

# Boosting creativity through targeted memory reactivation during slow-wave up states

Lorena Santamaria<sup>1</sup>, Ibad Kashif<sup>1</sup>, Simon Leclerc<sup>1</sup>, Niall McGinley<sup>1</sup>, Penny Lewis<sup>1</sup>

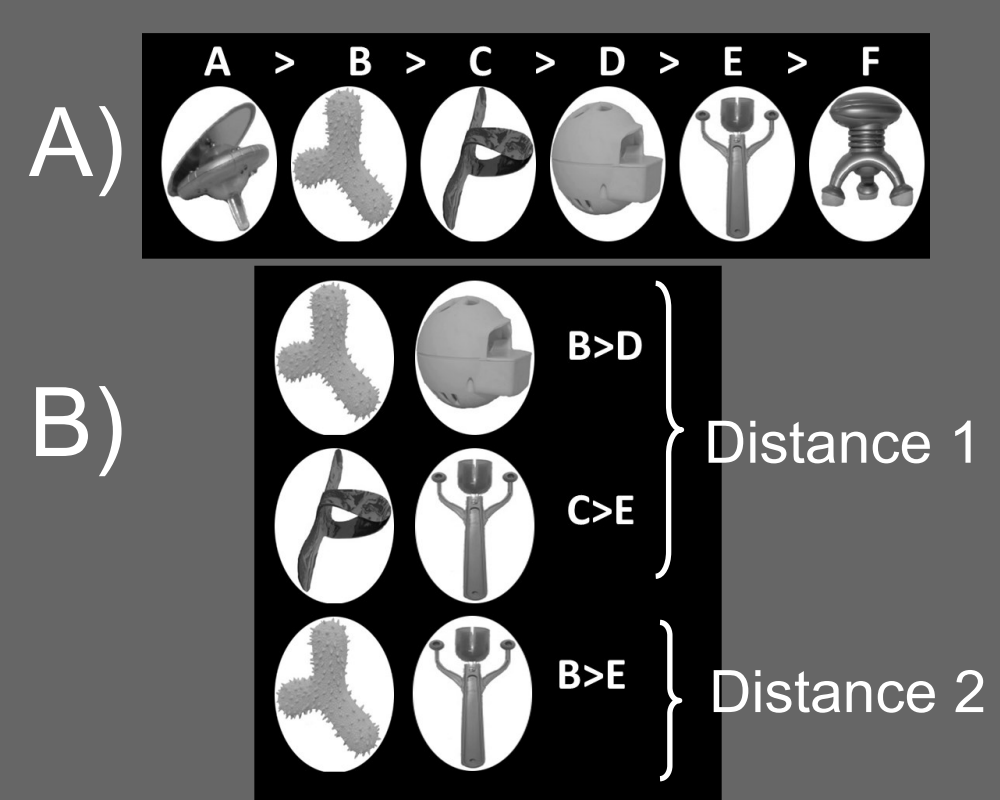
CUBRIC, Cardiff University, Wales, UK



## SUMMARY

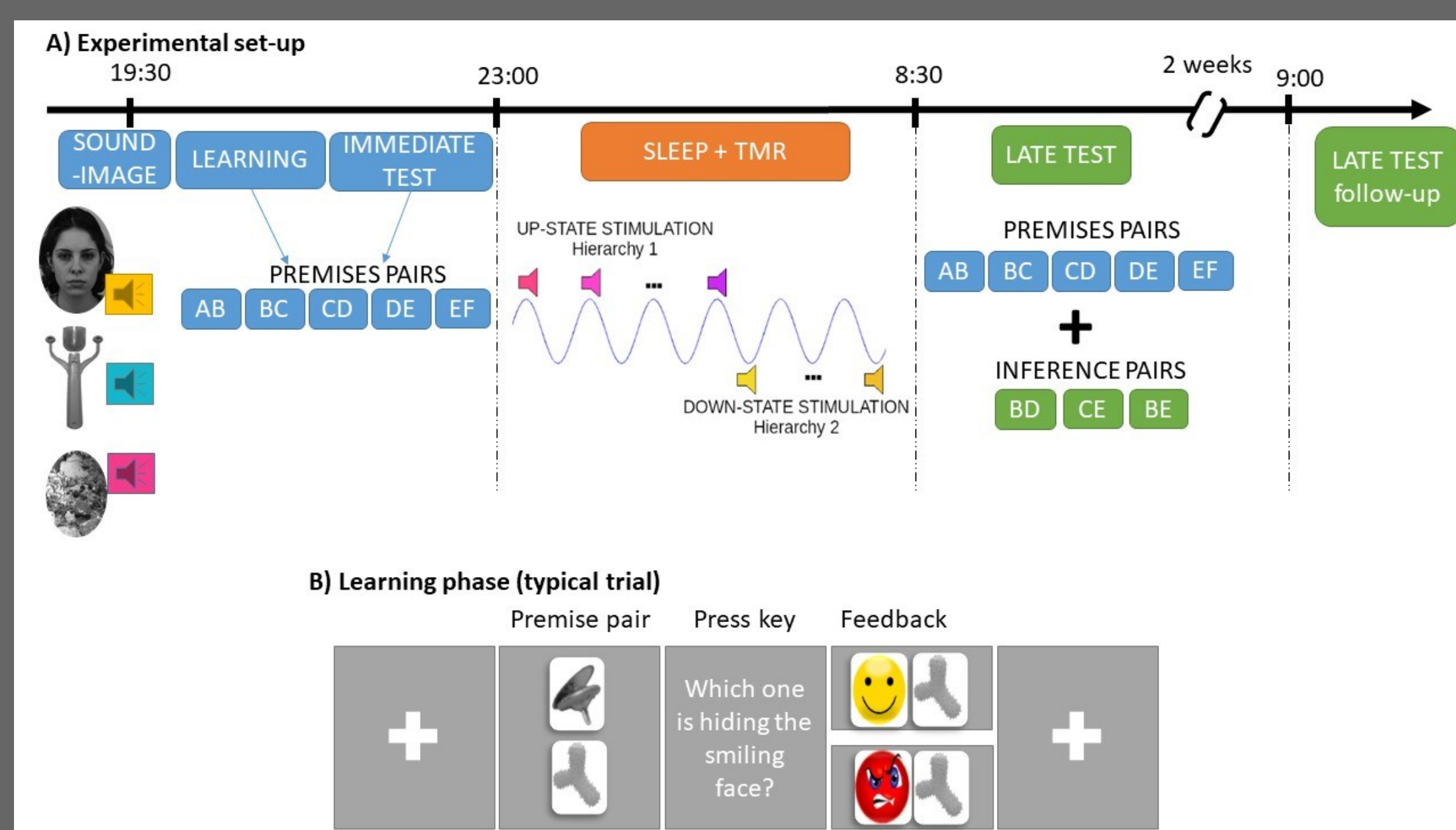
- Transitive inference learning task (hiding hierarchy) benefits from Sleep<sup>1,2</sup> and Targeted Memory Reactivation (TMR) in Slow Oscillations (SO).
- Stimulating in the up-state of the SO reports overnight benefits compared with control (non-cued) and down-state stimulation<sup>3,4</sup>.
- Down-state stimulation needs more time to help memory consolidation. Benefits appeared in the 2-weeks follow-up session.
- Inference learning displayed greater benefits for larger-distanced items within the hierarchy, only when stimulated in the up-state.

## 1. Experimental procedures



A) Example of one of the 3 implicit hierarchies presented to the participants.

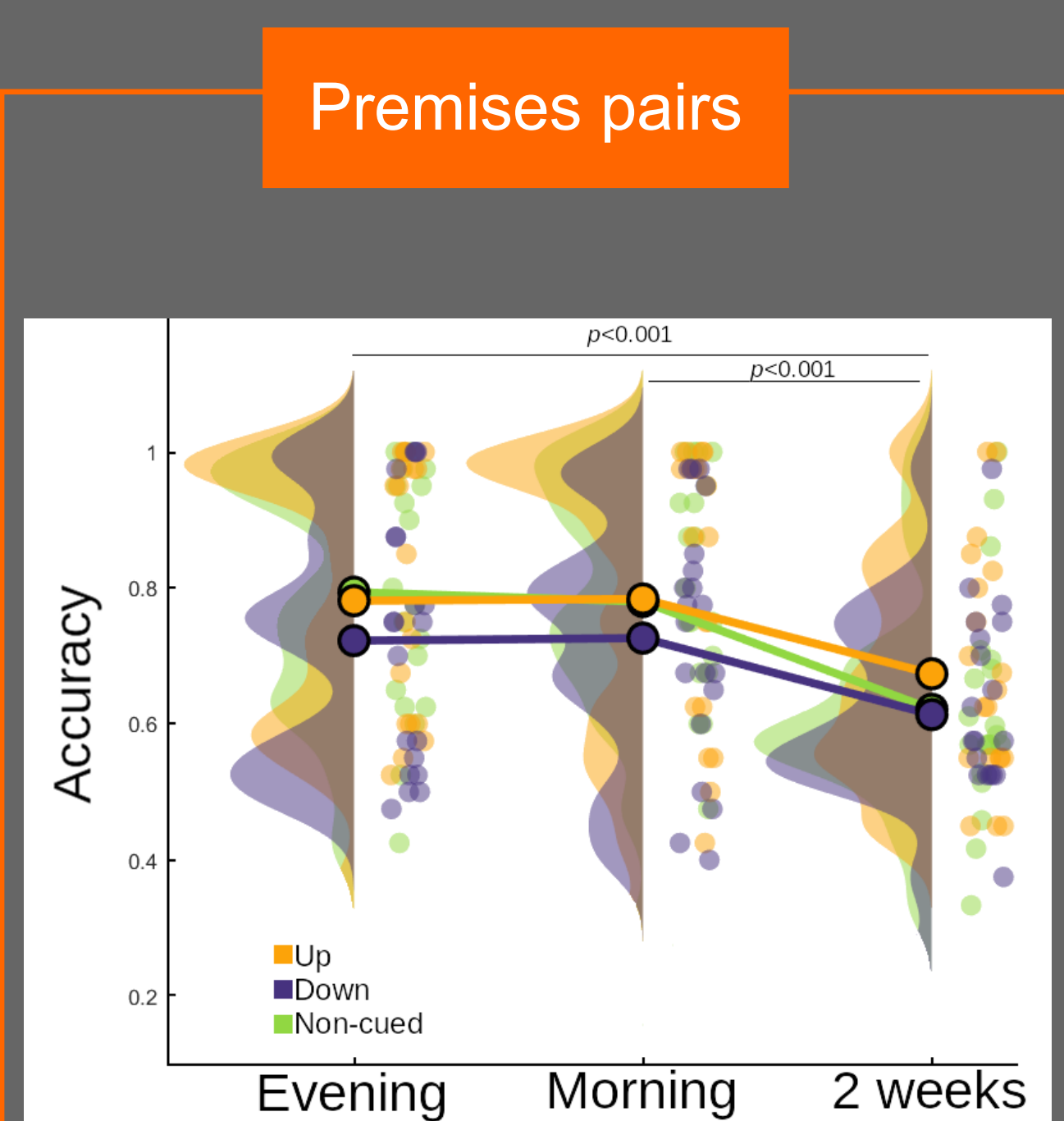
B) Inference pairs separated by 1 element (B-D, C-E) or two (B-E).



## 2. Methods

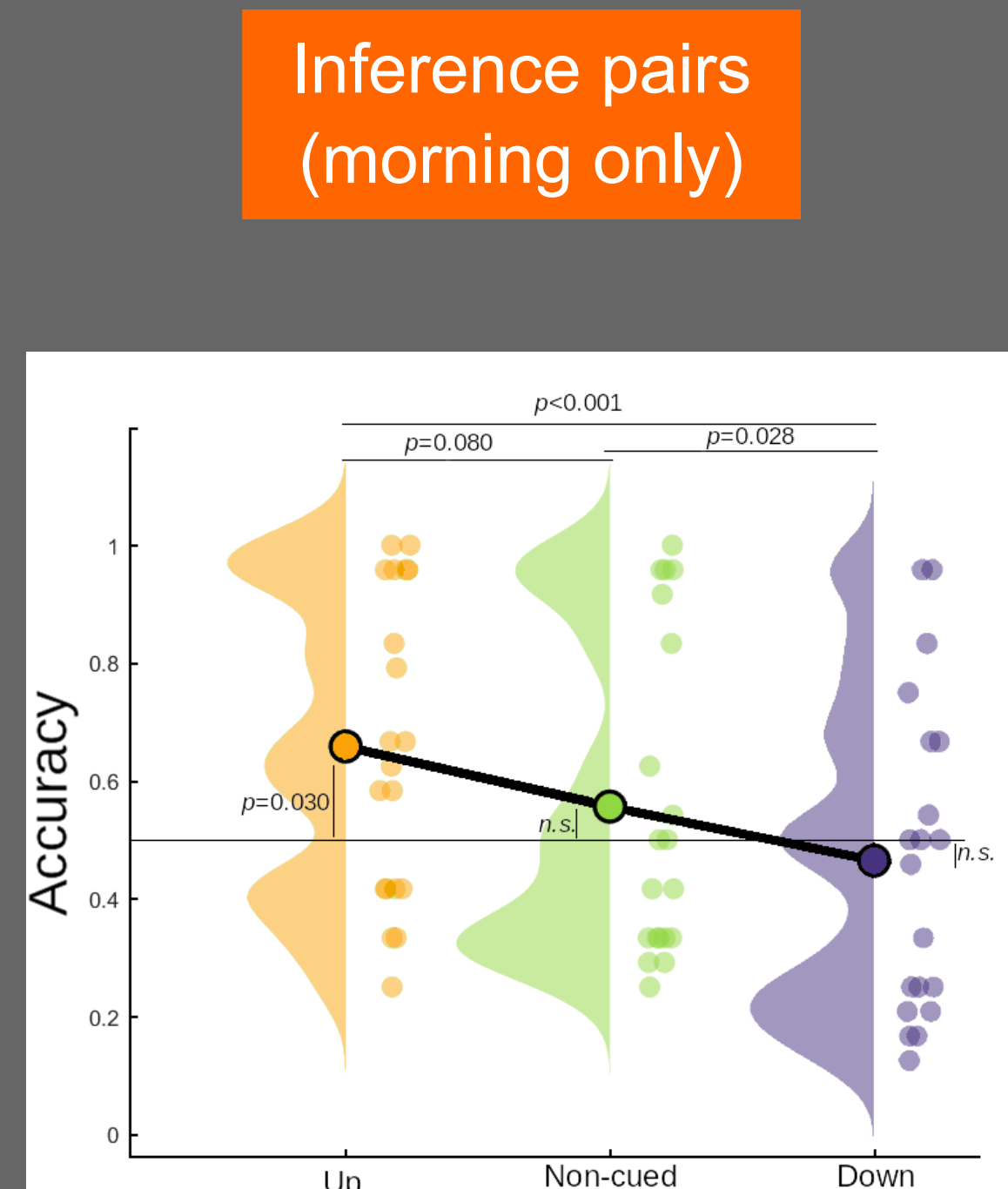
- 20 participants (17 completed the follow-up)
- 2 hierarchies stimulated overnight + 1 control
- TMR in the up and down stages of the slow waves
- Statistics (trial level):
  1. Repeated measures Anova
    - Between subjects: condition (up/down/non-cued)
    - Within subjects: session
      - evening/morning/2-weeks (premise pairs)
      - morning/2-weeks (inference pairs)
  2. One sample t-test (statistically significantly different from chance (0.5))

## 3. Results



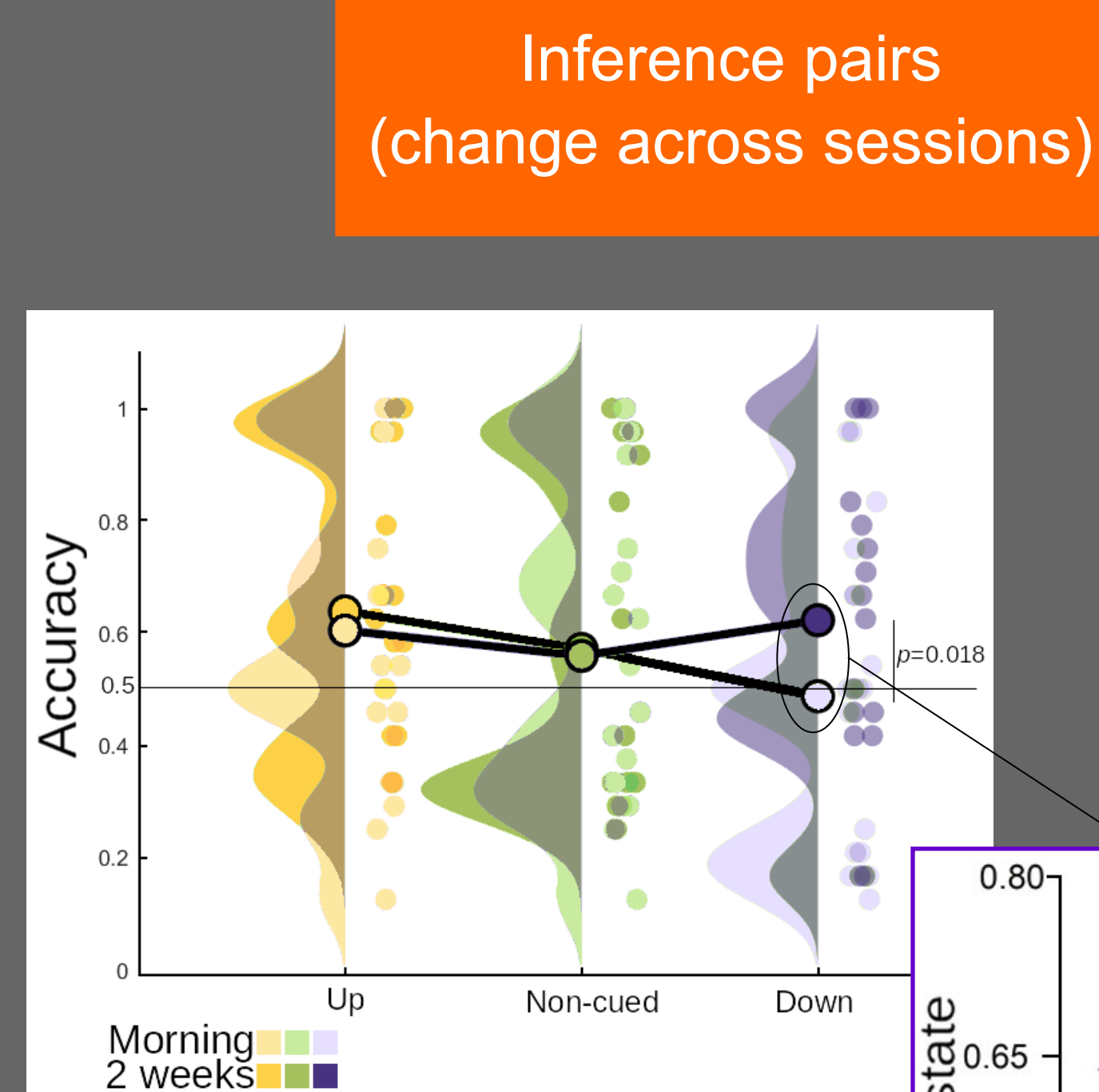
No significant differences between hierarchies within sessions or overnight effect.

Premises pairs' accuracy drops significantly after two weeks for all hierarchies



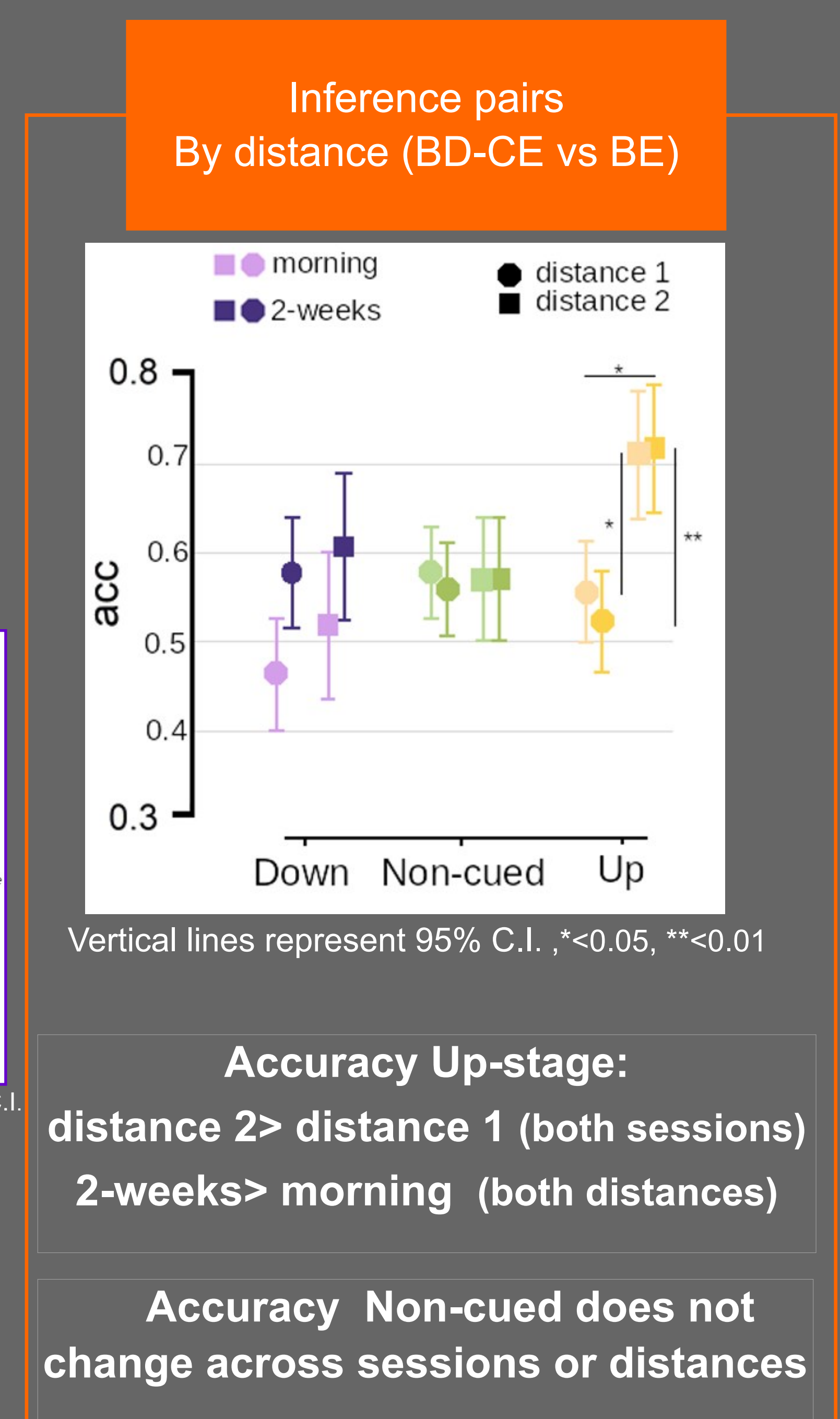
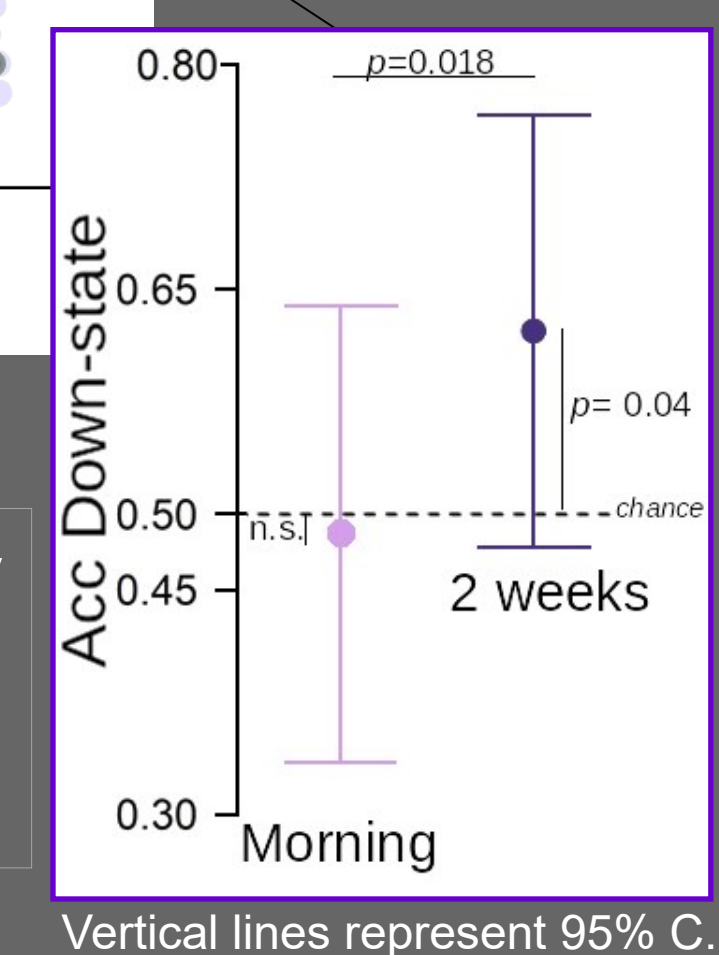
Down-state stimulation reduces accuracy on inference pairs but not on the premises pairs.

Up-state stimulation benefits accuracy in the inference pairs



Down-state accuracy increased after two weeks.

After two weeks, the accuracy for all conditions is equivalent.



1. Ellenbogen et al., 2007. "Human relational memory requires time and sleep", PNAS, 104 (2007), pp. 7723-7728.

2. Wechan, D.M. & Gomez, R.L., 2013. "Generalizing memories over time: Sleep and reinforcement facilitate transitive inference", Neurobiology of Learning and Memory, 100 (2013), pp. 70-76

3. Goldi et al, 2019. "Increased neural signatures of targeted memory reactivation during slow-wave up states", Nature Scientifics Reports, 9 (2019), number 2715

4. Shimizu et al, 2018. "Closed-loop target memory reactivation during sleep improves spatial navigation", Frontiers in Human Neuroscience, 12, number 1662