



Effects of Sleep on Knowledge Integration and Automaticity of Processing

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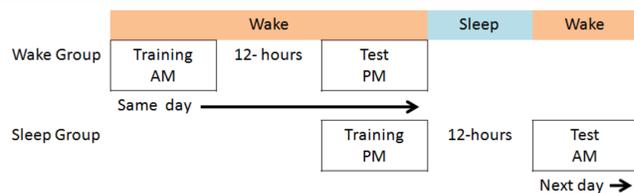
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Background

Recent research indicates that sleep benefits consolidation of declarative memory^{2, 4} such as novel words^{1, 3}. We investigated effects of sleep on knowledge integration and automaticity of processing using **Size Congruity Effects (SCEs)** and **Semantic Distance Effects (SDEs)** in second-language learning. SCEs occur when participants compare semantic or physical font size of written-word pairs: correct responses are faster when both dimensions are congruent (e.g., BEE-COW). SDEs involve swifter semantic size judgements for distant items (e.g., BEE-COW) compared with closer items (e.g., DOG-COW). These effects reflect automaticity in activating meanings⁵; well-integrated novel words should exhibit greater SCE and SDE effects than unintegrated items.

- We predicted that participants who slept between learning and testing would show greater SCEs and SDEs for novel words learnt during training than those who remained awake for a comparable duration.
- By correlating sleep polysomnography (PSG) data with behavioural performance, we aim to investigate if different aspects of sleep are related to automaticity of processing.

Methods



Experiment 1: Behavioural study

- 24 native English speakers were randomly allocated into Wake (n=12) and Sleep (n=12) groups.

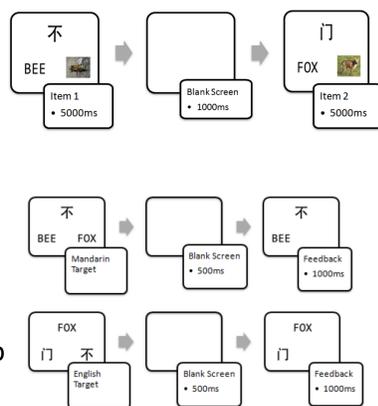
Training

i) Exposure

- Participants learned 6 Mandarin characters referring to different sized animals by associating them with existing English words

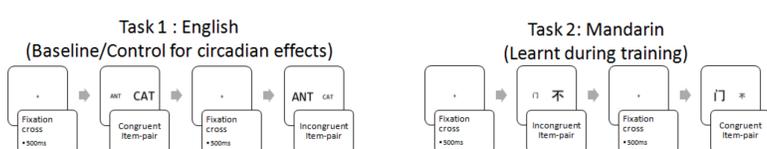
ii) 2 Alternative Forced Choice Task

- Participants had to select the item with the same meaning as the target
- Feedback was always given
- After training there was a 12-hour interval where participants remained awake (Wake group) or experienced a night of normal sleep (Sleep group)



Test

- During testing, participants saw animal-pairs differing in both:
 - ❖ Physical (font) difference: 1mm or 4mm
 - ❖ Semantic (referent) distance: small (small-medium/medium-large animal) or large (small-large animal)
- In half the trials, relative physical and semantic sizes were congruent and in half they were incongruent.
- Two comparison tasks were conducted where participants had to always select the semantically larger animal. The first task consisted of English stimuli to control for circadian effects and the second task consisted of the Mandarin stimuli participants learnt during training.



Experiment 2: Behavioural Study with Sleep Polysomnography

- 31 native English speakers learned 9 Malay words (alphabetic in nature) referring to different-sized animals in the evening (N=15) or morning (N=16), and tested after 10-hours of sleep or wake.
- Manipulation of experimental stimuli during training and the test session was similar to Experiment 1.
- Additional Sleep Polysomnography (PSG) recordings were collected for the Sleep group.

Results

1. Size Congruity Effect (SCE)

Novel Words (Figure 1)

- Experiment 1: The Sleep group experienced significantly greater SCEs compared to the Wake group ($p < .05$).
- Experiment 2: For comparisons with larger semantic distances and physical differences between item-pairs, the Sleep group experienced significantly greater SCEs than the Wake group ($p < .05$).

English words

- Experiment 1 & 2: There were no equivalent differences between groups, hence results were not confounded by circadian effects.

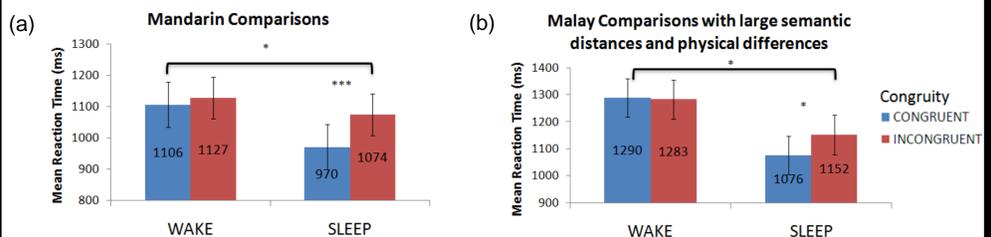


Figure 1: Size Congruity Effect for novel words: Mean reaction times for congruent and incongruent trials in (a) Experiment 1, and (b) Experiment 2. Error bars indicate \pm standard error.

2. Semantic Distance Effect (SDE)

Novel Words (Figure 2)

- Experiment 1: The Sleep group experienced significantly stronger SDEs ($p < .05$) compared to the Wake group.
- Experiment 2: For congruent trials, the Sleep group experienced significantly stronger SDEs ($p < .05$) compared to the Wake group.

English words

- Experiment 1 & 2: There were no significant differences between groups hence results were not confounded by circadian effects.

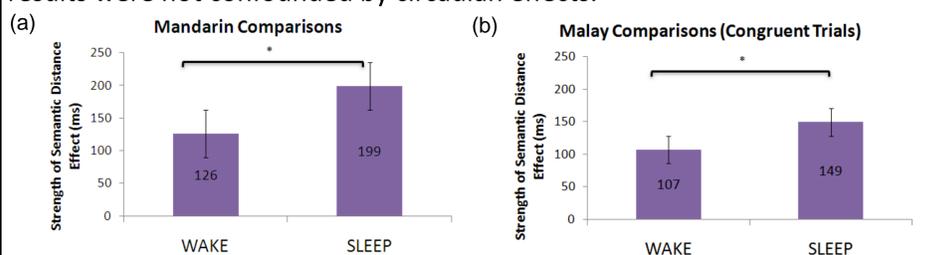


Figure 2: Strength of Semantic Distance Effect for novel words: Difference in mean reaction times for items with small vs. large semantic distances in (a) Experiment 1, and (b) Experiment 2. Error bars indicate \pm standard error.

Sleep Polysomnography (Figure 3)

- In Experiment 2 time spent in slow wave sleep (N3) was associated with:
 - (a) larger SDEs for novel Malay words: $r = .661, p < .05$ (corrected),
 - (b) No correlation for English words: $r = -.053, p = 1.0$ (corrected).

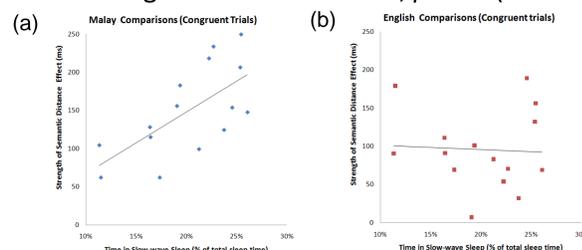


Figure 3: Correlation between strength of Semantic Distance Effect and time spent in slow-wave sleep (% of total sleep time) in Experiment 2 for (a) Malay comparisons and (b) English comparisons

Conclusions

- Both experiments support our prediction that participants who slept between learning and testing will show greater SCEs and SDEs for novel words learnt during training than those who remained awake for a comparable duration.
- There were no equivalent findings for English words, indicating that results were not affected by circadian confounds.
- Our results suggest that sleep plays an important role in word learning by enhancing automaticity of processing novel words.
- Correlations between PSG and behavioural data further suggests that greater time spent slow wave sleep (N3) is associated with greater automaticity of processing novel words.

References

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