

# Differentiating consciousness from unconsciousness in non-rapid eye movement sleep: a combined transcranial magnetic stimulation and high-density EEG study

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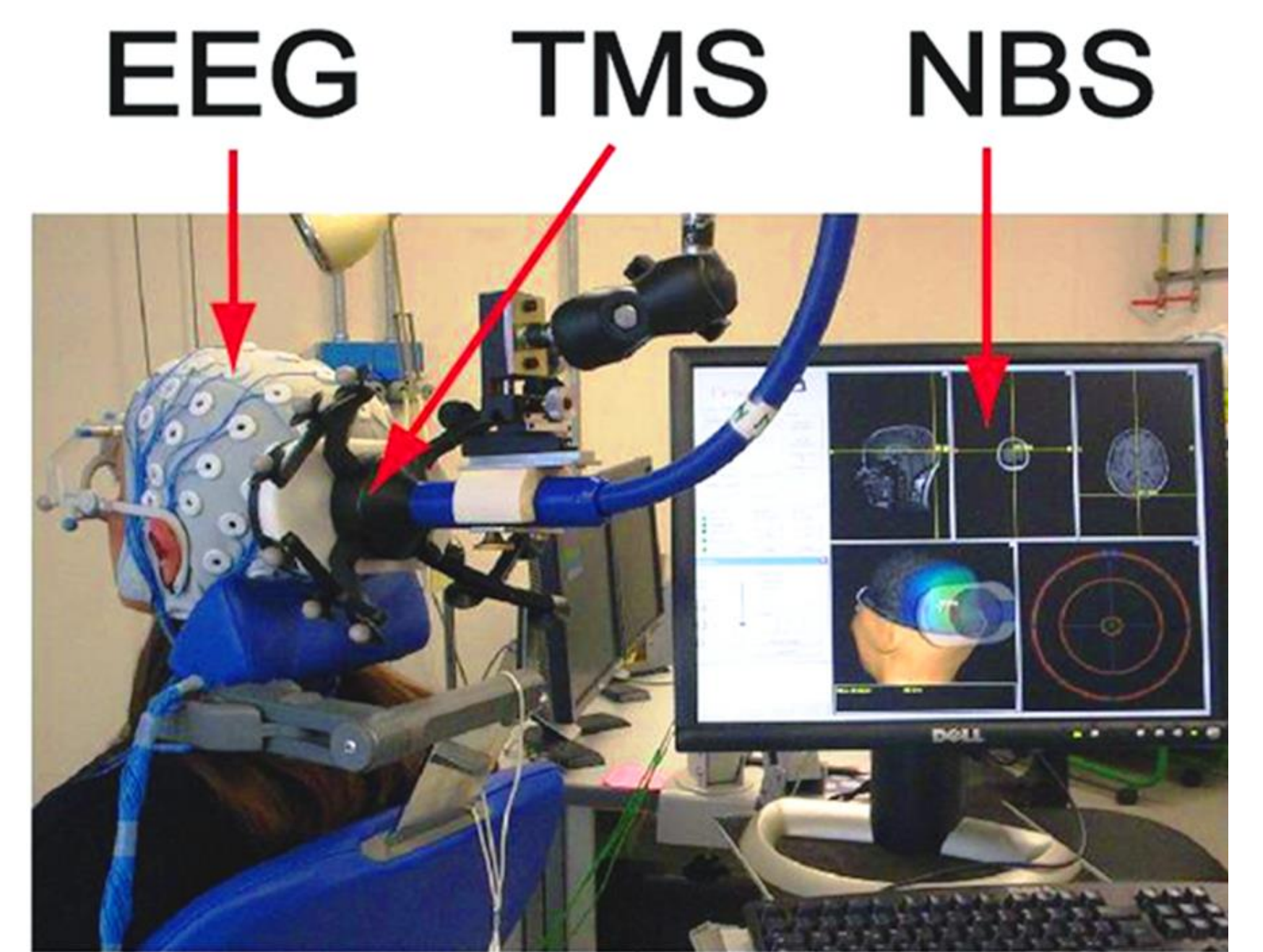
## Background

Combined transcranial magnetic stimulation and high-density electroencephalography (TMS–EEG) allows assessing changes in brain activity after non-invasive stimulation of the cortex. Previous studies<sup>1–3</sup> have shown differences in TMS–EEG responses between wakefulness, rapid eye movement

(REM), and non-REM (NREM) sleep. It still remains unclear whether TMS–EEG is sensitive to variations in the level of consciousness within the same physiological state; for example, subjects awakened from NREM sleep report having conscious dream-like experiences about half of the time<sup>4</sup>.

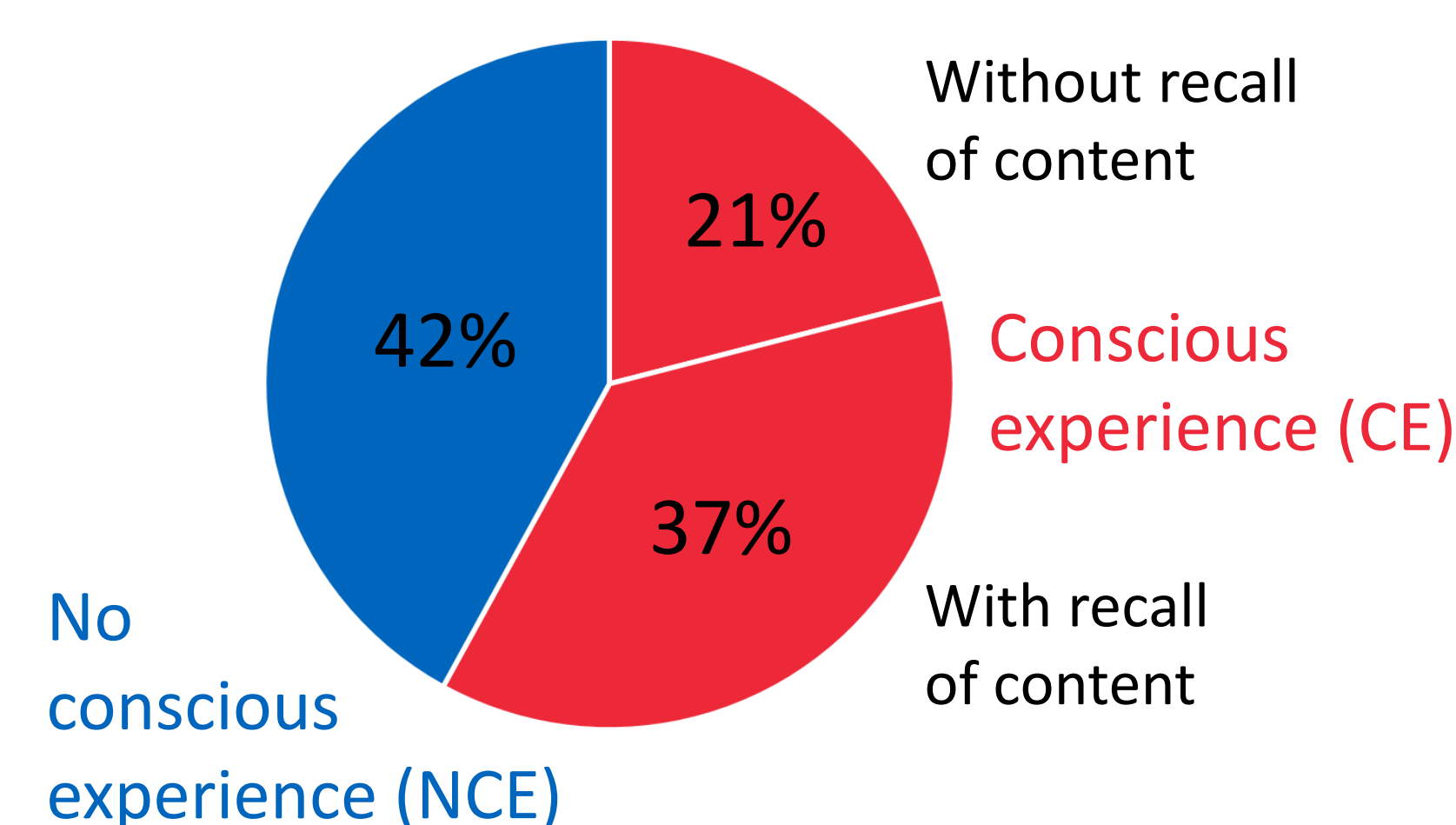
## Methods

- 6 healthy participants included in the analyses (1 female, 19–30 years old)
- 29 overnight TMS–EEG recordings (Nexstim eXimia, 60-channel EEG, navigated TMS using individual MRIs of the subjects) targeting the medial superior parietal lobule
- 187 awakenings in NREM sleep (based on AASM) with questionnaire to assess consciousness
- Up to 16 TMS sessions (10–284 single pulses per session) recorded in one night
- Artifact-free filtered data (1.5–45 Hz) of the last 30 s before the awakenings were averaged and the phase-locking factor (PLF) was computed. Statistical analyses were performed and differences between conditions were thresholded at cluster-level  $p < 0.05$ .



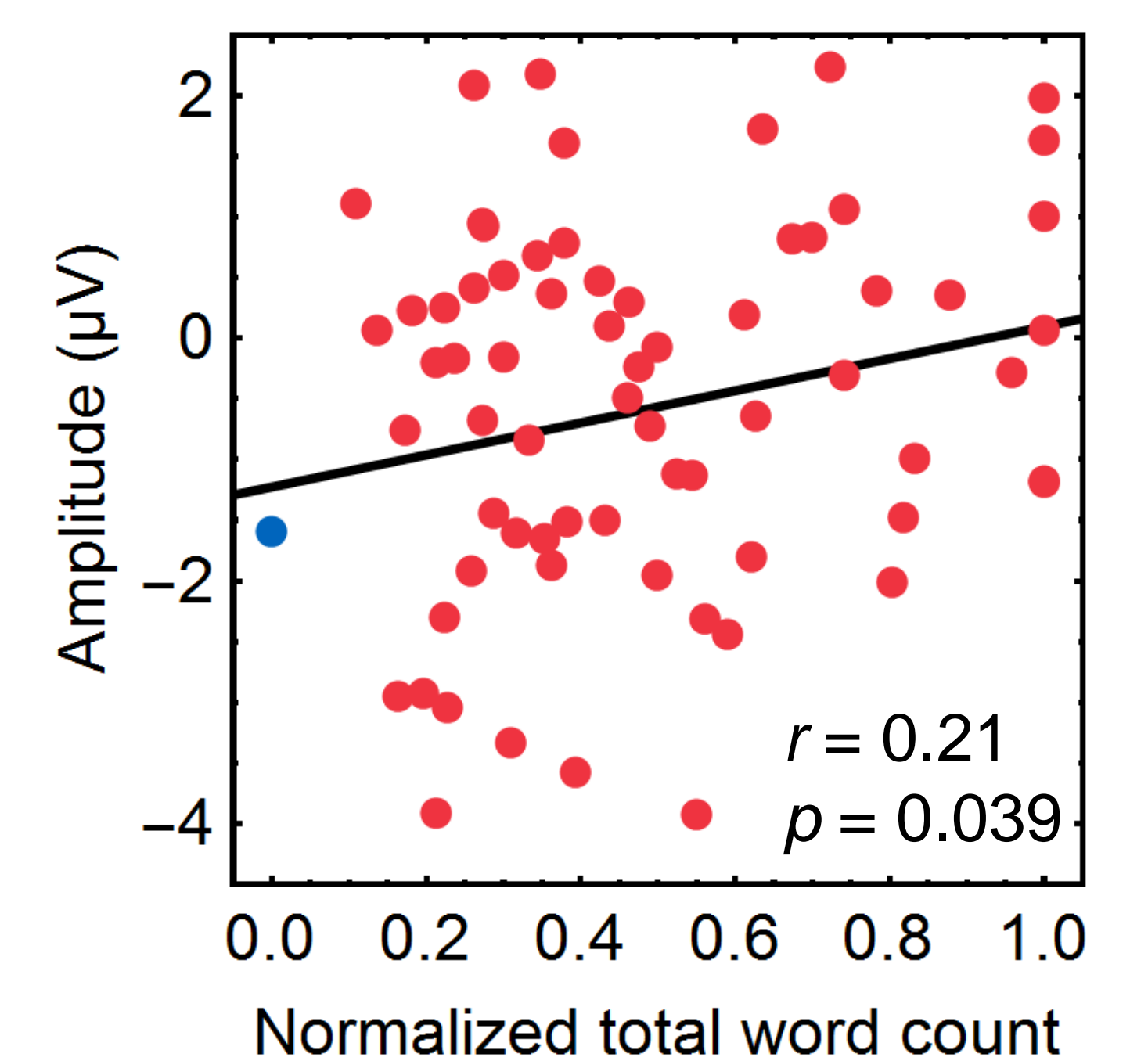
## Results

### 1. Behavioral responses

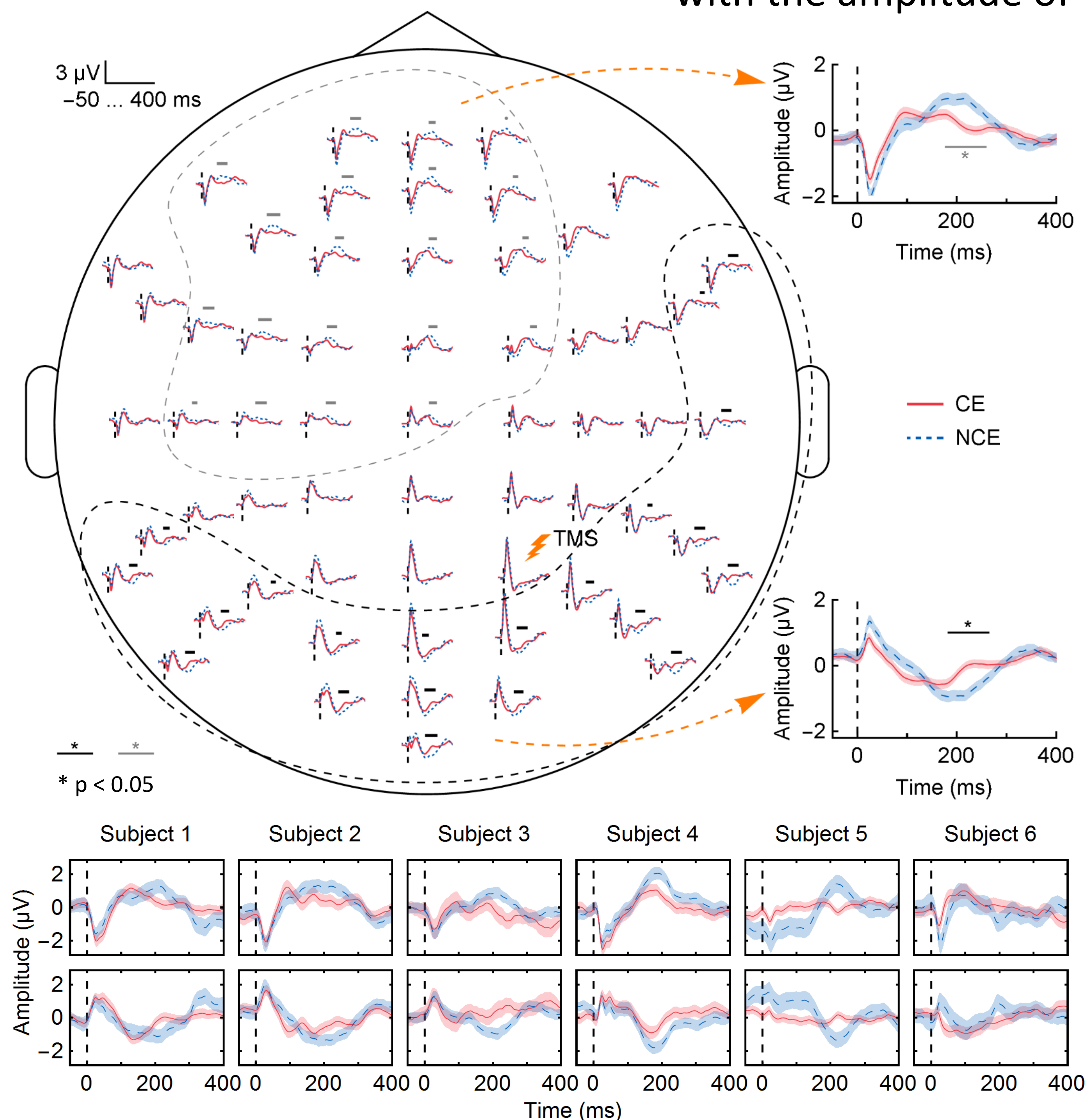


In NREM sleep, subjects reported conscious experiences (CE) in 58% of the cases. When subjects reported no conscious experience (NCE), the peak amplitude of the TMS–EEG response at around 200 ms was larger than when they did report a conscious experience. This reflects the putative downstate and increased bistability when subjects do not experience any conscious experience. Phase-locking (a measure of the duration of the deterministic effect of TMS) was longer in the CE condition than in the NCE condition. Finally, the length of the dream reports inversely correlated with the amplitude of the negative TMS–EEG deflection.

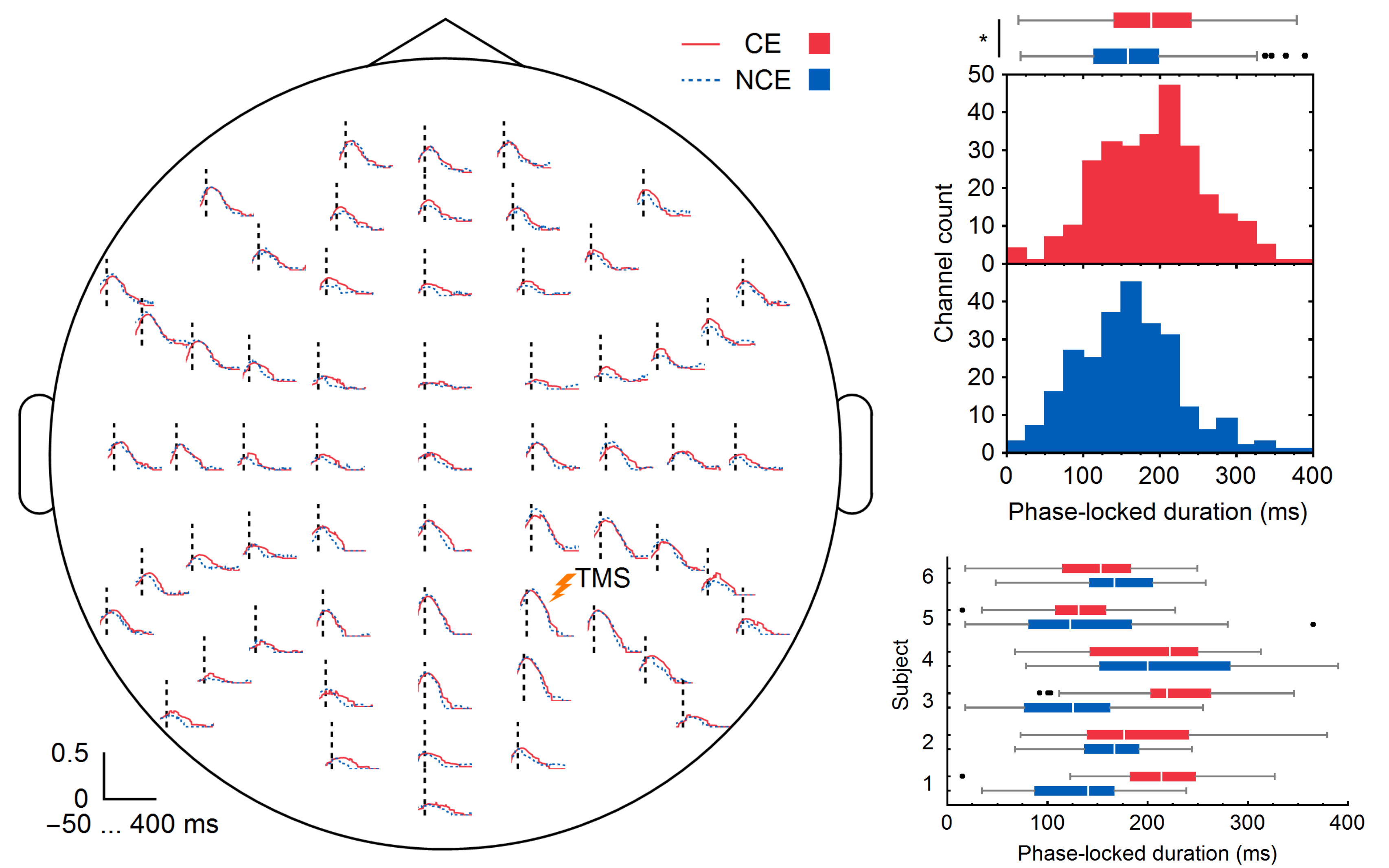
### 4. Word count and peak amplitude



### 2. TMS–EEG responses



### 3. Global phase-locking (8–13 Hz)



## Acknowledgement

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## Conclusion

Our findings suggest that variations in the level of consciousness within the same physiological state (here NREM sleep) are associated with changes in the underlying bistability in cortical circuits. This study shows that TMS–EEG is able to differentiate consciousness from unconsciousness within the same physiological state.

<sup>1</sup>Massimini *et al.* Cogn Neurosci. 2010 1:176–183. <sup>2</sup>Massimini *et al.* Science. 2005 309:2228–32. <sup>3</sup>Massimini *et al.* Proc Natl Acad Sci USA. 2007 104:8496–501. <sup>4</sup>Siclari *et al.* Front Psychol. 2013 4:542.