

# Boosting slow oscillation during sleep potentiates memory

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*Discussion by  
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# Background

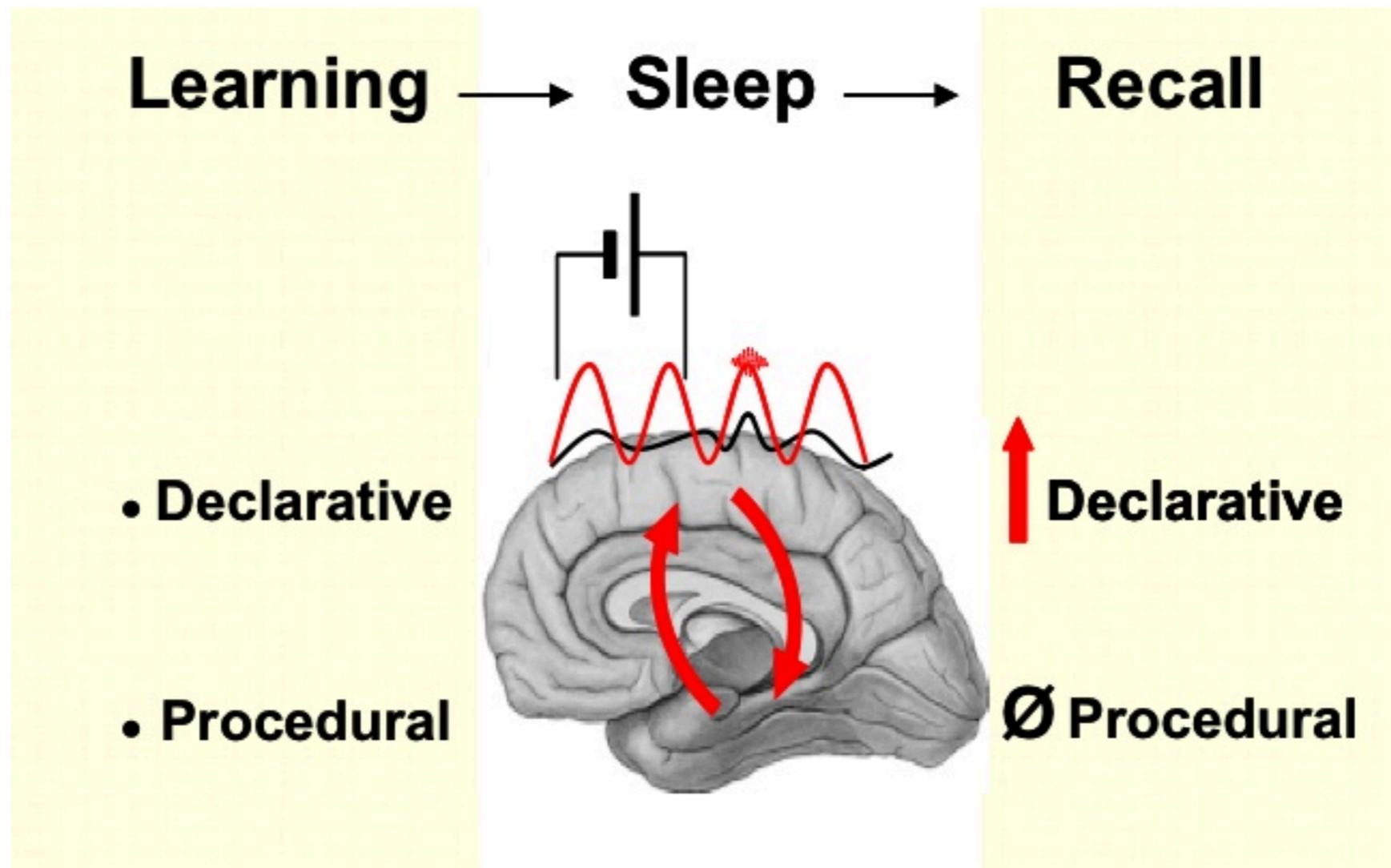
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- Recall is improved following sleep
- Slow wave oscillations synchronize activity within neocortex, thalamus and hippocampus
  - Declarative memory = hippocampus-dependent, early slow wave sleep
  - Non-declarative procedural memory = late REM sleep

**Are slow wave oscillations responsible for the consolidation of hippocampus-dependent declarative memory?**

# Methods: Overview

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# Methods: Learning Period ( $n=13$ )

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- Declarative - paired-associates task
  - Study phase: DOCTOR-NURSE
  - Test phase: DOCTOR - ?
- Procedural - finger tapping task
  - Given sequence (e.g. 4-2-3-1-4)
  - Test: Tap as quickly as possible for 30 seconds
- Cognitive function control tests
  - Word fluency task
  - Digit span test
  - Mood assessment tests

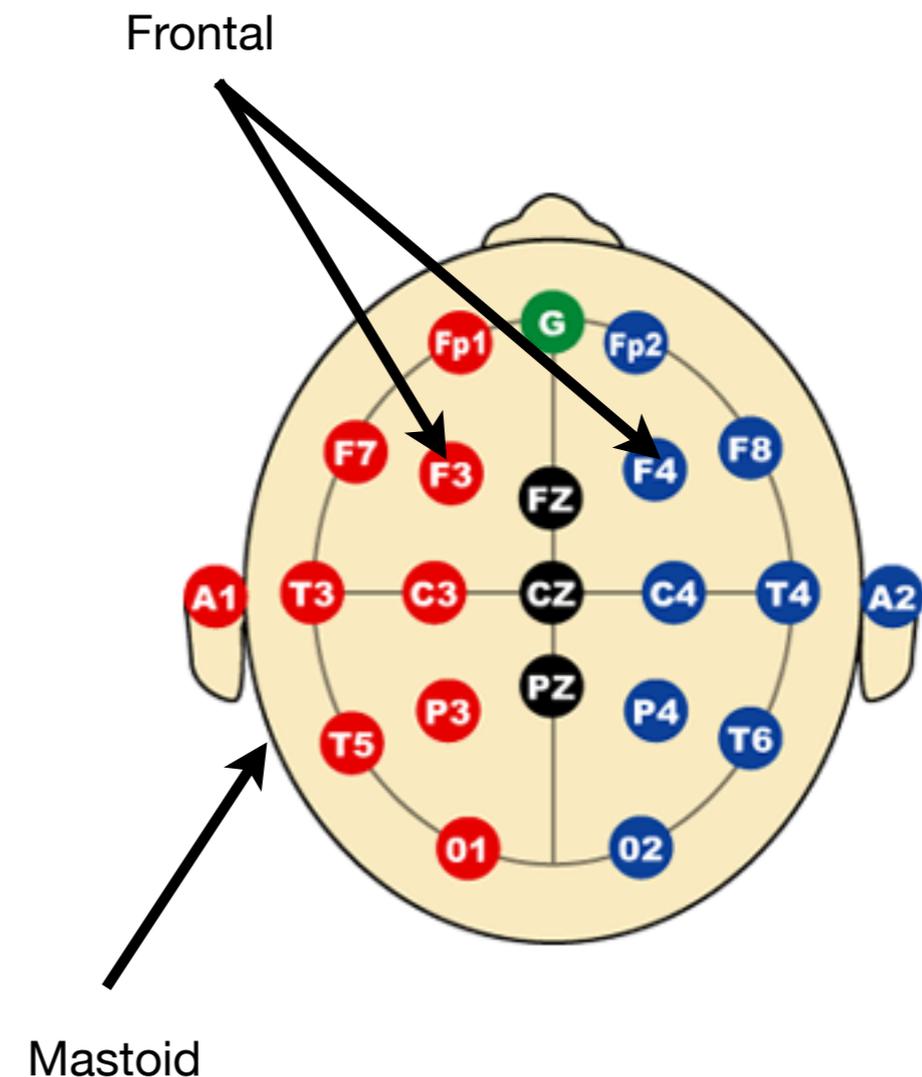
# Methods: Additional Tasks ( $n=10$ )

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- Non-verbal declarative memory
  - Paired-associates with geometric or non-geometric line-drawings
- Mirror-tracing task
  - Trace line drawings of meaningless figures as fast as possible

# Methods: Stimulation

- Frontal and Mastoid electrodes
- Endogenous slow wave oscillations originate in prefrontal cortex
- Sham condition - electrodes applied but not turned on
- All participants participated in both sham and stimulation sessions



# Methods: Stimulation

- Started after 4 min of non-REM sleep stage 2
- Five 5 min intervals of 0.75 Hz stimulation
- One minute intervals with no stimulation

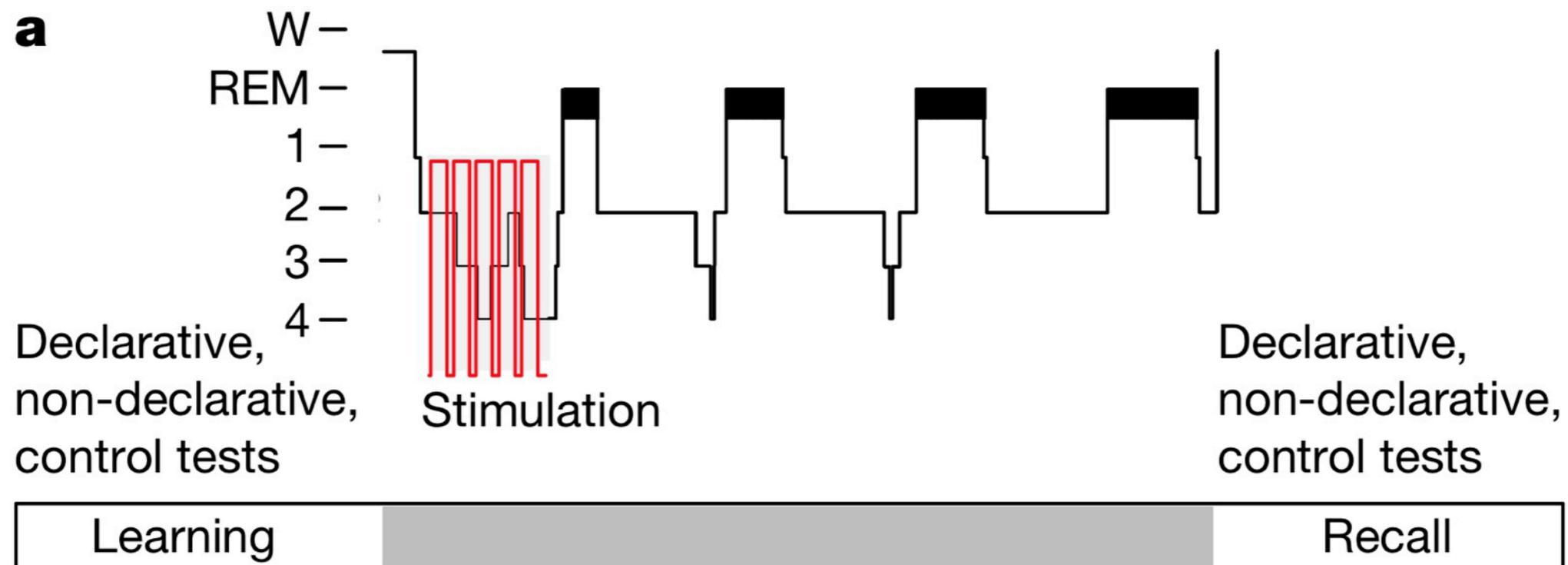


Figure 1a

# Methods: Morning Test Period

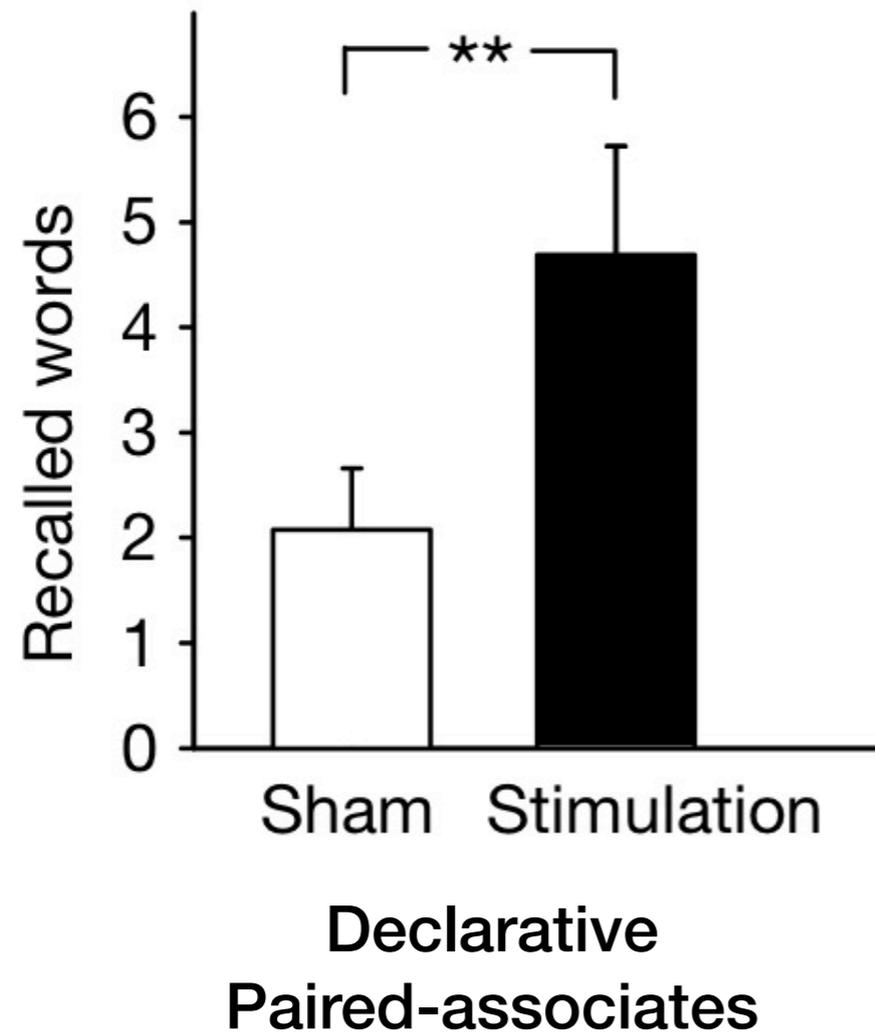
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- 30 minutes after waking retrieval was measured
  - Retention = recall after sleep - recall before sleep
- After recall cognitive control tasks were administered again

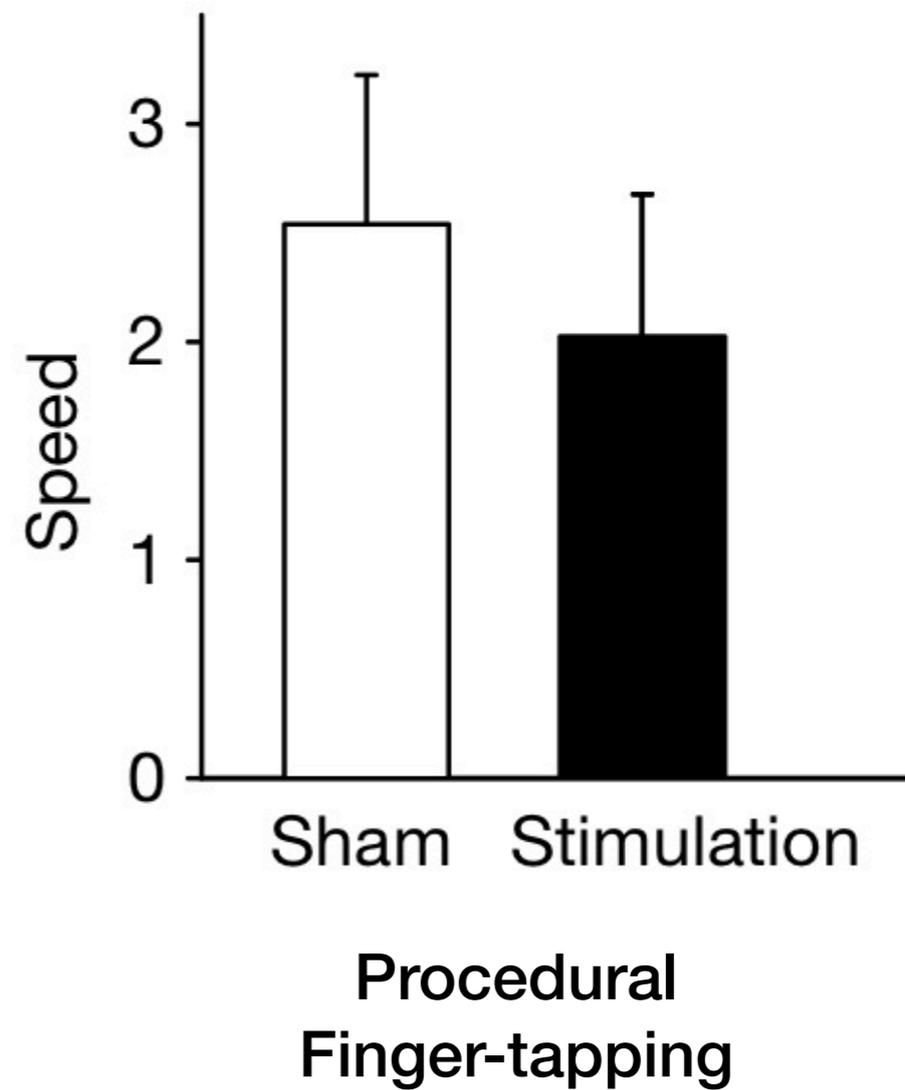
# Results: Memory Tasks

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**b**

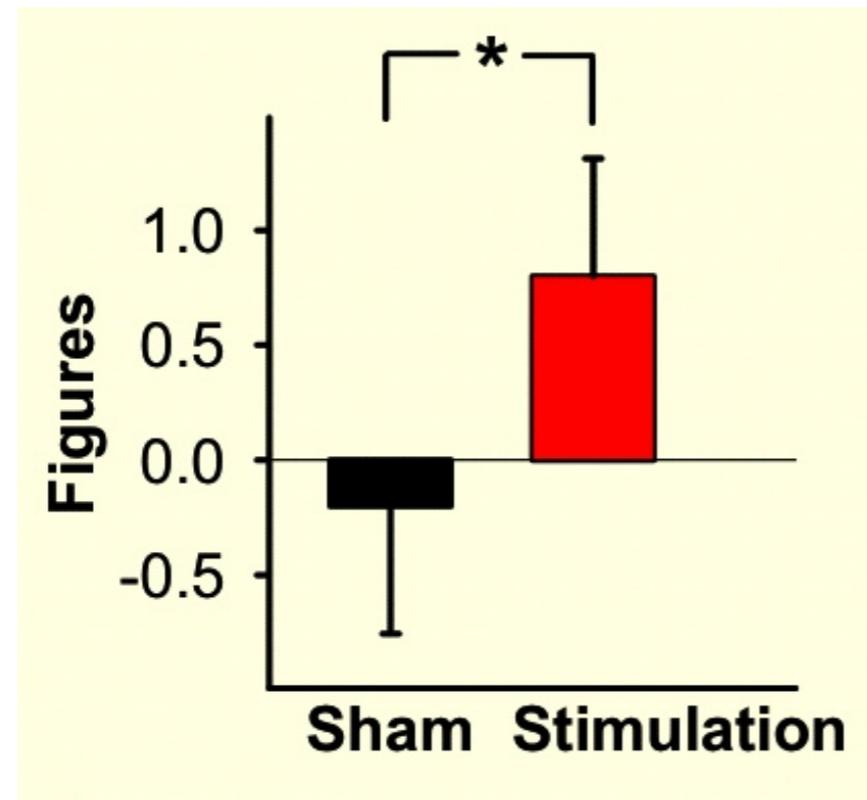


**c**

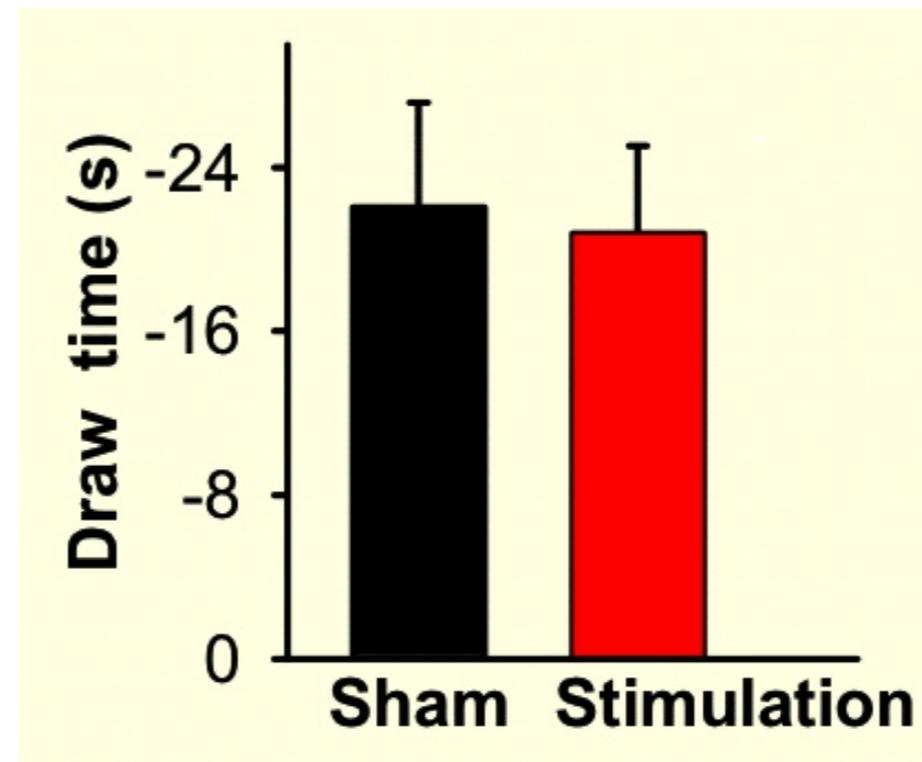


Figures 1b & 1c

# Results: Alternative Tests



**Declarative**  
**(Non-verbal paired associates)**



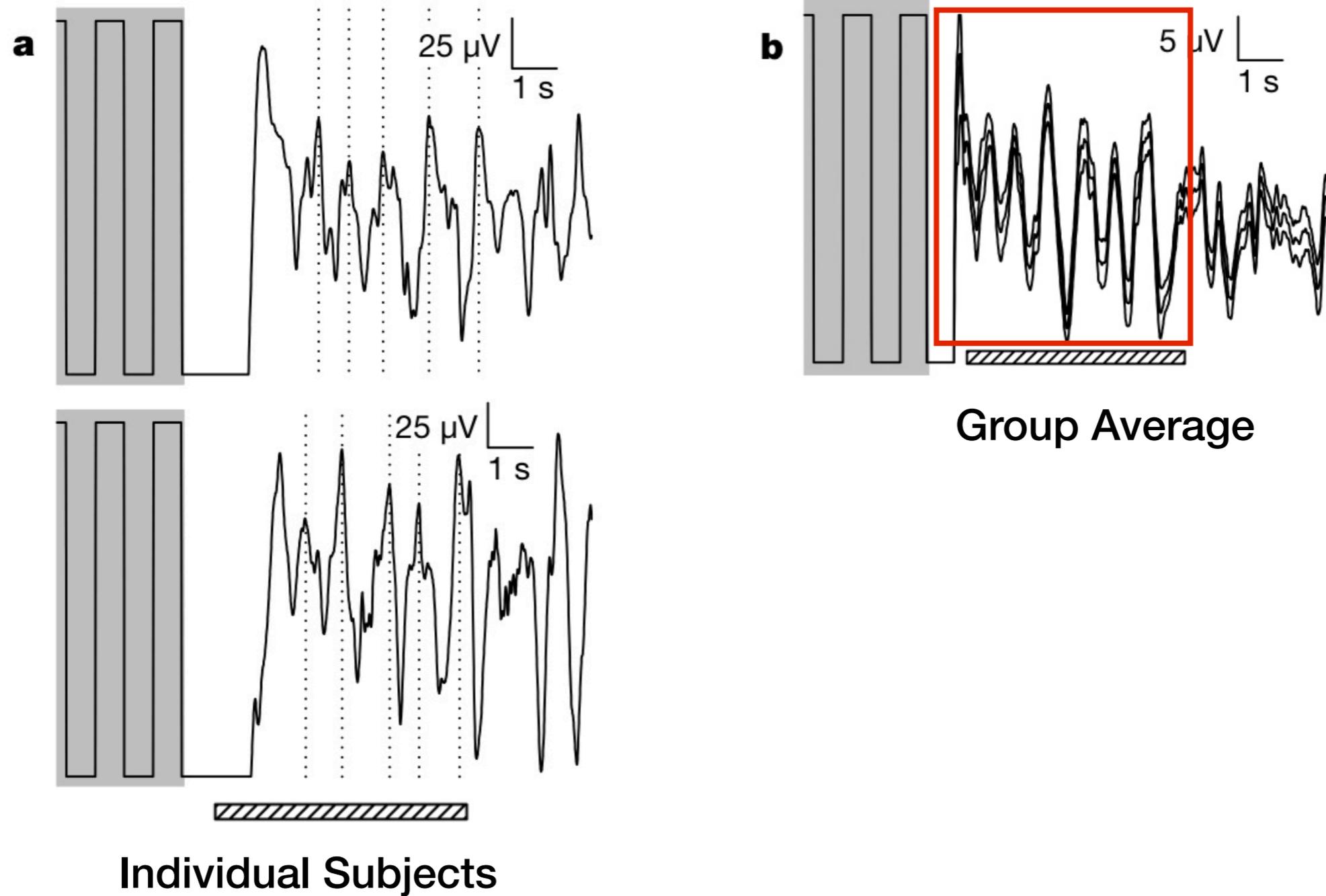
**Procedural**  
**(Mirror tracing)**

# Results: Sleep Analyses

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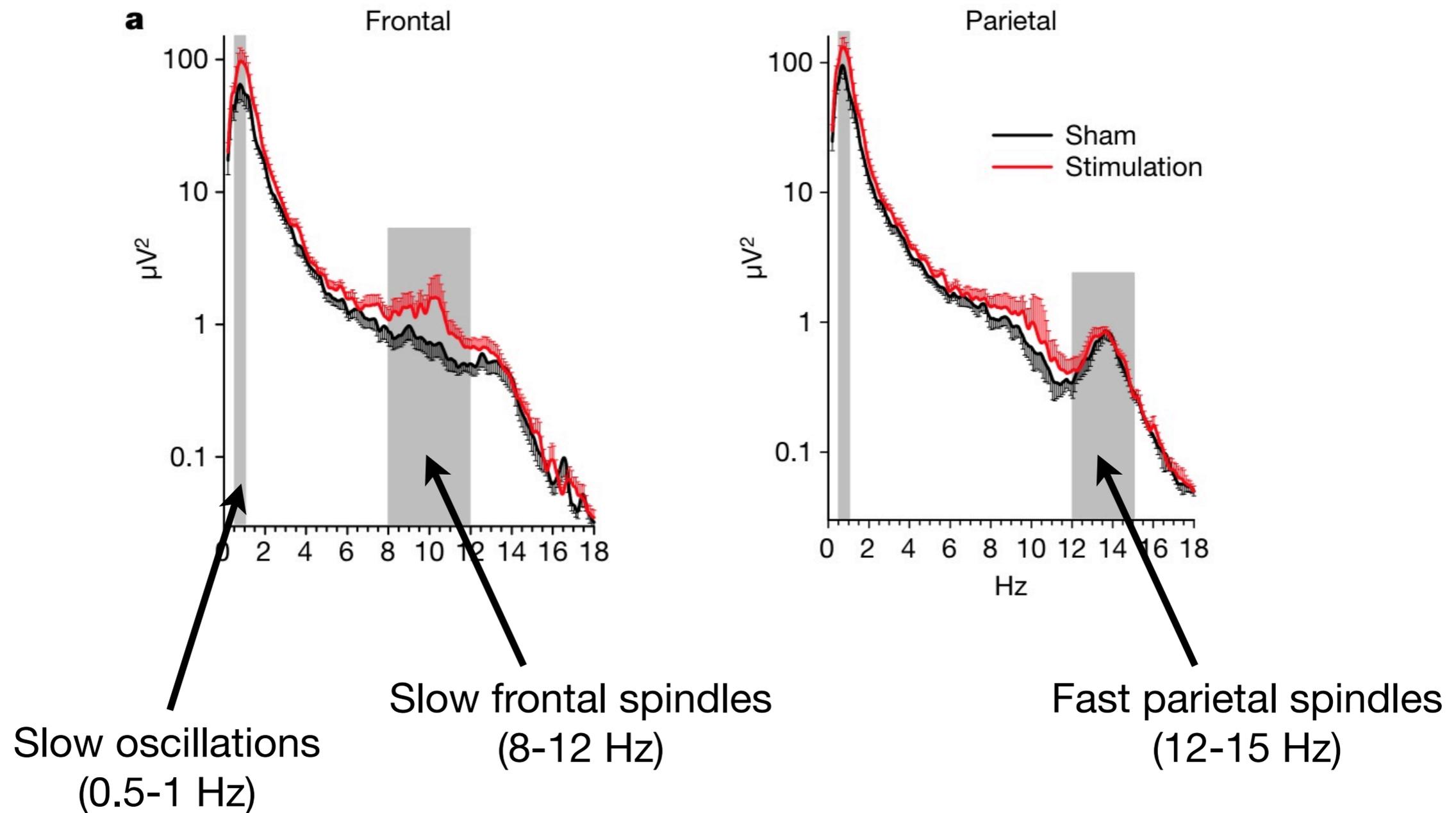
- Evaluation of sleep stage (REM or non-REM)
  - Intervals between stimulation periods: Evaluated every 10 seconds
  - Remainder of night: Evaluated every 30 seconds
- EEG power spectra
  - Intervals between stimulation
- Spindle counts
  - Number of slow and fast

# EEG - Interstimulation Intervals

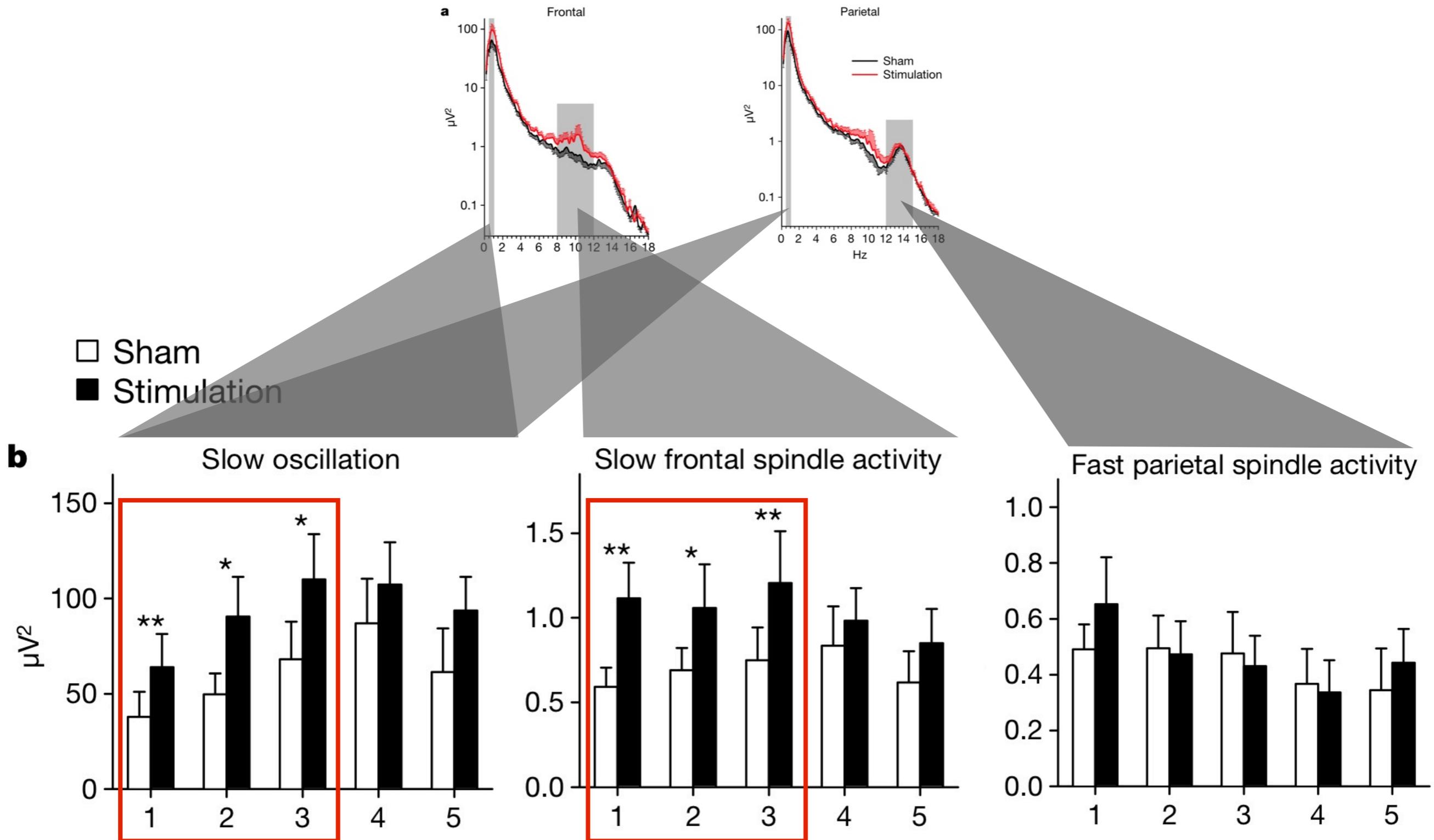


Figures 2a & 2b

# EEG Power Spectra - Interstimulation Intervals



# EEG Power Spectra - Interstimulation Intervals



# Overall EEG Analysis

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- Interstimulation intervals - more time spent in slow wave sleep following stim
- First hour after stimulation - no difference between sham & stimulation
- Entire night - no difference between sham & stimulation

# Controls

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- Not observed for 5 Hz (theta) oscillations
- No improvement when stimulation is shifted later in sleep
- No change in blood hormone levels
- No difference in cognitive function tasks before and after sleep

**No non-specific changes from slow wave stimulation are responsible for declarative memory enhancement**

# Possible Mechanisms

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- Slow oscillations -> spindle activity -> calcium transients
- Repeated spindle activation can trigger long-term memory formation
- Strengthen neocortical connections

# Conclusions

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- Slow oscillations early in sleep have causal role in consolidating hippocampus-dependent memory
- This is not due to:
  - General stimulation effects
  - Changes in mood at recall
  - Changes in hormone levels
- Can't differentiate between slowed decay vs actual gain. Why not? How could they?