpart of intrinsic activity: the task

Vanhaudenhuyse* & Demertzi* et al, Journal of Cognitive Neuroscience 2011
(*equal contribution)
The cognitive counterpart of intrinsic activity

External-internal: $r = -0.44$, $p < .02$
Mean switch: 0.05Hz (range: 0.01-0.1)

Anticorrelated brain connectivity is modified in hypnosis

Demertzi, Soddu, Faymonville et al, Progress in Brain Research 2011
Behavior is modified in hypnosis

Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, in press
Awareness is modified in hypnosis

Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, in press
Awareness is modified in hypnosis

Disorders of consciousness | Active/Activation paradigms | Resting state | Conclusions

Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, J Physiol Paris in press
Disrupted DMN in patients

Vanhaudenhuyse & Noirhomme et al, Brain 2010
Multiple RSNs in DOC: issues

A challenge....

Disorders of consciousness | Active/Activation paradigms | Resting state | Conclusions

Heine et al, Frontiers in Psychology 2012
Smith et al, PNAS 2009
Beckmann et al, Phil. Trans. R. Soc. B 2005
Multiple RSNs in DOC: an approach

1. Goodness-of-fit calculation

ICA (n=30)

$g_{i,j}$

2. Multiple template assignment

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<tr>
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<th>T2</th>
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3. “Neuronality” test

Demertzi & Gómez et al, Cortex 2014
Fewer “neuronal” networks in DOC

Demertzi & Gómez et al, Cortex 2014
Voxel-wise group comparisons

Demertz & Gómez et al, Cortex 2014

Controls N=27
MCS N=24
VS/UWS N=24
Classification feature: “neuronality”

<table>
<thead>
<tr>
<th>Performance measures</th>
<th>Accuracy</th>
<th>TPR healthy</th>
<th>TPR patients</th>
<th>Selected RSNs</th>
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<tbody>
<tr>
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<td>Healthy vs. all patients</td>
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<tr>
<td>Occurrence</td>
<td>85.3</td>
<td>.82</td>
<td>.87</td>
<td>Auditory, DMN</td>
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<td>Occurrence &amp; GOF</td>
<td>82.6</td>
<td>.70</td>
<td>.89</td>
<td>Auditory, DMN, Visual lateral</td>
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<td>GOF</td>
<td>80</td>
<td>.78</td>
<td>.81</td>
<td>Auditory, DMN, ECNL, Visual lateral</td>
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</table>
The studied networks

**Default mode network**

**Frontoparietal network**

**Salience network**

**Auditory network**

**Somatosensory network**

**Visual network**

Demertzí & Antonopoulou et al, Brain 2015
Network connectivity in healthy disorders of consciousness

Demertzi & Antonopoulos et al, Brain 2015
Intrinsic connectivity reflects level of C

Demertzki & Antonopoulos et al, Brain 2015
Finding the discriminative features

MCS > VS/UWS

DEFAULT MODE

FRONTOPARIETAL

SALIENCE

AUDITORY

SENSORIMOTOR

VISUAL

FWE p<0.05 (cluster-level)

Demertzis & Antonopoulos et al, Brain 2015
Training dataset: patients (Lg)

- 26 MCS, 19 VS/UWS
- 14 trauma, 28 non-trauma, 3 mixed
- 34 patients assessed >1m post-insult

Demertz & Antonopoulos et al, Brain 2015
Validation dataset: patients (NY, Sal)

Clinical diagnosis

- MCS
- VS/UWS

Distance from decision plane

Demertzi & Antonopoulos et al, Brain 2015
Generalization dataset: healthy

Demertzi & Antonopoulos et al, Brain 2015
Echoes from structural connectivity?

Gray matter

White matter

Demertz & Antonopoulos et al, Brain 2015
Cross-modal interaction during conscious processing

Bekinschtein et al, PNAS 2009
Cross-modal interaction demolishes under propofol anesthesia

Boveroux et al, Anesthesiology 2010
Translational research

Medico-ethical issues in DOC

Biomarkers (fMRI, PET, EEG)

Diagnostic & prognostic use (multimodal imaging)

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Laureys & Boly, Nature Clinical Practice 2008
Owen, Schiff & Laureys, Progress in Brain Research 2009
Jox, Bernat, Laureys and Racine, Lancet Neurology 2012
Niko Schiff & Henning Voss, Weill Cornell Medical College
Julia Sophia Crone & the Salzburg team
The departments of Neurology and Radiology in Liege and Paris
...but mostly patients and their families!

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