Slow waves and sleep consciousness

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Background and Aims

Dreaming is a particular form of consciousness that occurs during sleep. Although mental activity is most frequently and vividly recalled when awakening from REM sleep, it is also reported in up to 80% of Non-REM (NREM) sleep awakenings.
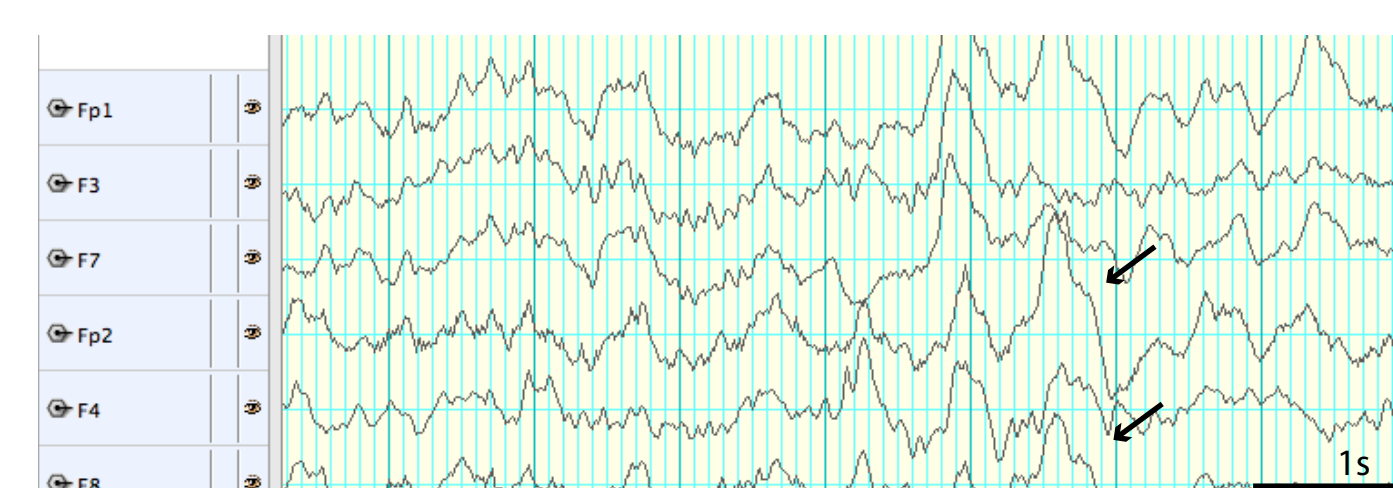
Slow waves, the hallmark of NREM sleep, reflect a slow oscillation of cortical neurons between up and down states. It has been suggested that the brain's capacity to integrate information and generate conscious experiences is reduced whenever the brain is in such a bistable state [1].
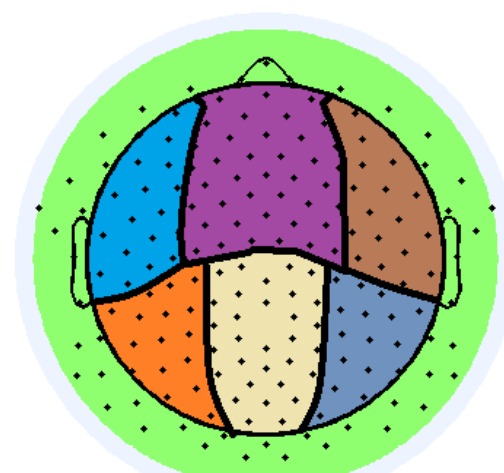
Are slow waves negatively associated with sleep consicousness?

Can machine-learning techniques distinguish between periods with consciousness and unconsciousness in sleep?

Methods

- Two healthy participants
- 16 overnight hd-EEG recordings (256 electrodes)
- 290 awakenings (222 in N2 and N3)
- Many awakenings, few subjects to account for interindividual variation in sleep consciousness and EEG
- Assessment of sleep consciousness:
  - No conscious experience
  - Conscious experience without recall of content
  - Conscious experience with recall of content
- Assessment of richness and length of dream
- Time frequency transform of EEG signal 2 min before awakening
- Slow-wave detection algorithm for identification of slow waves [2]
- Multivariate pattern analysis (L2-regularized logistic regression) for EEG signal within delta band (1-4.5 Hz)
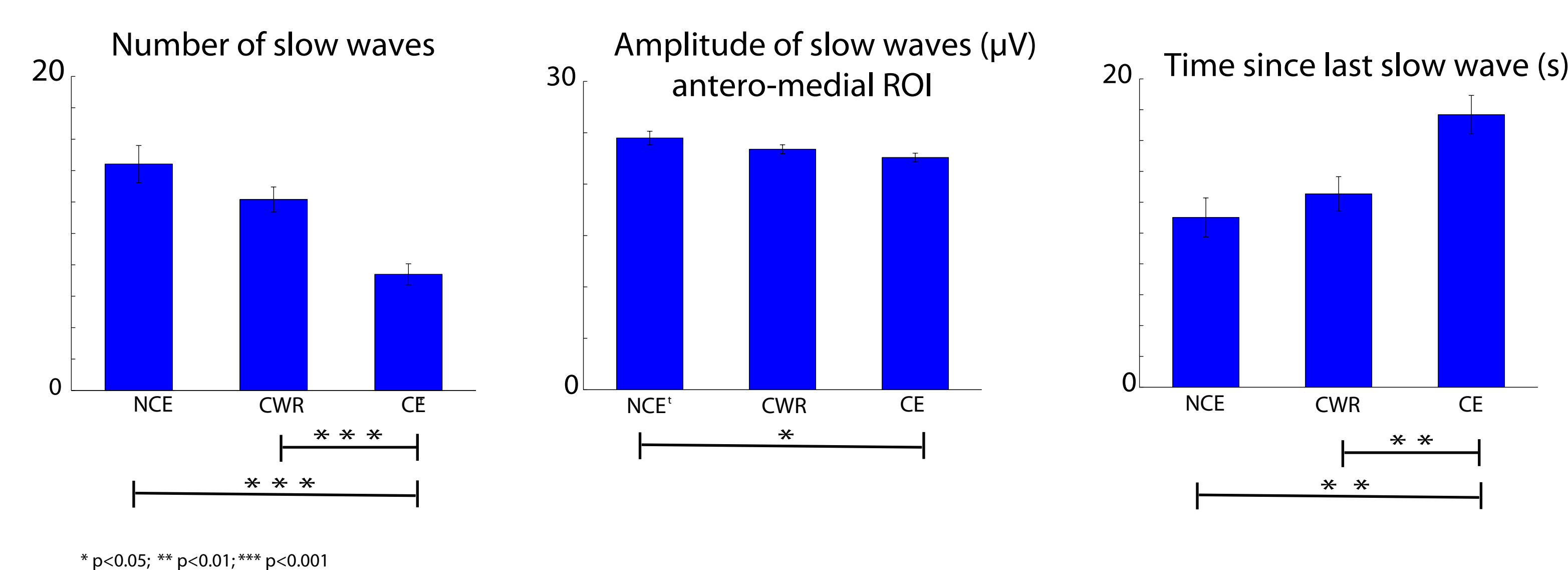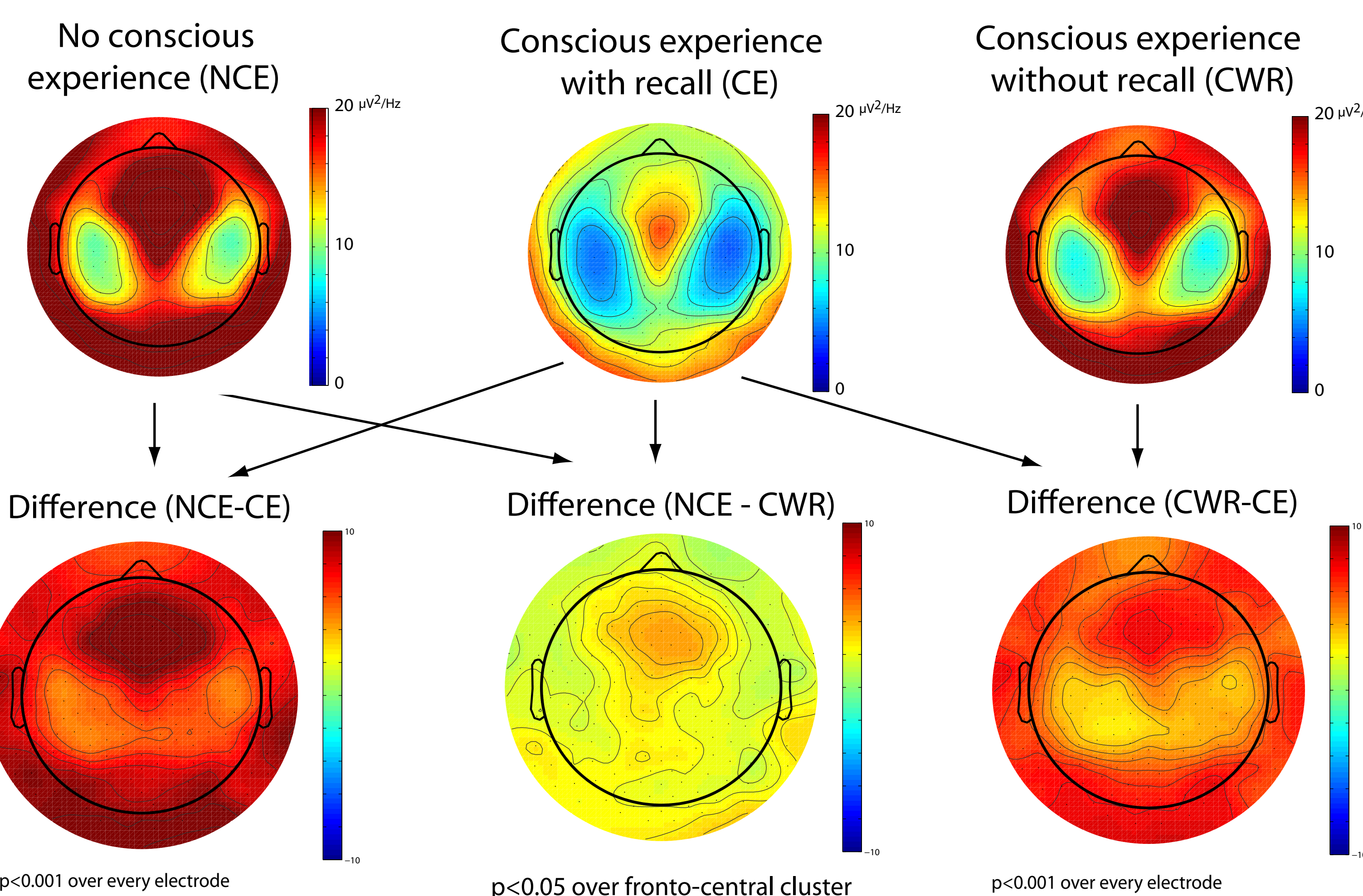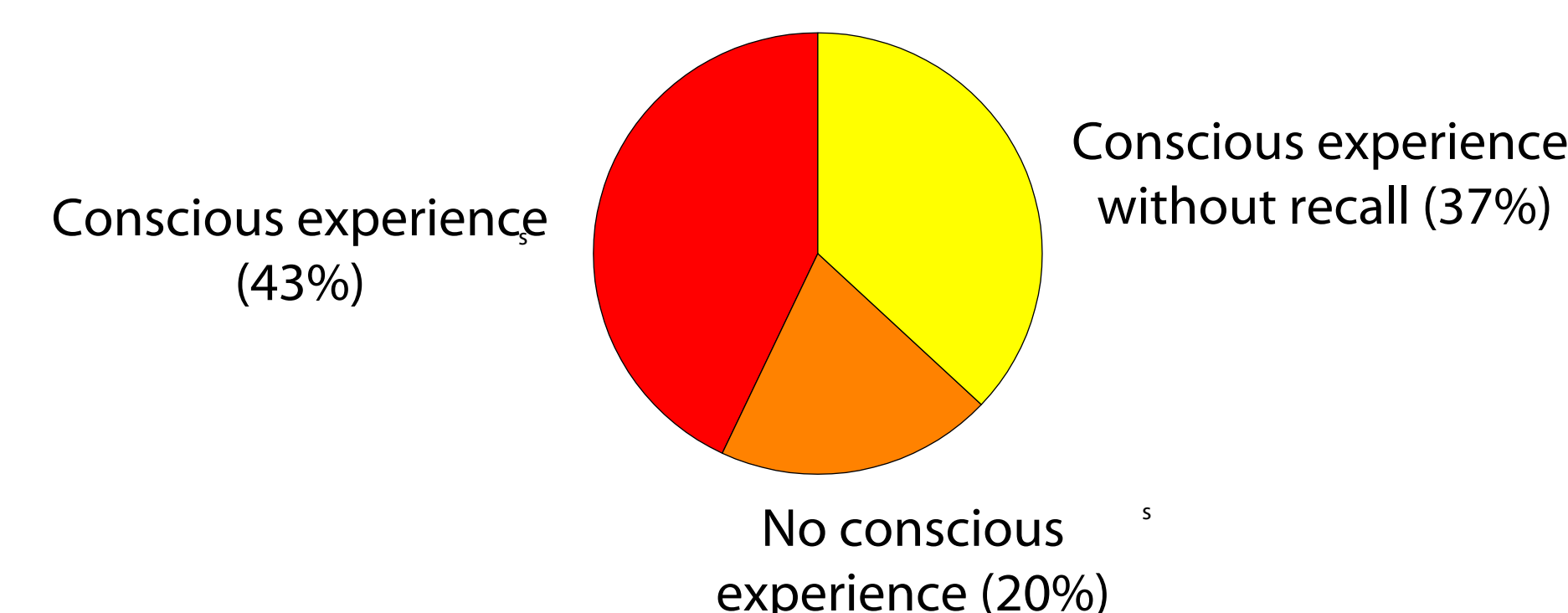
Regions of interest (ROI)

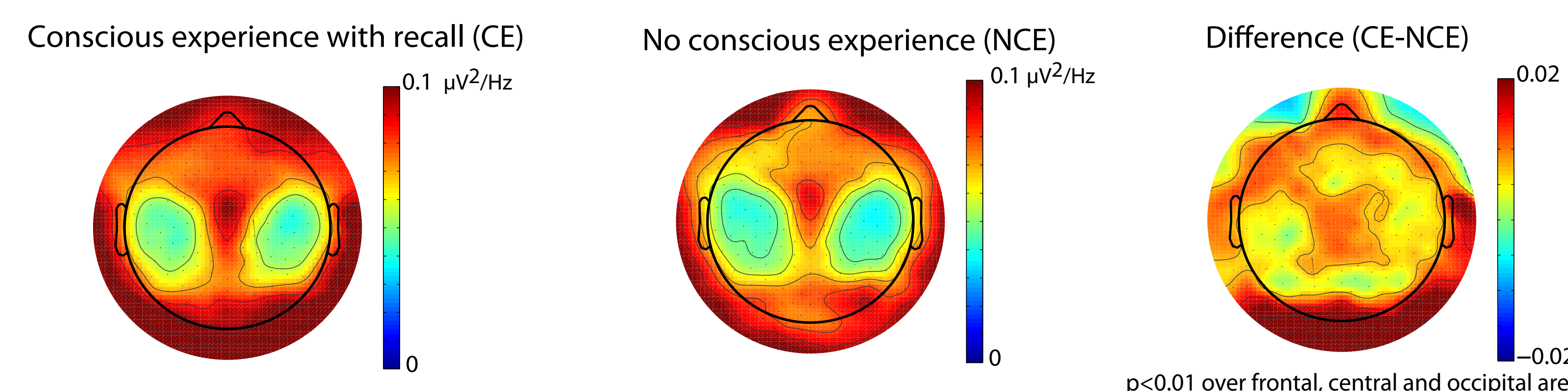## Slow waves are negatively associated with conscious experience in sleep

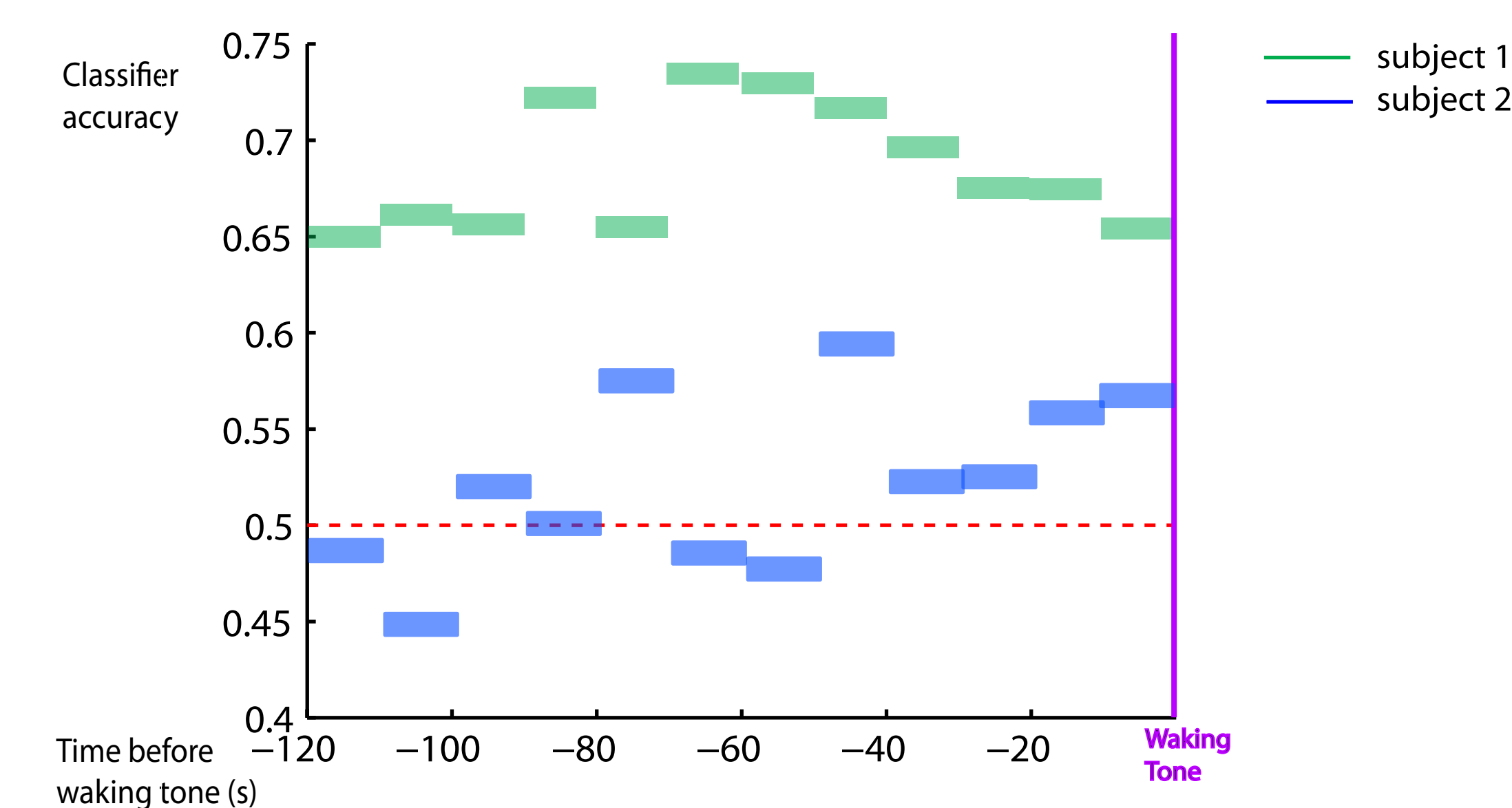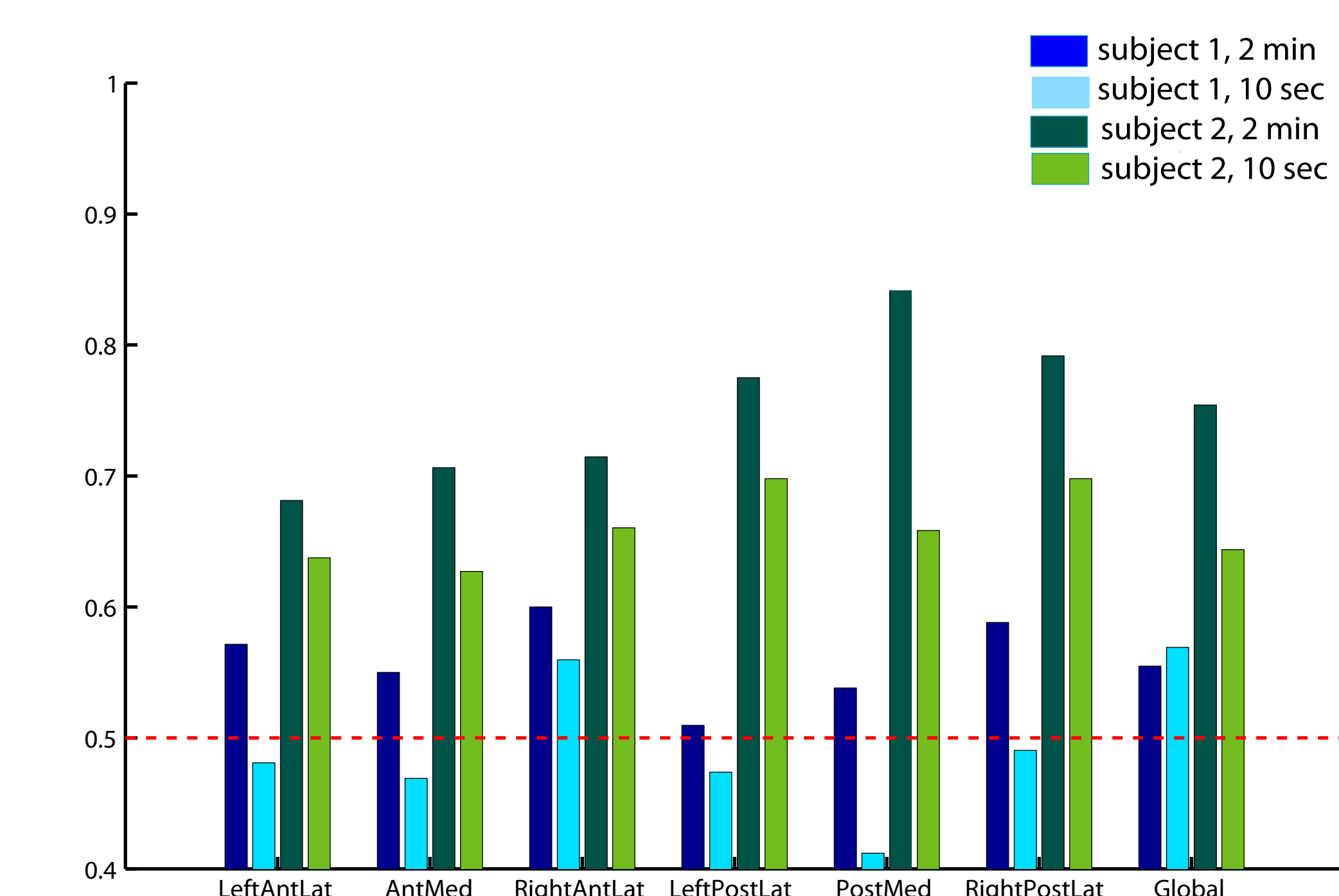Proportion of questionings in different stages (290 awakenings)

N1 (4%) Wake (3%) REM (14%)
2 (49%) N3 (30%)
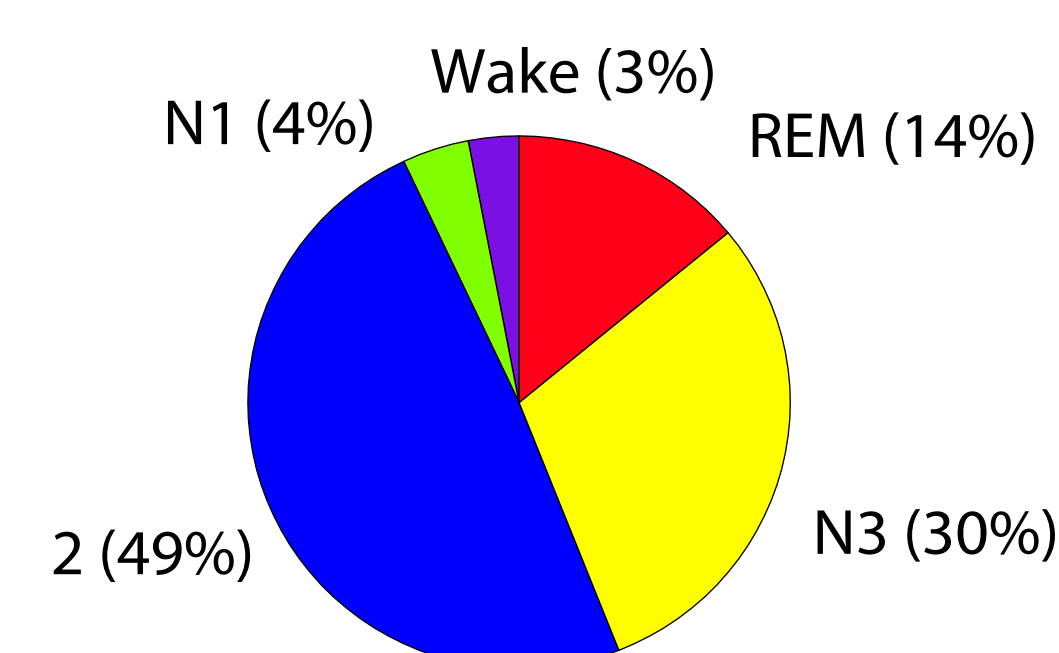
Conscious experiences in stages N2 and N3 (222 awakenings)

Conscious experience (43%)
Conscious experience without recall (37%)
No conscious experience (20%)

No conscious experience (NCE) 20 μV²/Hz 10 0

Conscious experience with recall (CE) 20 μV²/Hz 10 0

Conscious experience without recall (CWR) 20 μV²/Hz 10 0

Difference (NCE-CE)

Difference (NCE - CWR)

Difference (CWR-CE)

p<0.001 over every electrode

p<0.05 over fronto-central cluster

p<0.001 over every electrode

Number of slow waves

Amplitude of slow waves (μV) antero-medial ROI

Time since last slow wave (s)

NCE CWR CE
*** ***

NCE' CWR CE
*

NCE CWR CE
* *

* p<0.05; ** p<0.01;*** p<0.001

Conscious experience is associated with higher power in the beta range (18-25 Hz)

Conscious experience with recall (CE) 0.1 μV²/Hz 0

No conscious experience (NCE) 0.1 μV²/Hz 0

Difference (CE-NCE) 0.02 −0.02

p<0.01 over frontal, central and occipital area

Pattern classification successfully predicts sleep consciousness based on slow wave power

subject 1, 2 min
subject 1, 10 sec
subject 2, 2 min
subject 2, 10 sec

LeftAntLat AntMed RightAntLat LeftPostLat PostMed RightPostLat Global

Classifier accuracy

subject 1
subject 2

Time before waking tone (s) −120 −100 −80 −60 −40 −20 Waking Tone

Pattern classification predicts dream recall for both subjects and all ROIs. Performance is higher for 2 min of data compared to 10 sec.

Conclusions

Our results suggest that the brain's capacity to generate conscious experience during sleep is reduced in the presence of slow waves. Initial analyses indicate that machine learning techniques can predict the presence of sleep consciousness.

References

1. Tononi G. Consciousness as integrated information: a provisional manifesto. Biol Bull 2008;215:216-42.
2. Riedner et al. Sleep homeostasis and cortical synchronization. Sleep 2007; 30 (12), 1643-57.