# The effect of sleep deprivation before and after encoding on memory: A meta-analysis.

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## 1 Introduction

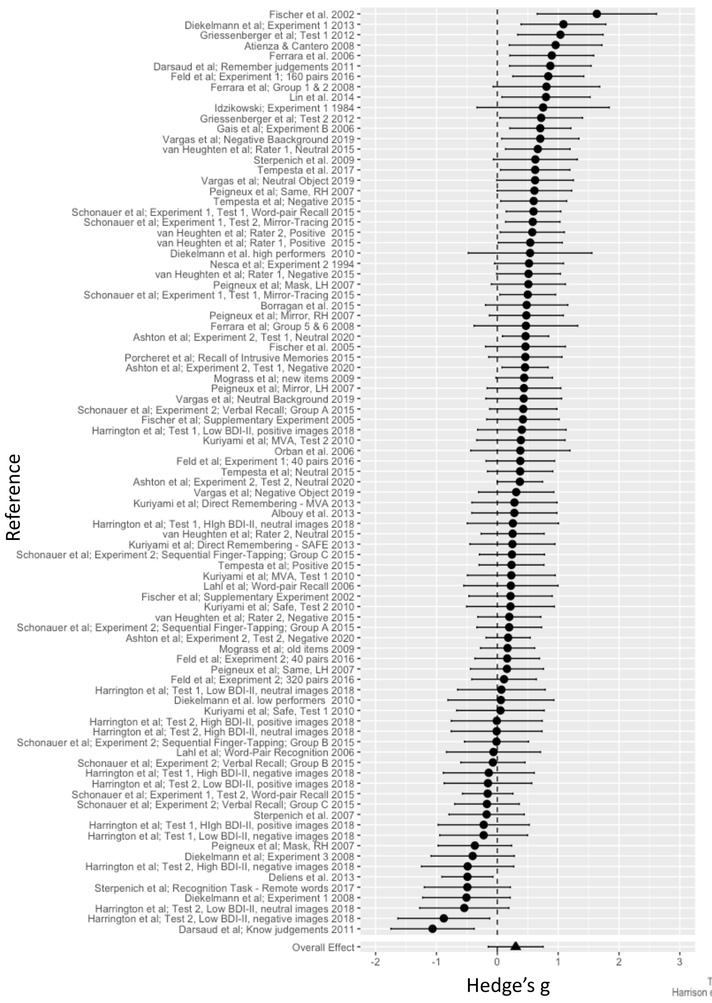
- Current theories of sleep and memory posit that sleep before learning restores encoding capacity[1] and sleep after learning supports consolidation of previously learned memories.[2]
- Sleep deprivation before or after learning has a detrimental effect on learning and memory.[3,4]
- A comprehensive analysis of the literature is needed to determine the size and strength of sleep deprivation effects on long-term memory.
- Potential moderators:
  1. Procedural v. declarative memory
  2. Recall v. recognition tasks
  3. Recovery sleep before testing
  4. Study quality
  5. Statistical power

**Research Question:**
What is the size and strength of the effect of sleep deprivation, before and after learning, on long-term memory?

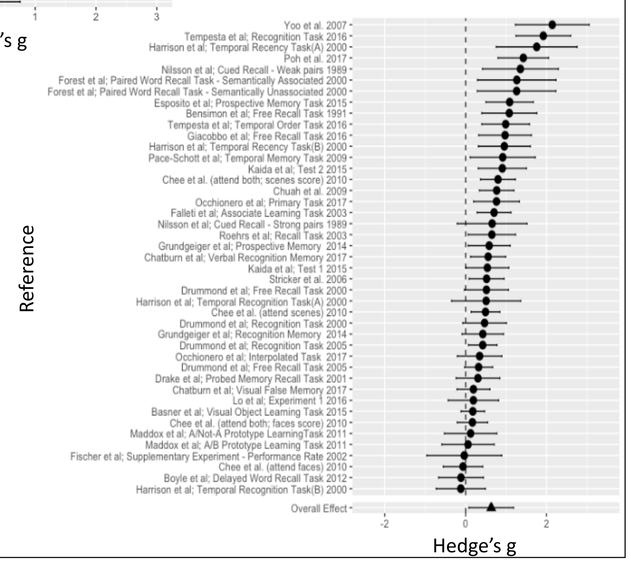
## 2 Methods

**Inclusion criteria:**

- Healthy adults
- 1+ nights of total sleep deprivation v. control sleep
- Learning or long-term memory task
- Independent encoding and retrieval phases
- If other interventions were assessed (e.g. drugs), only the control sleep deprivation and sleep groups were included.




Sleep deprivation after learning meta-analysis: **89 independent effect sizes**




Sleep deprivation before learning meta-analysis: **43 independent effect sizes**

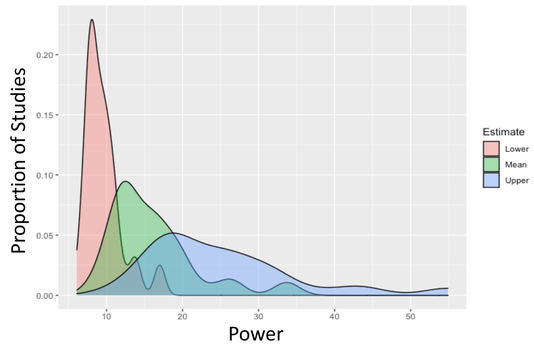
## 3 Results

### Sleep Deprivation After Encoding Meta-Analysis.

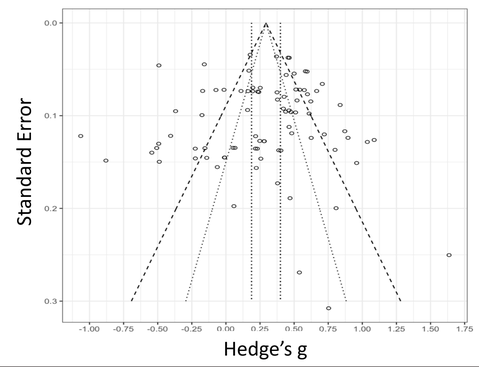
- **Small effect** (Hedge's $g$ = 0.30; $p$ <.001) of sleep deprivation after encoding impairing memory performance.

*Small effect = 0.2*
*Medium effect = 0.5*
*Large effect = 0.8*

- Recovery sleep was a significant **moderator** ($p$ = .011)
  - Small effect of sleep deprivation after recovery sleep ($g$ = 0.206)
  - Medium effect of sleep deprivation without recovery sleep ($g$ = 0.405).
- Mean statistical power of just **16%** to detect meta-analytic effect size, which raises uncertainty as to the size of the true effect.

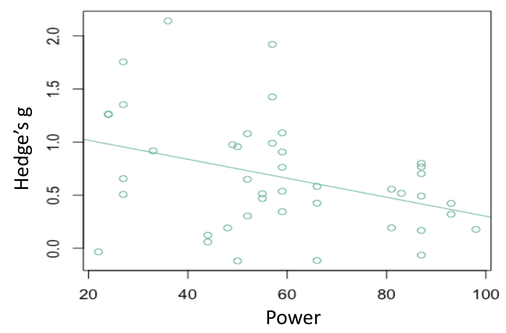


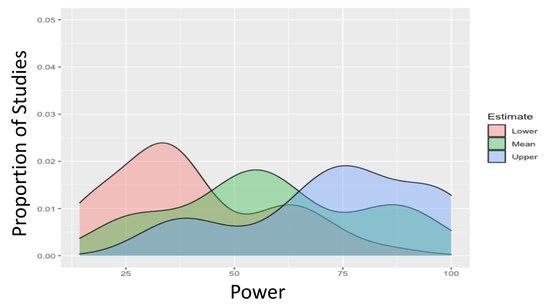

- Egger's regression test for funnel plot asymmetry indicates no evidence of publication bias ($z$ = -0.103; $p$ = .918).



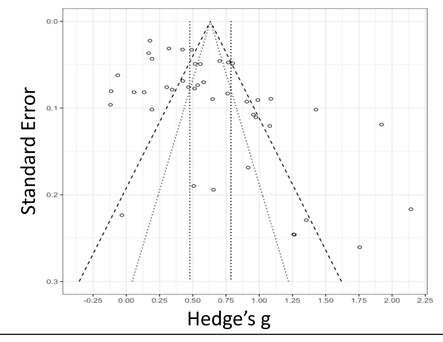

### Sleep Deprivation Before Encoding Meta-Analysis.

- Sleep deprivation before encoding impairs memory with a **medium effect size** ($g$ = 0.63; $p$ <.001).
- Statistical **power** to detect meta-analytic effect size was a significant moderator ($p$ = .020)
  - Low power was associated with large effects and high power was associated with medium effects
  - Mean power of **58%** to detect the meta-analytic effect size.




- Evidence of **publication bias** (p < .001), but adjusting for bias still yielded a medium effect size ($g$ = 0.52).




## 4 Conclusions

- Sleep deprivation before learning impairs memory.
- Sleep deprivation after learning impairs memory, but subsequent recovery sleep reduces the impairment by 50%.
- High-powered, pre-registered direct replications are needed to verify these conclusions.


1. Saletin, J. M., & Walker, M. P. (2012). Nocturnal mnemonics: Sleep and hippocampal memory processing. *Frontiers in Neurology, 3*, 59.
2. McClelland, J. L., McNaughton, B. L., & O'reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, *102*(3), 419.
3. Yoo, S. S., Hu, P. T., Gujar, N., Jolesz, F. A., & Walker, M. P. (2007). A deficit in the ability to form new human memories without sleep. *Nature Neuroscience*, *10*(3), 385.
4. Gais, S., Albouy, G., Boly, M., Dang-Vu, T. T., Darsaud, A., Desseilles, M., ... & Maquet, P. (2007). Sleep transforms the cerebral trace of declarative memories. *Proceedings of the National Academy of Sciences*, *104*(47), 18778-18783.