

Power Naps and Episodic Memory: Differential Benefits of Stage 2 Sleep and Slow Wave Sleep

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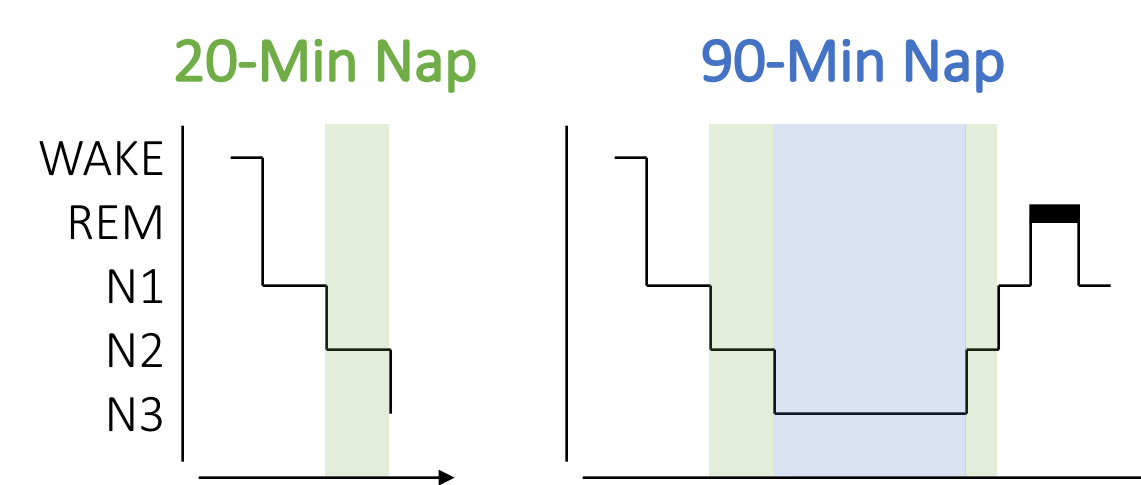
BACKGROUND

- Sleep plays a critical role in episodic memory consolidation. However, "power naps" (~20 min), which contain primarily stage 1 and stage 2 sleep, may not confer the same memory benefits as naps that contain a full sleep cycle (~90 min).
- Some studies suggest that stage 2 sleep, which is characterized in the EEG by sleep spindles (12-15 Hz), is sufficient for memory consolidation^{1,2}.
- However, spindles also occur during slow wave sleep (SWS), and some research suggests that SWS and slow oscillations (SOs; < 1 Hz) are necessary to observe episodic memory benefits^{3,4}.
- It remains unclear whether stage 2 sleep *alone* is sufficient for spindle-related memory benefits, or if SWS is essential for memory consolidation (e.g., via SO-spindle-ripple events)^{5,6}.
- In this study, we hypothesized that:
 - episodic memory retention would be greater following a nap containing SWS, as compared to both a nap with no SWS and active wakefulness.
 - slow oscillations and spindles during SWS, but not spindles during stage 2 sleep, would be uniquely associated with memory performance.

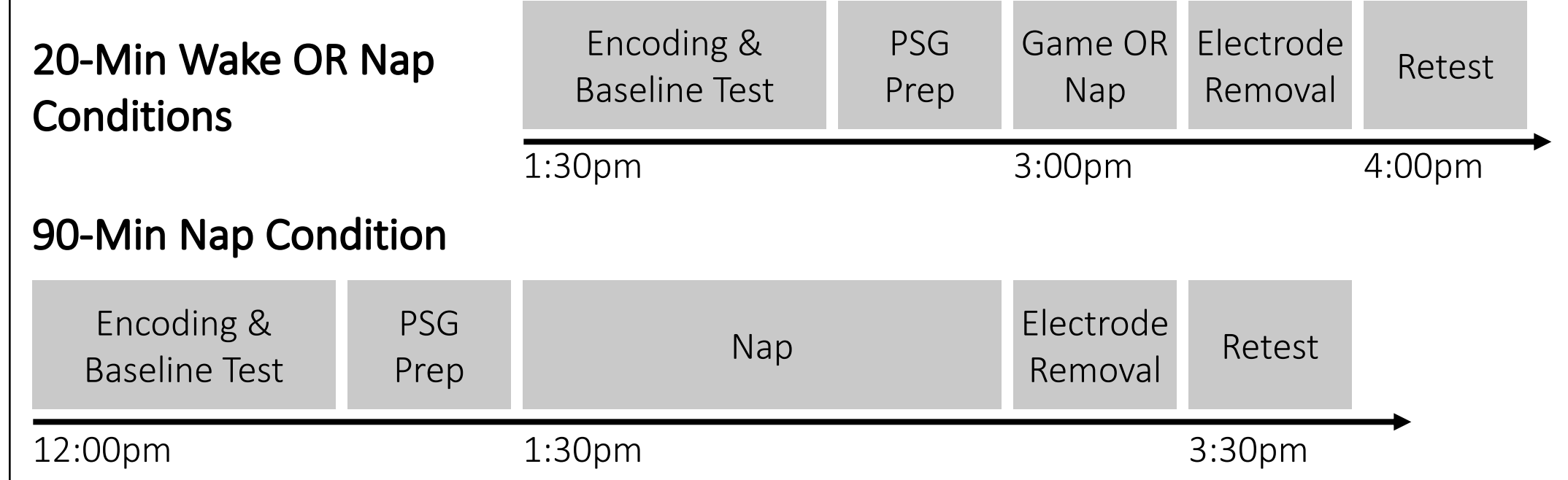
METHOD

- 149 healthy young adults (96 female; 18-22 years)
- Three conditions:

20-Min Wake: $n = 53$
 20-Min Nap: $n = 43$
 90-Min Nap: $n = 53$

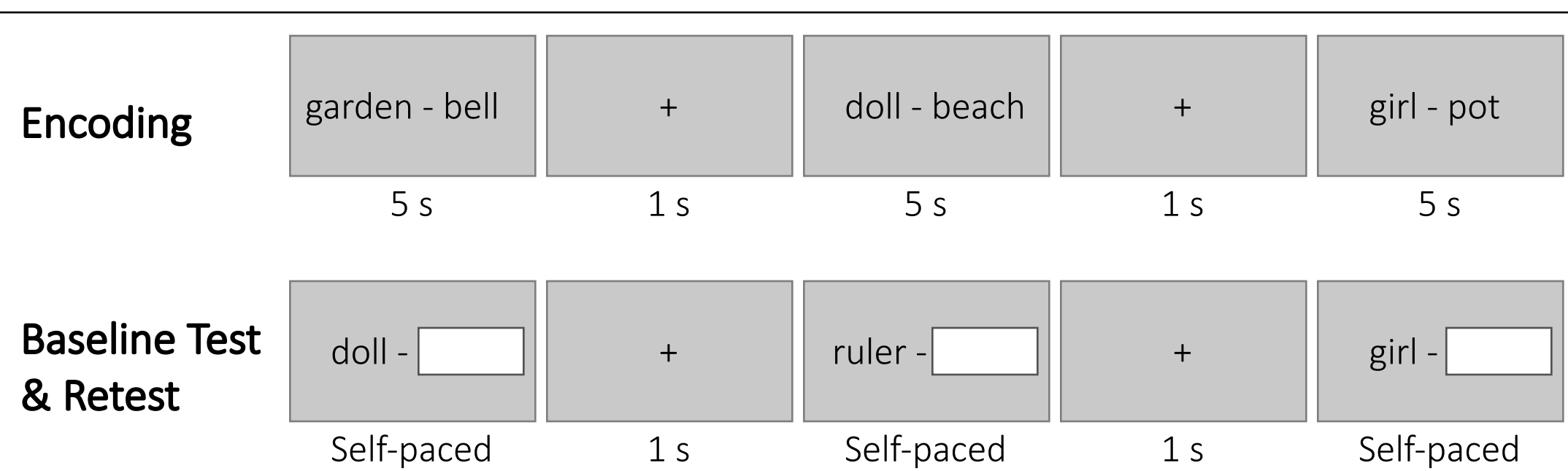


PROCEDURE



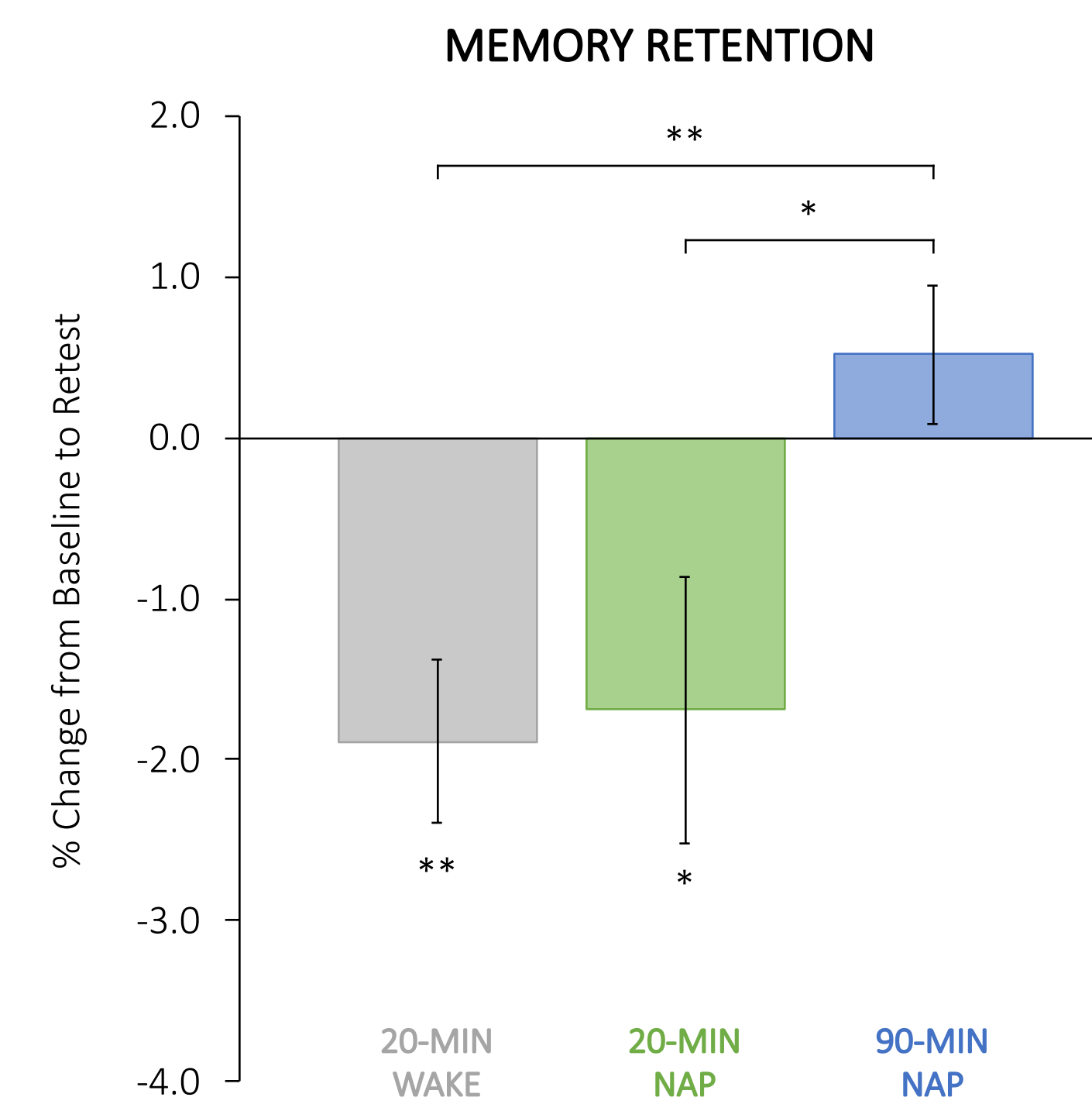
UNRELATED WORD PAIR ASSOCIATES TASK

- Episodic memory retention was measured as the percent change in recall from baseline to retest (i.e., forgetting).



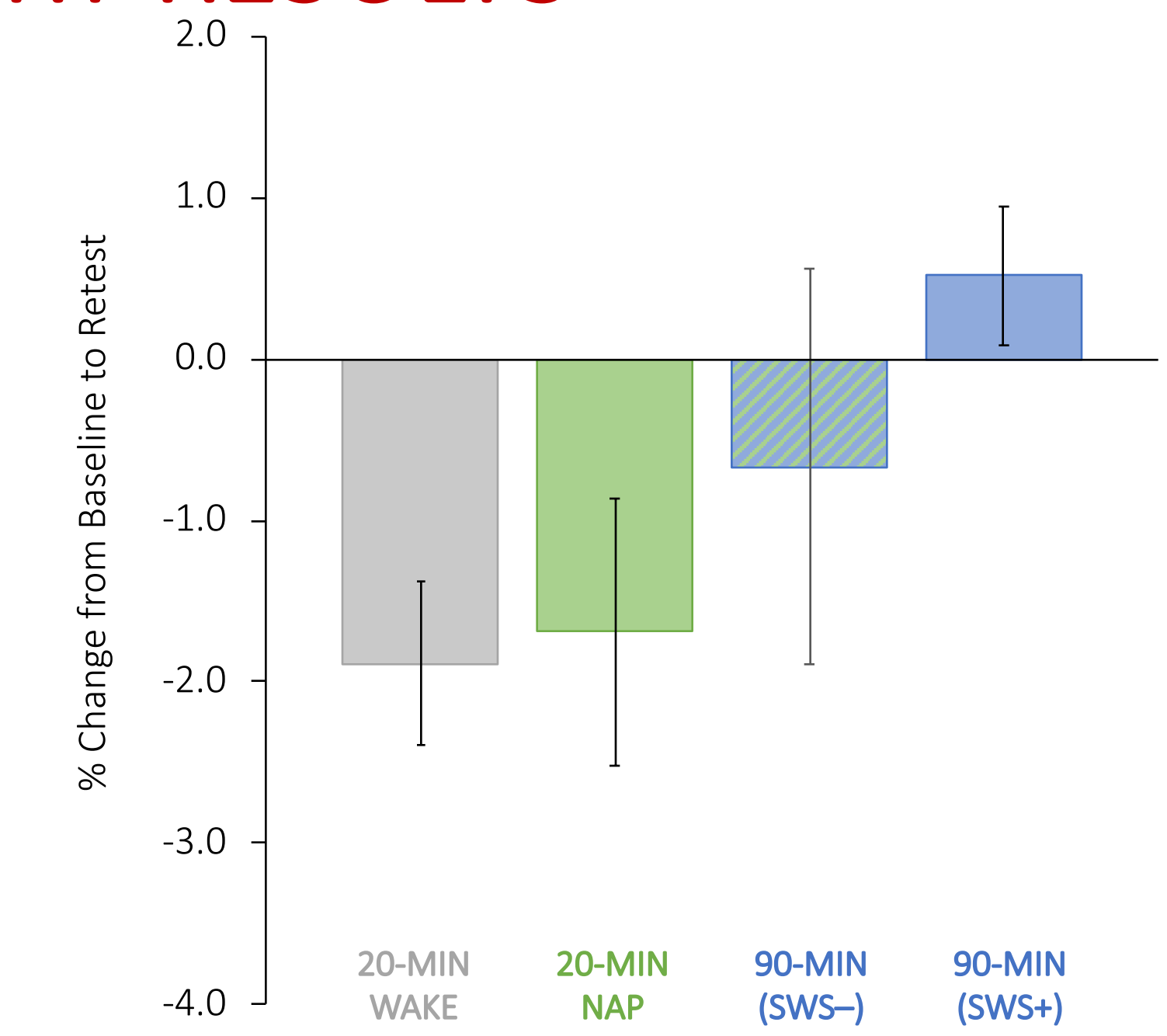
BEHAVIORAL RESULTS

- Overall, there was a significant group difference in memory retention $F(2, 146) = 5.467, p < 0.01$.
- 20-Min Wake vs. 90-Min Nap: $t(104) = 3.605, p < 0.01$
- 20-Min Nap vs. 90-Min Nap: $t(63.8) = 2.503, p < 0.05$
- Retention in the 20-Min Wake and 20-Min Nap conditions differed significantly from zero ($t(52) = 3.691, p < 0.01$; $t(42) = 2.049, p < 0.05$, respectively).
- There were no significant group differences either at baseline ($F(2, 146) = 0.496, p = 0.610$) or at retest ($F(2, 146) = 0.180, p = 0.835$).

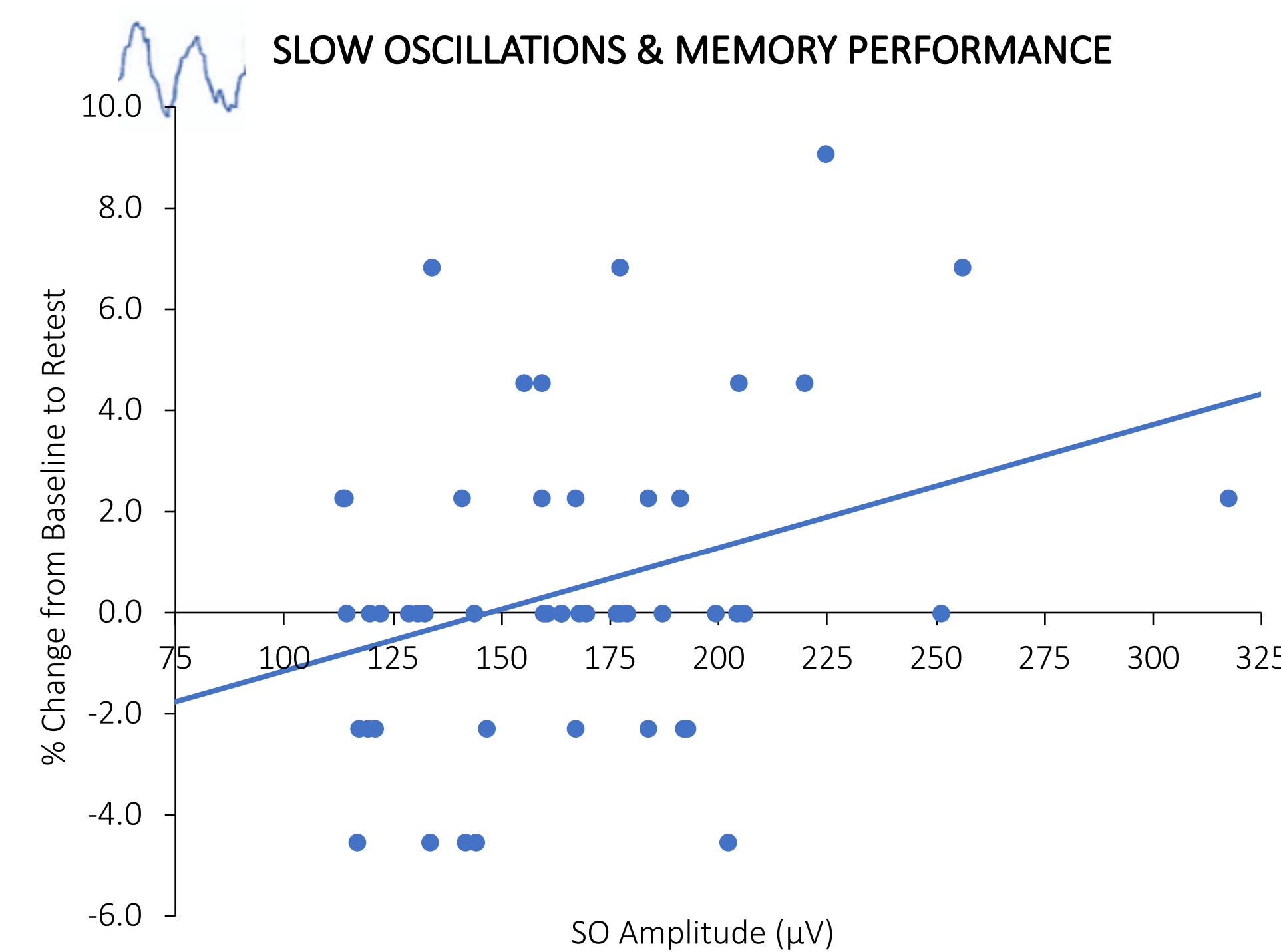


EXPLORATORY RESULTS

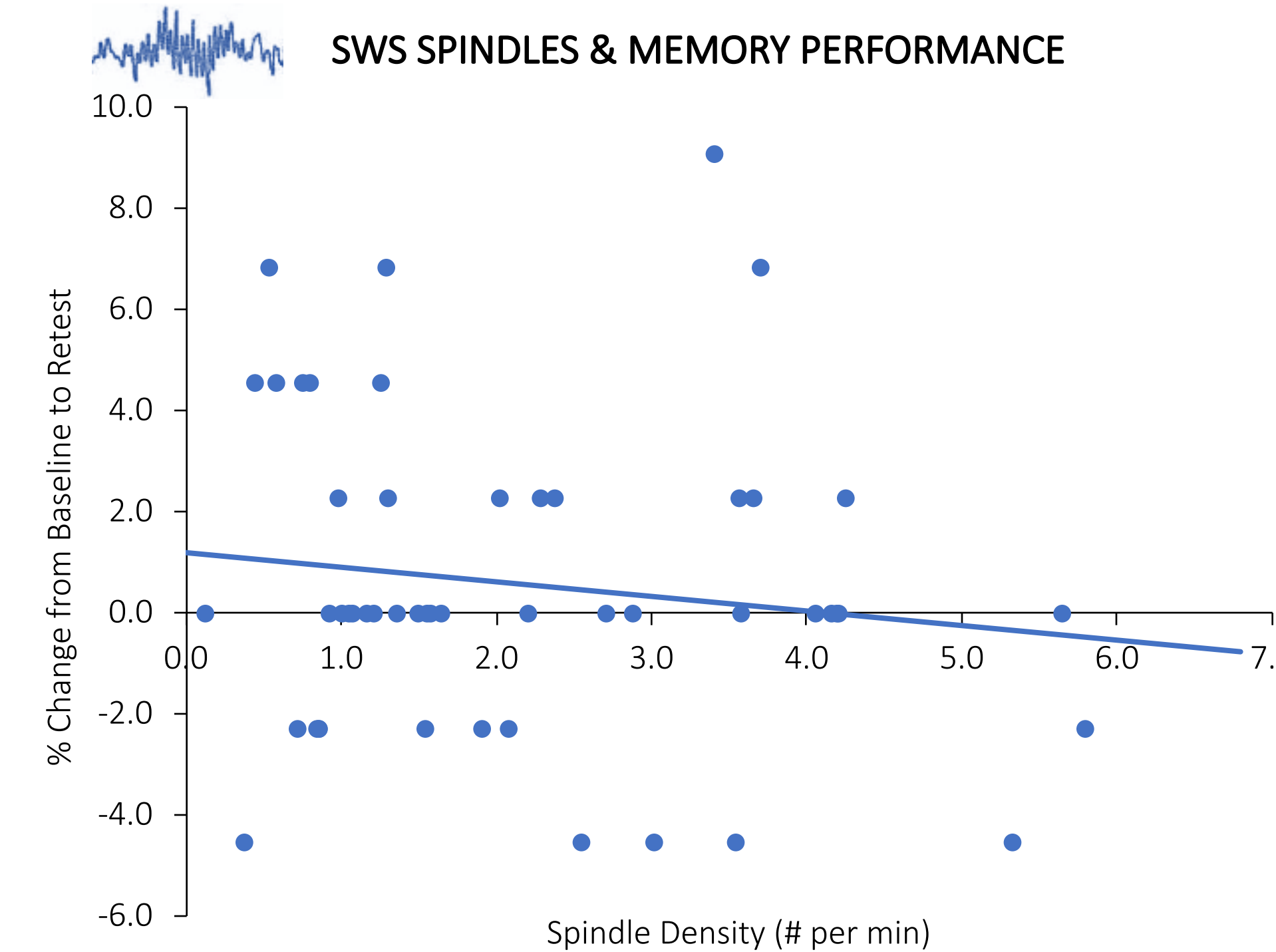
- An additional 17 participants in the 90-Min Nap group did not obtain any SWS (SWS-).
- Numerically, their memory retention fell between the 20-Min Nap and 90-Min (SWS+) conditions.



SLOW WAVE SLEEP & MEMORY

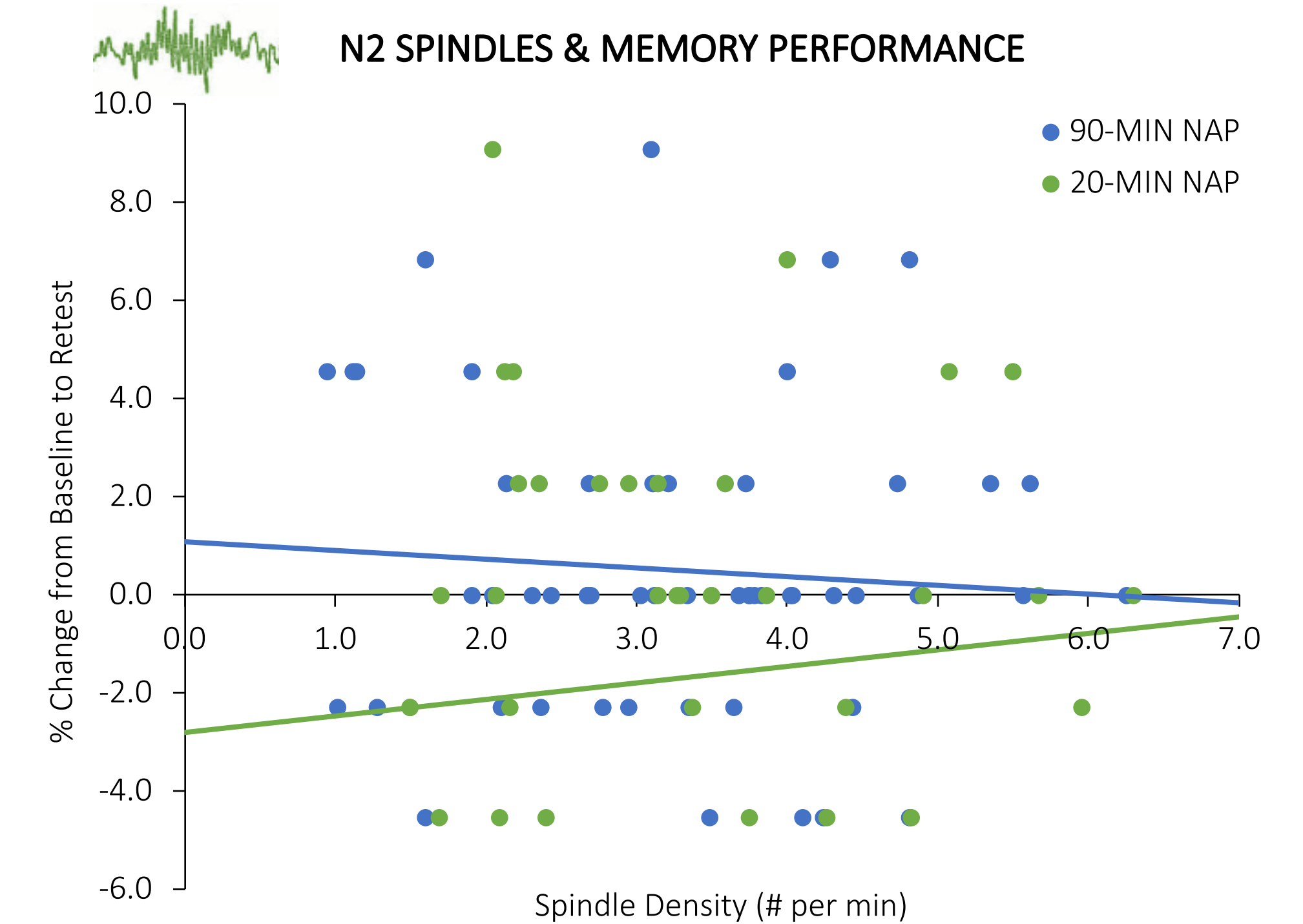


- Higher SO amplitude in SWS predicted greater memory retention ($b = 0.024, p < 0.05$).
- Other SO measures (count, density, duration) did not predict memory retention.



- Contrary to hypotheses, spindle measures (count, density, duration, amplitude, frequency) in SWS did not predict memory retention. (Spindle density depicted here.)

STAGE 2 SLEEP & MEMORY



- Spindle measures (count, density, duration, amplitude, frequency) in stage 2 sleep did not predict memory retention in either nap condition. (Spindle density depicted here.)

SLEEP ARCHITECTURE

	20-MIN NAP		90-MIN (SWS-)		90-MIN (SWS+)	
	Mean	SD	Mean	SD	Mean	SD
TST (min)	14.87	3.08	66.88	12.65	68.95	11.72
Latency (min)	3.98	3.02	5.74	4.38	5.32	5.52
WASO (min)	1.56	1.85	11.74	9.00	3.91	4.95
SE (%)	73.48	16.09	79.01	11.40	88.58	9.10
Wake (min)	5.53	3.61	17.47	9.40	9.23	8.38
N1 (min)	7.44	3.27	20.91	11.33	10.83	6.23
N2 (min)	7.16	3.37	32.65	13.95	29.24	8.58
SWS (min)	0.00	0.00	0.00	0.00	21.59	10.74
REM (min)	0.27	1.17	13.32	15.59	7.29	8.89
N1 (%)	50.61	20.00	33.04	20.85	16.11	10.18
N2 (%)	47.82	19.49	49.12	19.84	42.81	11.79
SWS (%)	0.00	0.00	0.00	0.00	31.64	15.30
REM (%)	1.57	6.50	17.84	19.92	9.44	10.40

CONCLUSIONS

- To our knowledge, this study is the first to experimentally isolate stage 2 from SWS to examine stage-specific relationships between sleep features and episodic memory.
- In contrast with prior research⁷, a short nap without SWS did not benefit episodic memory, nor did stage 2 spindles predict memory retention, suggesting that stage 2 sleep alone may not suffice for sleep-dependent memory consolidation.
- SWS, and specifically slow oscillations during SWS, may be necessary to observe episodic memory benefits⁸.
- These findings advance our knowledge on sleep's role in episodic memory, and provide evidence that the duration and composition of a daytime nap may affect consolidation.

REFERENCES

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