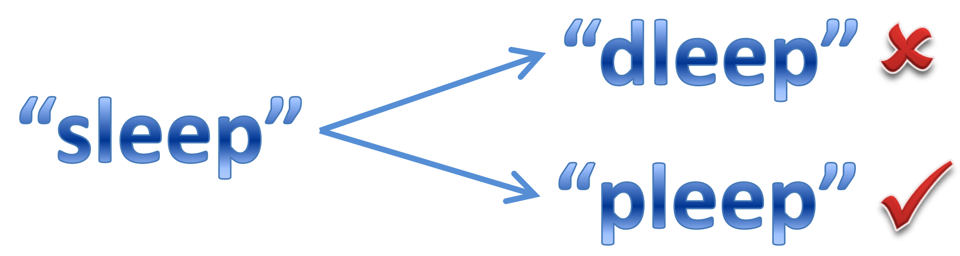
Sleep Facilitates Acquisition of Implicit Phonotactic Constraints in Speech Production

Gareth Gaskell[1], Jill Warker[2], Rebecca Frost[1], James Guest[1], Reza Snowdon[1], Abbi Stackhouse[1]
University of York, United Kingdom[1] University of Scranton, USA[2]

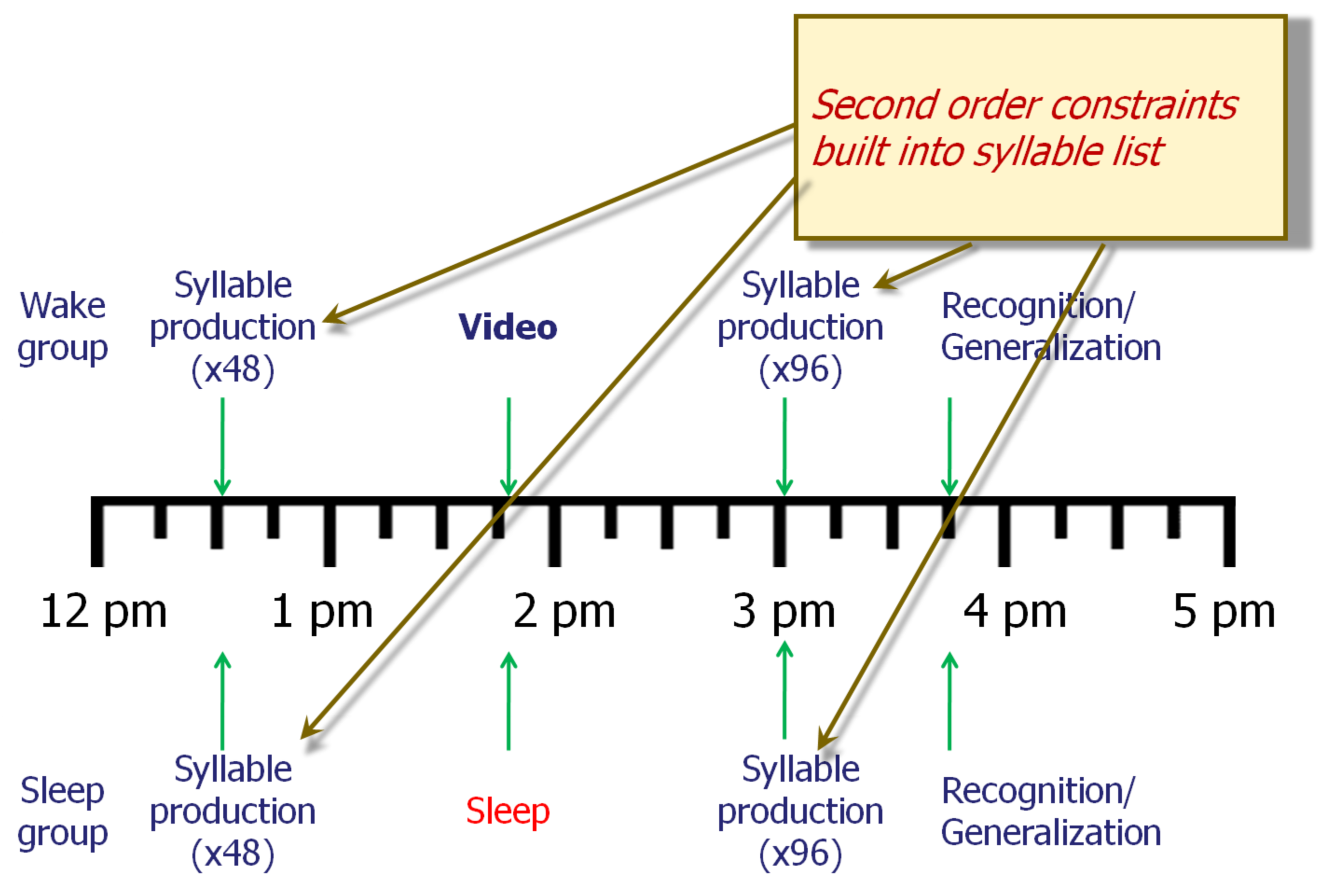
Introduction

Speech errors are not random – they reflect **phonotactic constraints** in the speaker's language. These constraints are malleable: people can learn new constraints implicitly in the lab [1]. But **second-order constraints**, which involve combinations of phonemes in specific syllable positions, tend to be found only after a delay [2]. Here we addressed whether sleep affects the acquisition of these implicit constraints using a nap paradigm.



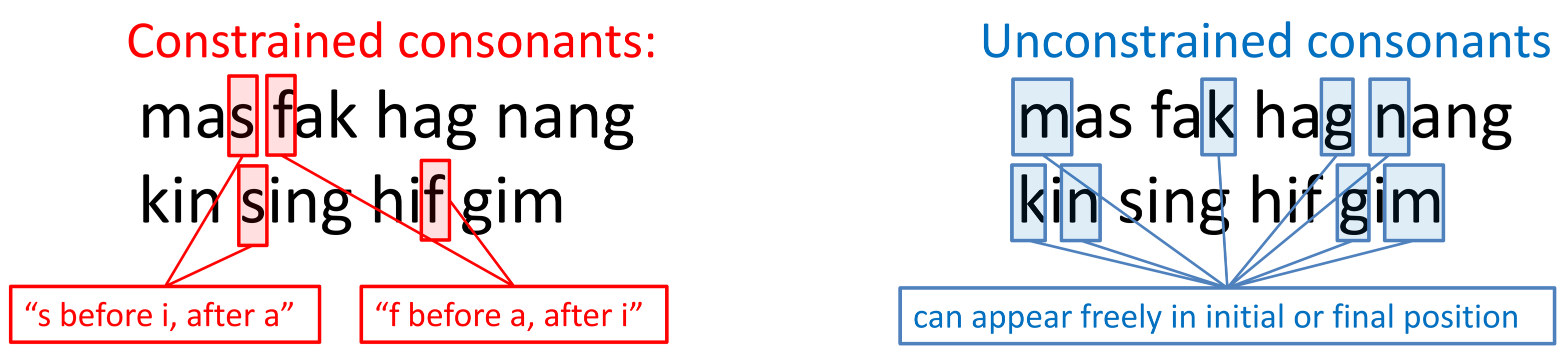
- Do participants who nap after repeating sequences containing new constraints show stronger adherence to these constraints in later errors?
- Can people become aware of these implicit constraints after sleep?
- What aspects of sleep underlie the acquisition of implicit and explicit language knowledge?

Methods



Participants: 37 adults (19 sleep, 18 wake)

Syllable production: participants repeated sequences of 4 syllables in time to metronome. 48 sequences x 3 prior to retention interval. Embedded in the sequences were new phonotactic constraints (see below).



Retention interval: participants watched a video with little language content (wake) or slept in the lab with polysomnographic recording.

Testing:

1. **Syllable production:** 96 more sequences as above. Speech errors analysed to examine adherence to pre-interval constraints.
2. **Recognition:** Participants presented with pairs of syllables, one previously presented (legal – from training set), one not (illegal – from counterbalanced training set). Participants selected familiar one.
3. **Generalization**: Participants presented with pairs of new syllables containing a new consonant (from /tdlz/) alongside old restricted consonants.
   e.g., sit vs. zaf
   One from each pair adhered to the experiment-wide constraints. Participants selected which "best fitted the training material".
   For **Neutral** items, both alternatives contained new consonants. For biased items only one item contained a new consonant (**Biased-New** items: correct item contains new consonant; **Biased-Old** items: correct item contains old consonant).

References

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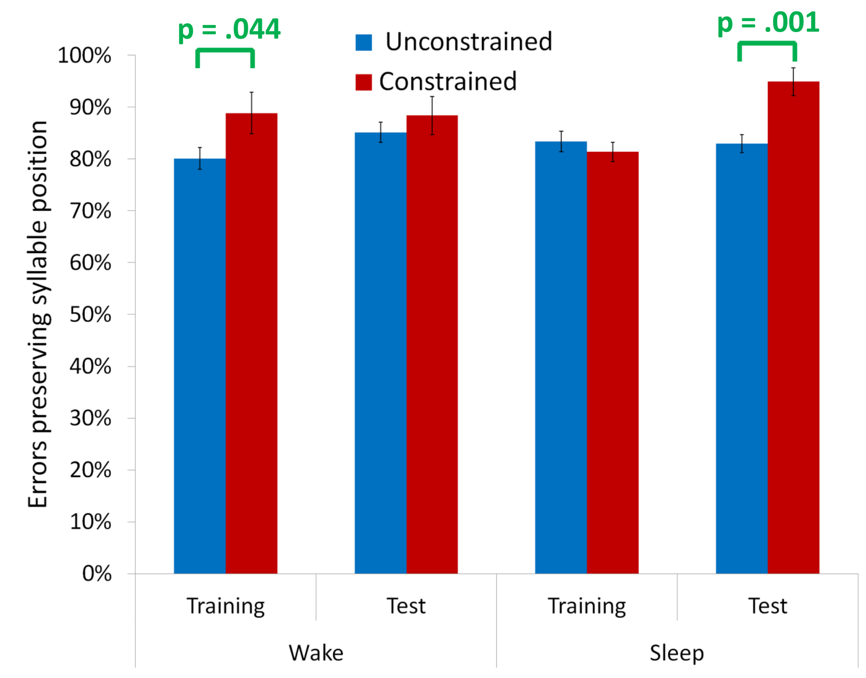
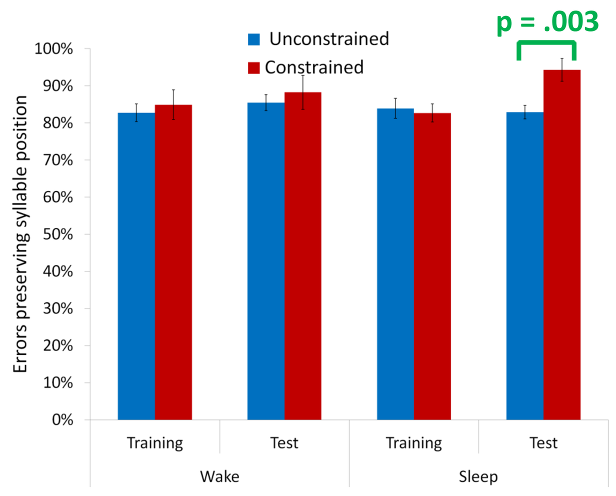
Results

1. Syllable production errors

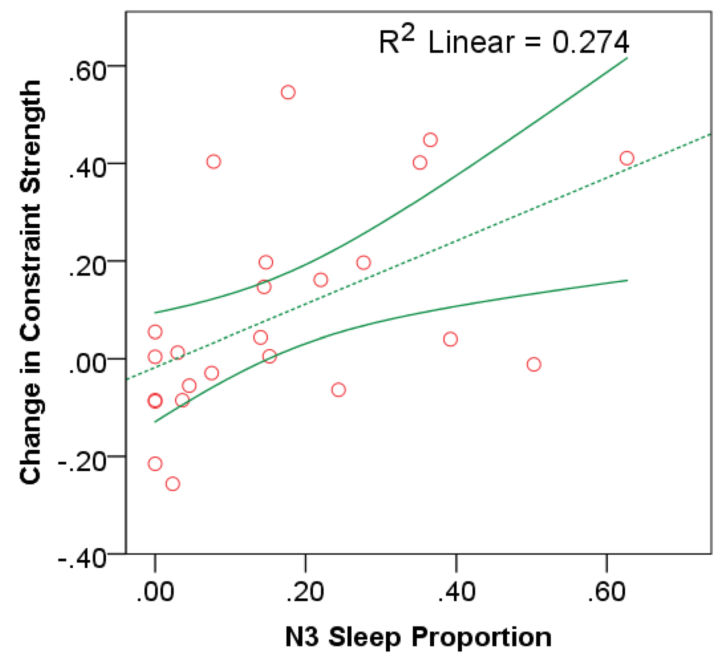
- Sleep strengthens phonotactic constraints leading to their implicit application in speech production. No such effect for wake (Block x Constraint x Group p = .009).
- However, unexpected constraint effect for wake group alone during training.





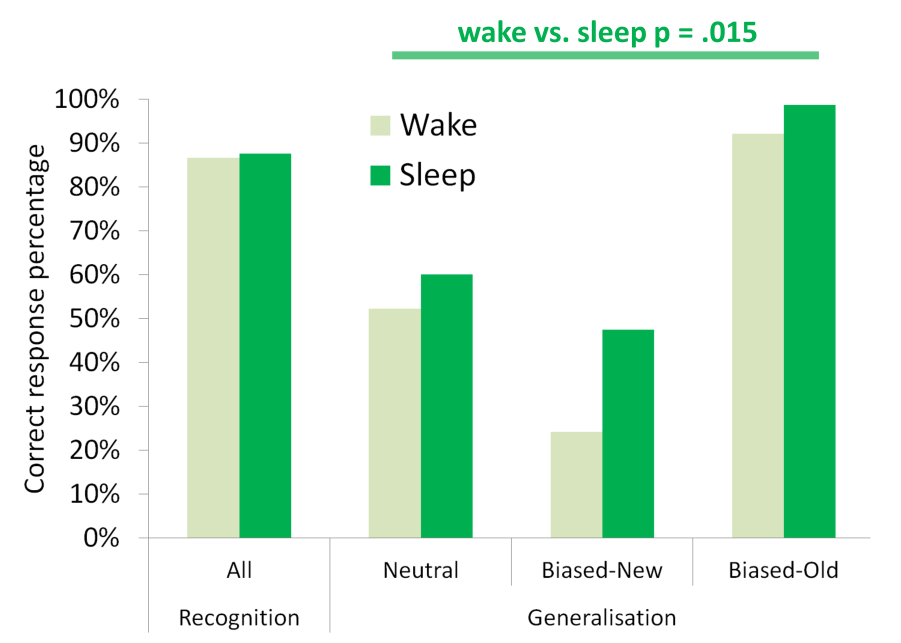
- Sleep effect remains for subset (N=28) matched on training performance.

- Implicit change in performance correlated with SWS, p < .05 uncorrected.
- With further 6 participants included, p < .05 corrected.



2. Recognition and Generalization

- Recognition of training material high in both groups (ns).
- But generalization of phonotactic rules to new materials benefited by sleep (p = .015).
- This tendency is numerically strongest for the most difficult items, when the correct response is to reject an item made up of familiar training consonants (Biased-New)



Conclusions

- Sleep facilitates the extraction of regularities in the language environment, leading to the formation of new phonotactic constraints following a short nap.
- These constraints are pervasive enough to influence speech errors, with this effect associated with slow-wave sleep prevalence.
- Sleep is also associated with a better ability to make explicit judgement on fit of new materials with their training instances, perhaps reflecting a drive to better "gist" of the constraints [3].
- In combination with other research this demonstrates the crucial role of sleep in language learning [4][5].

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Contact: Gareth Gaskell, Department of Psychology, University of York, YO10 5DD, U.K. (g.gaskell@psych.york.ac.uk)