A Heartbeat Away From Consciousness:
Heart Rate Entropy can assess Consciousness

Francesco Riganello¹,²*, Stephen Karl Larroque¹*, Mohamed Ali Bahri³, Lizette Heine⁴, Charlotte Martial¹, Manon Carrière¹, Vanessa Charland-Verville¹, Charlène Aubinet¹, Audrey Vanhaudenhuyse⁵, Camille Chatelle¹, Steven Laureys¹ and Carol Di Perri¹,⁶

¹Coma Science Group, GIGA-Consciousness, University & Hospital of Liege, Belgium; ²Research in Advanced NeuroRehabilitation, Istituto S. Anna, Crotone, Italy; ³GIGA-Cyclotron Research Center In Vivo Imaging, University of Liege, Belgium; ⁴Centre de Recherche en Neurosciences, Inserm U1028 - CNRS UMR5292, University of Lyon 1, France; ⁵Sensation & Perception research Group, GIGA-Consciousness, University & Hospital of Liege, Belgium; ⁶Centre for Clinical Brain Sciences, University of Edinburgh, Edinburgh, UK; *These authors contributed equally to this work.

stephen.larroque@uliege.be
Diagnosing consciousness?

Can we better diagnose by monitoring the heart?

Neuroimaging helps, but is expensive and difficult in daily clinical setting.

Healthcare differs if patient is unresponsive (UWS) or minimally conscious (MCS).

~35% clinical diagnosis error which can impact life and death decisions.

→ Can we better diagnose by monitoring the heart?
Methods – from heart rate to complexity index

From heart rate to multi-scale entropy to **COMPLEXITY INDEX** in the short term ($\text{Cl}_s$) and long term ($\text{Cl}_l$):

- 14 UWS & 16 MCS (n=30) sedated patients, assessed by Coma Recovery Scale – Revised (CRS-R).
- Matched for age, gender and onset.
- Electrocardiographic activity (ECG) and photoplethysmographic sensor (PPG) acquired for 10 minutes, simultaneously with MRI (3T Siemens Magnetom TrioTim).
- PPG and ECG cleaned with a Fourier Transform (SigView software).
- $\text{Cl} = \text{area under the sample entropy timescale curve over multi-scale entropy}$ (HRV Advanced Analysis software v2.2).
- MRI T1 and EPI BOLD (n=21) preprocessed with SPM12 and 2$^{nd}$-level correlation analyses with CONN 17f with $\text{Cl}_s$ & $\text{Cl}_l$ as covariates of interest in a parametric regression.
Results

MCS have higher CI than UWS on average CIₜ (z=-3.346, p<0.001) and CIᵢ (z=-4.095, p<0.0001) using a Mann-Whitney’s test.

S1 includes all patients (n=30), S2 fMRI included (n=21)

Cl correlates with CAN fMRI connectivity recovery

(Riganello & Larroque, 2018)
Results & Conclusion

CI reliably discriminates MCS from UWS

Using a One-R classifier with 10-fold cross-validation:
-> CI selected as the best predictor
-> 90% accuracy, 7% false positive and 13% false negative rates
-> In comparison:
  • Zero-R (always predicting MCS) = 53% accuracy
  • Clinical consensus without CRS-R ≈ 35% false negative
-> Lower error than clinical consensus

Confusion Matrix

<table>
<thead>
<tr>
<th></th>
<th>MCS (true positive)</th>
<th>MCS as UWS (false negative)</th>
<th>UWS as MCS (false positive)</th>
<th>UWS (true negative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCS</td>
<td>15</td>
<td>1</td>
<td>1</td>
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<tr>
<td>MCS as UWS</td>
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Complexity Index has high discriminative power and low false negative & positive rates
-> Might provide an inexpensive way to diagnose MCS & UWS and screen/monitor CAN connectivity changes
-> Works even if extensive brain damage
-> Future: investigate in a bigger cohort and in non-sedated patients


This research was supported by: University and Hospital of Liège, F.R.S.-F.N.R.S., French Speaking Community Concerted Research Action (ARC 12-17/01), Center-TBI (FP7-HEALTH- 602150), Human Brain Project (EU-H2020-fetflagship-hbp-sga1-ga720270), Luminous project (EU-H2020-fetopen-ga686764), James McDonnell Foundation, Mind Science Foundation, IAP research network P7/06 of the Belgian Government (Belgian Science Policy), Public Utility Foundation "Université Européenne du Travail", "Fondazione Europea di Ricerca Biomedica", Bial Foundation, Belgian National Plan Cancer (139), European Space Agency, Belspo and European Commission.
Bonus slides
Background

• Healthcare differs if patient is unresponsive (UWS) or minimally conscious (MCS)
• ~35% clinical diagnosis error which can impact life and death decisions
• Neuroimaging helps, but is expensive and difficult in daily clinical setting
• Heart and brain’s Central Autonomic Network (CAN) are connected in a two-way dynamic interaction through the Autonomic Nervous System (ANS).

→ Can we better diagnose by monitoring the heart?
Results 3 - CI reliably discriminates MCS from UWS

One-R classifier with
10-fold cross-validation:
→ CI selects as the best predictor
→ **90% accuracy**, 7% false positive
and **13% false negative rates**
→ In comparison, Zero-R (always predicting MCS) has 53% accuracy
→ **Lower error than clinical consensus**

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Confusion Matrix

![Graph 1](image1.png)

Graph 1: CI short time scale

Graph 2: CI long time scale