Vocabulary acquisition during sleep

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Introduction

Current state of research: Humans process and understand simple sentences during sleep (Daltrozzo et al., 2012), and can form implicit memories for single words (Ruch et al., 2014) and novel tone-odor associations (Arzi et al., 2012) while asleep. Sleep-played stimuli can enhance and entrain slow-waves, which in turn boost memory consolidation. (Ngo et al., 2013).

Aim: Teach new vocabulary (i.e. semantic associations) during deep sleep.

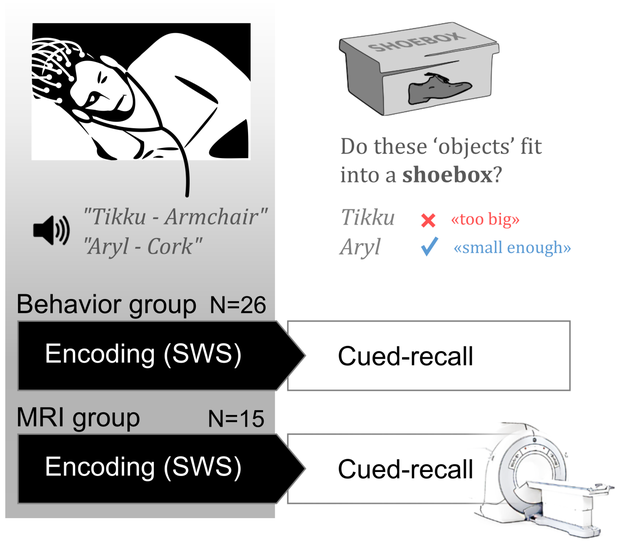
Assumed mechanism: Associations are formed by way of hippocampus. Depolarizing peaks of cortical slow waves (upstates) provide window of opportunity for encoding.

Method

We presented 48 German-foreign word pairs to 41 participants who were in deep NREM sleep during an afternoon nap.

Following sleep, participants performed a 2-alternative forced-choice task which assessed semantic knowledge of sleep-played foreign words.

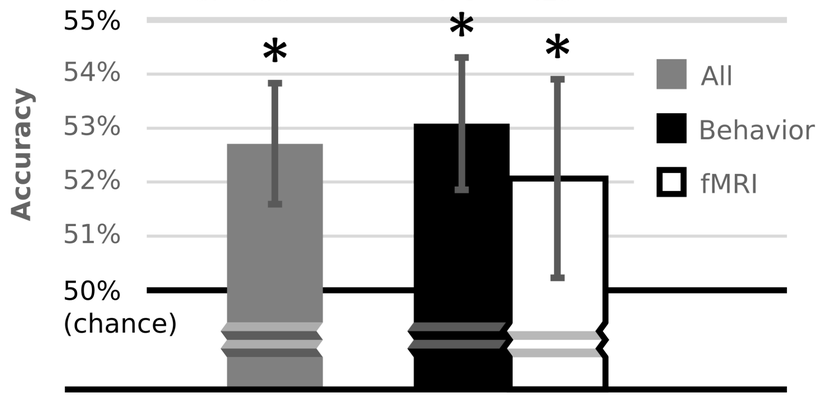
15 of the 41 participants underwent fMRI recording during retrieval.



Results

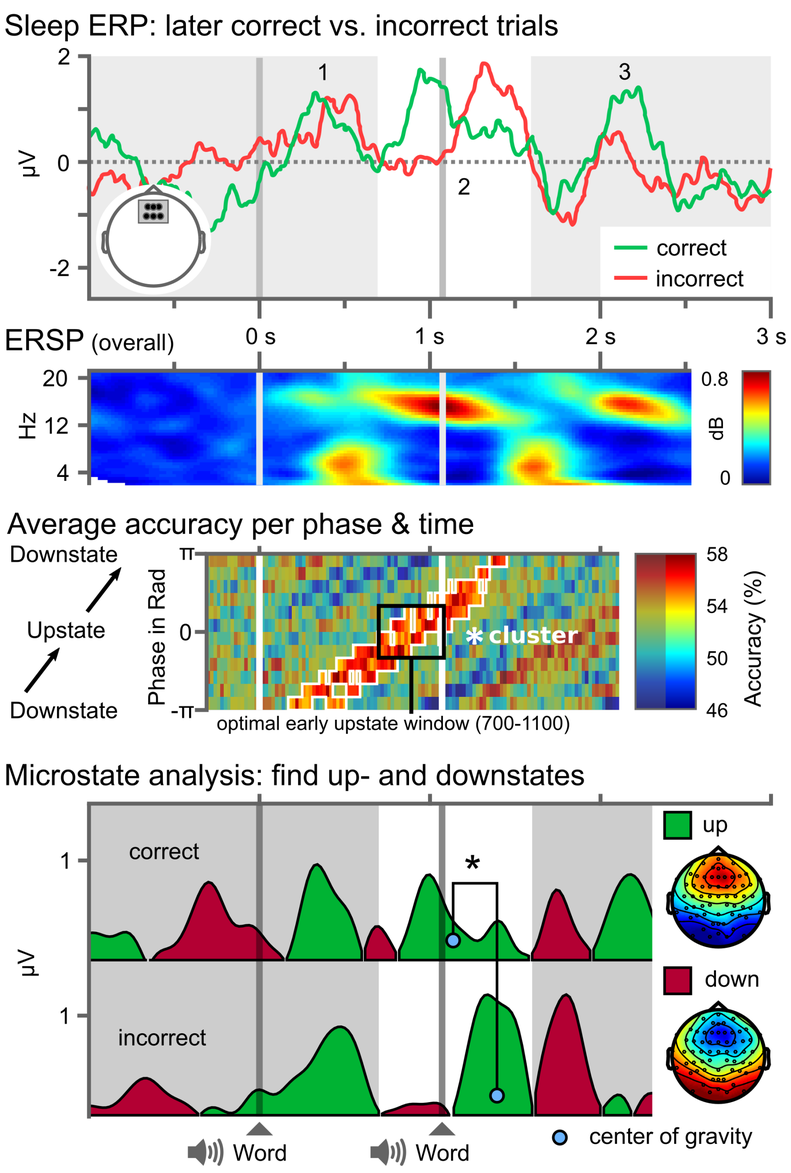
Behavior

Participants identified semantic attributes (size) of sleep-played vocabulary significantly above chance accuracy.



EEG during Sleep

Stimuli produced three consecutive slow-wave peaks (upstates). The second upstate led to correct responses if it occurred early, i.e. before the 2nd stimulus.



Phase analysis confirmed an early upstate is significantly associated with successful retention.

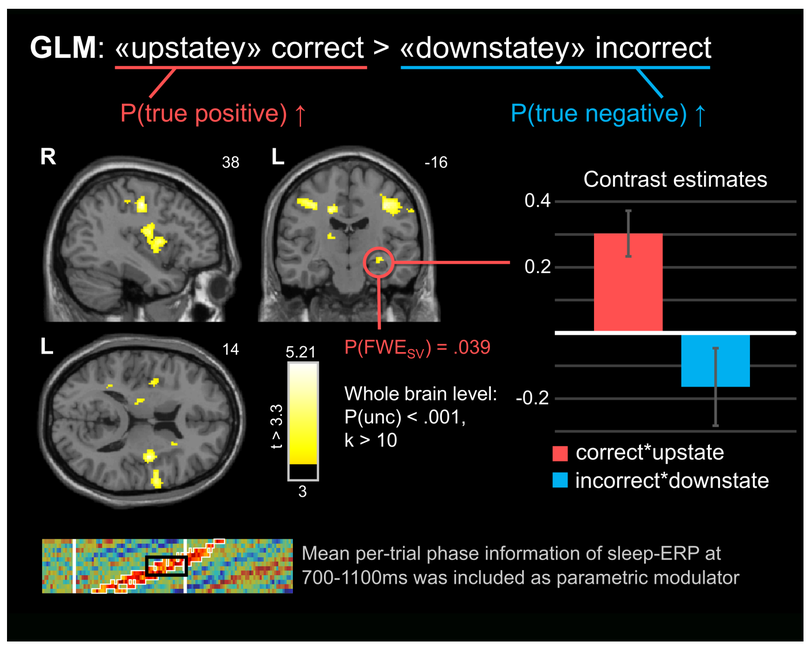
Microstate analysis confirmed evoked up- and downstates as dominant features in response to stimuli.

Second evoked upstate occured significantly earlier for later correct vs incorrect trials.

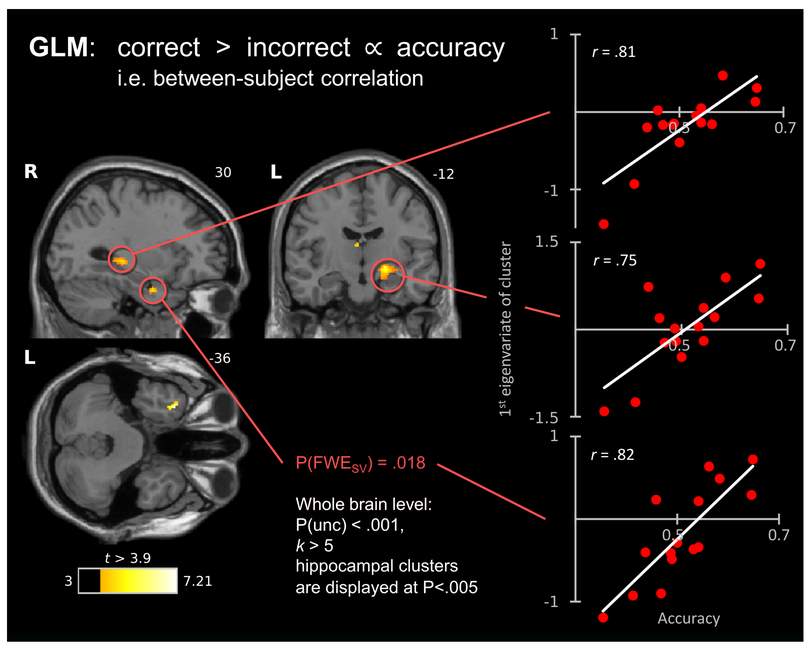
fMRI

Hippocampus is positively associated with successful retrieval of sleep-played vocabulary.

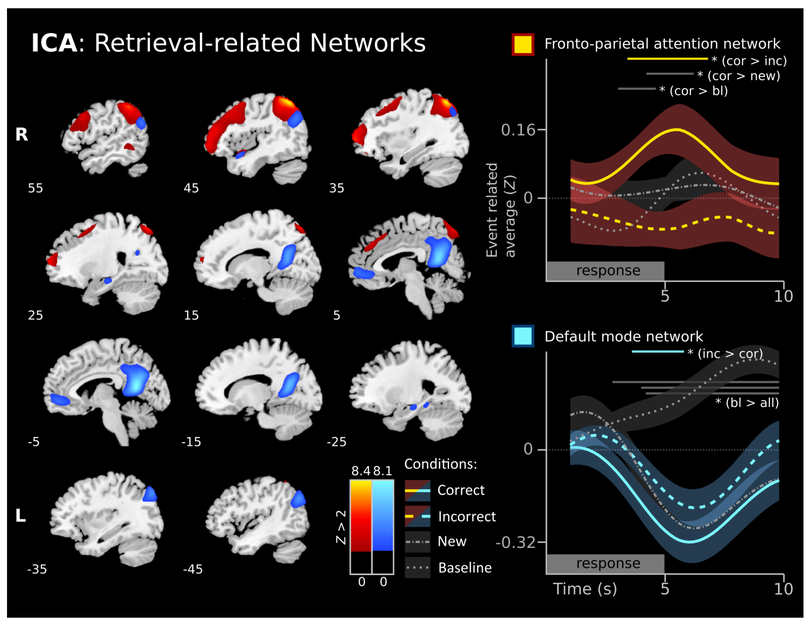
Therefore, hippocampus putatively has mediated sleep-learning.



Hippocampal signal linearly related to retrieval performance across subjects.



Two functional networks could significantly differentiate between correct and incorrect trials: The right hemispheric fronto-parietal, task-positive attention network (red/yellow) and the task-negative default mode network (blue).



Conclusion

- Verbal, associative learning is possible during sleep
- Early peaks of slow-waves support learning by providing «window of opportunity»
- Hippocampus mediates sleep-learning
- Task–positive and –negative functional networks are associated with successful retrieval of sleep-learned associations

References

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