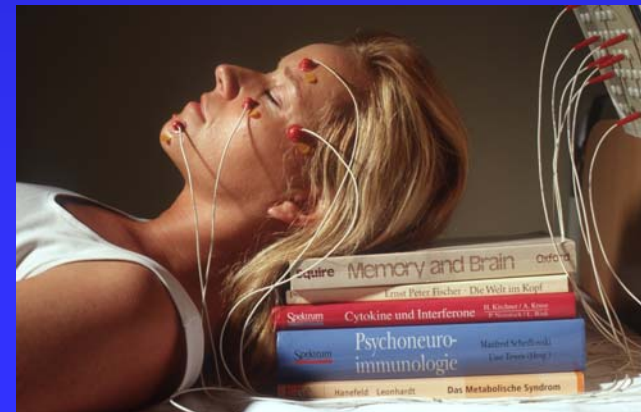


The memory function of sleep

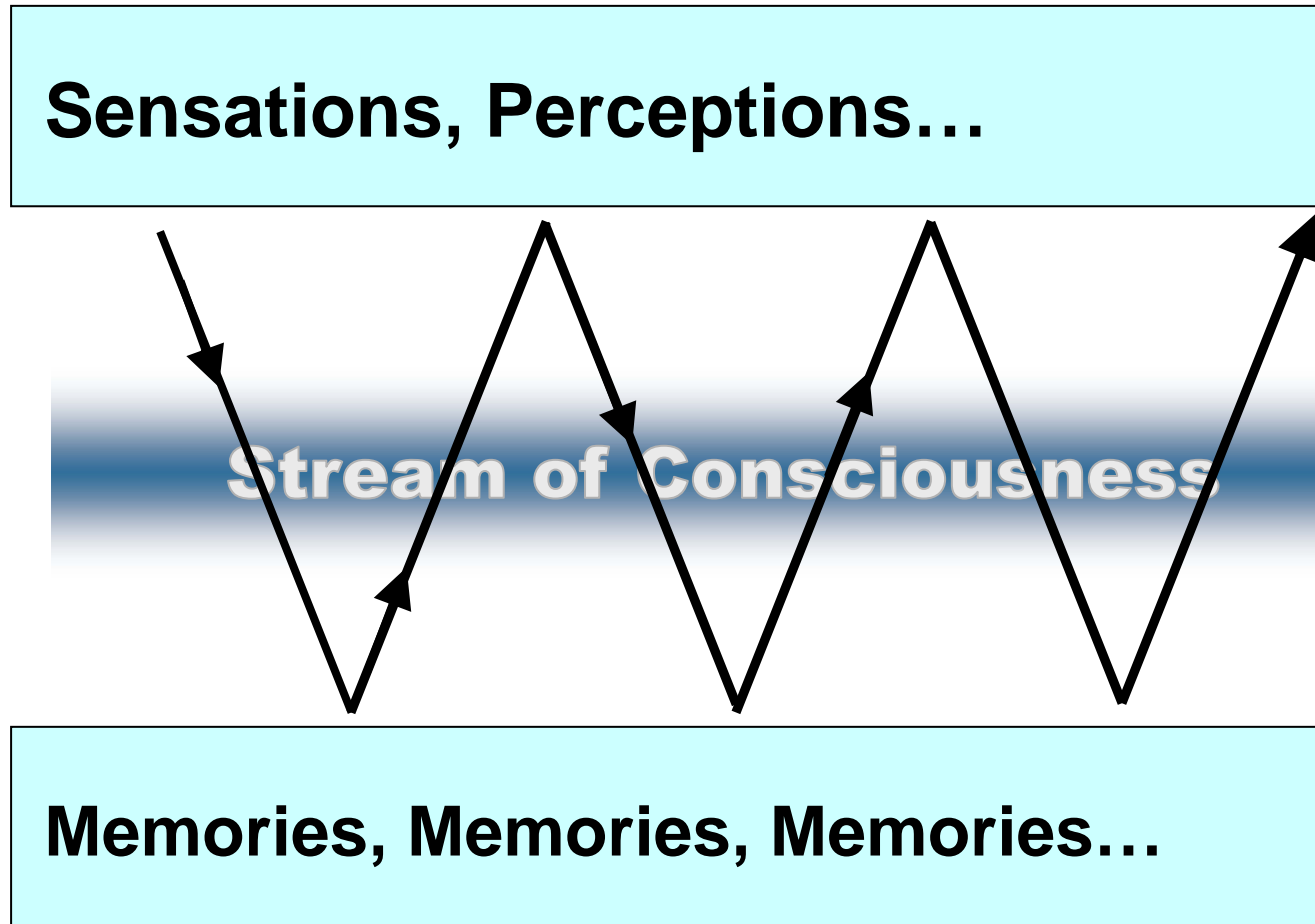
Jan Born

Christian Benedict, Sonja Binder, Gordon Feld, Susanne Diekelmann, Stoyan Dimitrov, Spyridos Drosopoulos, Stephan Fischer, Steffen Gais, Manfred Hallschmid, Rosi Krug, Tanja Lange, Lisa Marshall, Matthias Mölle, Barbara Ölke, Volker Ott, Christiane Otten, Anja Otterbein, Björn Rasch, Ullrich Wagner, Ines Wilhelm

Department of Neuroendocrinology, University of Lübeck



The Role of Memory for Establishing Consciousness



René Descartes
1596-1650



Immanuel Kant
1724-1804



William James
1842-1910

Memory

Learn



Consolidate



Recall

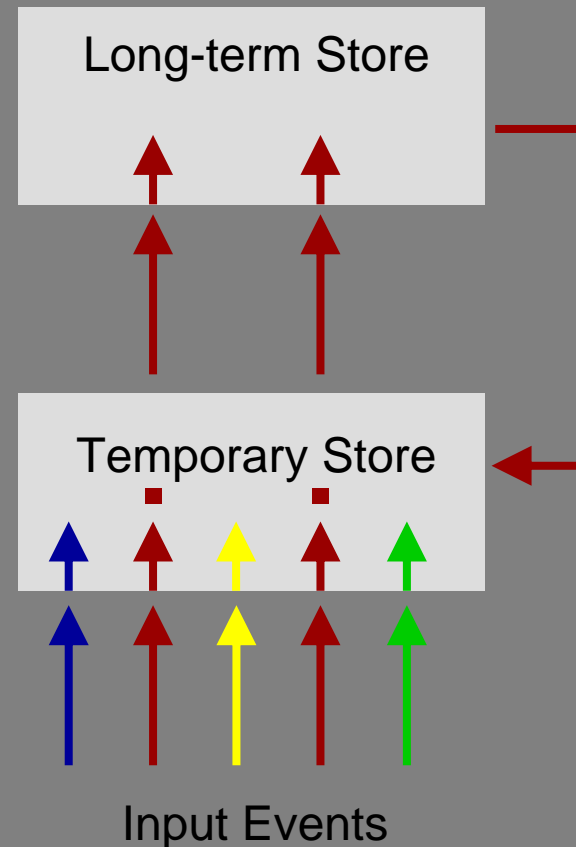


Concept

Why offline during sleep?

- Long-term memory formation requires systems consolidation.
- Systems consolidation allows the extraction of “gist” from newly encoded memories and its integration within the long-term store.
- Systems consolidation would interfere with the brain’s regular processing of stimuli in the wake state.

Two-stage Memory System



TASKs

Declarative

- Paired-associate learning

Kleidung – Hut

Flut – Meer

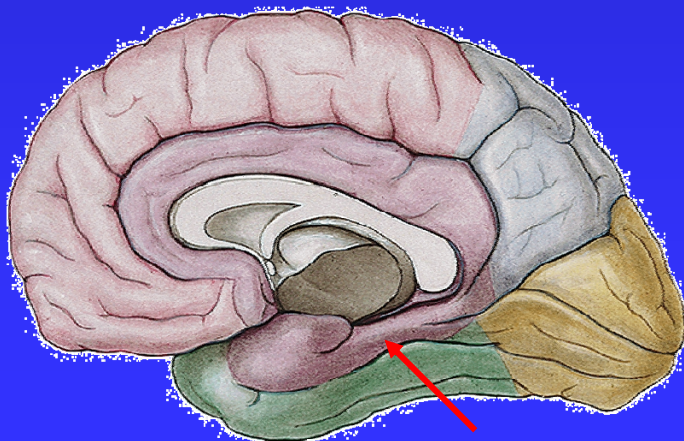
...

...

...



- Spatial rotation
- Stories
- ...



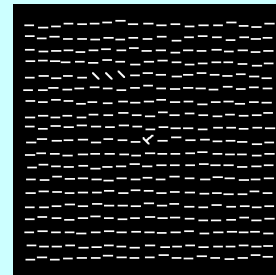
Hippocampus

Non-Declarative / Procedural

- Mirror tracing

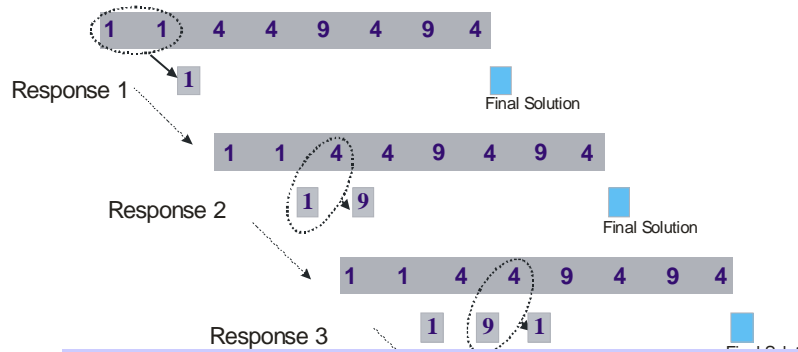


- Wordstem priming
- Visual texture discrimination



- Motor sequence
(finger-to-thumb opposition)

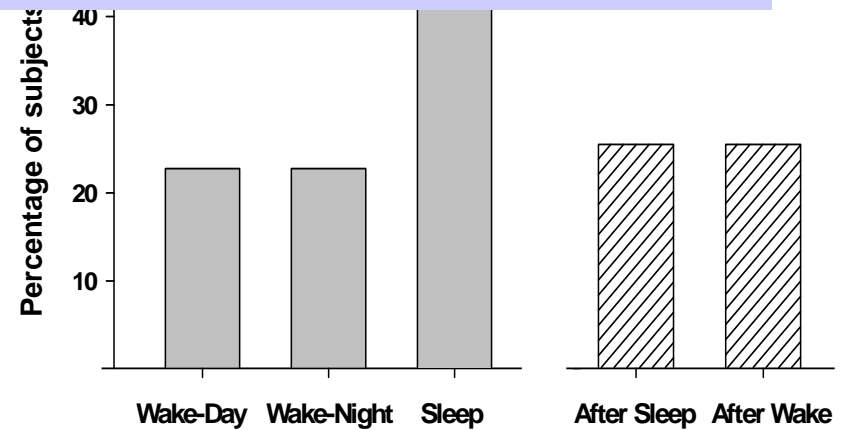
Number Reduction Task

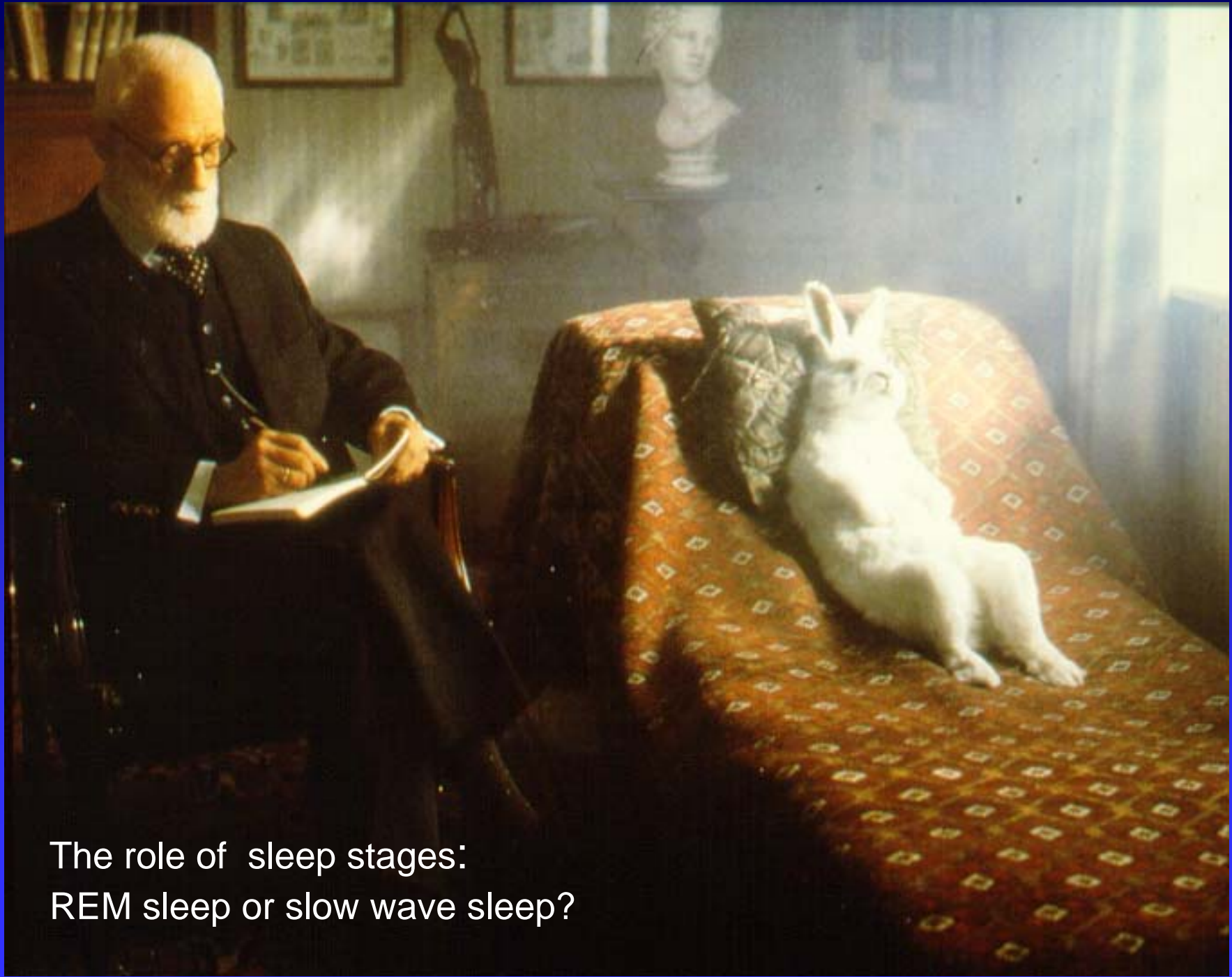


% Subjects Gaining Insight

Sleep consolidates memory by reorganizing memory representations and thereby can induce a gain of procedural skill or explicit knowledge.

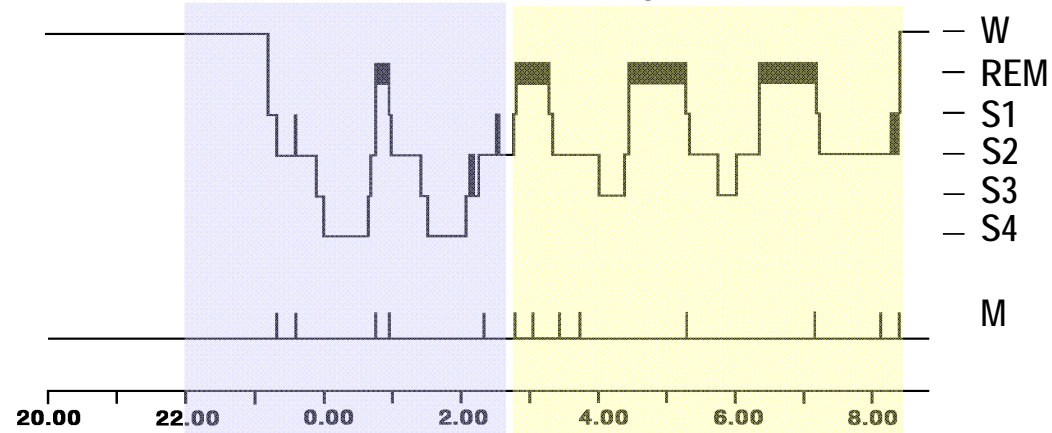
3 Blocks	SLEEP 23:00-7:00 h	10 Blocks
3 Blocks	WAKE 23:00-7:00 h	10 Blocks
3 Blocks	WAKE 11:00-19:00 h	10 Blocks



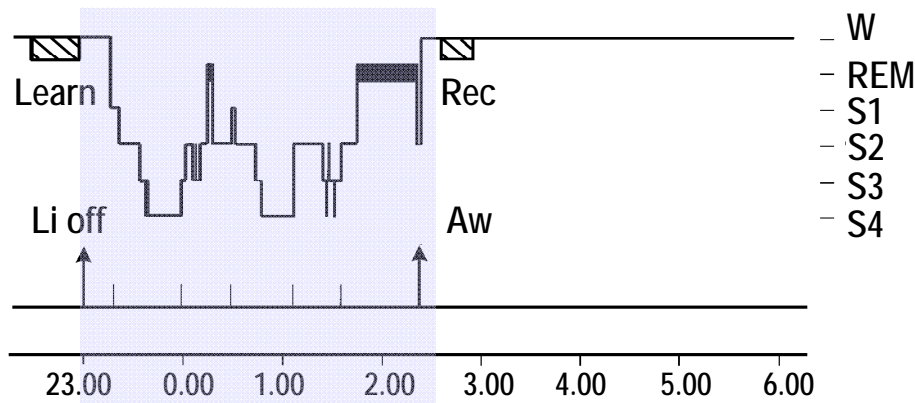


The role of sleep stages:
REM sleep or slow wave sleep?

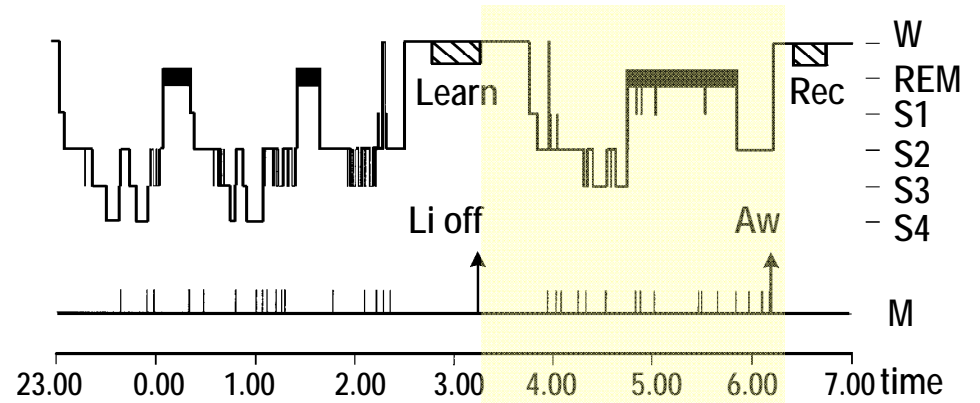
Total Sleep



Early Sleep



Late Sleep



Learn



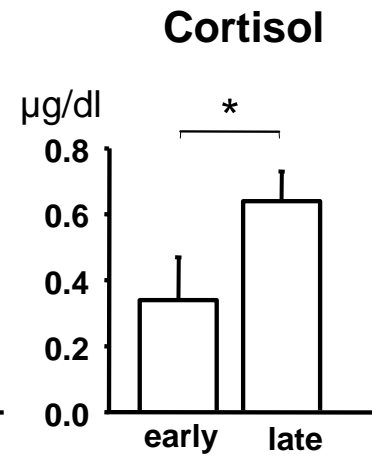
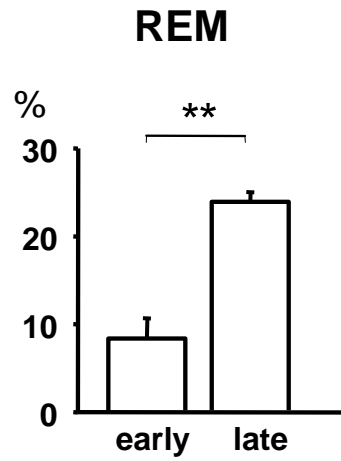
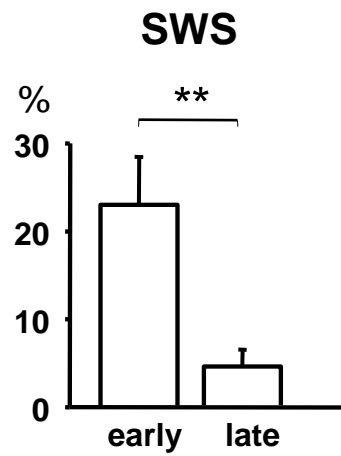
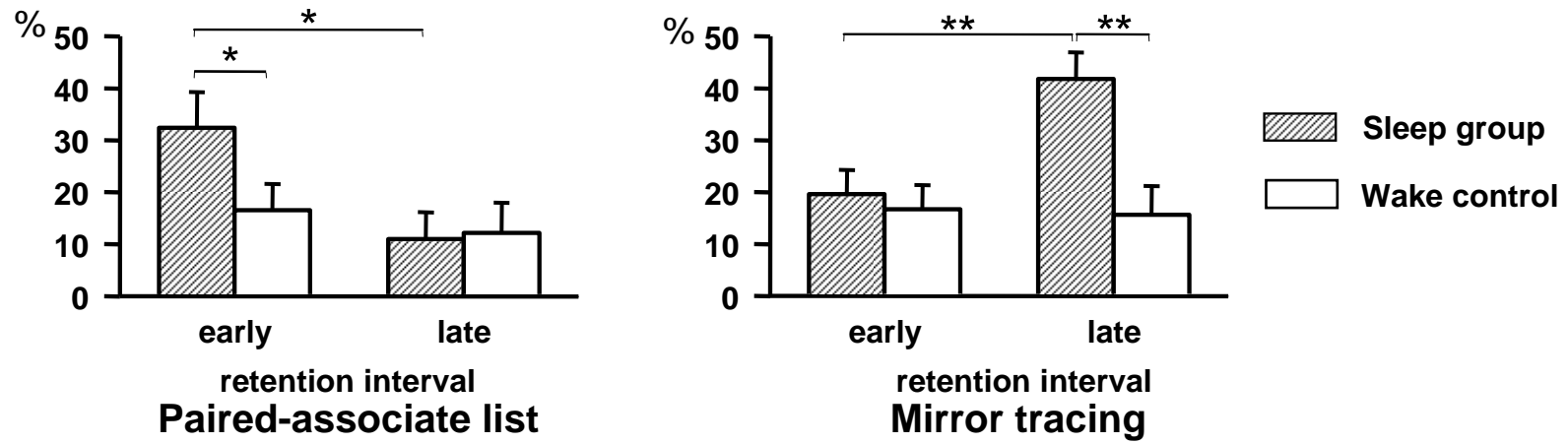
Consolidate



Recall



% - Improvement

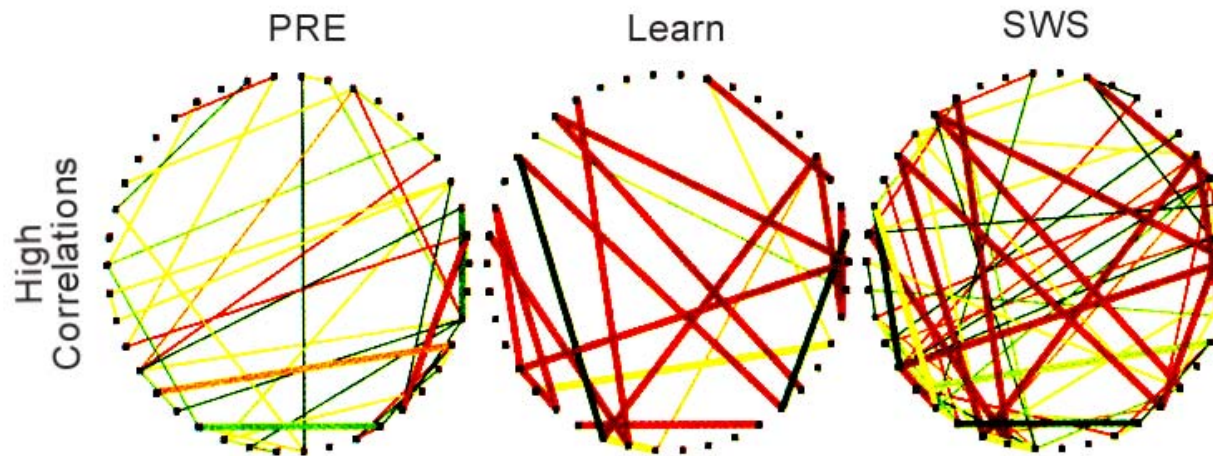


Memory consolidation during sleep depends on the type of memory system

- Declarative memory depending on the hippocampus benefits particularly from SWS-rich periods of sleep
- Procedural and emotional memory not depending on the hippocampus benefits particularly from REM sleep-rich sleep

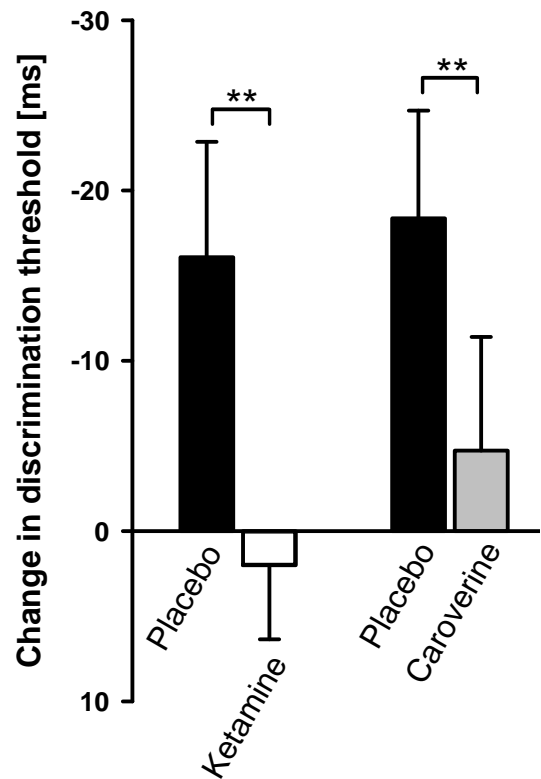
Reactivation of neuronal patterns during SWS after learning

Activity of single neurons (place cells) in rat hippocampus



Reactivation Model of Declarative Me

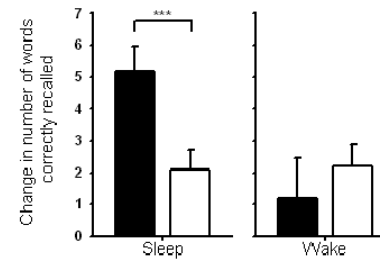
Glutamate receptor blocker block sleep-dependent gain in visual texture discrimination



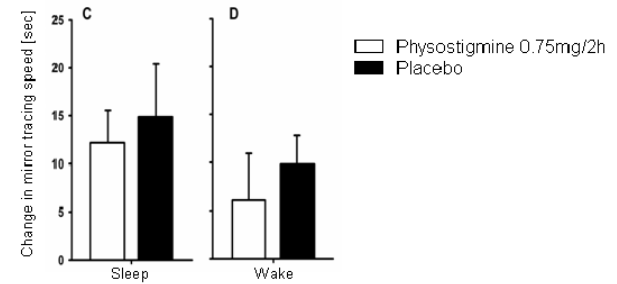
Gais et al. 2008, J Neurosci

Effect of Physostigmine on Memory Consolidation in Sleep

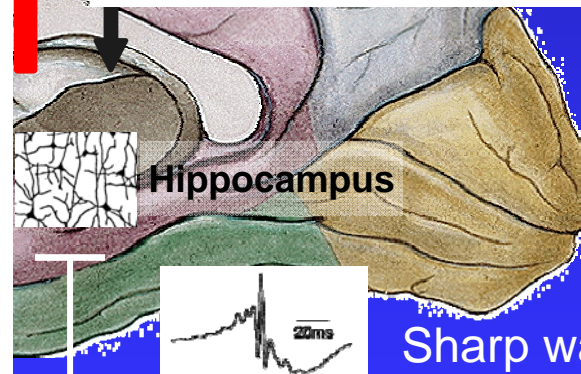
Paired Associate Word Lists



Mirror Tracing



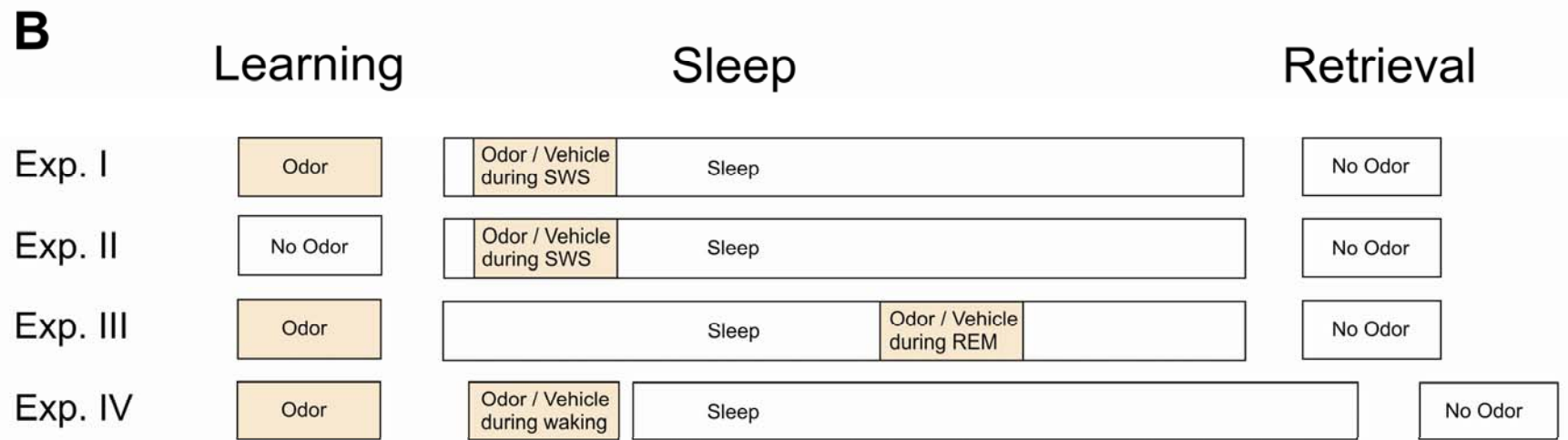
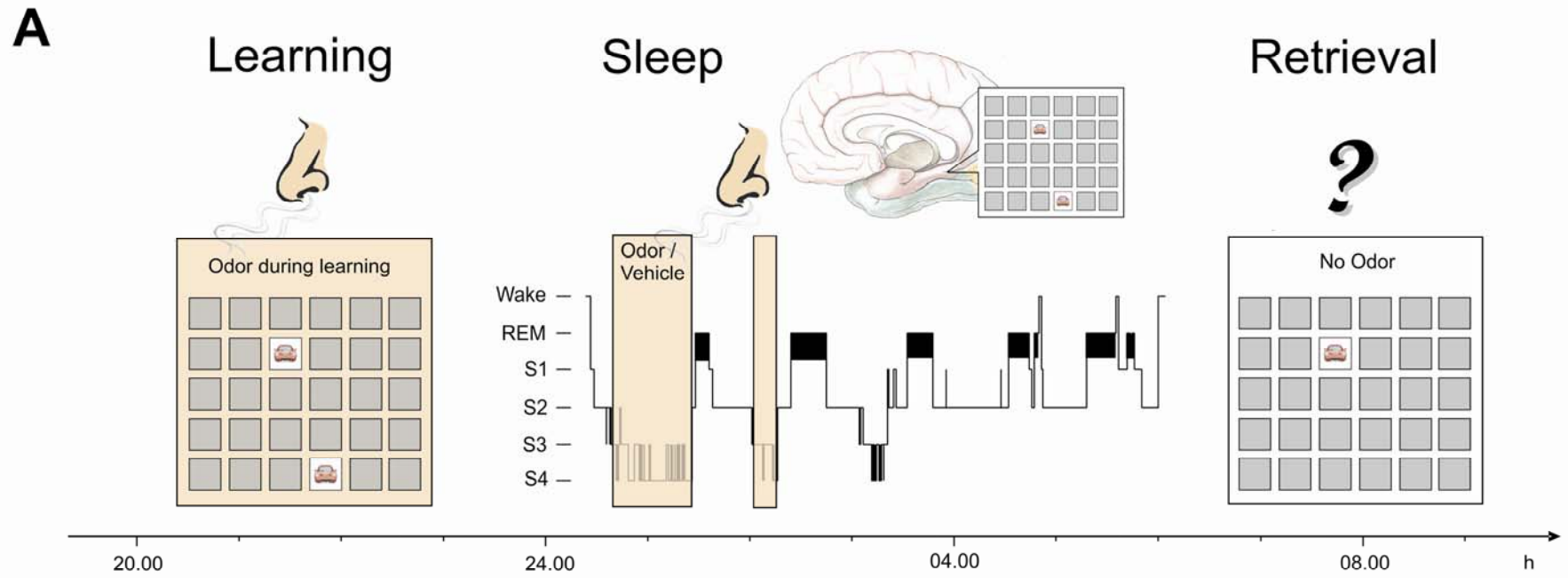
Gais and Born 2004, PNAS

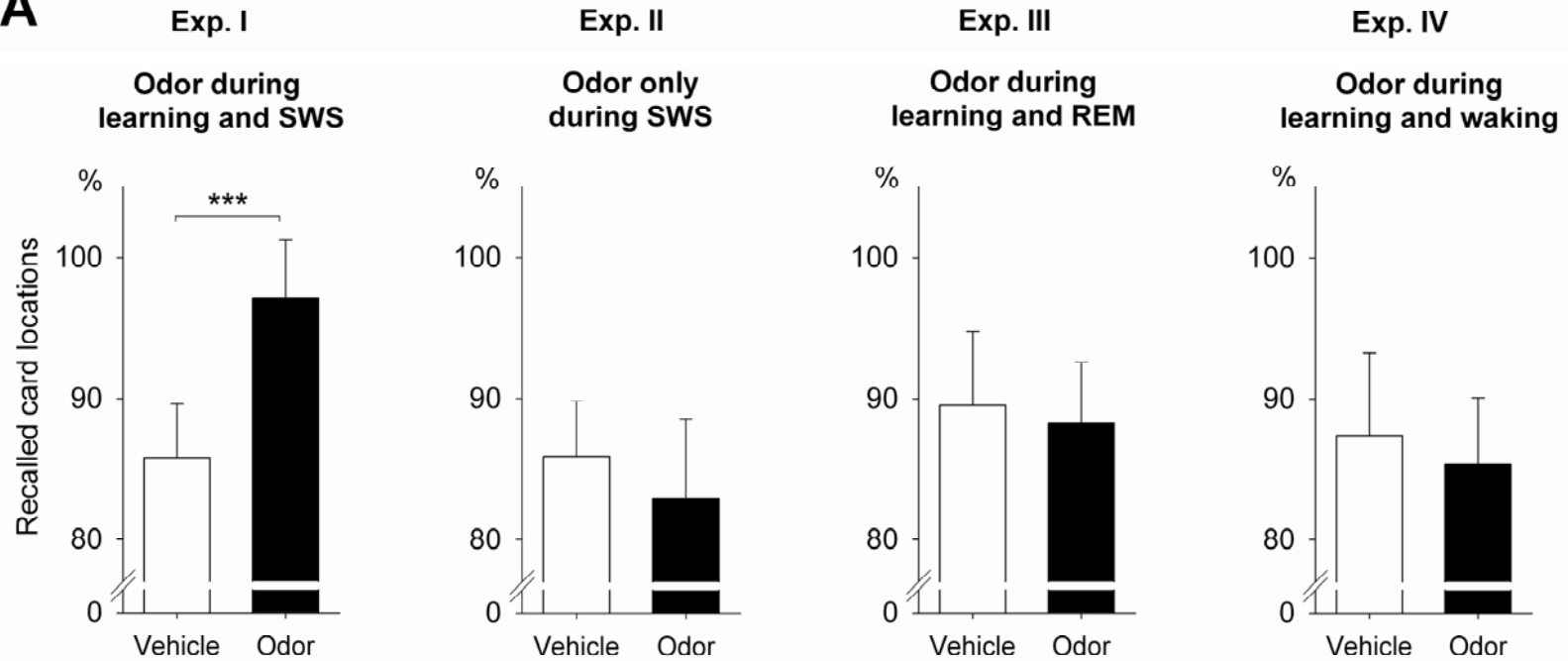
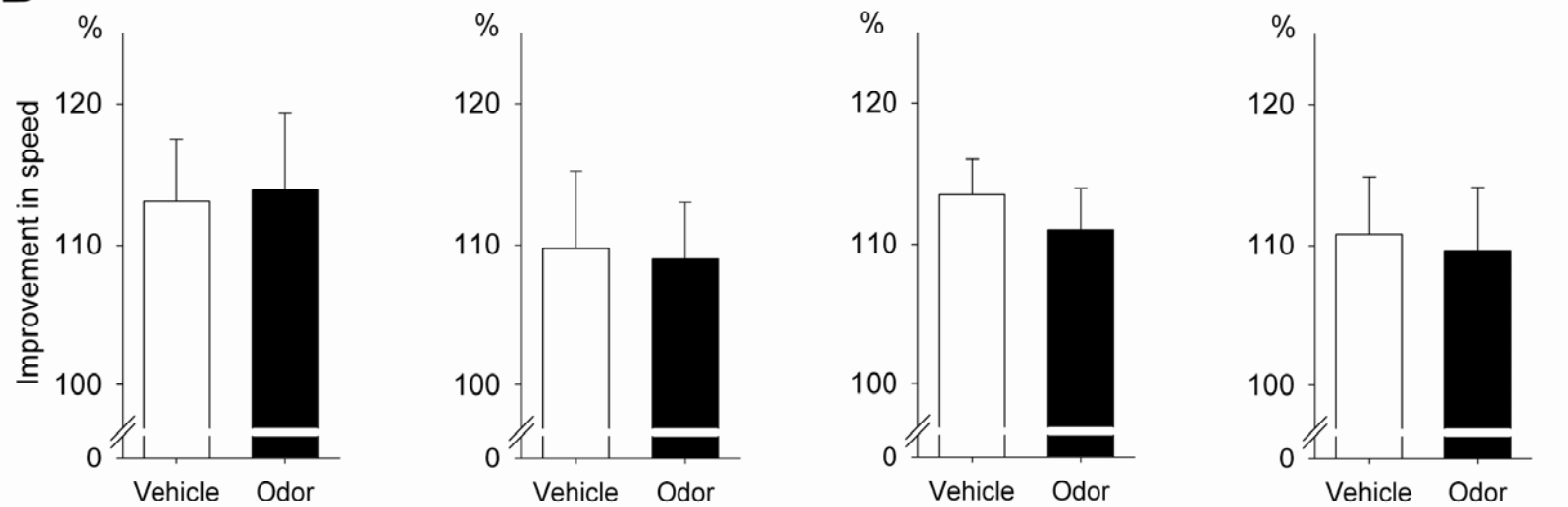


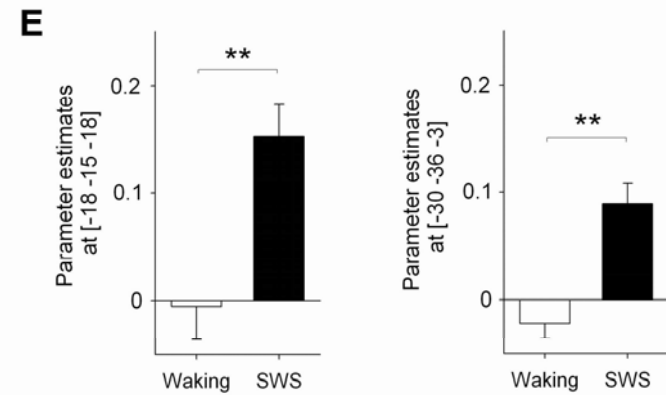
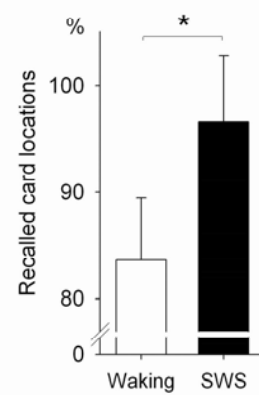
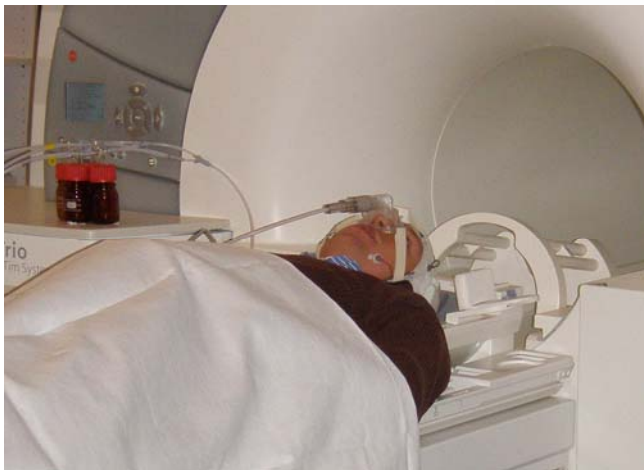
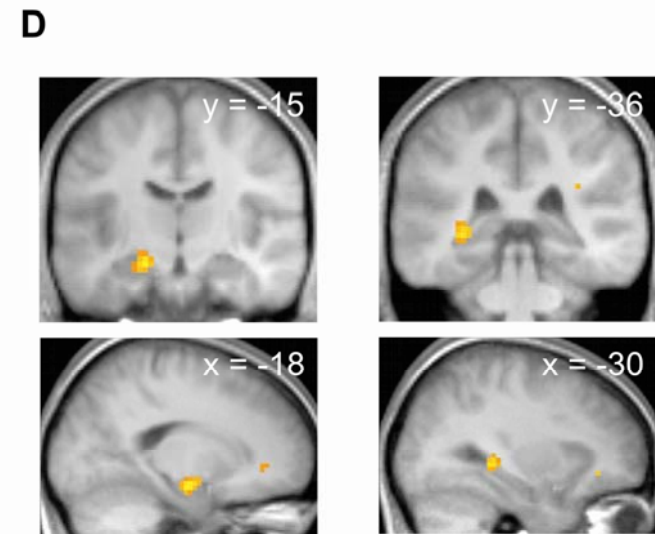
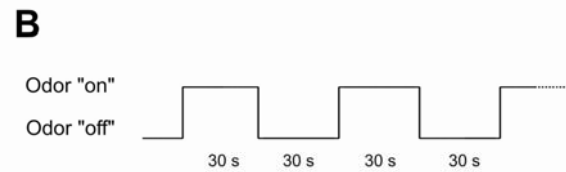
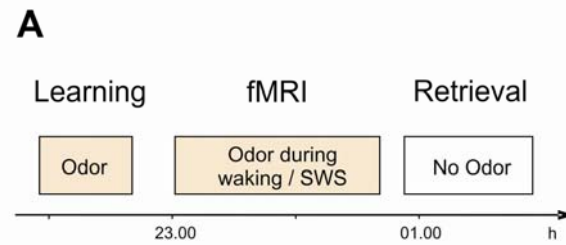
Hippocampus

Sharp wave-ripple
Memory replay

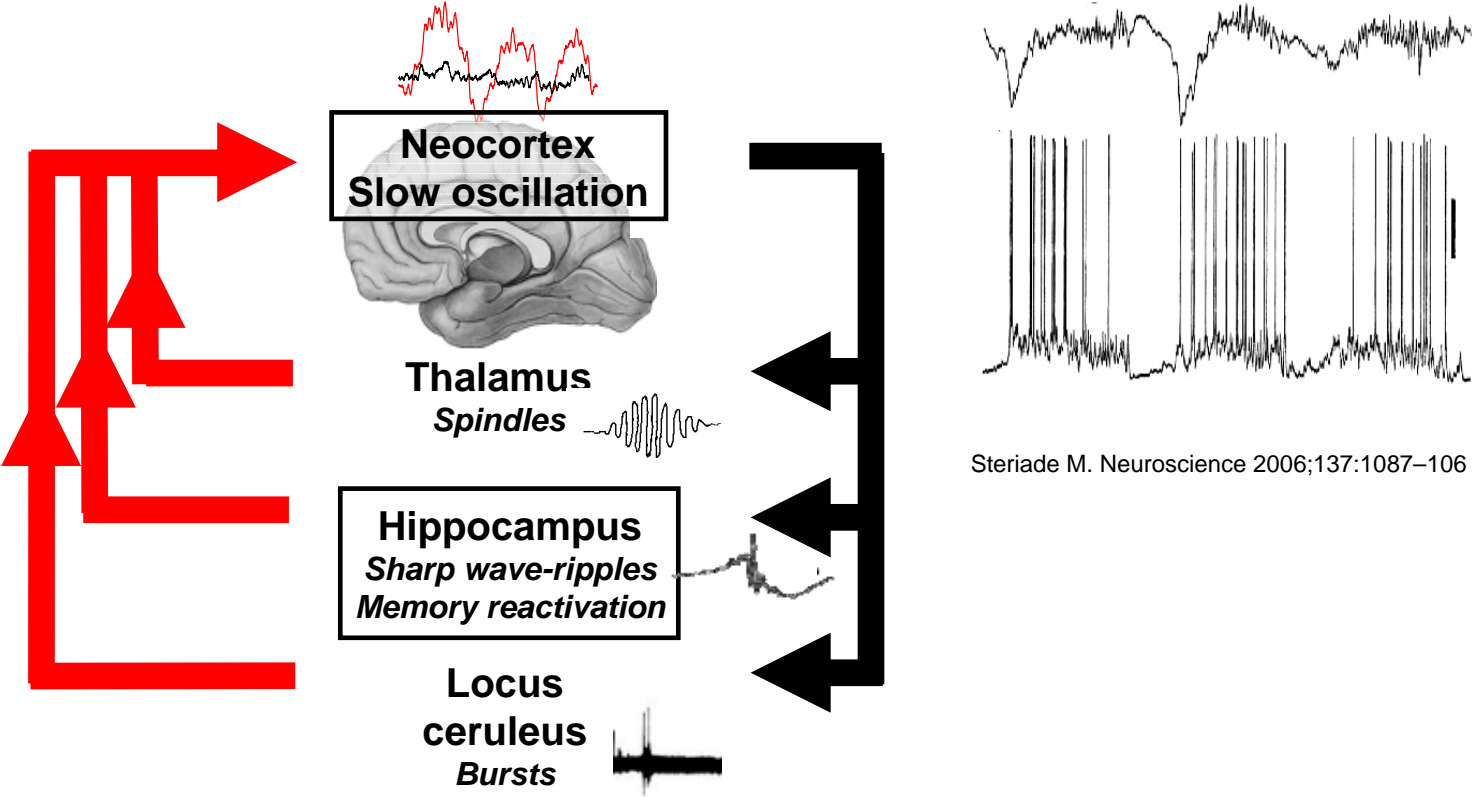
etylcholine,
rtisol, etc.



A**B**

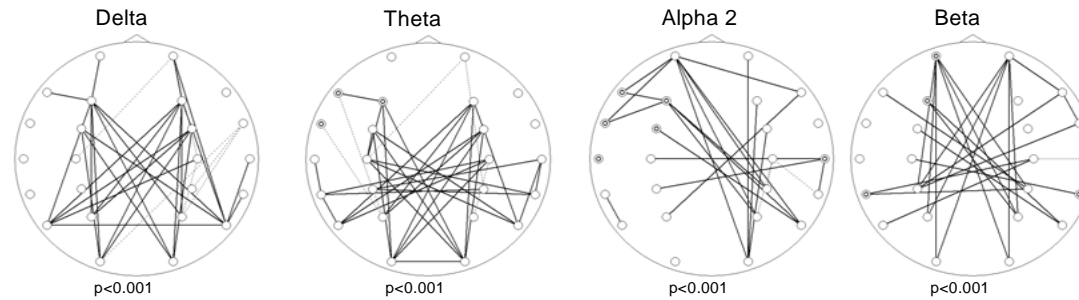


SWS transfers memories to long-term store



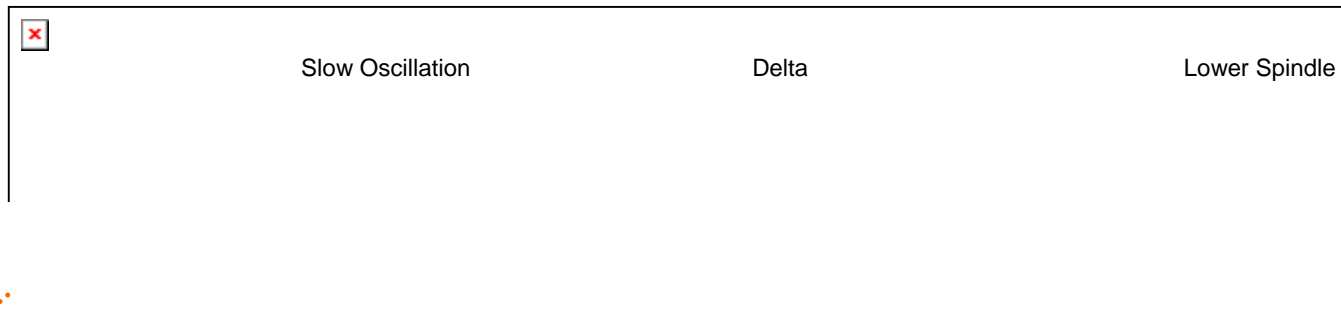
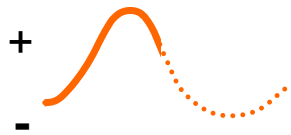
EEG-coherence (learning > non-learning)

Learning

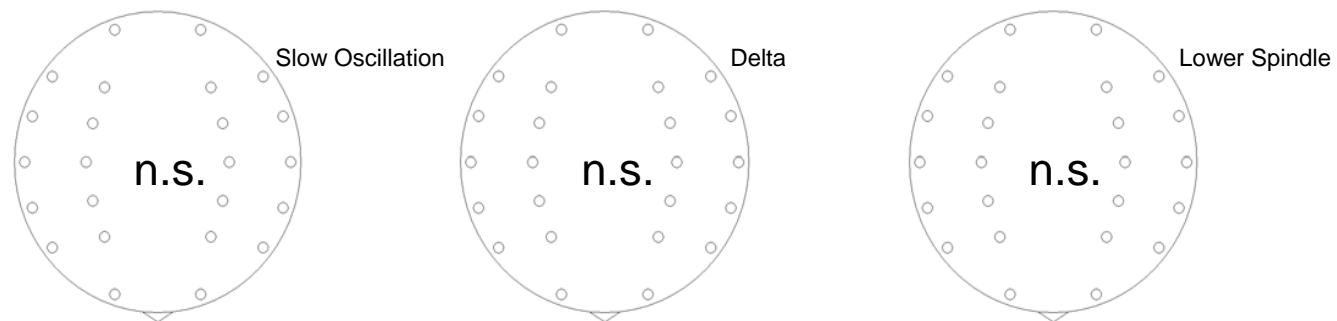
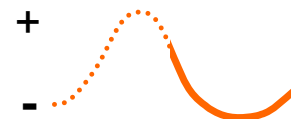


Sleep

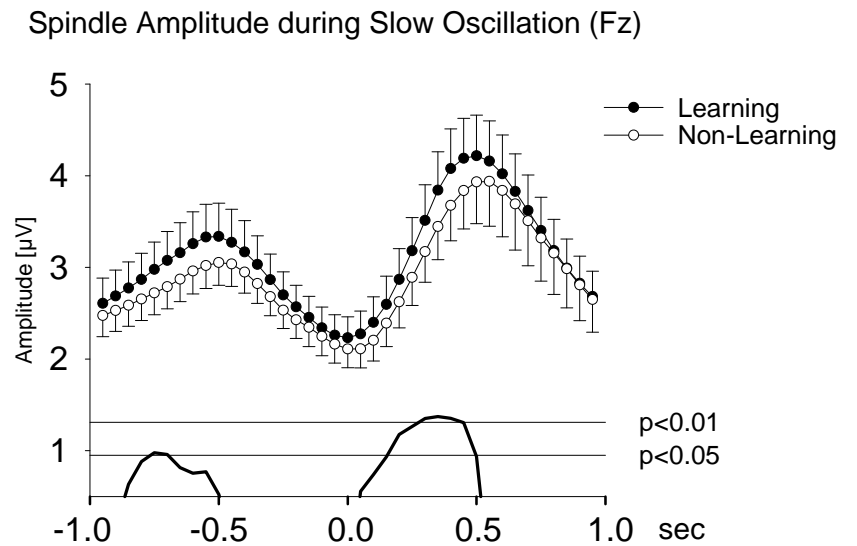
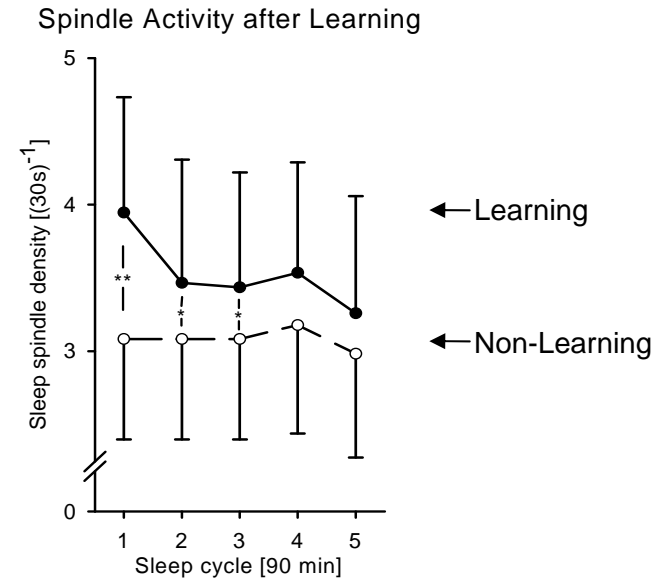
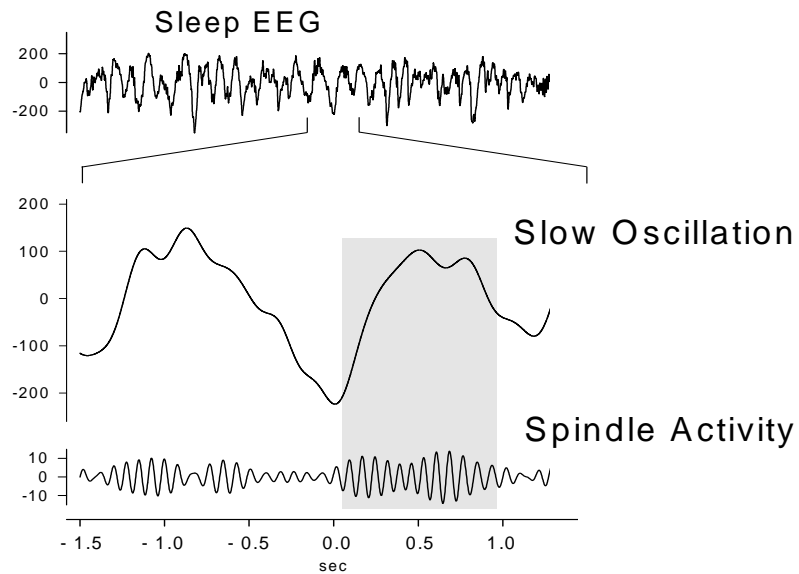
Slow oscillations
positivity



Slow oscillations
negativity

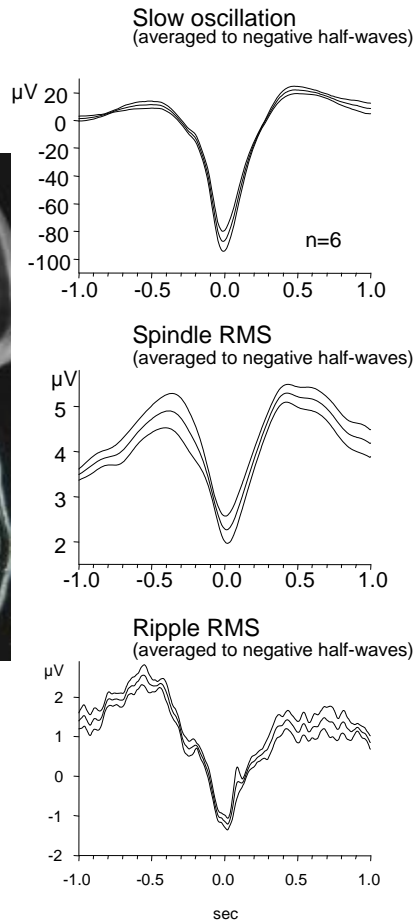
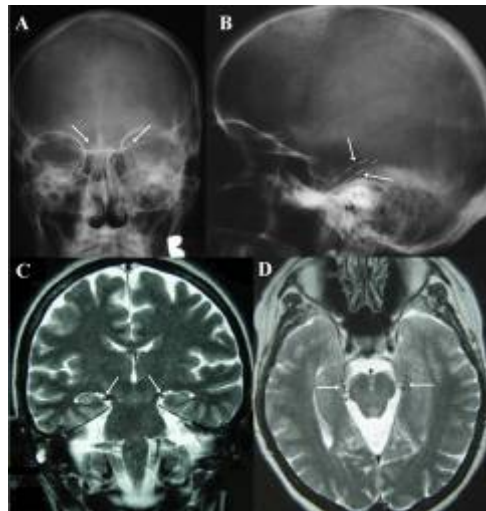


Slow oscillations drive thalamo-cortical spindles

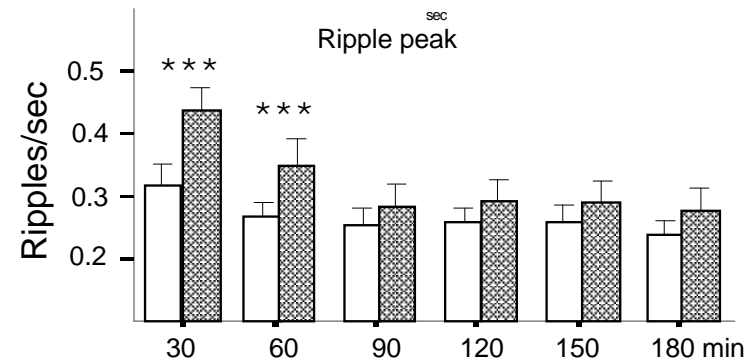
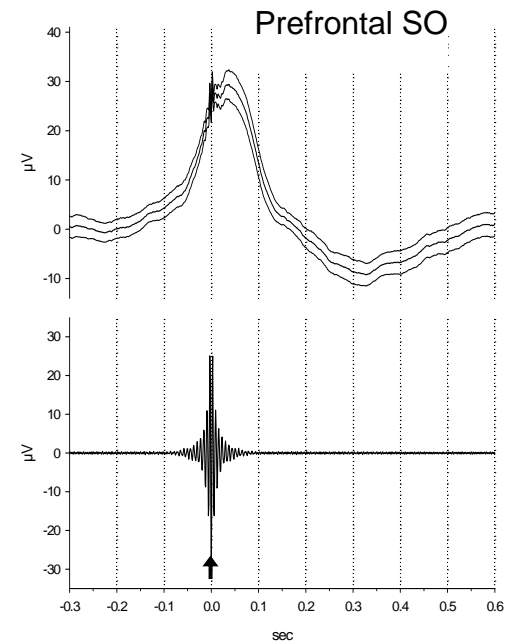


Slow oscillations drive hippocampal ripples

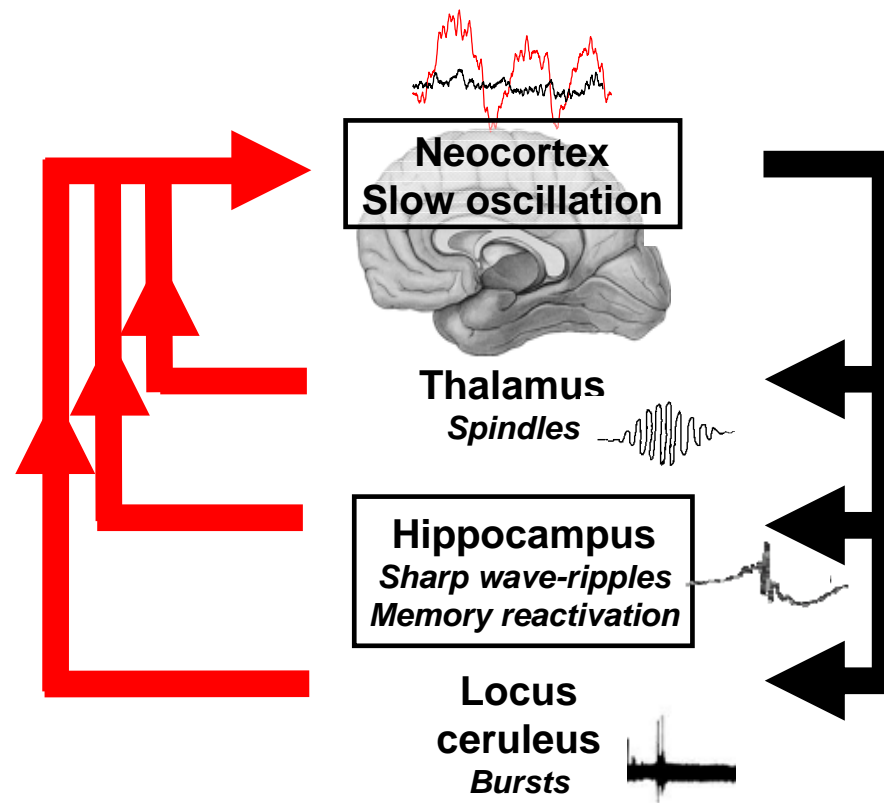
Epileptic patients



Rats

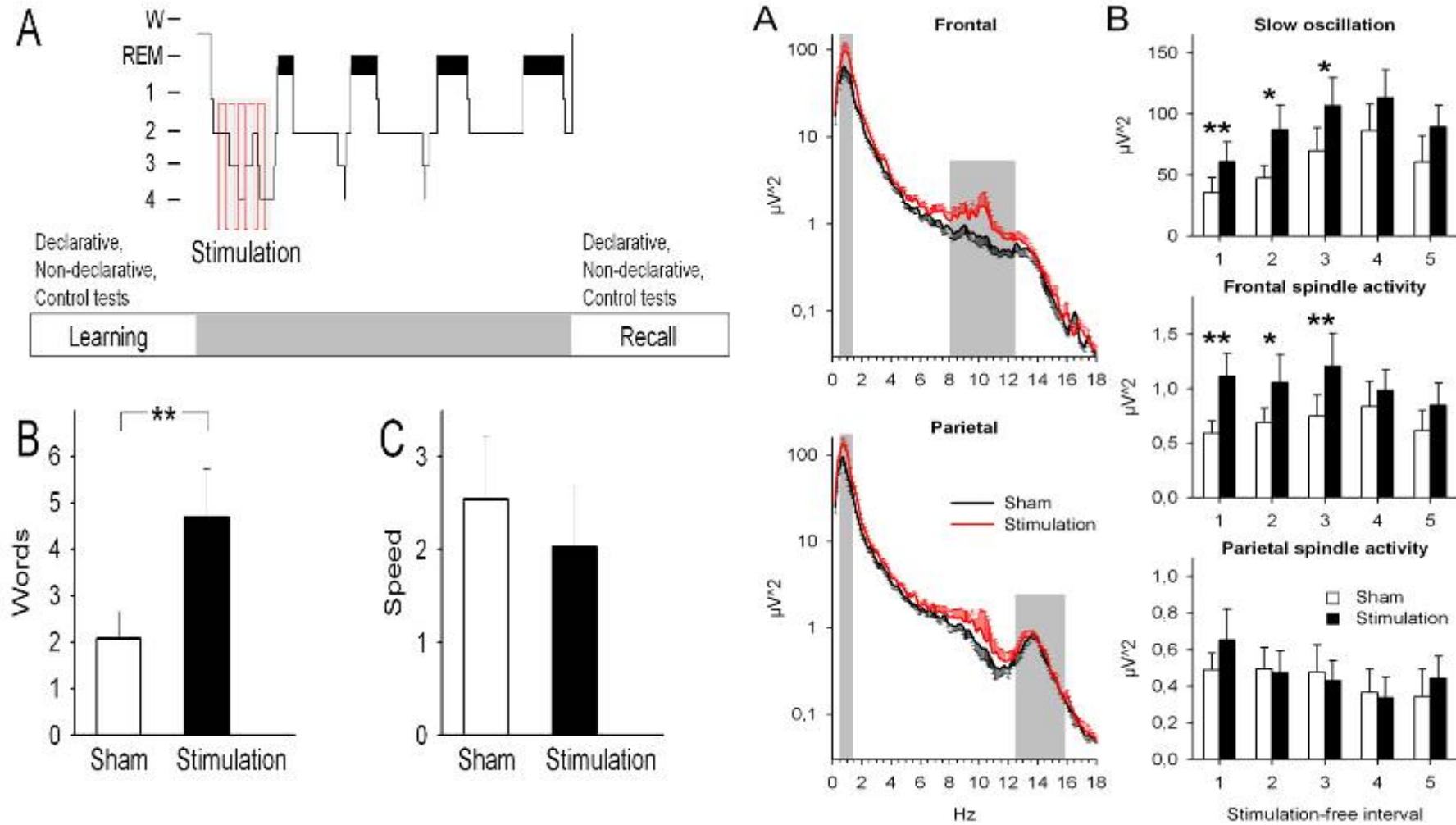


SWS transfers memories to long-term store

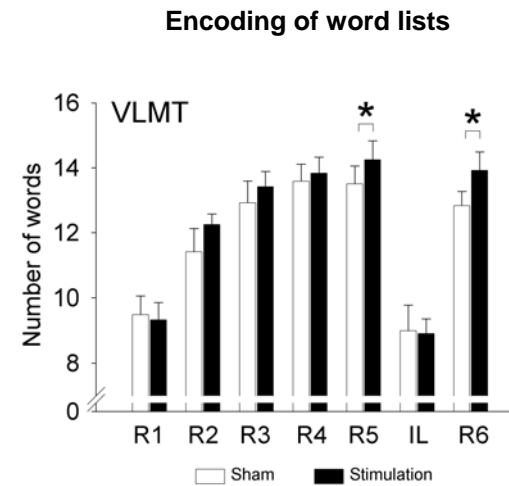
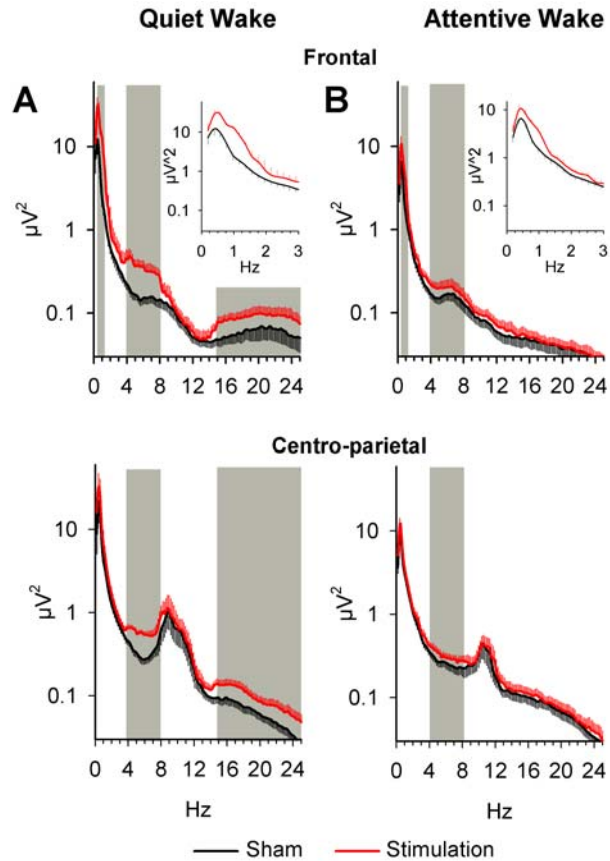


The slow oscillation provides a temporal frame that synchronizes the transfer of hippocampal memories to the neocortex with the simultaneous occurrence of spindles in the neocortex.

Inducing slow-oscillating potentials improves memory consolidation



Slow-oscillation stimulation during waking induces theta-activity and improves encoding



Summary

- Sleep supports the consolidation of memory.
- This is an active 'system consolidation' process in which memories are reactivated to be transferred from a temporary into a long-term store.
- Reactivation and transfer of memories take place during SWS under the control of the slow oscillation.