

Cardiac responses to auditory expectations during sleep track variations of hierarchical processing across arousal states

Matthieu Koroma¹, Paradeisios Alexandros Boulakis¹, Federico Raimondo², Mélanie Strauss^{3*}, and Athena Demertzi^{1*}



¹Physiology of Cognition Lab, GIGA-CRC In Vivo Imaging, University of Liège, Liège, Belgium
²Forschungszentrum Jülich, Heinrich-Heine-Universität, Düsseldorf, Germany
³UR2NF, Université Libre de Bruxelles, Brussels, Belgium
 *These authors are co-last authors

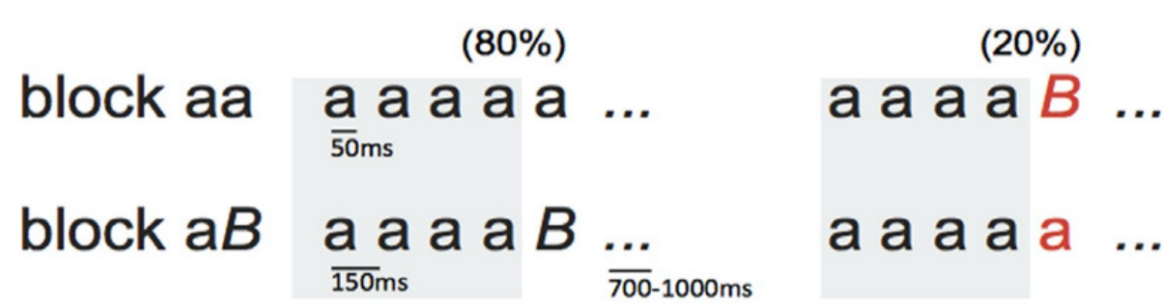


Introduction

- Can **bodily signals** inform the classification of **low-arousal non-communicative states**?
- Cardiac responses to hierarchical auditory deviants vary across **disorders of consciousness** and **inform their classification** of above and beyond cerebral markers (Raimondo et al., 2017)
- Brain responses to violations of hierarchical auditory expectations vary across **wakefulness and sleep** (Strauss et al, 2015)
- We hypothesize that **cardiac responses** to hierarchical auditory expectations vary across **wakefulness and sleep** and inform the classification of **arousal states**

Methods

- **Auditory deviants during sleep** (Strauss et al., 2015; Strauss et al., 2022)
- Local-global paradigm with M/EEG, EOG and ECG recordings
- Morning nap paradigm following light sleep restriction
- N=22 in wakefulness, 16 in N2, 9 in REM, 14 in HORI 1-4, 8 in HORI 5-8

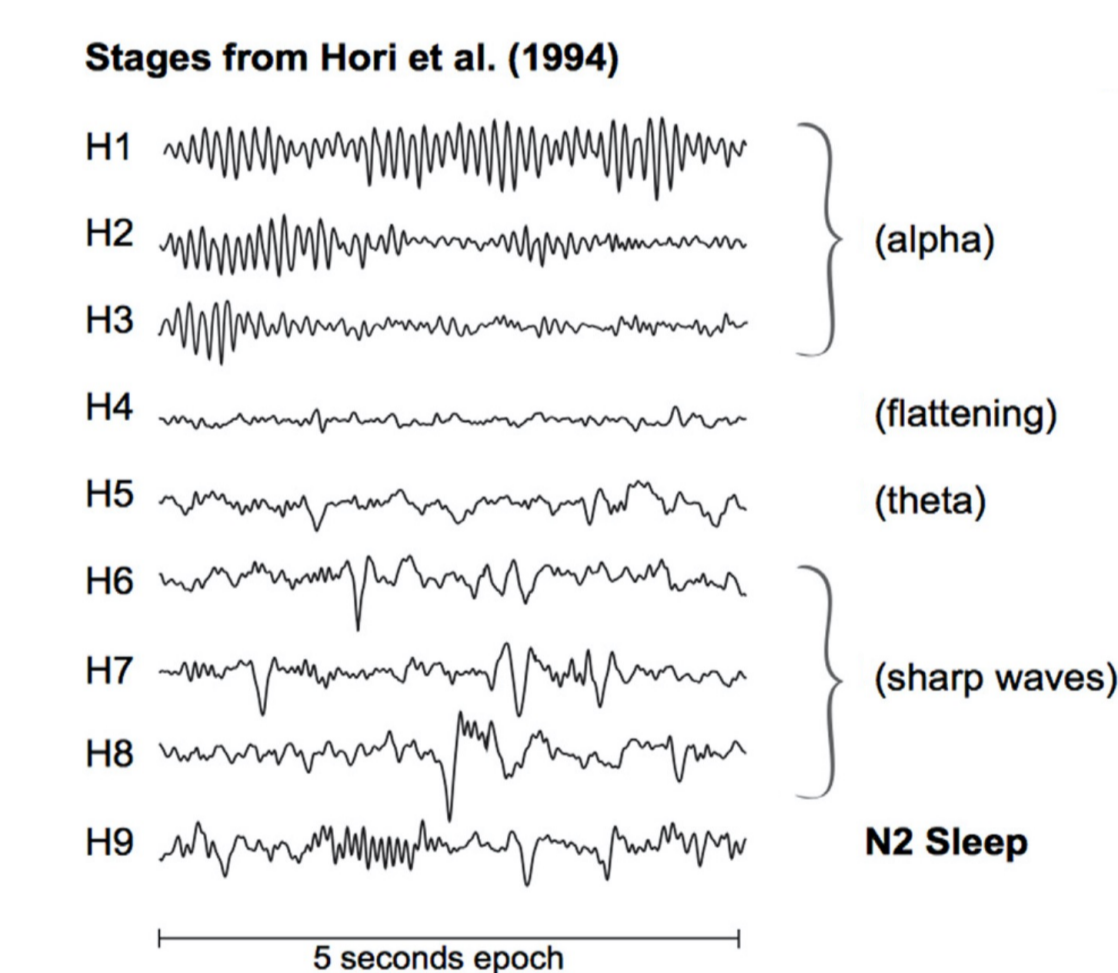
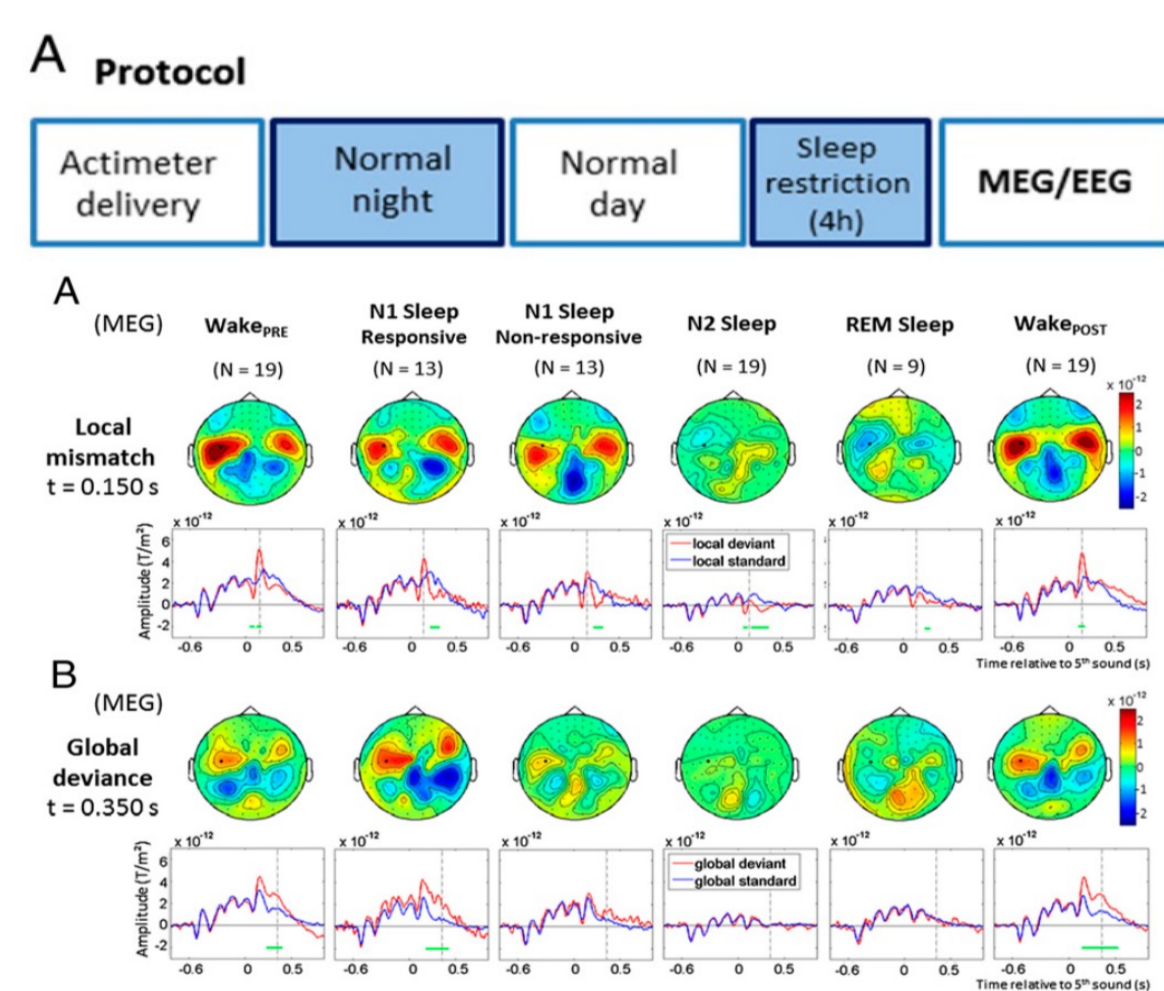


Non-specific response
 Ongoing brain activity (spectral density, entropy, connectivity ...)

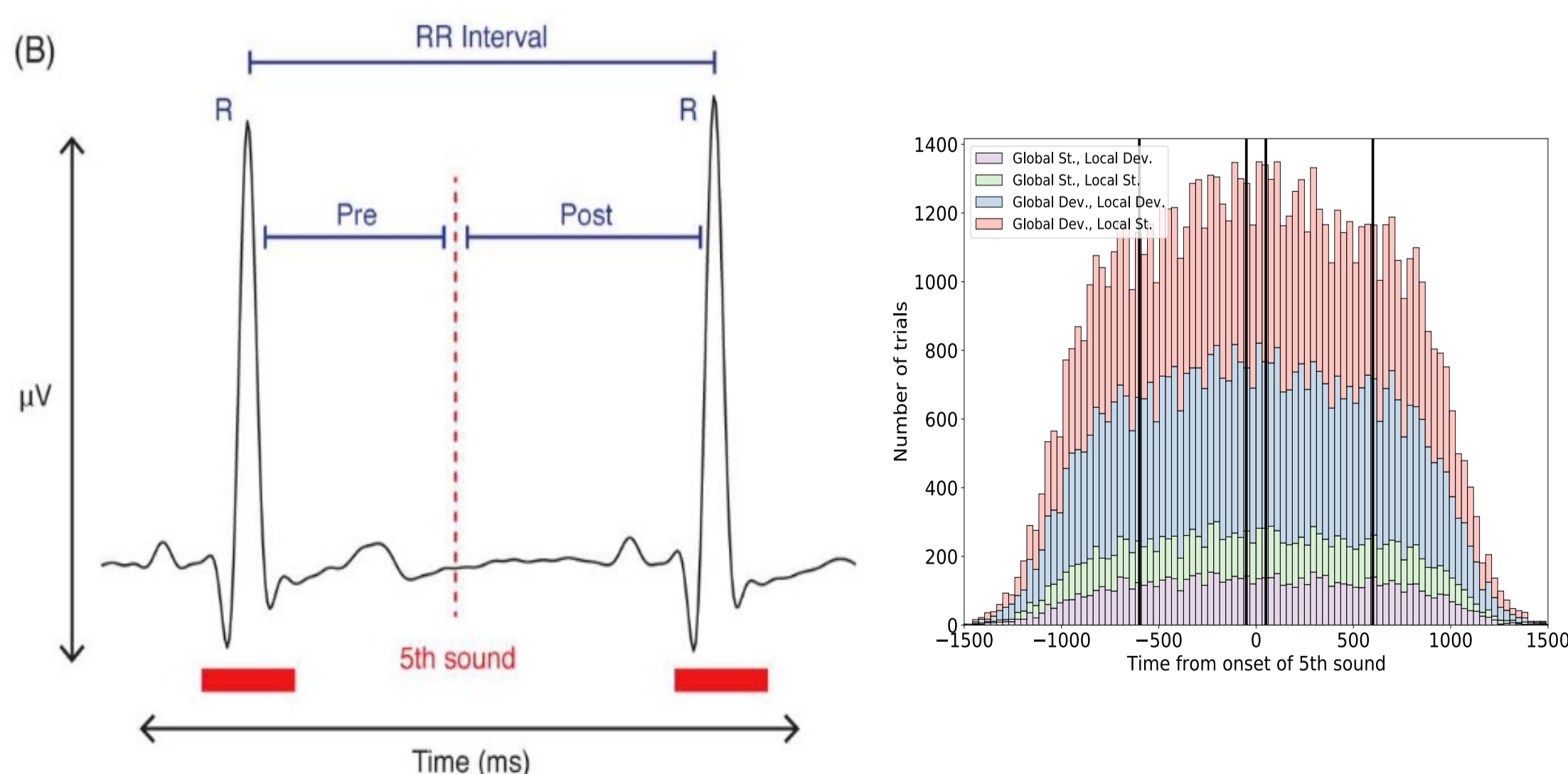
Response to deviancy
LOCAL DEVIANTS (Mismatch)
 global deviants (P300)

Local mismatch effect =
 Local deviants – Local standards

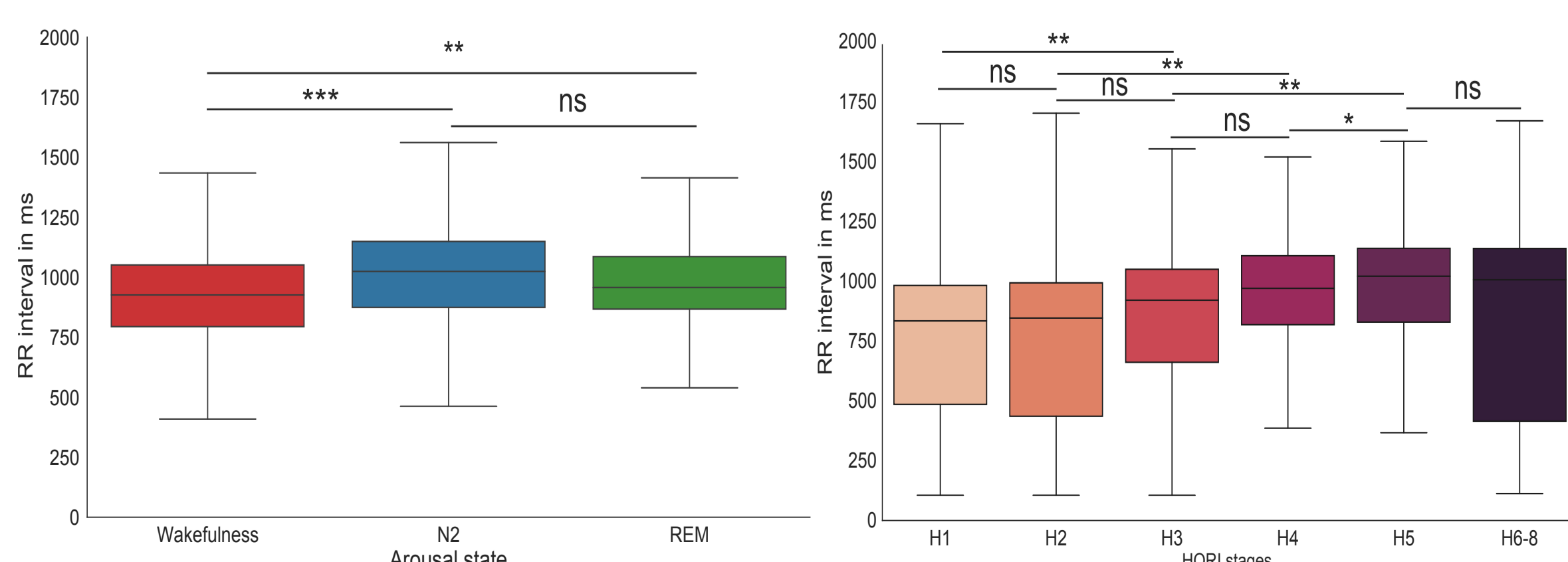
Global deviance effect =
 Global deviants – Global standards



- **Cardiac responses to auditory deviants** (Raimondo et al., 2017)
- R-peak extraction using Systole toolbox (Legrand and Allen, 2022)
- PRE and POST intervals around the onset of the 5th sound
- R-peak between 20 and 600 ms around the onset of the 5th sound

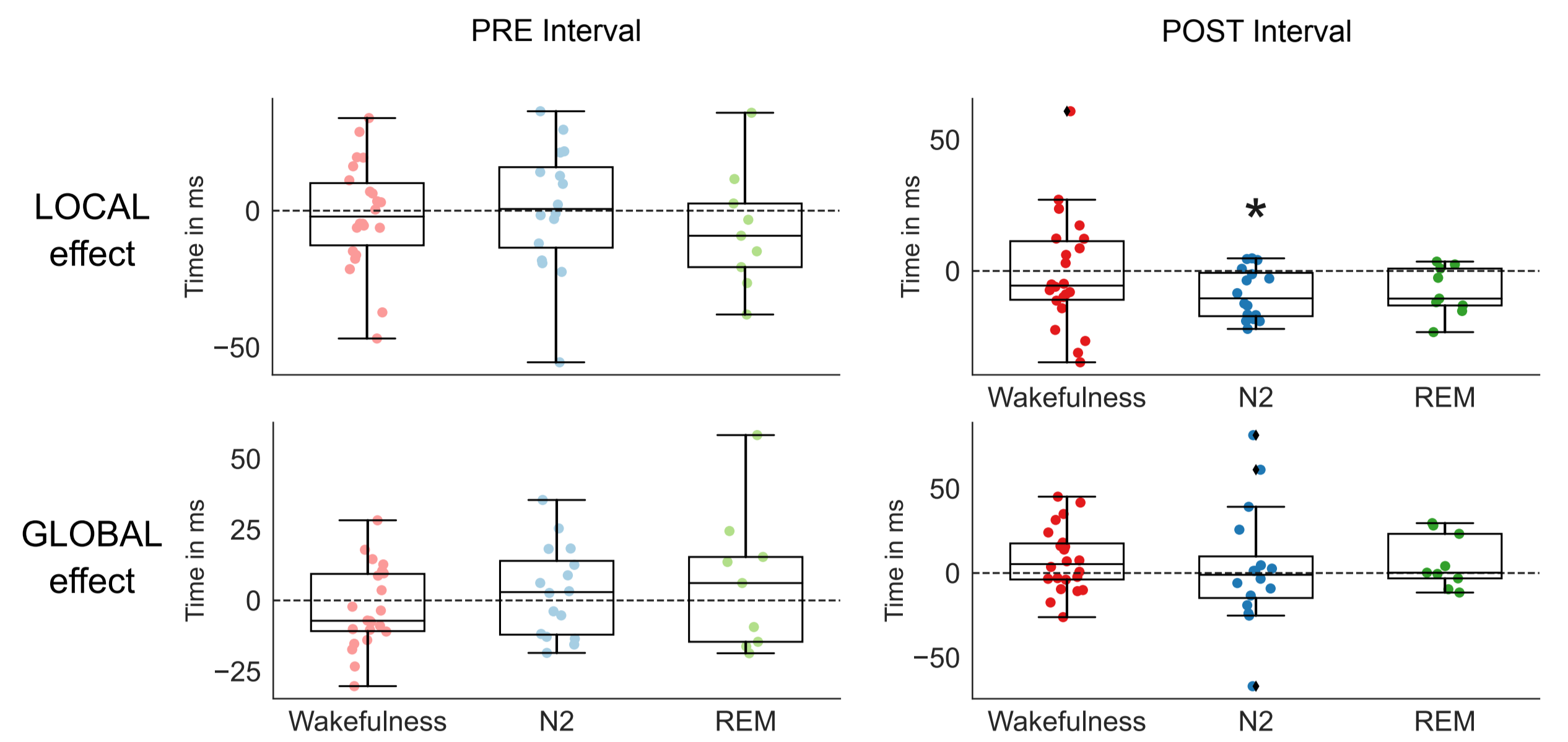


- **Classification using cerebral & cardiac activity** (Raimondo et al., 2017)
- EKGvg: heart rate and standard deviation of heart rate
- EKGcg: cardiac responses (pre and post) to local deviants
- EEG: 97 markers comprising connectivity, complexity and spectral measures

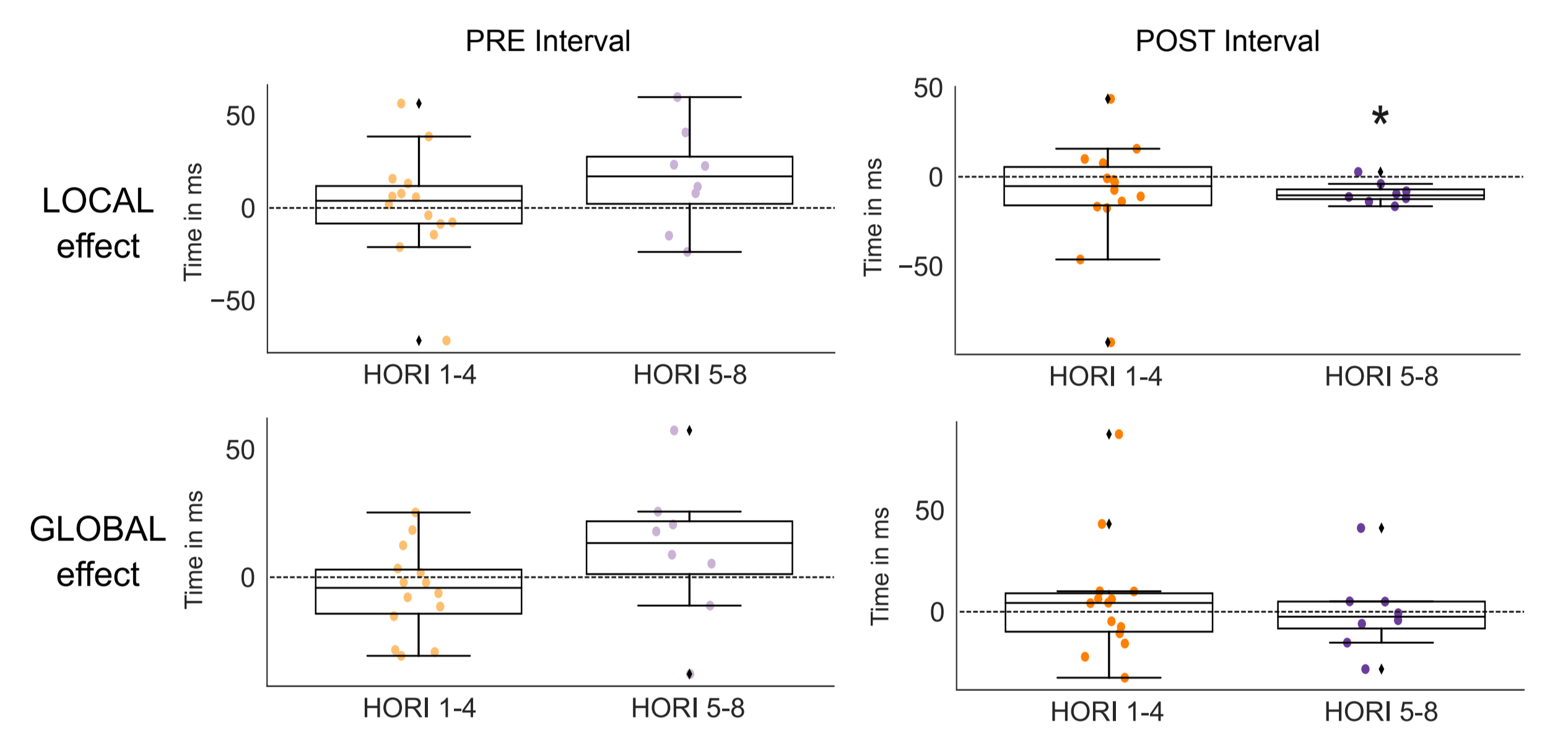


Results

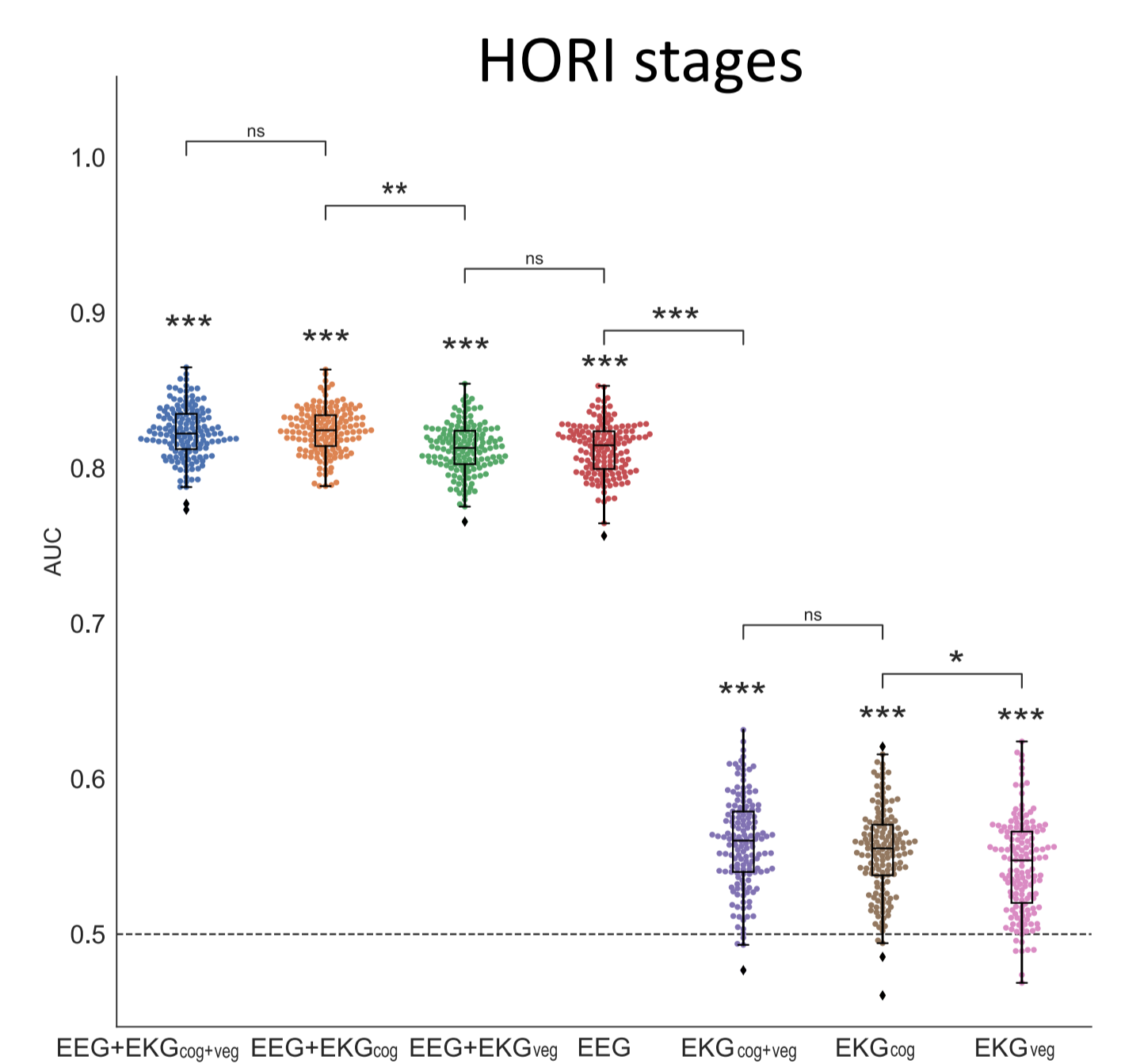
- Cardiac **acceleration** after **local deviants** during sleep



- Cardiac **acceleration** after **local deviants** in **late sleep onset**



- Evoked cardiac activity informs **above and below** cerebral activity



Discussion

- **Classification of arousal and HORI states based on cardiac activity**
 - Slowing down of continuous cardiac activity from wakefulness to sleep
 - Cardiac acceleration to local deviants in late sleep onset and light NREM sleep
 - Cardiac responses boosts the classification of arousal beyond cerebral activity alone
- **Hierarchical responses to auditory expectations**
 - Cardiac acceleration to local deviants extend cerebral findings (see Strauss et al., 2015)
 - Unconclusive evidence in REM sleep due to a lower number of subjects
 - No evidence for cardiac responses to global deviants (but see Raimondo et al., 2017)

References

Strauss et al. (2015). Disruption of hierarchical predictive coding during sleep. *PNAS*, 112(11), E1353-E1362 [link](#)
 Raimondo et al. (2017). Brain–heart interactions reveal consciousness in noncommunicating patients. *Ann. Neurol.*, 82(4), 578-591 [link](#)
 Strauss, ..., & Raimondo, F. (2022). Predicting the loss of responsiveness when falling asleep in humans. *NeuroImage*, 251, 119003 [link](#)

- **Contact:** matthieu.koroma@uliege.be
- **OSF:** <https://osf.io/wxent/>
- **Github:** <https://tinyurl.com/4yrxe364>

➤ **Qr code**