Grammar Learning in Adults: A Role for Offline Memory Consolidation and Prior Knowledge

Isabelle O'Halloran and Jelena Mirković

School of Education, Language and Psychology, York St John University

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Background

The Complementary Learning Systems model (CLS; McClelland, 2013) posits that the reactivation of newly learned hippocampal representations during offline periods (e.g., post-learning sleep) enables their long-term consolidation (i.e., integration with the long-term neocortical knowledge). However, when new knowledge is consistent with existing knowledge, there may be less need for integration to occur offline. Instead, the availability of existing knowledge supports new learning and in doing so advances neocortical integration (James et al., 2019). In line with this hypothesis, immediately after training, newly learned words that are related to existing knowledge phonologically or semantically are recalled better than words that are unrelated to it. This is unlike new words that are unrelated to existing knowledge, which are recalled better after offline consolidation (James et al., 2019). The aim of the present study was to test this hypothesis in grammar learning. Moreover, there is mixed evidence for a role of sleep-related offline consolidation in grammar learning with some research reporting improvements in learning following a period of sleep (e.g., Batterink et al., 2014) where others have found no influence (Mirković & Gaskell, 2016). Therefore, by focusing on the role of prior knowledge, this study set out to further explore the extent to which CLS applies to grammar learning.

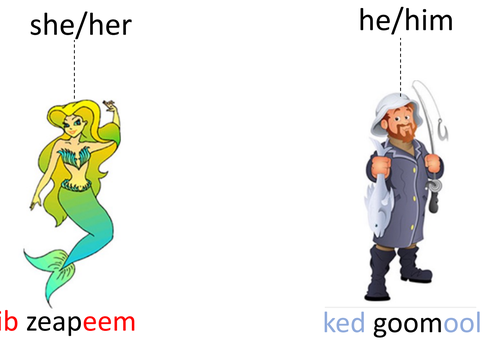
Here we use an artificial language paradigm to investigate: the contributions of offline processes (in sleep and in wake) to the learning of different types of grammatical mappings: those that are dependent on prior knowledge versus those that are less dependent on prior knowledge.

Design

Training Language

Prior knowledge dependent mappings

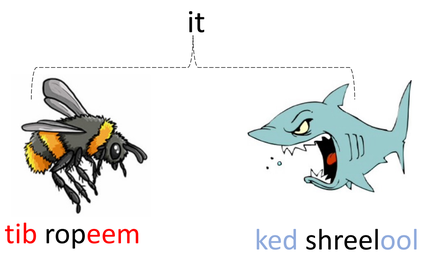
Characters:
female/male
16 exemplars
8/8



semantic-category	existing English knowledge	new knowledge
female character e.g., mermaid	she/her	tib/eem
male character e.g., fisherman	he/him	ked/ool

Prior knowledge independent mappings

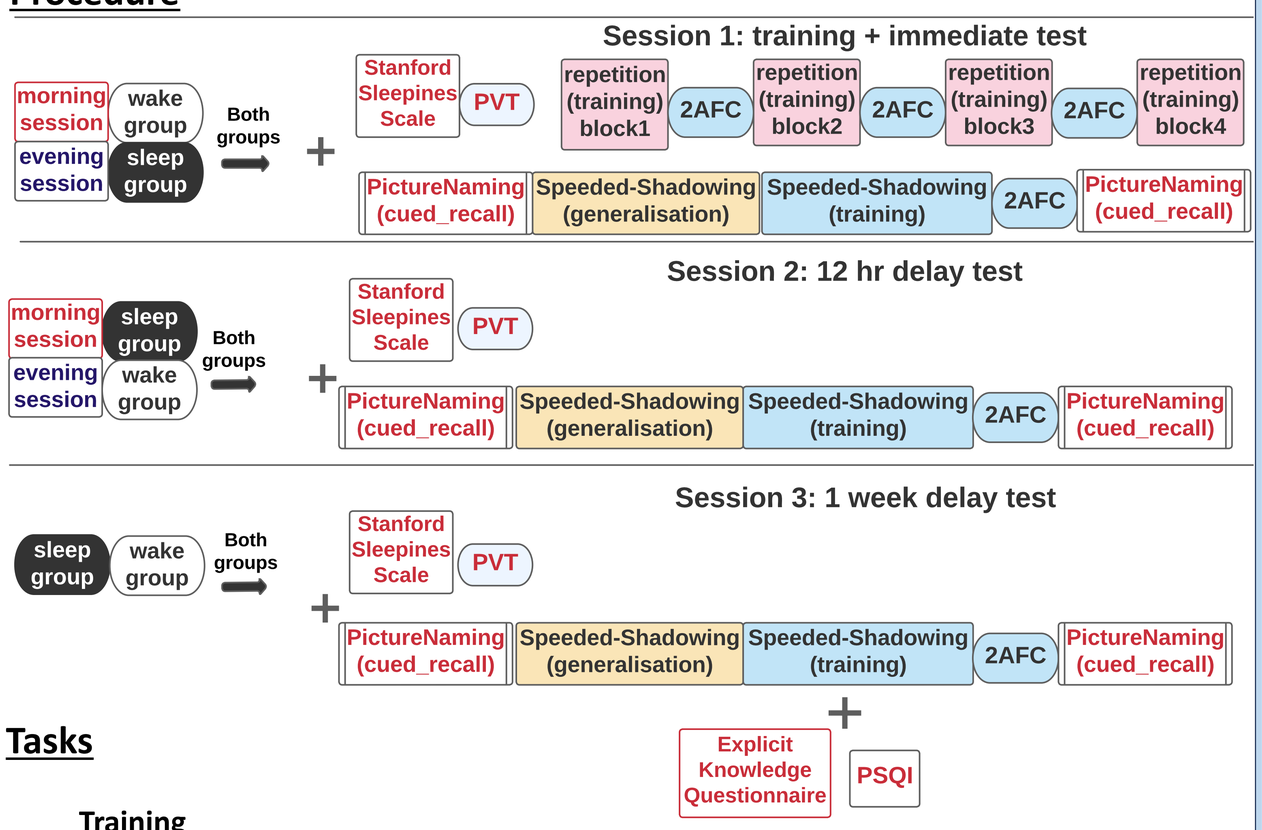
Animals:
insects/sea creatures
16 exemplars
8/8



Participants

60 participants (sleep group n = **30**; wake group n = **30**)

Procedure



Tasks

Training

- Repetition Task: **8** repetitions per word

Test tasks

Grammar learning: Determiners (tib/ked) + Suffixes (eem/ool)

- Picture Naming
- Speeded-Shadowing (training + generalisation)
- Explicit Knowledge Questionnaire – *'Did you notice any patterns in the items?'*

Word learning: Stems (e.g., zeap in tib zeapeem)

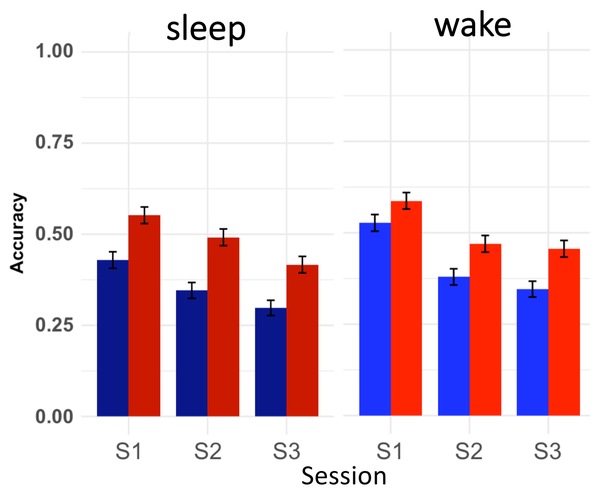
- Picture Naming + 2AFC

Design

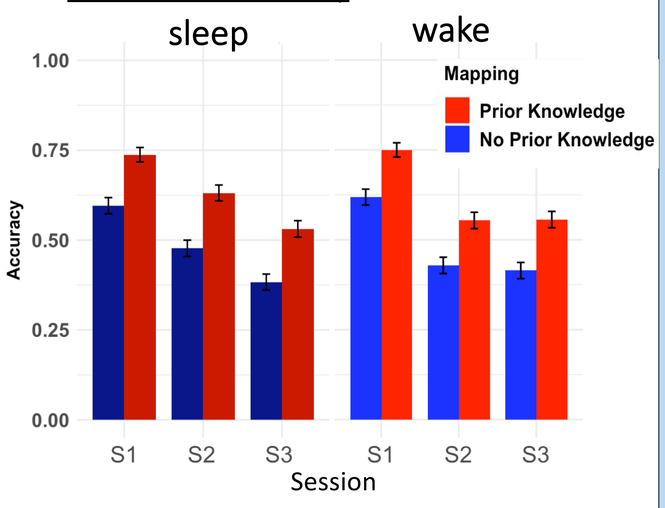
Picture Naming (cued recall)

Grammar learning

Determiner Recall Accuracy



Suffix Recall Accuracy



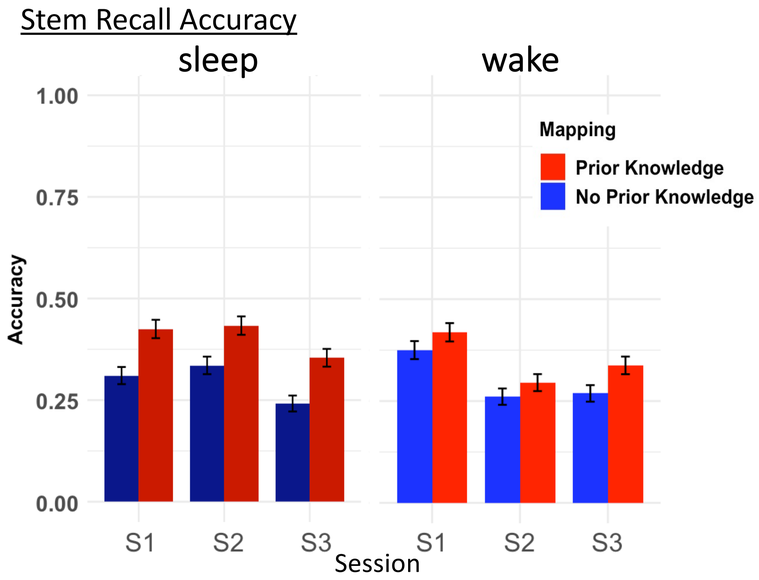
- We observed a main effect of mapping for determiners (β = 0.23, SE = 0.05, Z = 4.81, p < .001) and suffixes (β = 0.30, SE = 0.06, Z = 5.19, p < .001) with both groups demonstrating higher recall accuracy for the prior knowledge dependent grammatical mappings at session 1, 2 and 3.

- We observed a main effect of session 2 vs. session 1 for the determiners (β = - 0.34, SE = 0.04, Z = -8.98, p < .001) and suffixes (β – 0.52, SE = 0.04, Z = - 12.94, p < .001), with both groups showing a reduction in recall accuracy of the mappings at session 2, after a 12- hour offline consolidation interval.

- We also observed a main effect of session 3 vs. session 2 for determiners (β = - 0.26, SE = 0.04, Z = -6.78, p < .001) and suffixes (β = - 0.37, SE = 0.04, Z = - 9.49, p < .001), with both groups showing a reduction in recall accuracy of the mappings after 1 week, at session 3.

Word learning

Stem Recall Accuracy



- For the stems, a main effect of session 2 vs. session 1 was observed (β = 0.22, SE = 0.04, Z = -5.29, p < .001) and a main effect of session 3 vs. session 2 (β = - 0.18, SE = 0.04, Z = -4.38, p < .001).

- There was a significant interaction between session 2 vs. session 1 and group (β = 0.13, SE = 0.04, Z = 3.10, p = .001), with maintenance in recall accuracy for the sleep group, after a 12-hour consolidation interval and a reduction in recall accuracy for the wake group.

- We also observed a significant interaction between mapping and group (β = 0.07, SE = 0.03, Z = 2.10, p = .035), with the sleep group demonstrating higher recall accuracy for the prior knowledge dependent mappings.

Conclusions

Consistent with CLS, a prior knowledge benefit for the new grammatical mappings is present immediately after learning. This benefit remains after 12 hours and 1 week, and there is no influence of offline consolidation for the prior knowledge independent mappings. This suggests that the hippocampus might be less involved in grammar learning and therefore less influenced by sleep-related consolidation. By contrast, for word learning, there is evidence of sleep-related offline consolidation as there is maintenance in recall accuracy of the stems after a 12-hour sleep interval and forgetting after a 12-hour wake interval. This is consistent with previous findings (e.g., Dumay & Gaskell, 2007; Schreiner & Rasch, 2015) and provides further evidence, that unlike grammar, the hippocampus is involved in the learning and consolidation of new meaning—sound mappings in lexical learning.