

# Reduced sleep time is associated with increases in frontal sleep-like activity and emotion regulation failures

## BACKGROUND

- **Emotion self-regulation** relies on cognitive and behavioral strategies and consists in modulating the subjective experience of a given emotion and/or its prompted behavioral expression.
- A network encompassing **fronto-cingulate** and **parietal** brain areas is engaged during **successful emotion regulation** [Langner et al., *Neurosci Biobehav Rev*, 2018].
- **Sleep deprivation/restriction** is associated with an impairment in the regulation of emotional responses thought to depend on an **altered prefrontal control** [Yoo et al., *Curr Biol*, 2007].
- The physiological and functional mechanisms underlying failures in emotion suppression are still unclear.
- Here, we hypothesized that **local, sleep-like events**, may represent the functional link between insufficient sleep and emotion regulation failures.

## METHODS

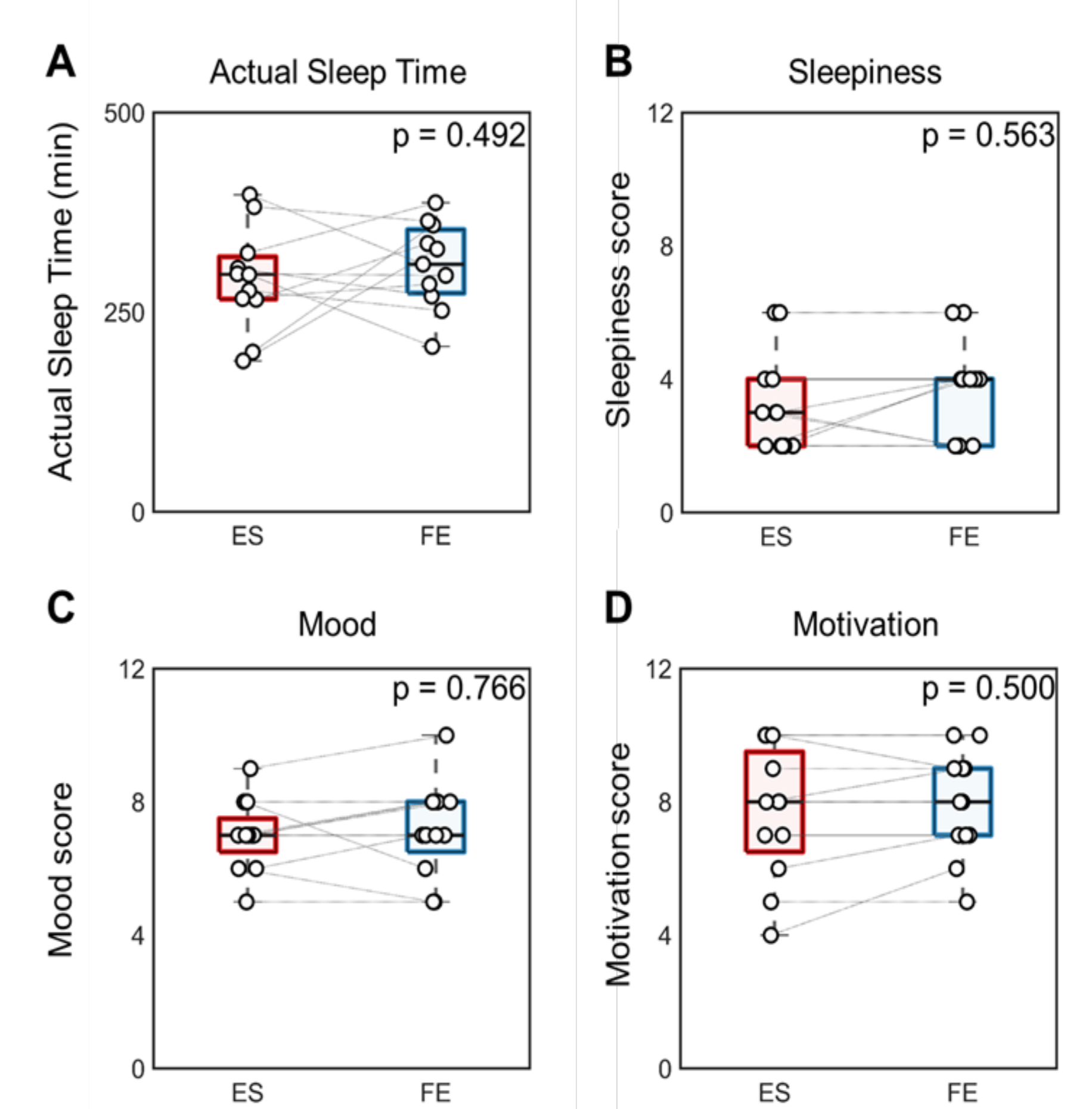
### Data Acquisition:

- 19 young adult healthy subjects (26 ± 3yrs, 10 females);
- **Actigraphy** (7 days), was used to monitor wake-sleep cycles and determine sleep time before experiments;
- **Two experimental visits** in consecutive days;
- Participants were presented with amusing video-clips:
  - **Emotion Suppression condition (ES)**: participants were asked to suppress their facial reactions;
  - **Free Expression condition (FE)**: participants were left free to express emotional responses.
- **Three task sessions** were completed in each experimental visit but only the first was initially analyzed to avoid fatigue effects;
- **Facial-view video** and **high-density(hd) EEG** (64-electrodes) were continuously recorded during the tasks;
- Self-reported measures of **sleepiness**, **mood** and **motivation** were obtained using Likert-scales (0-10).

### Data Analysis:

- Manual marking of **changes in facial expression** associated with congruent electromyographical (EMG) activity;
- **Preprocessing** of continuous hd-EEG recordings (filtering 0.5-45 Hz, bad channel detection, ICA-based artifact reduction).
- Source-modeling using **sLORETA** in Brainstorm.
- Computation of **signal power** in **4s-long epochs** immediately preceding the **onset of changes in facial expression**.

## ACTIGRAPHY AND SCALES

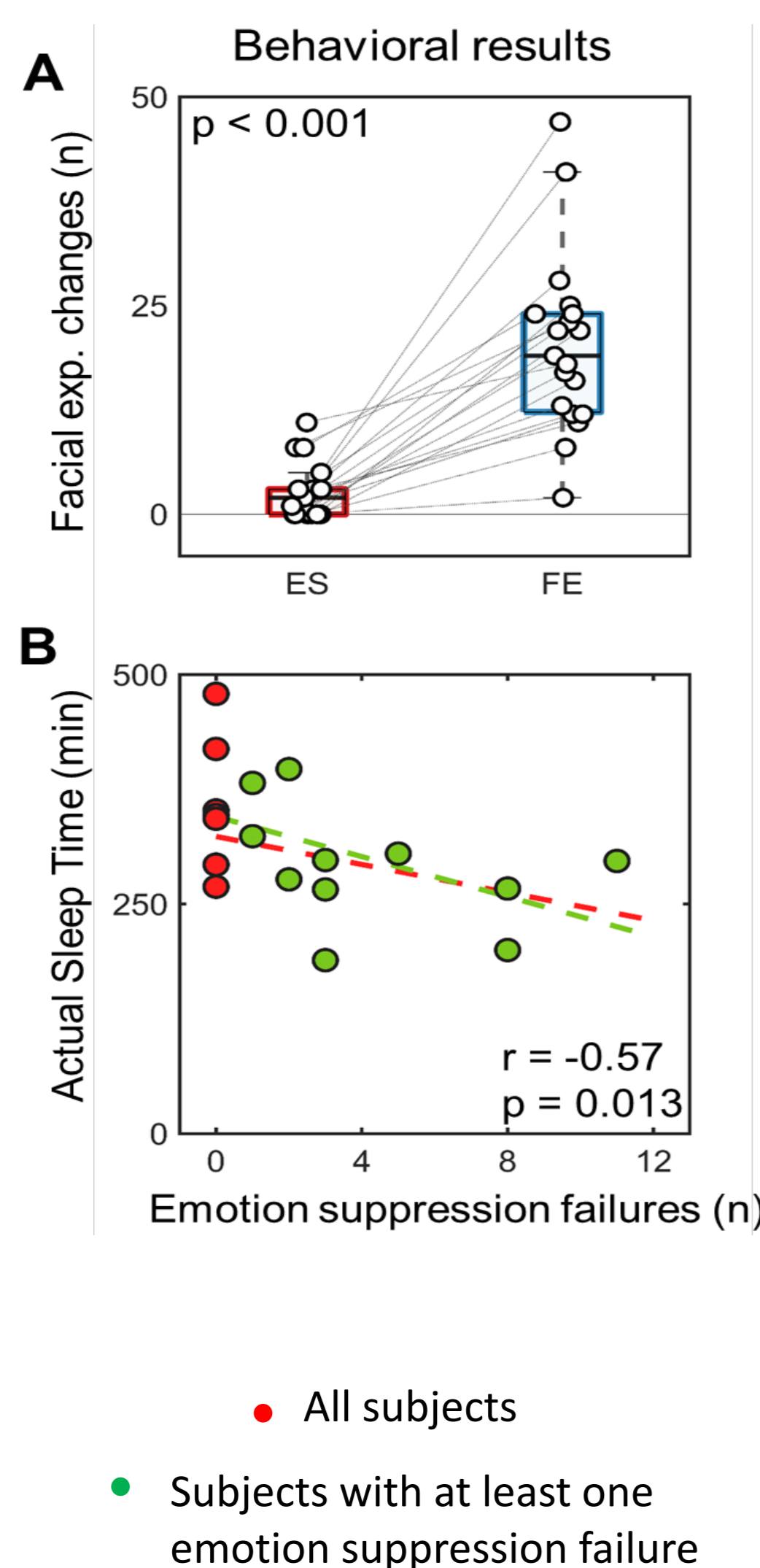


No differences across experimental conditions (ES, FE) were found for **actual sleep time (A)**, **sleepiness (B)**, **mood (C)** and **motivation (D)**. Non-parametric permutation test (N=18 for actual sleep time due to missing data in one subjects; N=19 for other comparisons).

## BEHAVIORAL RESULTS

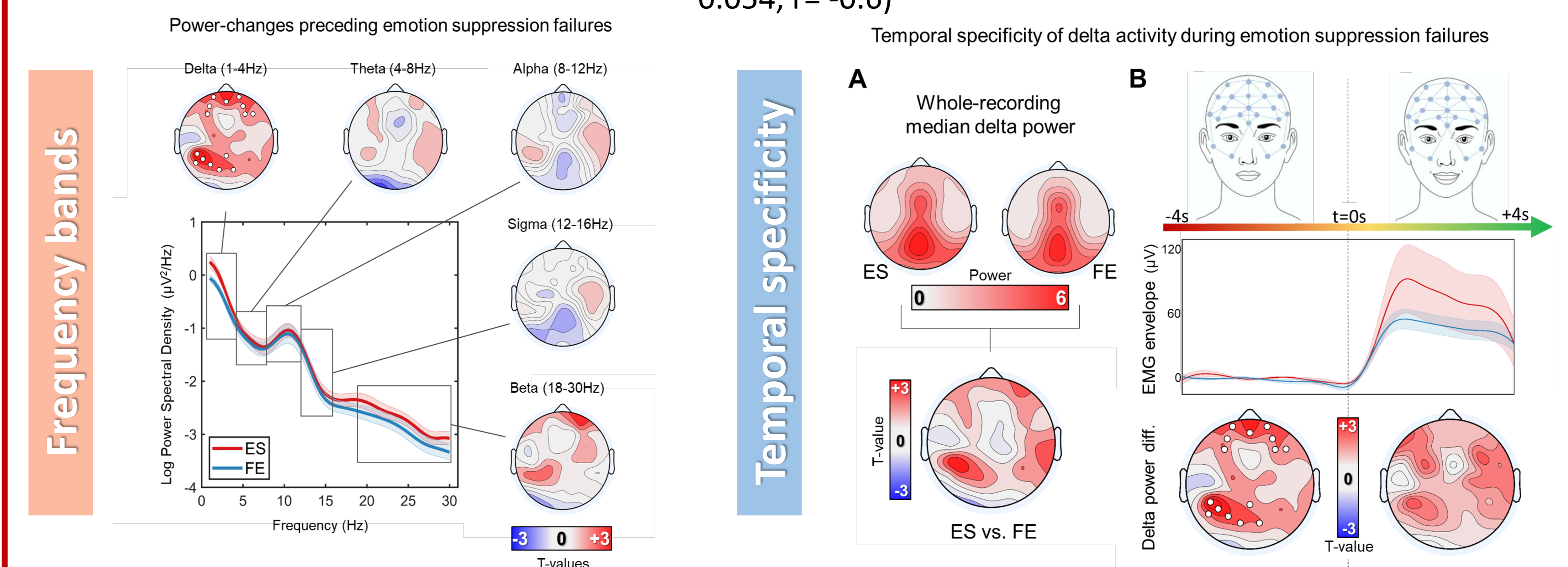
We found a negative correlation between **actual sleep time** in the night preceding the ES experiment and **absolute number of emotion suppression failures** (Spearman rho, non-parametric permutation test; N=19).

**Twelve participants** showed at least one emotion suppression failure during the first task-session, and thus were included in further analyses.



## EEG RESULTS

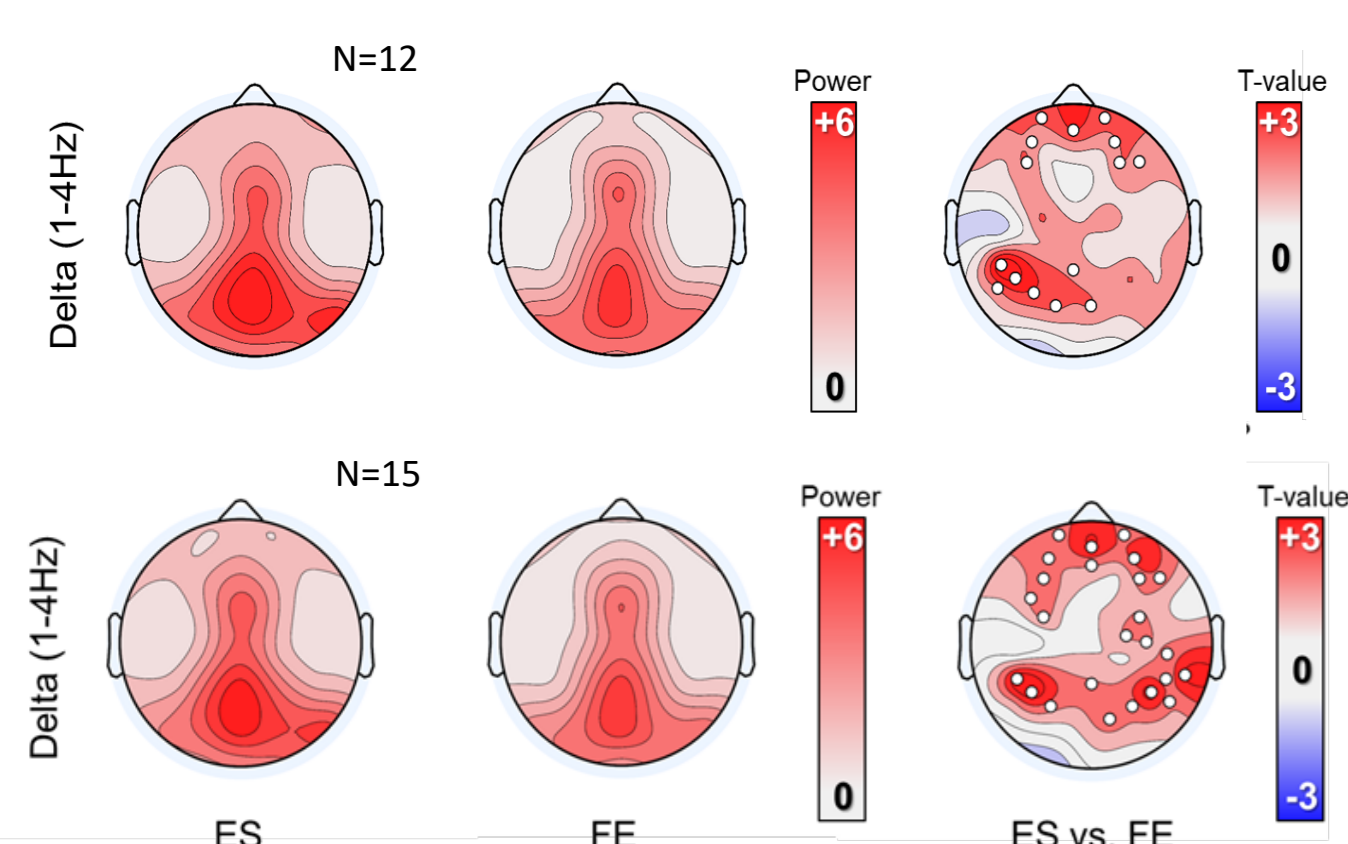
**Emotion suppression failures were preceded by increases in delta (1-4Hz) activity** in frontal and left temporo-parietal electrodes (p<0.05, corrected using permutation-based cluster-level thresholding). Of note, shorter sleep time the night before the experiment tended to be associated with higher delta activity in the frontal cortex (p = 0.054, r = -0.6)



No effects were observed for theta, alpha, sigma and beta frequency-bands. The power spectrum was obtained from the average of all scalp electrodes. Shaded areas correspond to SE.

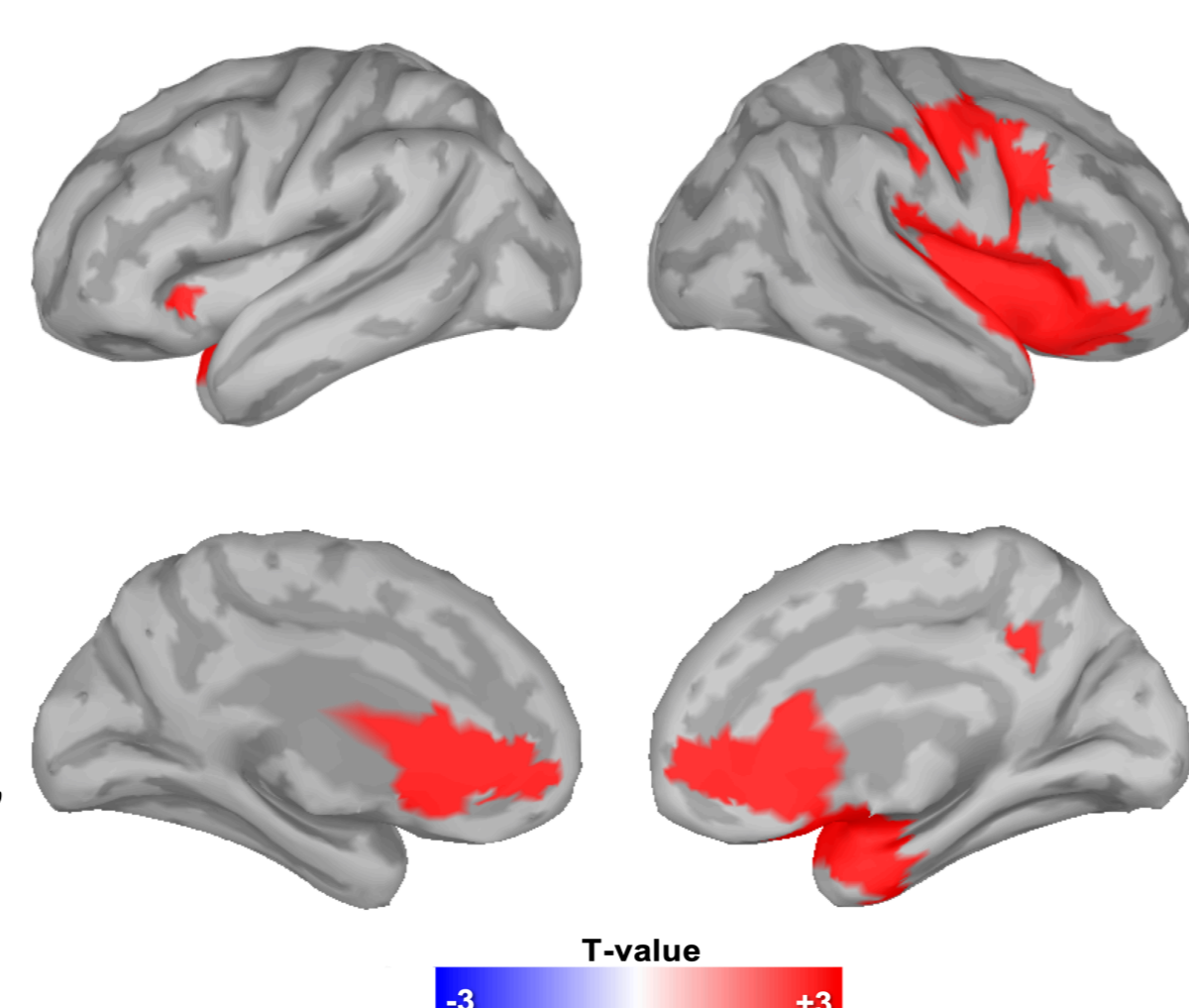
Median (or mean) task-related delta power computed for whole task-related EEG recordings was not different between experimental conditions (ES, FE).

## SOURCE MODELING



The selective increase in delta power preceding emotion suppression failures was confirmed when considering 15 subjects who had at least one emotion suppression failure across the three task sessions of ES (p<0.05, corrected).

Significant changes in delta activity associated with emotion suppression failures were found in bilateral anterior cingulate and medial frontal cortex, anterior insula, right precuneus, precentral gyrus, and middle and inferior frontal gyri (p<0.05, corrected; cluster-forming threshold set to uncorrected p<0.001; N=12).



## CONCLUSIONS

- Self-control failures in an emotion suppression task are preceded by increases in low-frequency, sleep-like activity over frontal, insular and parietal regions.
- Shorter sleep duration was associated with a poorer emotion regulation and tended to be associated with stronger delta activity especially in frontal areas.
- Intrusions of sleep-like activity in the brain network responsible for emotion regulation may affect the efficacy of emotion suppression in healthy individuals.
- These results indicate that local sleep-like activity may represent the cause of emotion suppression failures in humans, and may offer a functional explanation for previous observations linking lack of sleep, changes in frontal activity and emotional dysregulation.

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