



## New memory formation during sleep

### Research questions

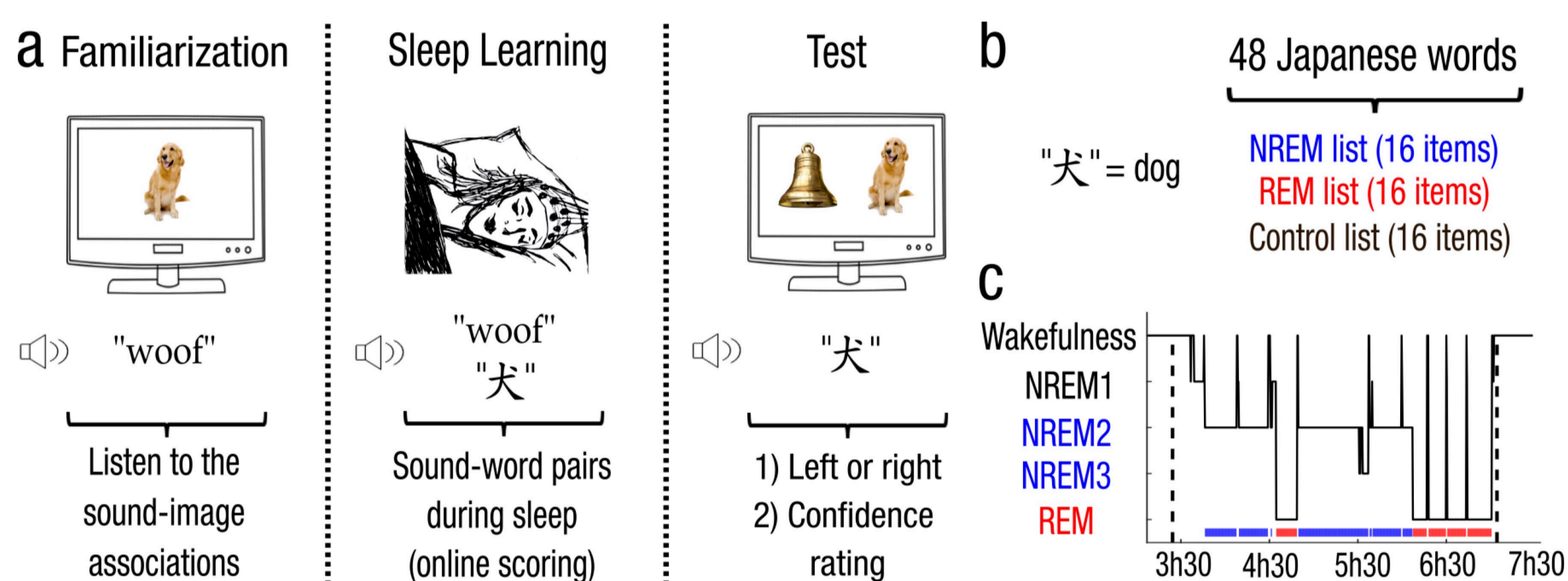
- The **extent and flexibility** of sleep learning remains uncertain (Puchkova, 2020 for a review; Ruch & Henke, 2020)
- The **implicit** nature of sleep learning is rarely directly tested (e.g., Ruch *et al.*, 2014; except Andrillon *et al.*, 2016)
- The role of **sleep micro- and macro-structure** is debated (Andrillon *et al.*, 2017; Züst *et al.*, 2019)

### Hypotheses

- Cross-modal generalization** of associations learnt sleep
- Implicit learning during sleep vs. explicit during wakefulness**
- Slow waves as neural signatures** of NREM sleep learning

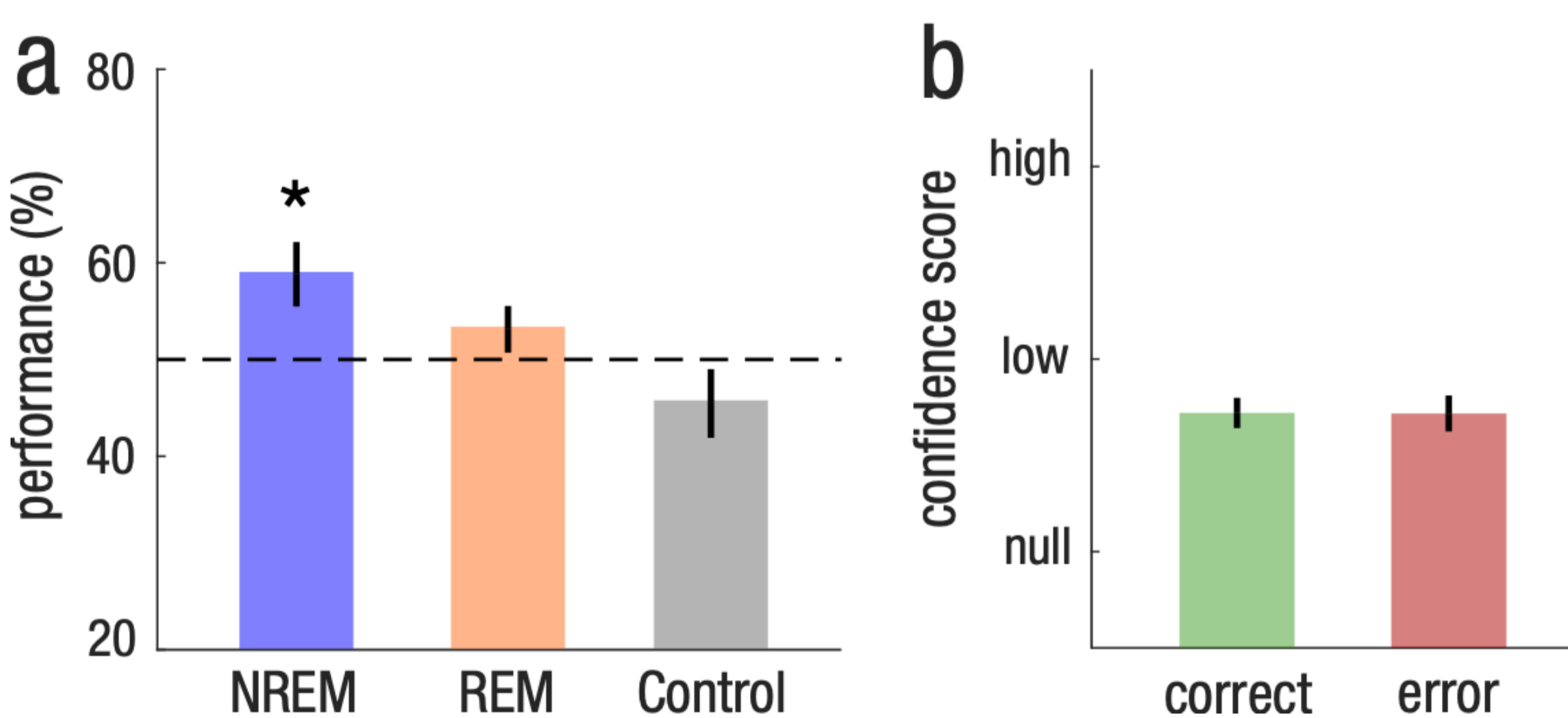
## An associative learning paradigm

- Participants:** healthy adults (20-35 yo) naïve to Japanese
- Online scoring and offline neural analyses:** 64-channels EEG
- Late night sleep:** ~40 repetitions in NREM and ~13 in REM

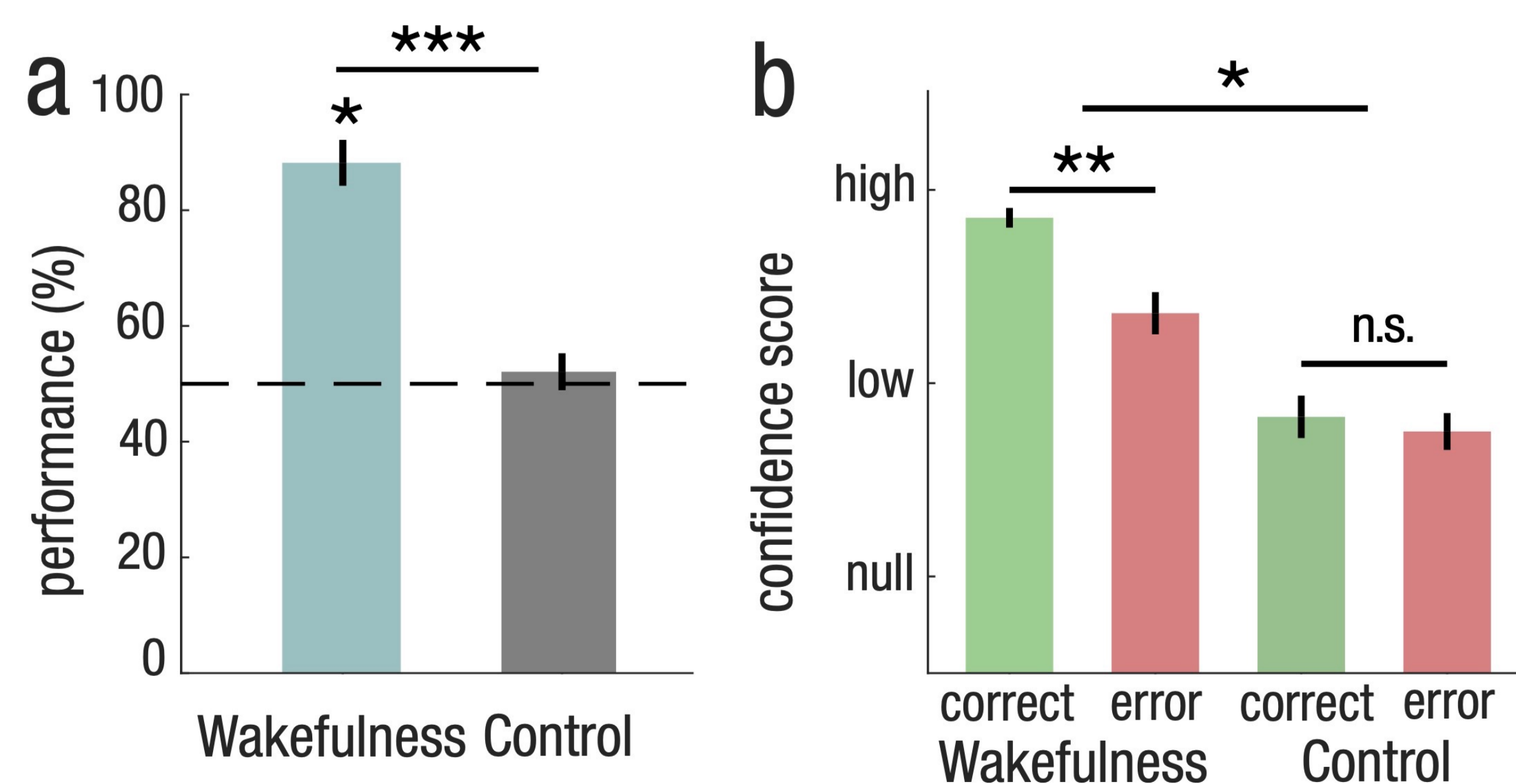


## Cross-modal generalization of new vocabulary

### Implicit learning in NREM sleep (main experiment, n=22)

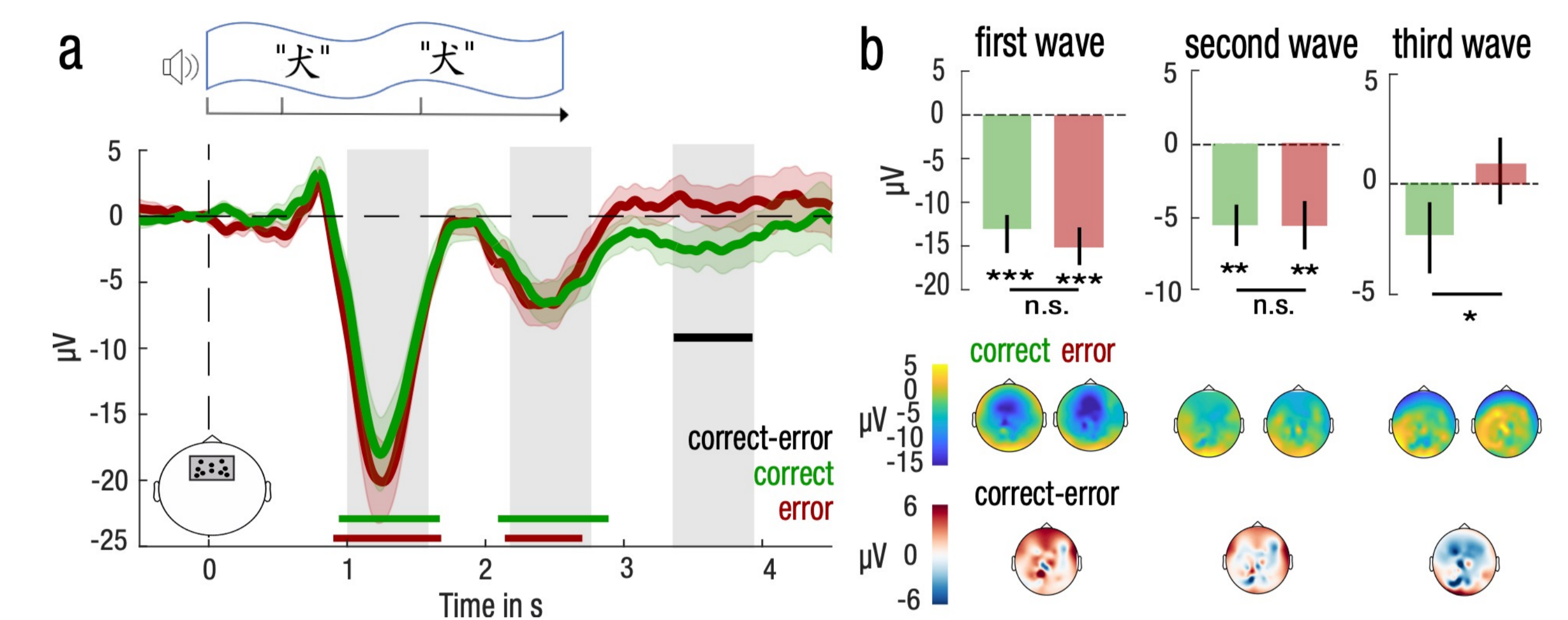


### Explicit learning in wakefulness (control experiment, n=12)

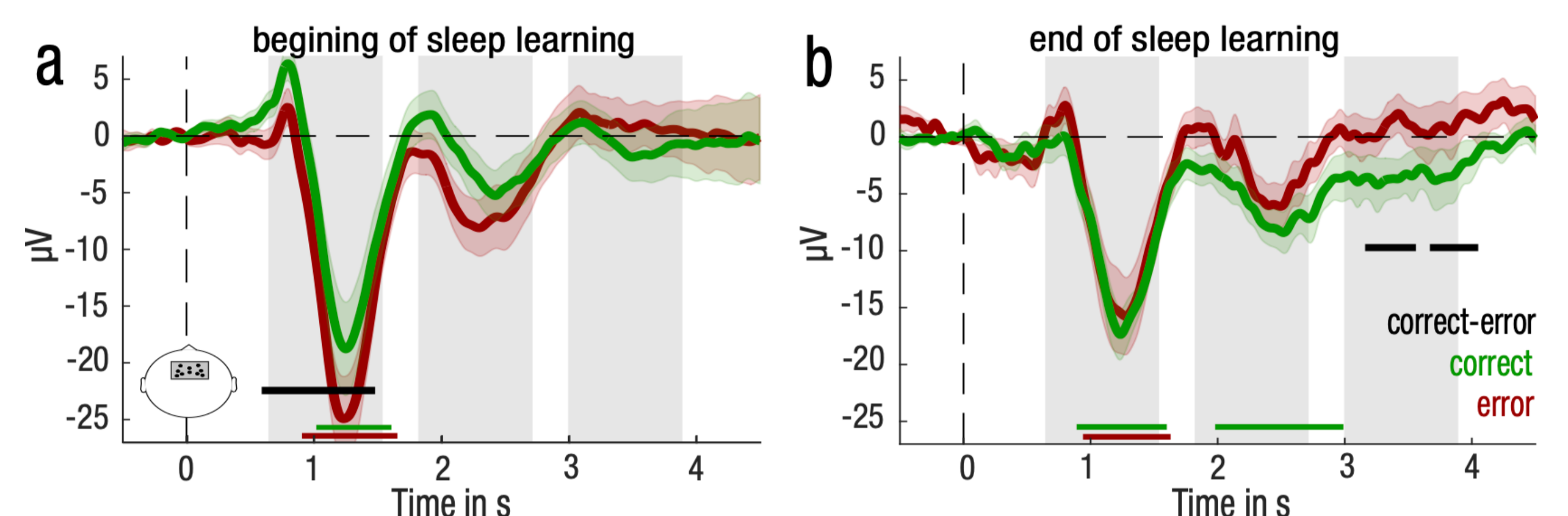


## Neural signatures of sleep learning

### Frontal slow waves predict sleep learning

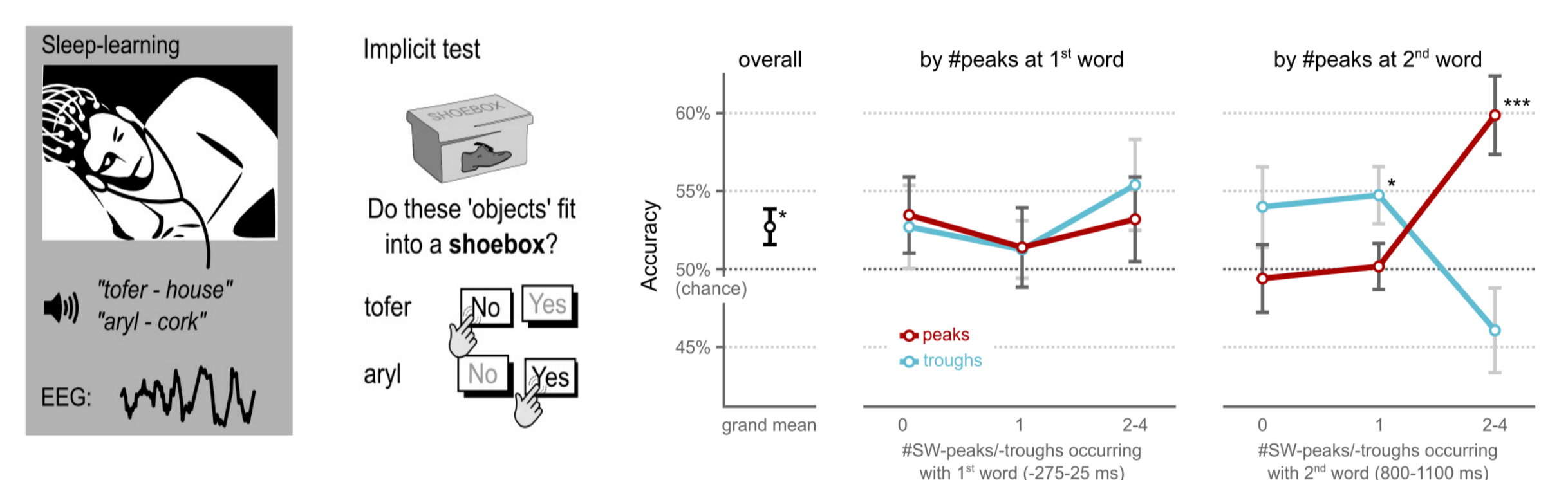


### Their dynamics track the sleep learning process

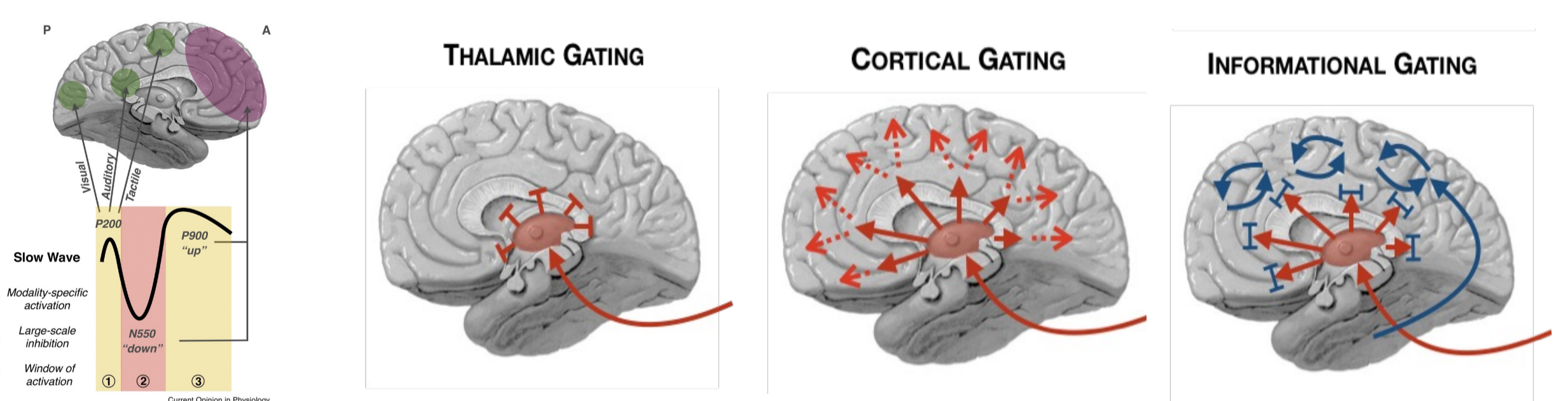


## Linking sleep physiology to memory formation

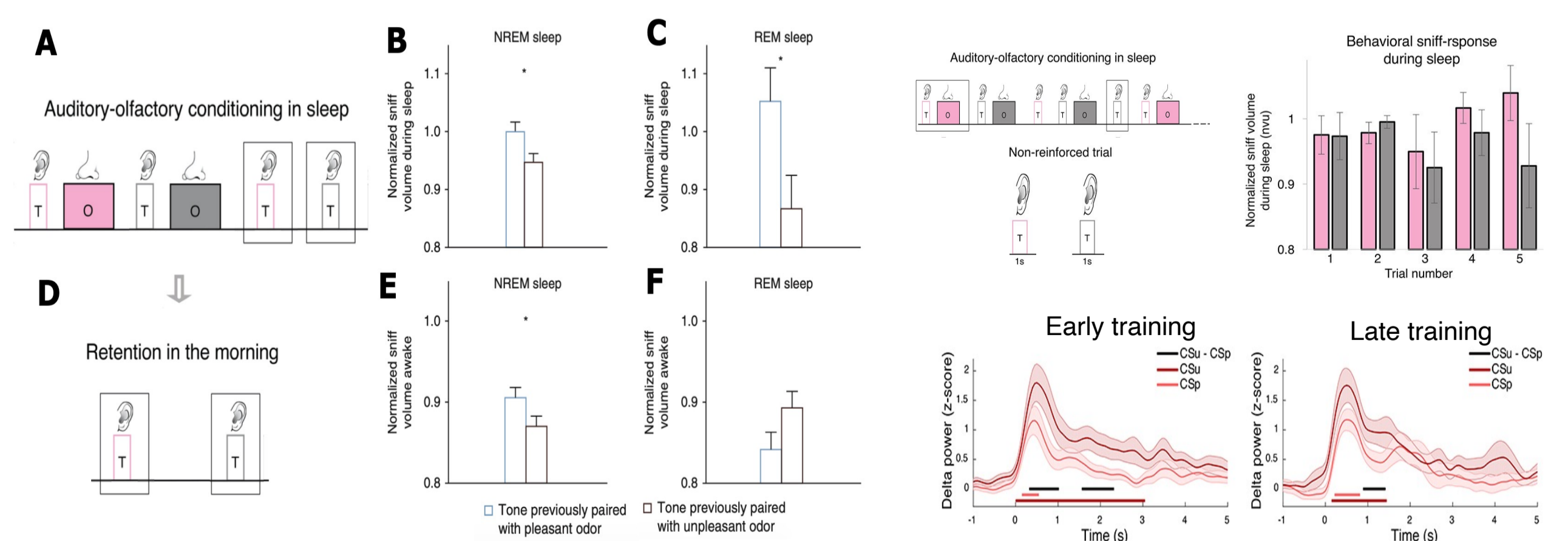
### Extension of previous results on sleep learning (Züst *et al.*, 2019)



### From sensory gating to sleep learning (Andrillon & Kouider, 2020)



### Learning process during NREM sleep and transfer to wakefulness (Arzi *et al.*, 2012; Canales-Johnson *et al.*, 2020)



## References

- Andrillon, T., & Kouider, S. (2016). Implicit memory for words heard during sleep. *Neuroscience of consciousness*, 2016(1).
- Andrillon, T., & Kouider, S. (2020). The vigilant sleeper: neural mechanisms of sensory (de) coupling during sleep. *Current Opinion in Physiology*, 15, 47-59.
- Andrillon, T., Pressnitzer, D., Léger, D., & Kouider, S. (2017). Formation and suppression of acoustic memories during human sleep. *Nature communications*, 8(1), 1-15.
- Arzi, A., Shedlesky, L., Ben-Shaul, M., Nasser, K., Oksenberg, A., Hairston, I. S., & Sobel, N. (2012). Humans can learn new information during sleep. *Nature neuroscience*, 15(10), 1460-1465.
- Canales-Johnson, A., Merlo, E., Bekinschtein, T. A., & Arzi, A. (2020). Neural dynamics of associative learning during human sleep. *Cerebral Cortex*, 30(3), 1708-1715.
- Ruch, S., & Henke, K. (2020). Learning during sleep: a dream comes true? *Trends in cognitive sciences*, 24(5), 170-172.
- Ruch, S., Koenig, T., Mathis, J., Roth, C., & Henke, K. (2014). Word encoding during sleep is suggested by correlations between word-evoked up-states and post-sleep semantic priming. *Frontiers in psychology*, 5, 1319.
- Züst, M. A., Ruch, S., Wiest, R., & Henke, K. (2019). Implicit vocabulary learning during sleep is bound to slow-wave peaks. *Current biology*, 29(4), 541-553.

➤ **Contact:** [matthieu.koroma@uliege.be](mailto:matthieu.koroma@uliege.be)  
 ➤ **Publication:** [10.3389/fnins.2022.801666](https://doi.org/10.3389/fnins.2022.801666)

