The Effects of Sleep on Category Structure Knowledge

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Introduction

- Sleep is believed to **facilitate memory consolidation**, or the gradual process of changes in memory storage after initial encoding that are vital to preserving the memory (Oudiette & Paller, 2013)
- Research suggests sleep helps with abstraction and creative thinking (Landmann, 2014).
- Time delays may be required to process recently learned material in abstract and creative ways (Landmann, 2014).

Gaps?

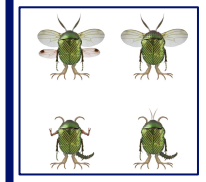
- Sleep preserves memory of unique features and enhances memory of shared category features (Schapiro et al, 2017)
- Internal structure of individual concepts has been ignored in past research

Big question: How does one night of sleep impact our memory of recently learned category structures?

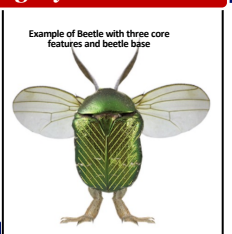
How my research will address this gap: How does sleep benefit knowledge of category structures beyond what would be expected over the course of the same time delay (12 hours)?

- *What kinds of information are more easily learned?*
- *How does sleep impact our ability to generalize our understanding of new information?*

Stimuli & Category Structure



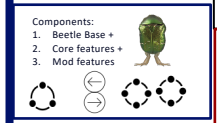
Observation Phase: 4 "intact" beetles



There are 11 unique features – of these features, some of them are core features.

These are the essential features of the beetle that subjects will be tested on during session two. The other features have mod. structure.

Components:
1. Beetle Base +
2. Core features +
3. Mod features



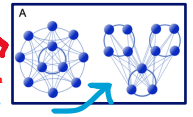


FIGURE A: What does ring/mod mean?
- "Modularity" – statistical measure of clustered features that appear together in a graph structure
- **Lower modularity ("ring") – features in ring network**
- **High modularity ("mod") – more clustering**

Methodology

- Subjects recruited using Amazon Mechanical Turk (USA)

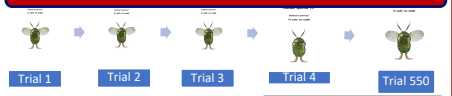
	Ring	Mod	total
Sleep Group	n = 20	n = 20	40
Wake Group	n = 20	n = 20	40
total	40	40	80

- Sequence of tasks
  - Session one (statistical exposure task + feature association task)
    - 12 hours pass (awake or sleep)
    - Session two (feature association task + explicit accuracy task)
- Pay: $2 base rate session one + $2 base rate session two + $6 * dPrime score = up to $10

Session One	Earliest/Latest Start Time	Earliest/Lastest Submit Time
(available ~ 5:00 to 9:00 PT) *no sleep condition*	04:47 to 08:13 PT	05:14 to 09:49 PT
(available from ~ 17:00 to 21:00 PT) *sleep condition*	16:37 to 21:48 PT	17:04 to 22:21 PT
Session Two		
(available from ~ 4:00 to 9:00 PT) *sleep condition*	05:14 to 09:05 PT	05:28 to 09:17 PT
(available from ~ 16:00 to 21:00 PT) *no sleep condition*	16:14 to 19:16 PT	16:17 to 19:18 PT
*pacific time = EST + 3 hours		

Methodology: statistical learning to understand concepts– form of unsupervised learning
- People can learn statistical occurrences
- Features that correlate with each other make it easier to learn the concept

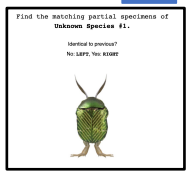
Tasks



*Brief exposure to stimuli (Observation Phase)

1. Statistical Exposure Task

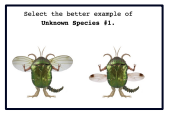
~ 25 mins & 550 trials
- shows statistical co-occurrences of features – based on assigned category structure ==== implicit learning task
- Familiarizes subject with the task: learning to identify a "new species" of bugs based on their visual features
- Subjects receive score of 0 or 1 on each trial (accuracy = 1)
- Button response
  - Right arrow = identical to previous image
  - Left arrow = not identical



2. Feature Two-Alternative Forced Choice Task (2afc)

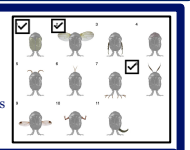
~ 5 mins & 24 trials
- Tests ability to recognize statistical co-occurrences of features previously learned in exposure task
- 8 core accuracy and 16 mod accuracy trials

Two exemplars are shown (each with six features): One of the exemplars structures is consistent with the previously learned structure, while the other is not.



3. Explicit Structure Task

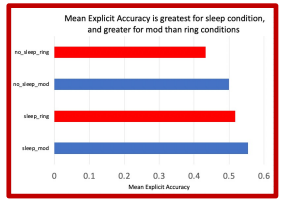
<5 mins & "11 choose 3" visual feats
- measured as 3 "explicit accuracy" scores
- considered the "core" features



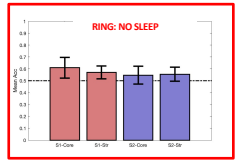
Looking at Data

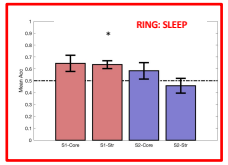
How do we test differences in accuracy based on category structure?

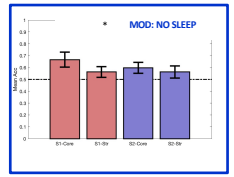
1. Statistical Exposure Task
   - D-Prime: measures individual's signal detection
   - Standard tool for assessing noise to signal ratio
2. Feature Two-Alternative Forced Choice Task (2afc)
   - Session one core accuracy, mod accuracy
   - Session two core acc, mod acc
3. Explicit Structure Task
   - There are always three core features
   - measured as explicit accuracy
     - zero is incorrect
     - one is correct

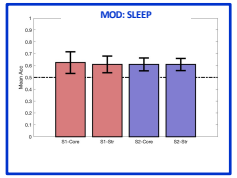


Results: 2afc task









p-value (≤ 0.05)*

Mean accuracy for session 2 core and mod structure are preserved in **MOD SLEEP** condition, mod structure is not significantly above chance on session 2 for other conditions. **RING SLEEP** mod structure mean accuracy on session 2 may fall below chance, suggesting prioritization of core structure knowledge for **RING SLEEP**.

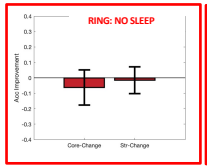
Results: Linear Regressions

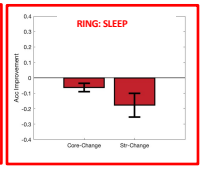
	SumSq	DF	MeanSq	F	pValue
Total	1.298	69	0.018811		
Model	0.068388	3	0.022796	1.2236	0.30814
Residual	1.2296	66	0.01863		
. Lack of fit	0.53062	26	0.020408	1.1679	0.32285
. Pure error	0.69899	40	0.017475		

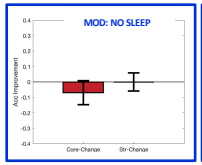
	SumSq	DF	MeanSq	F	pValue
Total	2.3359	69	0.033854		
Model	0.20444	5	0.040888	1.2277	0.30653
Residual	2.1315	64	0.033305		

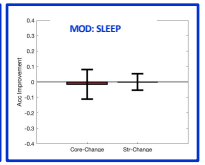
Model: above, s2mod and 3 predictive factors (s1mod, sleep condition,struct)
Below, s2core and 5 predictive factors (s1core, s1mod, s2mod, sleep cond, strc)

Results: 2afc analysis









For the ring conditions, **RING SLEEP** core knowledge is preserved while mod structure accuracy decreased. This pattern is only observable in the **RING SLEEP** condition, not in **RING NO SLEEP**. For mod conditions, **MOD SLEEP** core knowledge may be better preserved than in **MOD NO SLEEP** condition.

Conclusion: category structures with clustering of features are more readily learned than structures that lack clustering, but Sleep may prioritize learning of core structural knowledge over peripheral features in more challenging structures to learn.

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