



Targeted Memory Reactivation for Multiplication Problems During an Afternoon Nap

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Introduction

Multiplication Learning

- ❖ Academic success depends on learning skills and facts.
- ❖ Sleep has been found to benefit various types of skill learning.
- ❖ Multiplication learning is a type of skill learning that depends on practice¹ — here we sought evidence on whether it also depends on memory reactivation during sleep.

Research Question

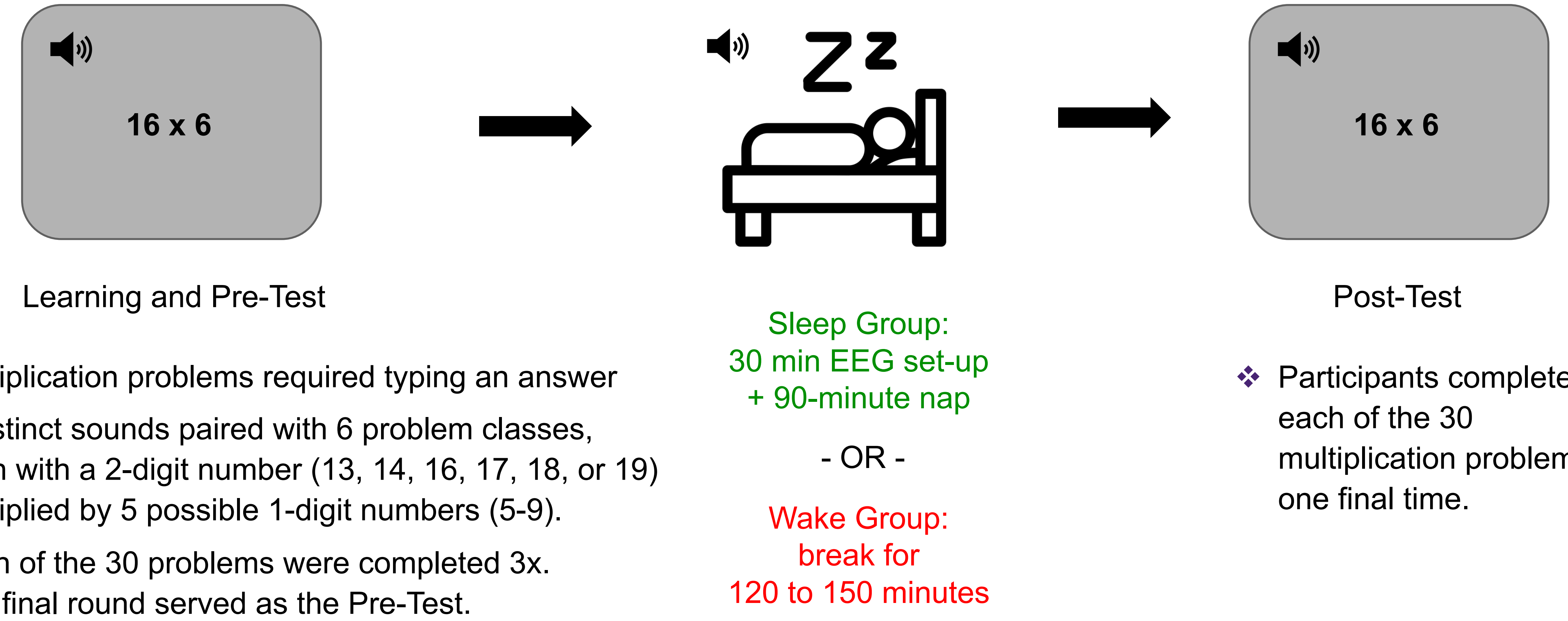
- ❖ This experiment was designed to test whether performance in a multiplication task would be influenced by memory reactivation during sleep or by sleep physiology signals.

Experimental Design

Sleep Subjects:
 ❖ 21 undergraduates,
 20.62 ± 2.29 years,
 who were requested
 to wake up 2 hours
 earlier than normal
 and to avoid caffeine

Wake Subjects:
 ❖ 19 undergraduates,
 21.00 ± 3.38 years

Experiment began
 between 11am – 3pm



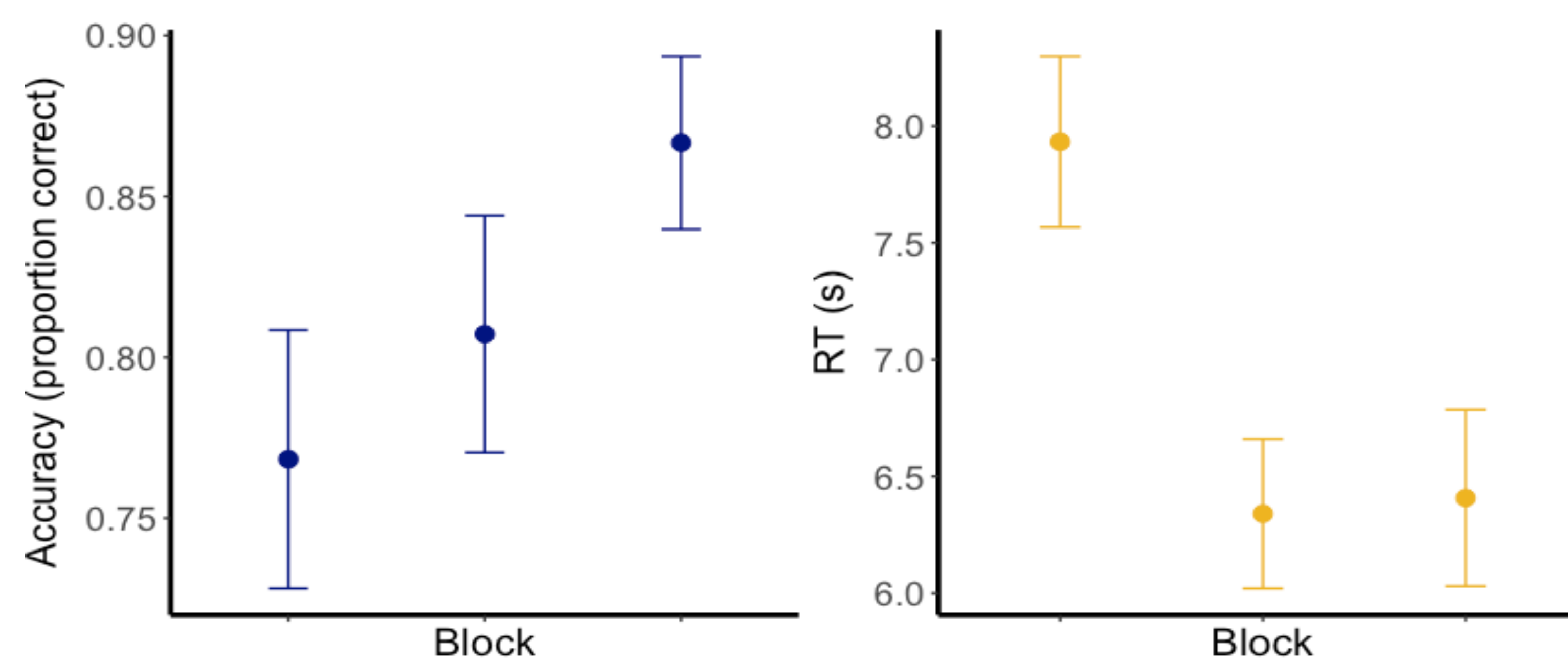
- ❖ Multiplication problems required typing an answer
- ❖ 6 distinct sounds paired with 6 problem classes, each with a 2-digit number (13, 14, 16, 17, 18, or 19) multiplied by 5 possible 1-digit numbers (5-9).
- ❖ Each of the 30 problems were completed 3x. The final round served as the Pre-Test.

Results

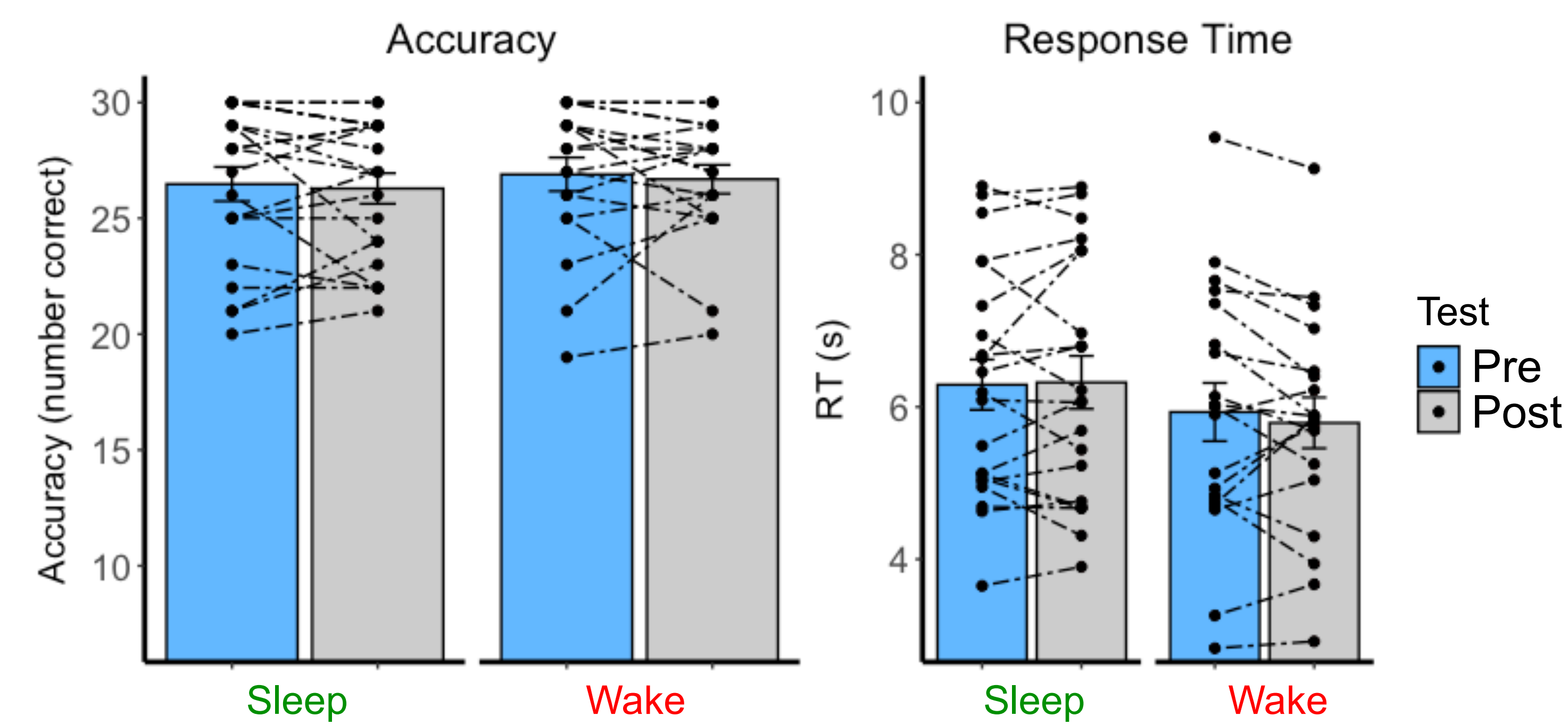
Targeted Memory Reactivation (TMR)

- ❖ Targeted memory reactivation is a technique that involves pairing cues with newly learned information that can later be presented during sleep to promote memory reactivation and later memory retrieval^{2,3}.
- ❖ TMR with auditory cues during slow-wave sleep can produce memory benefits for procedural memory and creative problem-solving tasks^{4,5}.
- ❖ The role of sleep and TMR have not yet been tested in students solving multiplication problems.

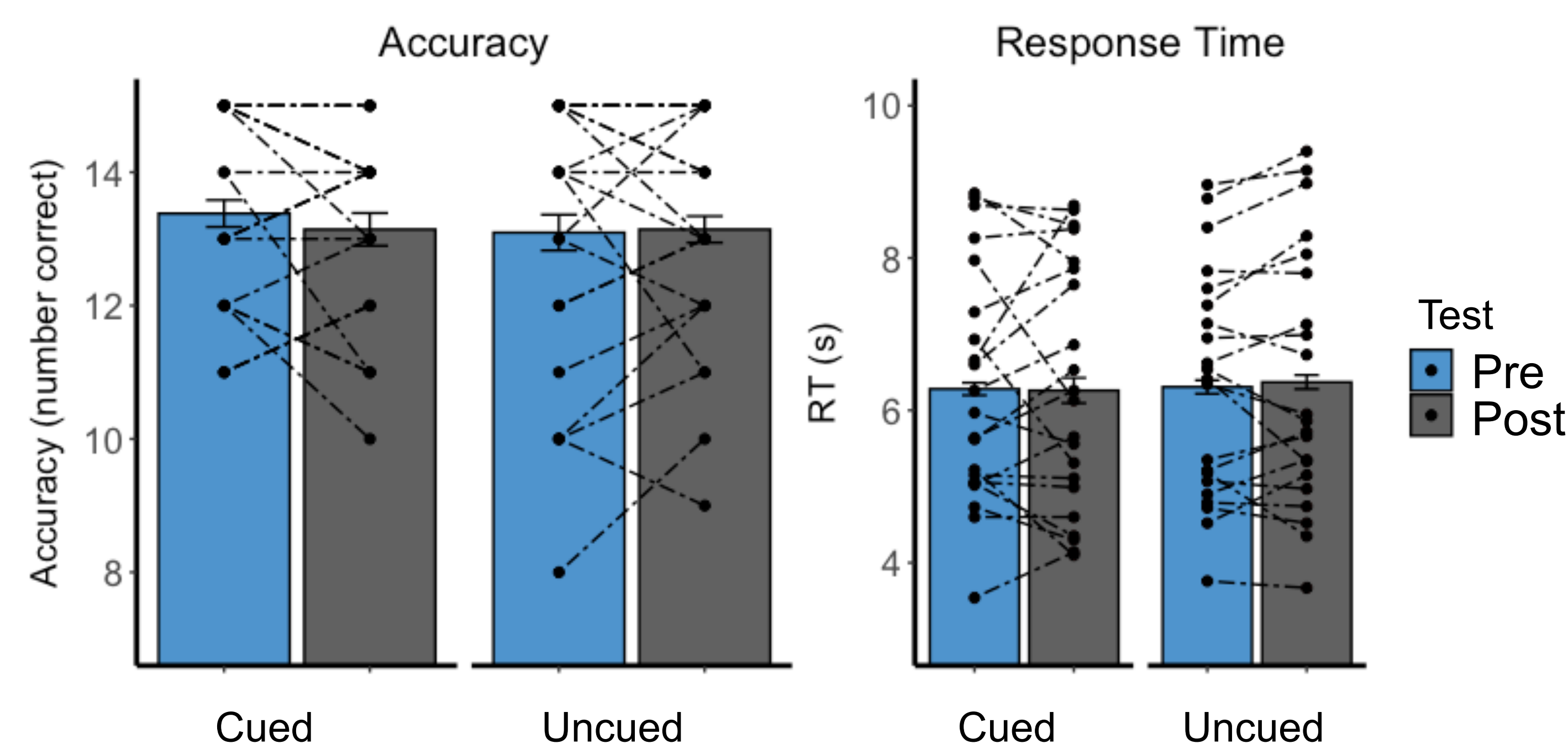
Learning produced higher accuracy and faster responses



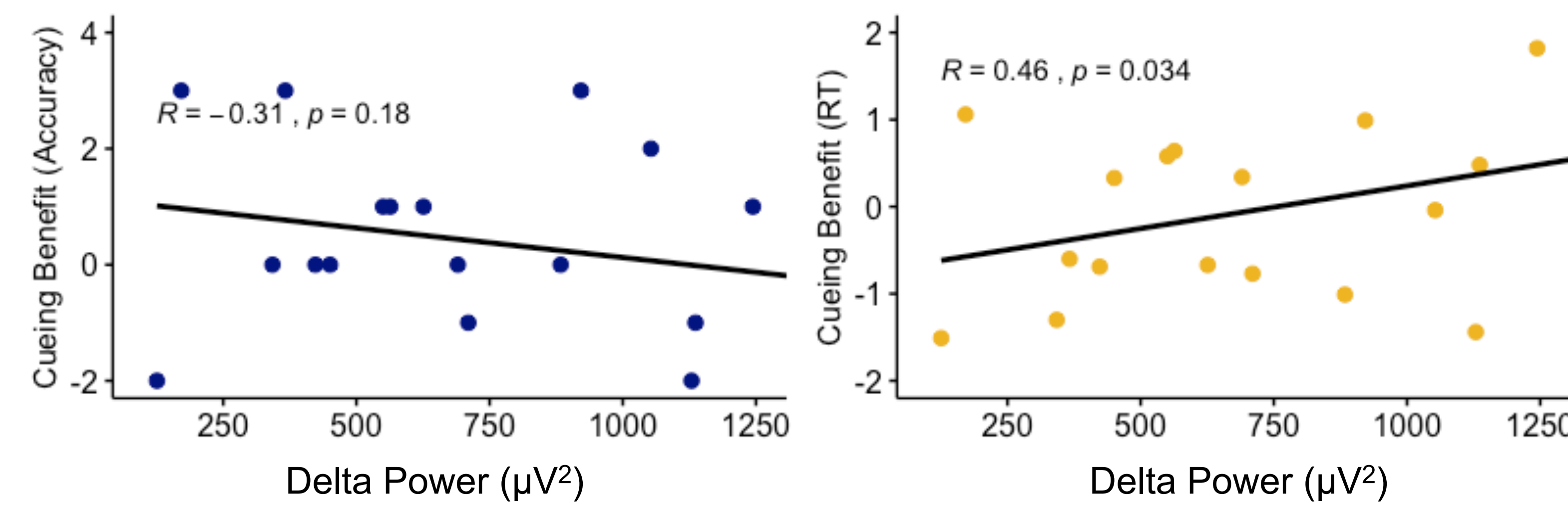
Performance was similar in sleep and wake groups across the two tests



Performance was similar for problems that were cued versus uncued



Higher delta power was associated with preferential speed-up for cued problems compared to uncued problems



Summary

1. Speed and accuracy measures showed that learning occurred, with no decline after the delay in both the Sleep and Wake groups.
2. Cues during sleep did not produce consistent effects, but stronger delta power (measured at 0.5-4 Hz at the Fz location) was associated with a TMR effect on response speed, suggesting possible sleep reactivation.
3. Behavioral results did not implicate sleep as was predicted, perhaps due to limitations of performance measures or other task parameters like delay.

Open Questions

1. Would testing after a longer delay reveal sleep-dependence?
2. Were sounds suitable cues for mathematical knowledge in this task?
3. Could further training lead to fact knowledge, beyond mere skill learning, that would have a greater dependence on sleep?

Reference

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4. Antony, J. W., Gobel, E. W., O'hare, J. K., Reber, P. J., & Paller, K. A. (2012). Cued memory reactivation during sleep influences skill learning. *Nature Neuroscience*, 15(8), 1114.
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