Sleep Aids the Consolidation of Spatial Relational Memories

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INTRODUCTION

- Prior research argues that sleep helps consolidate 'transitive inferences' (but not individual associations) into a hierarchy (Ellenbogen et al., 2007):

  B>D from learning B>C and C>D

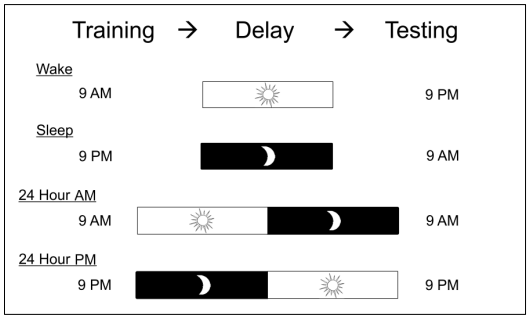
- In a hierarchy with one dimension, the distance and number of connections that separate items are always identical: items with more separating steps are always further apart
- But relational knowledge is not always like this
  - E.g., in spatial representations, relationships can have at least two dimensions (North-South and East-West)
- The addition of a second dimension disrupts the perfect correlation between steps and distance
  - E.g., The Euclidian distance to a destination can be smaller than the distance travelled to get there
- We asked whether sleep helps consolidate relational knowledge into a two-dimensional network, particularly when the number of learned connections separating items can diverge from the distance between them

METHOD

- 60 participants were tested: 20 in each 12-hour group and 10 in each 24-hour group

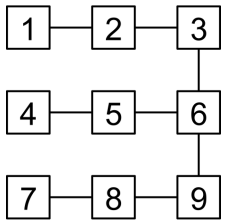
Training:

- Spatial associations were learned through trial-and-error by selecting one of two possible relationships to a target (e.g., North or South of target)
- Training stopped after reaching criterion
- Although not told to participants, the associations formed a spatial layout



Testing:

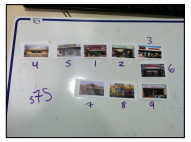
1) How accurate are participants' learned maps after wake or sleep? [map task]
   - For explicitly taught connections
   - For untaught relationships
2) How well are taught associations retained? [training test without feedback]
3) How accurate are participants' distance-judgments of items after wake or sleep? [which item is closer to the target?]



RESULTS

1) Participants who slept were more likely to create accurate maps (15 /19 correct compared to 8 / 20; $\chi2(1) = 6.11$, $p = 0.01$)

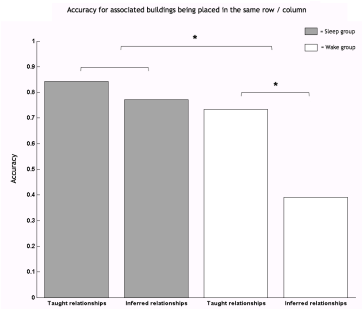
- The sleep group's maps had a larger number of correct taught relationships (M = 11.4 vs. M = 10.1, p = 0.008 in Wilcoxon rank sum test)
- The groups did not differ in correct untaught inferred relationships (sleep M = 4.0; wake M = 3.5; p = 0.41 in Wilcoxon rank sum test)



- Using a looser integration measure of whether buildings were correctly placed in the same column or row:

  The sleep group was more likely to correctly place associates together for untaught (M = 4.6 vs. M = 2.4; p = 0.01 in Wilcoxon rank sum test), but not explicitly taught associations (p = 0.10 in Wilcoxon rank sum test)

A significant interaction was present: Group x 'Inferred – taught' (p = 0.007 in Wilcoxon rank sum group test)



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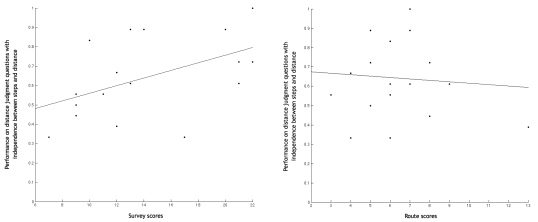
2) The groups did not differ in their retention decay of taught associations, tested using the training task (p = 0.17 in Wilcoxon rank sum test)
3) Unexpectedly, the groups also did not differ in their distance judgments of directly taught or inferred relationships

- We compared participants' preferences for using a 'survey' and 'route' based navigational strategy (QSR; Pazzaglia and Taylor, 2007) with their distance judgment performance
- We focused on questions where the correct landmark was closer in Euclidian distance but further in the number of steps connecting it to the target
- The sleep group's performance was related to their use of a survey style ($r(17) = 0.49$, $p = 0.04$), but not route style ($r(17) = -0.08$, $p = 0.75$; significantly different: $t(15) = 2.18$, $p = 0.046$)
- In contrast, the wake group's distance judgment performance was not related to either strategy ($p > 0.15$)



- The 24-hour groups did not differ in their performance, arguing against a circadian explanation

CONCLUSIONS

- A night of sleep begins to integrate learned associations into a two-dimensional relational network
- The beneficial effects of sleep on a distance judgment task might particularly aid people who navigate via a cognitive map
- A flexible map task was particularly sensitive to the effects of sleep

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