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

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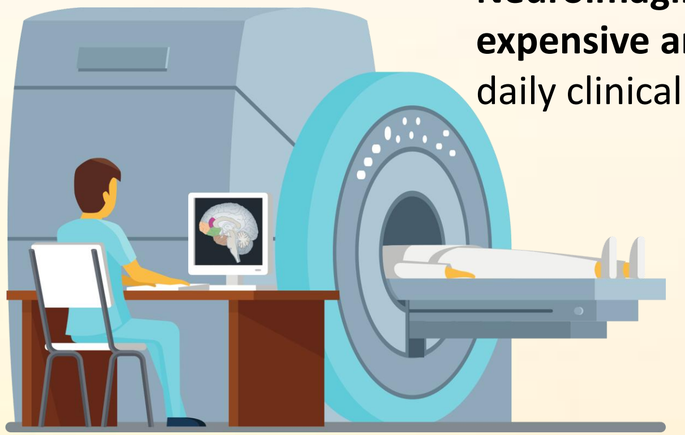
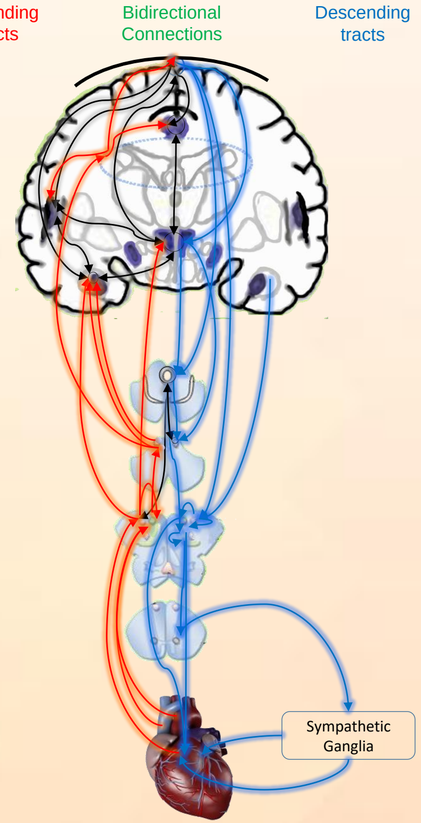
Diagnosing consciousness?



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**?

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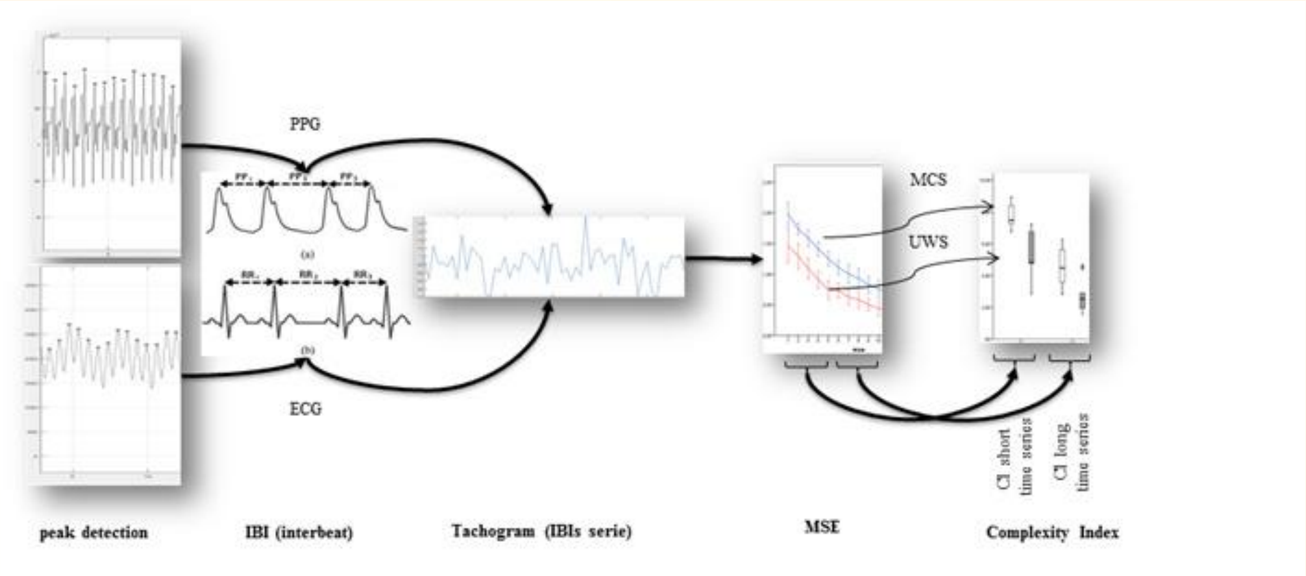
Methods – from heart rate to complexity index

From heart rate to multi-scale entropy to **COMPLEXITY INDEX** in the short term (CI_s) and long term (CI_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).
- CI = 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 2nd-level correlation analyses with CONN 17f with CI_s & CI_l as covariates of interest in a parametric regression.

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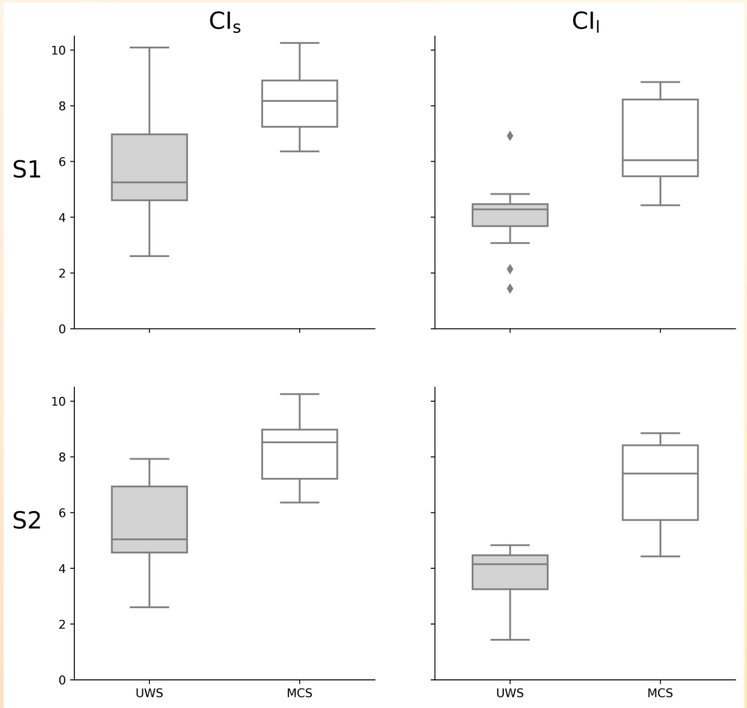
Results

(Riganello & Larroque, 2018)

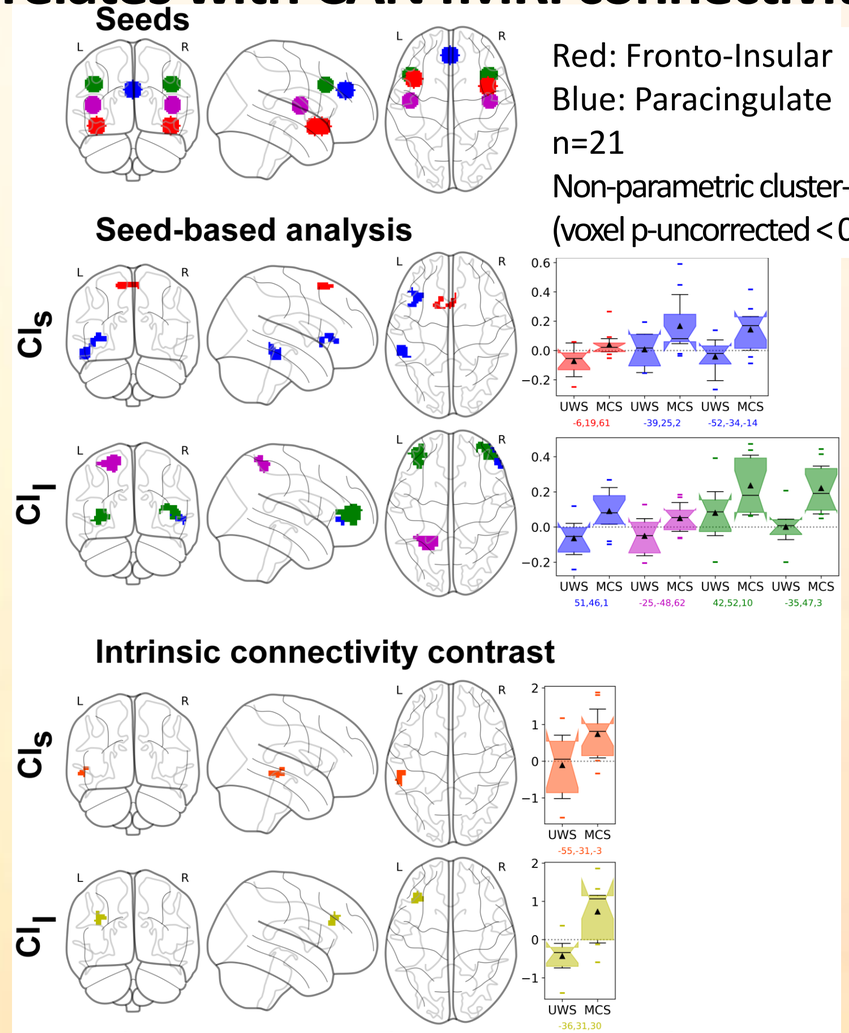
MCS have higher CI than UWS on average

CI_S (z=-3.346, p<0.001) and CI_I (z=-4.095, p<0.0001) using a Mann-Whitney's test.

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



CI correlates with CAN fMRI connectivity recovery



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Results & Conclusion

CI reliably discriminates MCS from UWS

Using a One-R classifier with
10-fold cross-validation:

→ CI_l 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	
MCS (true positive) 15	MCS as UWS (false negative) 1
1 UWS as MCS (false positive)	13 UWS (true negative)

→ 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

Reference: Riganello & Larroque, et al. "A Heartbeat Away From Consciousness: Heart Rate Variability Entropy can discriminate disorders of consciousness and is correlated with resting-state fMRI brain connectivity of the Central Autonomic Network." *Frontiers in Neurology* 9 (2018): 769.

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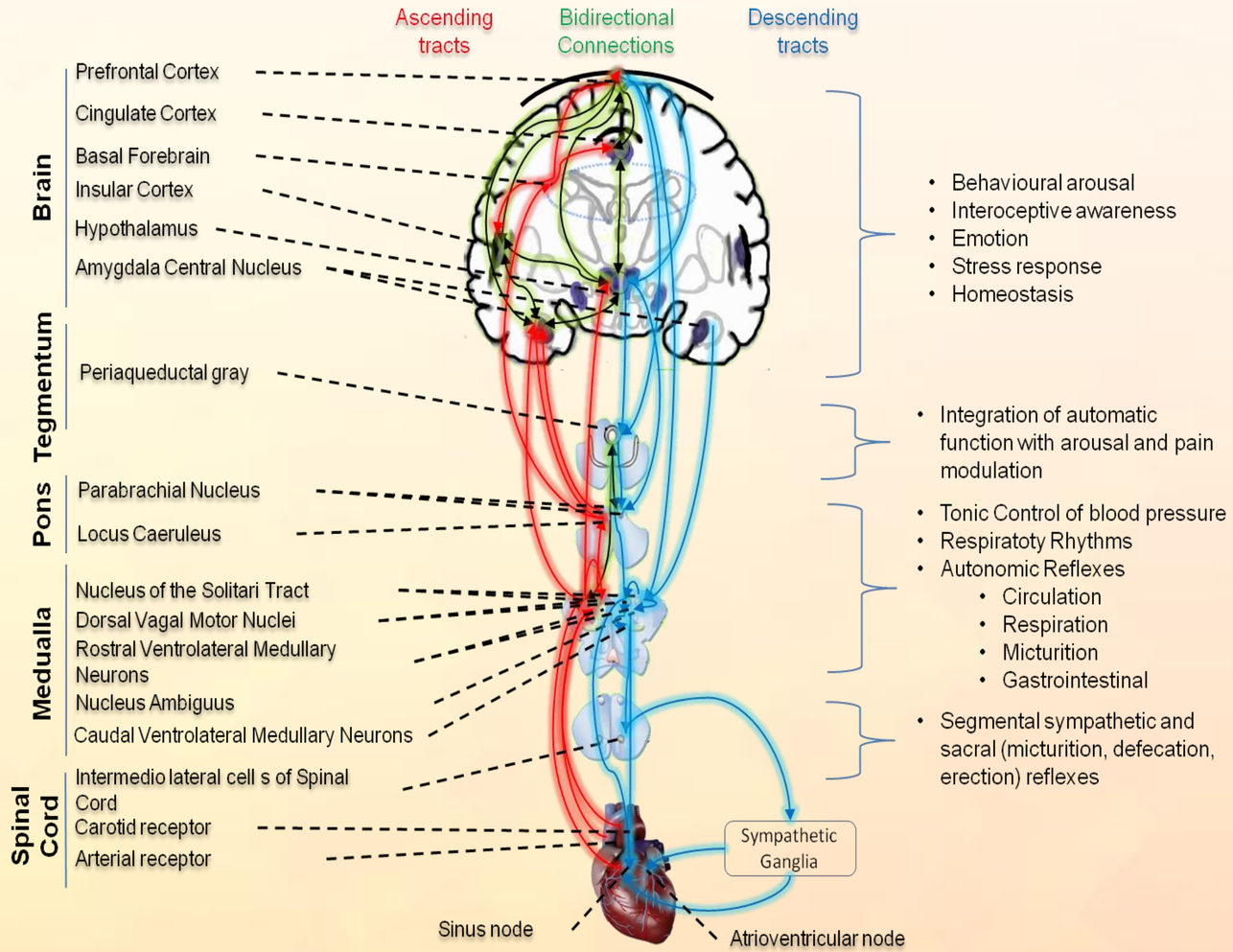
Bonus slides

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_I selected as the best predictor
→ **90% accuracy**, 7% false positive and **13% false negative rates**
→ In comparison, Zero-R (always predicting MCS) has 53% accuracy
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Confusion Matrix	
MCS (true) 15	MCS as UWS (false negative) 1
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