Associations between Sleep Slow Oscillation-Spindle Coupling and Declarative Memory in Early Childhood

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INTRODUCTION

Naps benefit memory in early childhood (3-5 years) even as children transition from biphasic to monophasic sleep. This memory benefit is thought to reflect sleep-dependent memory consolidation orchestrated by three oscillations in the sleep EEG[1].

Recent studies have observed the simultaneous activity of slow oscillations (SOs) and sleep spindles (SPs), referred to as SO-SP coupling, during childhood[2,3,4]. This coupling may be strengthened with development as it has been shown to be greater in adolescence relative to childhood[4]. Further, coupling strength has been shown to be positively related to memory consolidation[3,4]. How SO-SP coupling strength changes during early childhood and how it relates to memory consolidation remains unexamined.

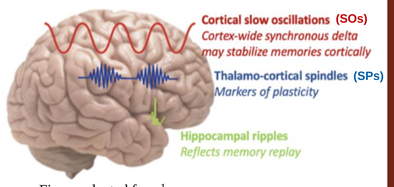


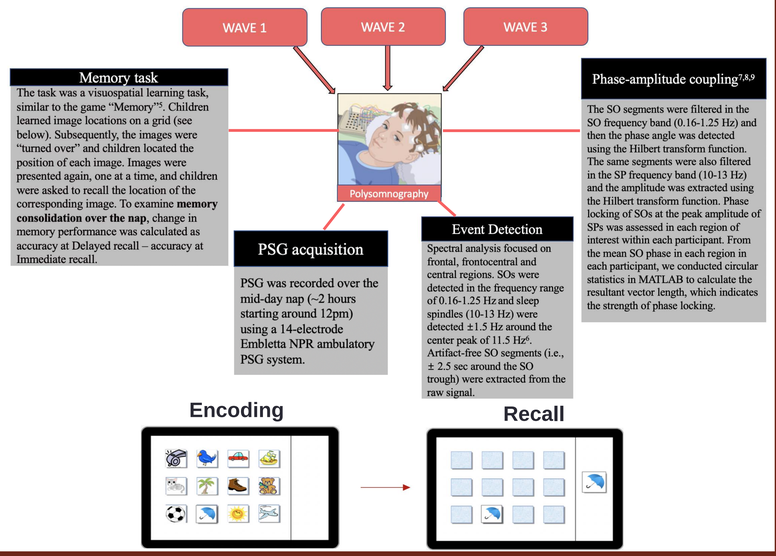
Figure adapted from[1]

We hypothesize that coupling strength increases with development, thus benefiting memory consolidation. Alternatively, naps may not be sufficient to observe changes in coupling strength.

METHODS

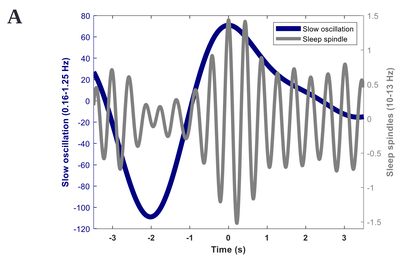
Study Design: This is a preliminary analysis of data from a longitudinal study examining polysomnography (PSG), memory, and brain development. Important to current analyses, there were 2-3 sleep and memory assessments over the course of a year (Wave 1: baseline; Wave 2: 6 months after Wave 1; and Wave 3: 12 months after Wave 1). Analysis involves two groups - children with Wave 1 and Wave 2 data (W1-2 group) and a separate group of children with Wave 2 and Wave 3 data (W2-3 group).

Participants: Participants were 20 preschool-aged children. The W1-2 group included data from 10 preschool-aged children (6 female, M_{age} = 4.03, SD = 0.60 at Wave 1) and the W2-3 group also included data from 10 preschool-aged children (5 female, M_{age} = 4.66, SD = 0.41 at Wave 2).



RESULTS

What is slow oscillation-spindle (SO-SP) coupling strength?



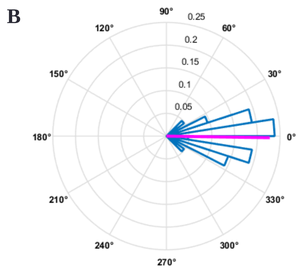
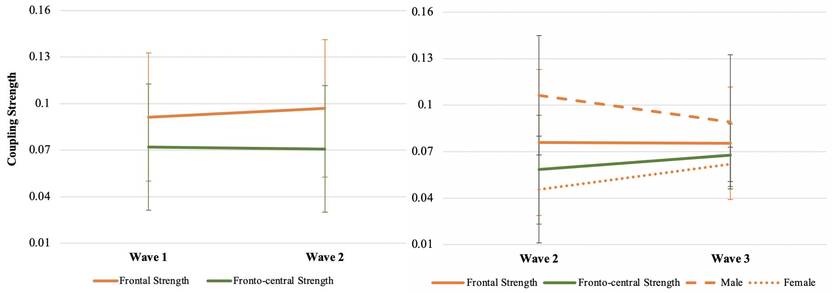


Fig A is an example of the fine-tuned coupling between SOs and SPs. A single subject will have a range of coupling of SO-SP events (**Fig B**, blue histogram) with the mean of these (angle of the pink line) representing their preferred phase and the variability of these (length of the pink line) reflecting the **coupling strength**.

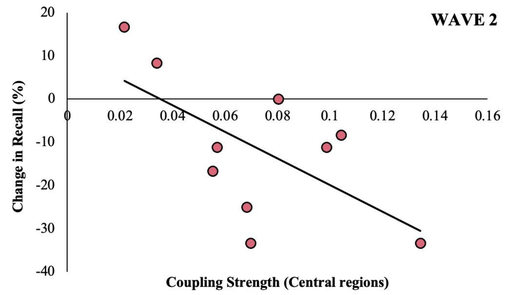
Does coupling strength increase with development?



We did not observe a significant change in coupling strength from Wave 1 to Wave 2 (ps > 0.67; **above left**). This remained the case even after controlling for age and gender (ps > 0.28). In the W2-3 group, while coupling strength overall was not significantly different between Wave 2 and Wave 3 (ps > 0.41; **above right**), there was a main effect of gender such that males had greater coupling strength in frontal derivations than females at Wave 2 ($F(1,9) = 6.93$, $p = 0.03$).

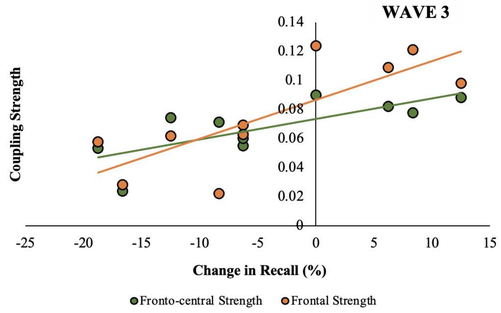
How does coupling strength relate to memory consolidation over the nap?

In the W1-W2 group, coupling strength at Wave 1 was not associated with memory consolidation over the nap at Wave 1. Similarly, coupling strength at Wave 2 was not associated with memory consolidation over the nap at Wave 2.



In the W2-3 group, coupling strength in central derivations at Wave 2 was marginally and negatively associated with memory consolidation over the nap at Wave 2 ($r = -0.62$, $p = 0.054$).

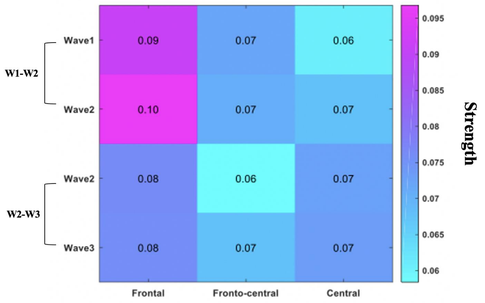
RESULTS CONT.



However, at Wave 3, coupling strength in frontal and fronto-central regions was positively associated with memory consolidation over the nap ($ps < 0.013$).

What is coupling strength at each ROI at each Wave?

The figure at the right illustrates coupling strength for frontal, fronto-central, and central regions at each wave. There was no systematic change in coupling strength across waves.



DISCUSSION

Our findings indicate that SO-SP coupling strength did not significantly change in the developing brain over a year. However, by Wave 3, we see that coupling strength in frontal regions during a nap became positively related to memory consolidation over the nap. This provides preliminary support that SO-SP coupling strength in naps in early childhood may contribute to the strength of memory consolidation to some extent.

Further, our results indicate that males had greater frontal strength than females. This finding is in line with work highlighting that between the ages of 12-14 years, there is a longitudinal increase in SP density in males, 31% greater compared to females[10]. This suggests that there may be sex differences in the maturational trajectories of SPs that may affect coupling strength of SO-SP events in early childhood.

Overall, these results suggest that physiological markers of brain and memory development may undergo changes during the biphasic to monophasic sleep transition. Specifically, these changes may reflect a molding of a more efficient frontal neural network that benefits memory consolidation. Future research with a greater sample size will allow us to disentangle effects of sex and nap transition status on coupling strength and the relationship between strength and memory consolidation.

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