# Simultaneous Segmentation and Generalisation from Nonadjacent Dependencies

**Rebecca Frost & Padraic Monaghan**
Department of Psychology, Lancaster University

## Background

A landmark study[1] tested learning from an artificial language that distinguished word-identification from learning grammatical dependencies between words. Although participants could identify words, they were unable to generalise the grammatical structure in the absence of additional cues (e.g. pauses). But is this a true reflection of learners' abilities? In Experiment 1, we assessed this by amending the test items used in previous studies to better assess generalisation.

Post-learning sleep benefits a variety of tasks in language acquisition[2]. Advantages of sleep-related consolidation have been shown for tasks involving abstraction of structure and grammar acquisition[3]. But does sleep benefit different language learning tasks equally? In Experiment 2, we extended this research by training participants on the same language, and testing their word-identification (segmentation) and generalisation skills 12- and 24- hours later.

A sleep-related boost to segmentation would indicate that sleep benefits learning specific information, whereas a sleep-related boost to generalisation would indicate that sleep facilitates abstraction of general information relating to language structure. We hypothesise that sleep will benefit learning for both tasks.

## Experiment 1: Segmentation & Generalisation

- 54 adults were randomly assigned to the Segmentation (N = 18), Moved-Syllable Generalisation (N = 18) and Novel-Syllable Generalisation (N = 18) conditions.

### The Language

- Continuous stream of trisyllabic items.
- Items had an AxC structure, where A predicts exactly C.
- There were 3 A_C pairings: [pu-ki], [be-ga], [ta-du]
- X was drawn from a varying set of intervening syllables.

### Training

- A 10.5-minute-long continuous speech stream.

### Testing

- Two Alternative Forced Choice Task.

***Segmentation***

18 word vs. part-word comparisons.

Part-words occurred in the training speech, but straddled word boundaries.

*e.g. puraki beliga tafodu*

***Moved-Syllable Generalisation***

9 part-word vs. rule-word comparisons.

Rule-words contained a trained A-C dependency, but replaced the trained X items with an A or C from a different pairing.

*e.g. pugaki, bepuga*

***Novel-Syllable Generalisation***

9 part-word vs. rule-word comparisons.

Rule-words contained trained A-C dependency, but replaced the trained X with a previously unseen item.

*e.g. puzowki, beveyga*

## Results

- Segmentation was significantly higher than chance (M = .719, $p < .001$).
- Moved-syllable generalisation was at chance level (M = .487, $p = .828$).
- Novel-syllable generalisation was significantly higher than chance (M = .693, $p < .001$).

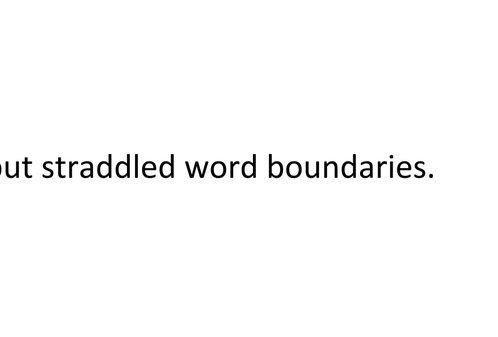


*Figure 1.* Mean accuracy scores for each test condition

## Experiment 2: Sleep, Segmentation and Generalisation

- 72 adults were randomly assigned to the Sleep-first (N = 36) and Wake-first (N = 36) conditions.

| | 9am | 9pm | 9am | 9pm |
|---|---|---|---|---|
| Sleep-first | | training → | test1 → | test2 |
| Wake-first | training → | test1 → | test2 | |

- **Training**: as before
- **Testing:** Segmentation and Moved-Syllable Generalisation (36 test pairs)

### Results: Immediate Testing

- No significant effect of consolidation condition on either task.
- As in Peña et al. (2002), participants significantly preferred words over part-words, but showed no preference for rule-words over part-words.

### Results: Delayed Testing

#### Segmentation

- Significant main effect of testing time ($p = .009$).
- Significant main effect of consolidation condition, ($p = 044$), with more improvement seen for the sleep-first than the wake-first group.
- No significant testing time by consolidation condition interaction ($p = .229$); the sleep-first group were consistently the most improved.

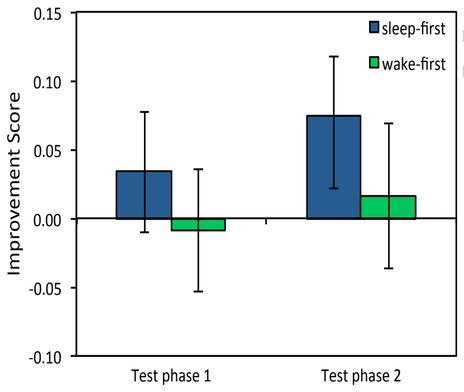


*Figure 2.* Mean improvement scores for word vs. part-word comparisons with 95% CI

#### Generalisation

- No significant effect of testing time ($p = .241$) or consolidation condition ($p = .643$).
- But significant testing time by consolidation condition interaction ($p = .016$), which indicated that performance was improved by immediate sleep.

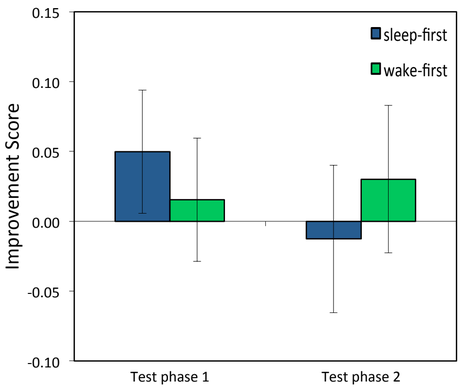


*Figure 3.* Mean improvement scores for rule-word vs. part-word comparisons with 95% CI

## Conclusions

- Learners can simultaneously segment and generalise from nonadjacent dependencies.
- Changes to the learner, dependent on sleep, affected performance on these two tasks differentially:
  - *There is a longer-lasting benefit of sleep for segmentation, regardless of whether that sleep is immediate or delayed.*
  - *There is a short term benefit of immediate sleep for generalisation.*

## References

1. Peña, M., Bonatti, L. L., Nespor, M., & Mehler, J. (2002). Signal-driven computations in speech processing. Science, 298, 604-607.
2. Walker, M. P., & Stickgold, R. (2010). Overnight alchemy: sleep-dependent memory evolution. *Nature Reviews Neuroscience, 11,* 218
3. Gomez, R. L., Bootzin, R. R., Nadel, L. (2006). Naps promote abstraction in language-learning infants. Psychological Science, 17, 670-674.

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**Contact: Dr Rebecca Frost, Department of Psychology, Lancaster University, r.frost1@lancaster.ac.uk**