

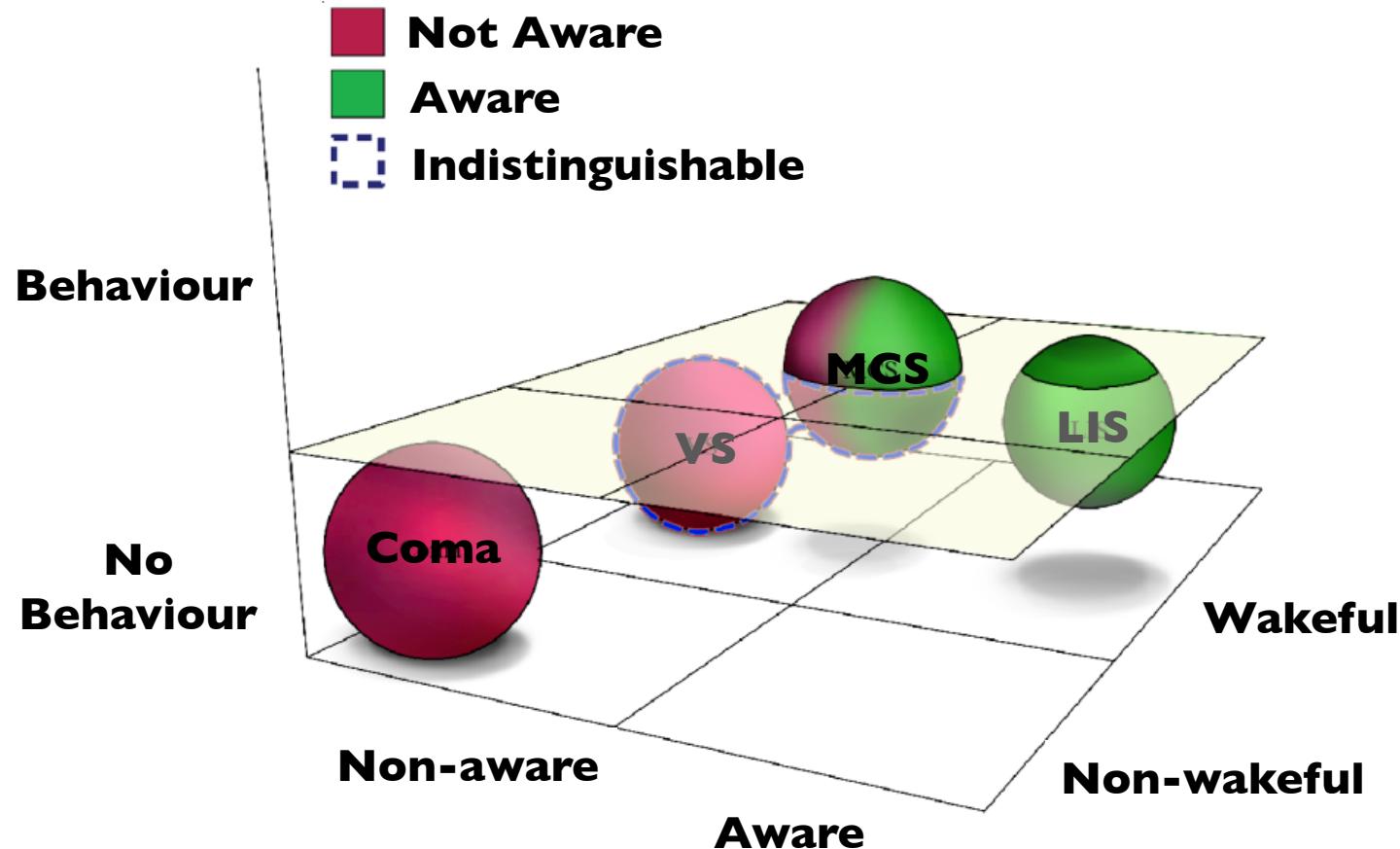
Real-Time Detection of Covert Awareness

Srivas Chennu, *PhD*

Department of Clinical Neurosciences
University of Cambridge



Disorders of Consciousness



Covert Awareness in DoC

NHS

National Institute for
Health Research

Owen et al., 2006, *Science*

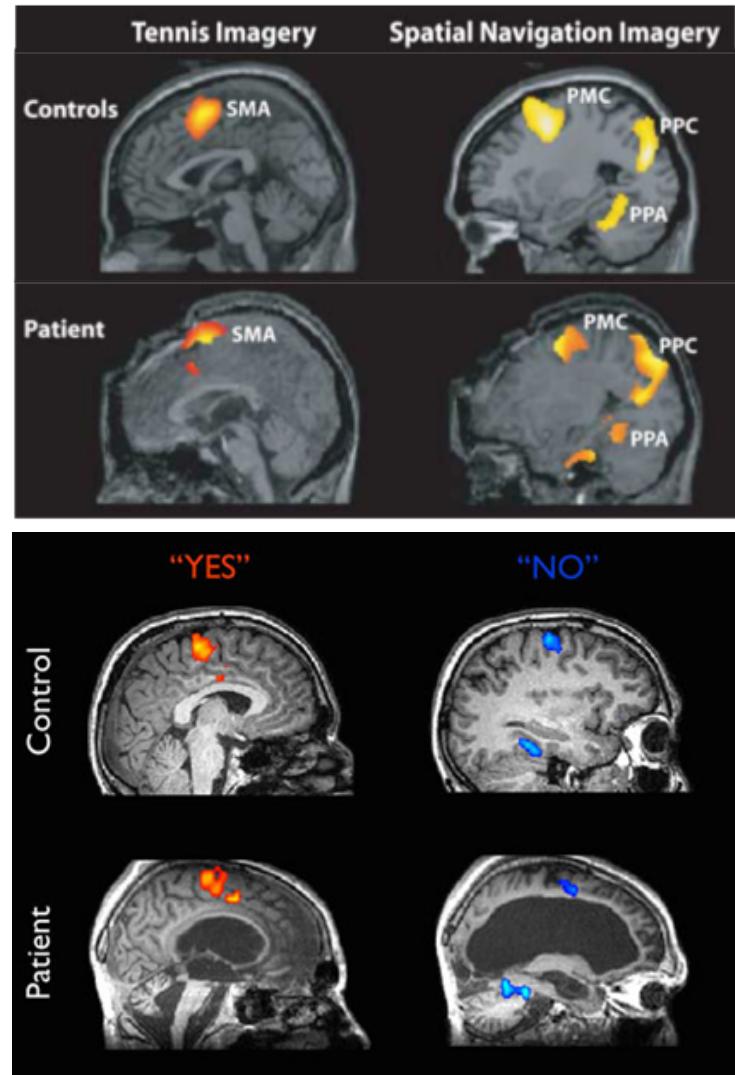
- “Imagine playing tennis”
- “Imagine moving around your house”

A vegetative patient produces brain activation like healthy volunteers

Monti et al., 2010, *New England Journal of Medicine*

- “Imagine playing tennis to say yes and moving around your house to say no”

A vegetative patient correctly answers 4 out of 5 questions



fMRI vs EEG

fMRI is great, but

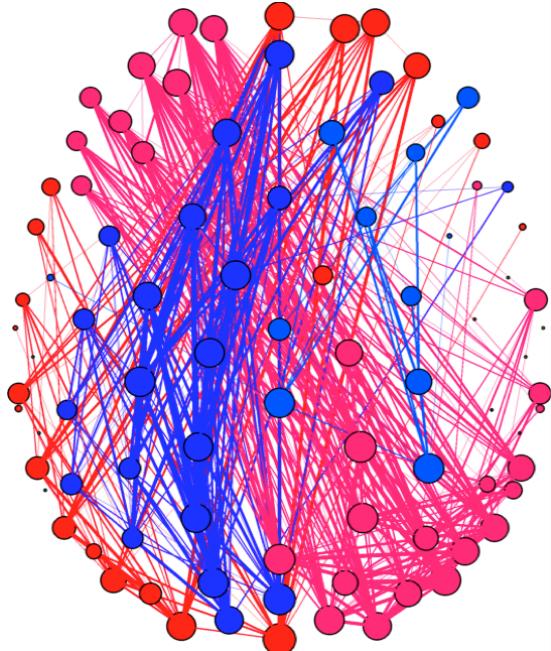
- Accessibility issues for patients
- Expense / Availability
- Metallic implants – plates/pins
- Physical stresses



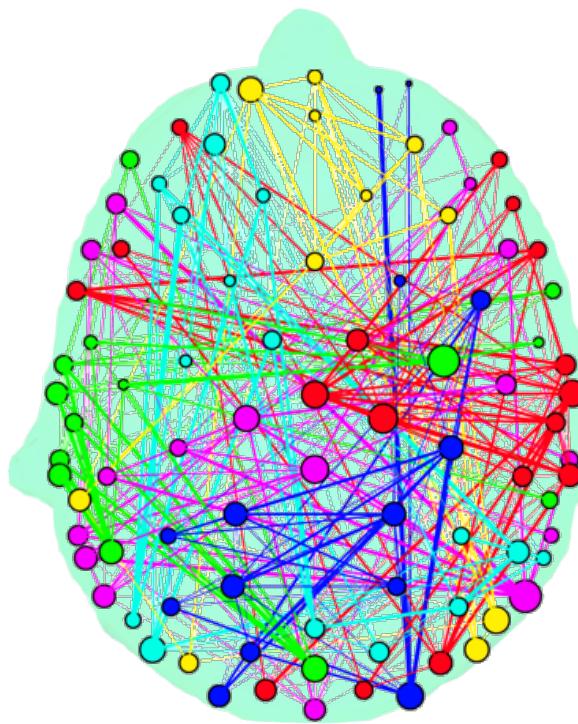
EEG

- Lower resolution
- Relatively inexpensive
- Can be used at the bedside
- Greater number of measurements

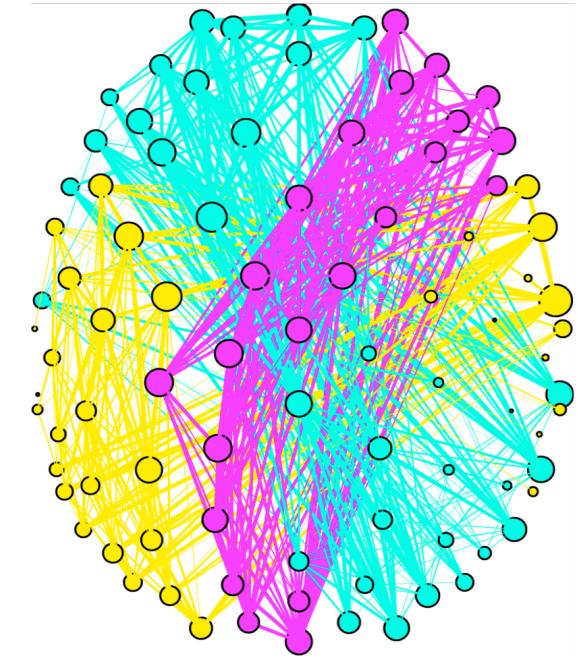
Modern high-definition EEG



Healthy adult



Vegetative Patient A

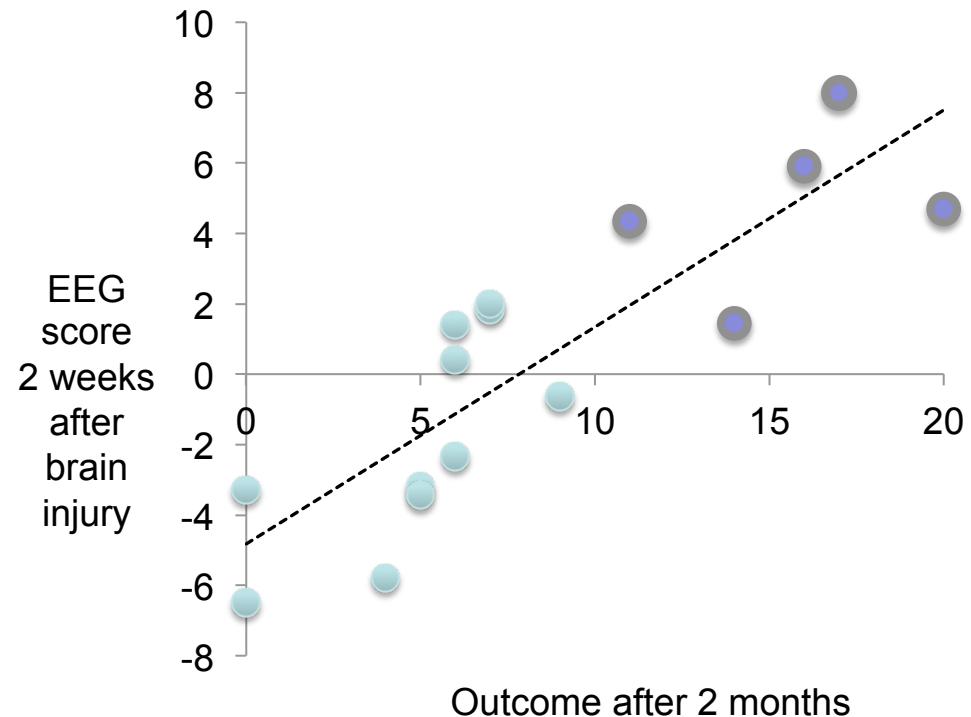


Vegetative Patient B

Some vegetative patients have brain networks that could support consciousness

EEG for Prognosis

- Early EEG tests of brain function
- in acute neurocritical states
- Can predict eventual behavioural recovery

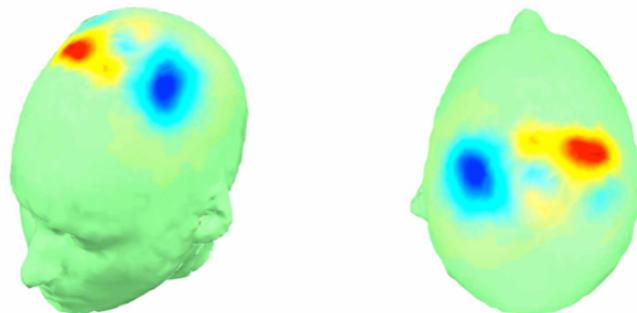


Motor Imagination with EEG

Cruse, Chennu et al., *The Lancet*

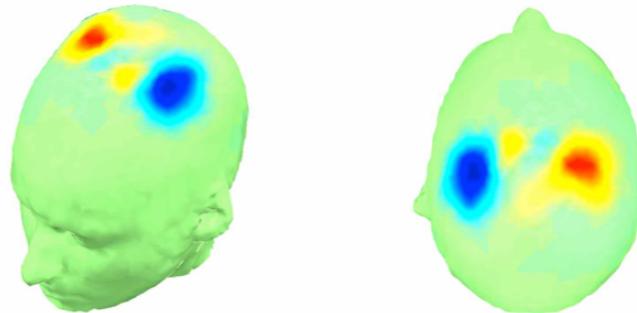
“Imagine moving your right hand”

Vegetative Patient



Some vegetative patients able to follow commands at the bedside

Healthy Volunteer

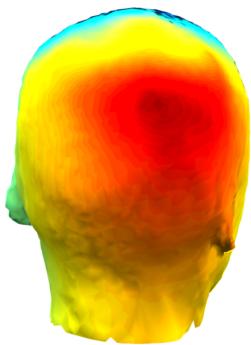


Replicated in:
Cruse, Chennu et al., 2012,
Neurology
Cruse et al., 2012, *PLoS ONE*

Paying Attention to EEG

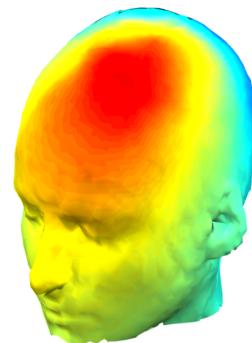
Chennu et al., 2013, *Neuroimage: Clinical*

Attend to “yes”

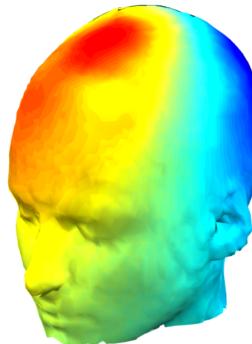
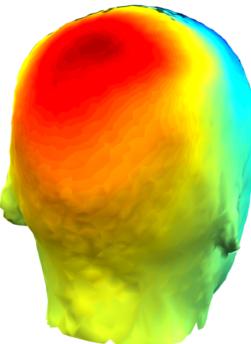


**Vegetative
Patient**

Ignore “no”



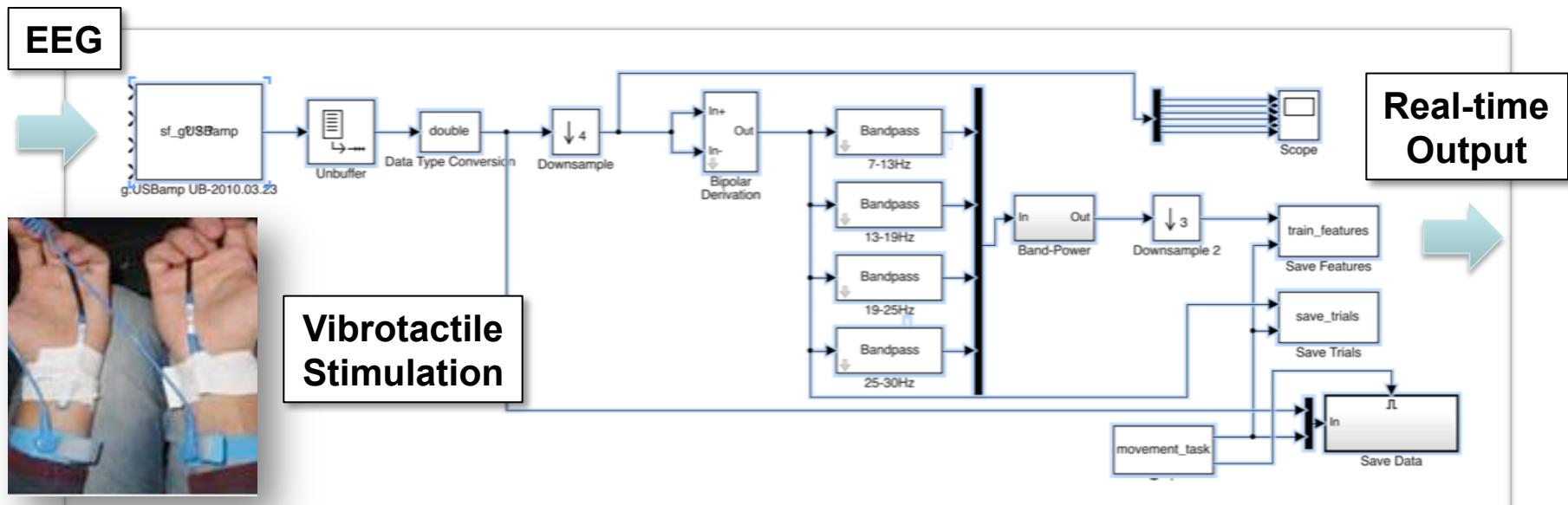
**Healthy
Volunteer**



*A vegetative patient
not just ‘aware’
but also able to ‘pay attention’*

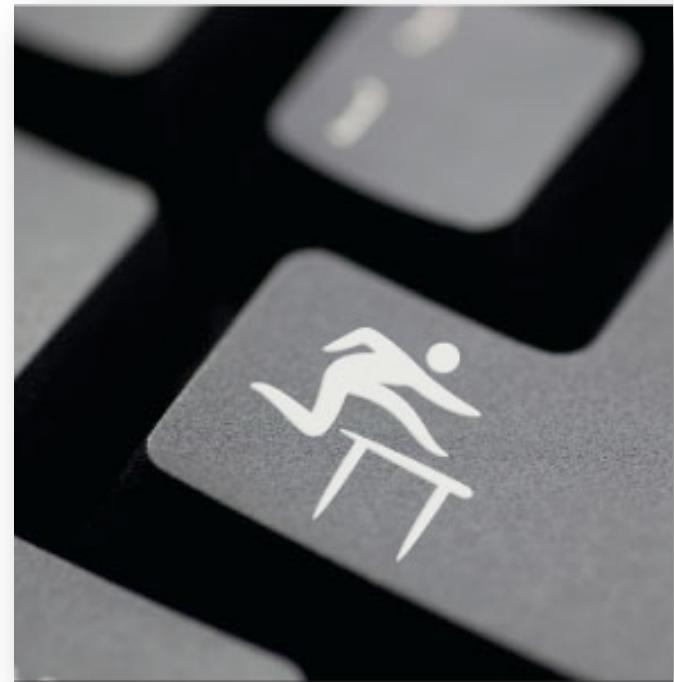
Real-time Brain Computer Interfacing

- Portable **high-density EEG** at the bedside
- Functional prototypes** being validated
- Real-time decoding** of
 - Motor imaginations
 - Attentional awareness

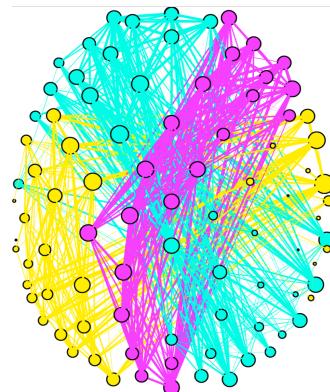


Ongoing Challenges

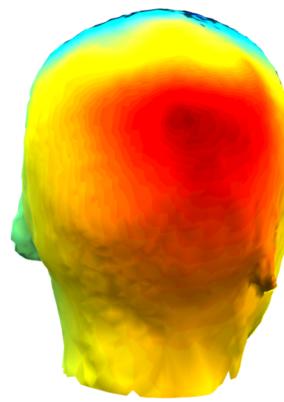
- But significant **divergence** across measurements
 - Large variations in patient arousal
 - Motivation and cognitive state
 - Signal quality and reliability
- Many of these challenges are not purely technological
- But need to be addressed if real-time tools are to be viable
 - Repeated, well-controlled, on-site assessments
 - Cognitively and emotionally engaging contexts
 - Therapeutic and pharmacological interventions



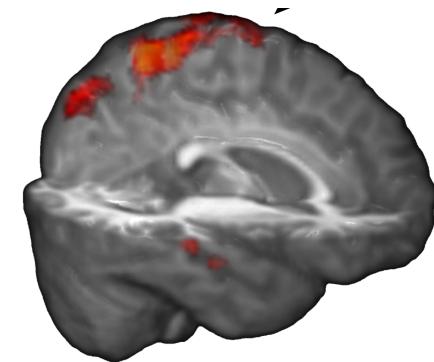
Promising Convergence



Robust Brain Networks



Attentional Control



Tennis Imagery

Promising convergent evidence in one vegetative patient!

Patient 1611

- Young father
- Traumatic brain injury
- Tested when behaviourally vegetative 3 months post injury
- Convergent pattern of evidence extremely unlikely to be by chance
- Made substantial recovery in following year!

*Could he benefit from a
brain-computer interface?*

Thanks!



Prof. John Pickard



Prof. David Menon



Dr. Tristan Bekinschtein



Dr. Adrian M. Owen

Division of Neurosurgery
University of Cambridge

Division of Anaesthesia
University of Cambridge

MRC CBU
Cambridge

The Brain and Mind Institute
University of Western Ontario

NIHR/Wellcome Trust Cambridge CRF

**Royal Hospital for Neuro-disability
Royal Leamington Spa Rehabilitation
Hospital**

**The Gardens Neurological Centre
Chalfont Lodge Nursing Home**

Patients and their families!