The Role of Transitional Probability in Cortical Tracking of Hierarchical Linguistic Structures

Fan Bai [1, 2], Antje S. Meyer [1, 2], and Andrea E. Martin[1, 2]
1, Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands;
2, Donders Institute for Brain, Cognition, and Behaviour, Radboud University, Nijmegen, The Netherlands

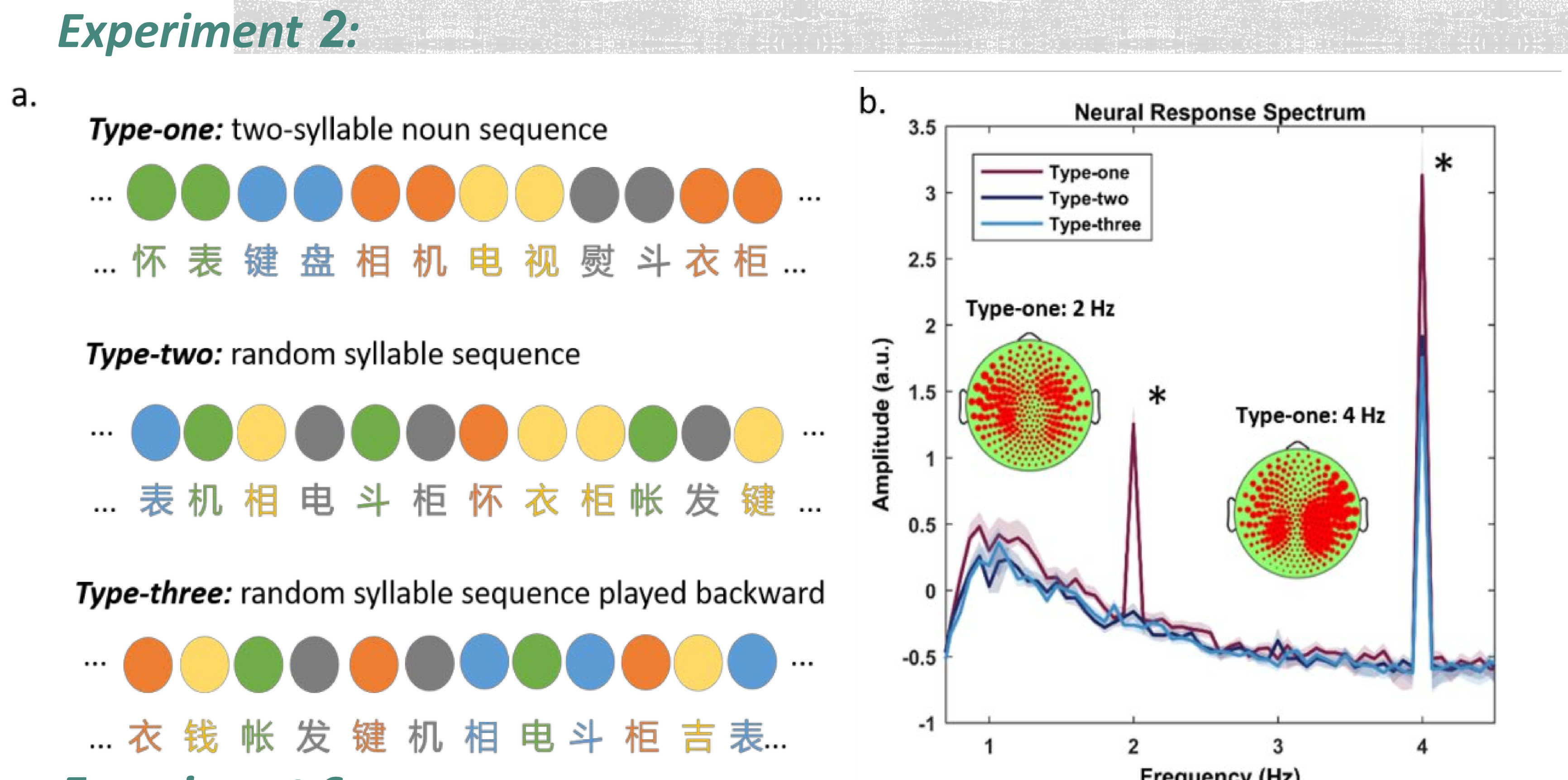
Introduction

A fundamental question in speech comprehension is how continuous speech signals are segmented by the brain. A study by Ding et al. (2016) suggested that the rhythm of hierarchical structures in speech can be reflected in the neural activities at the corresponding frequencies. The authors explained the phenomenon as the cortical tracking of linguistic units by endogenous grammatical chunking. However, online chunking clearly benefits from statistical information (e.g., transitional probability) between linguistic units. Saffran, Aslin, et al. (1996) found that infants could extract 'words' from fluent 'speech' after a two-minute exposure, in which transitional probabilities were considered as a key in speech segmentation. A natural question raised by comparing the conclusion of these two studies is whether the cortical tracking effect could also be driven by the transitional probabilities.

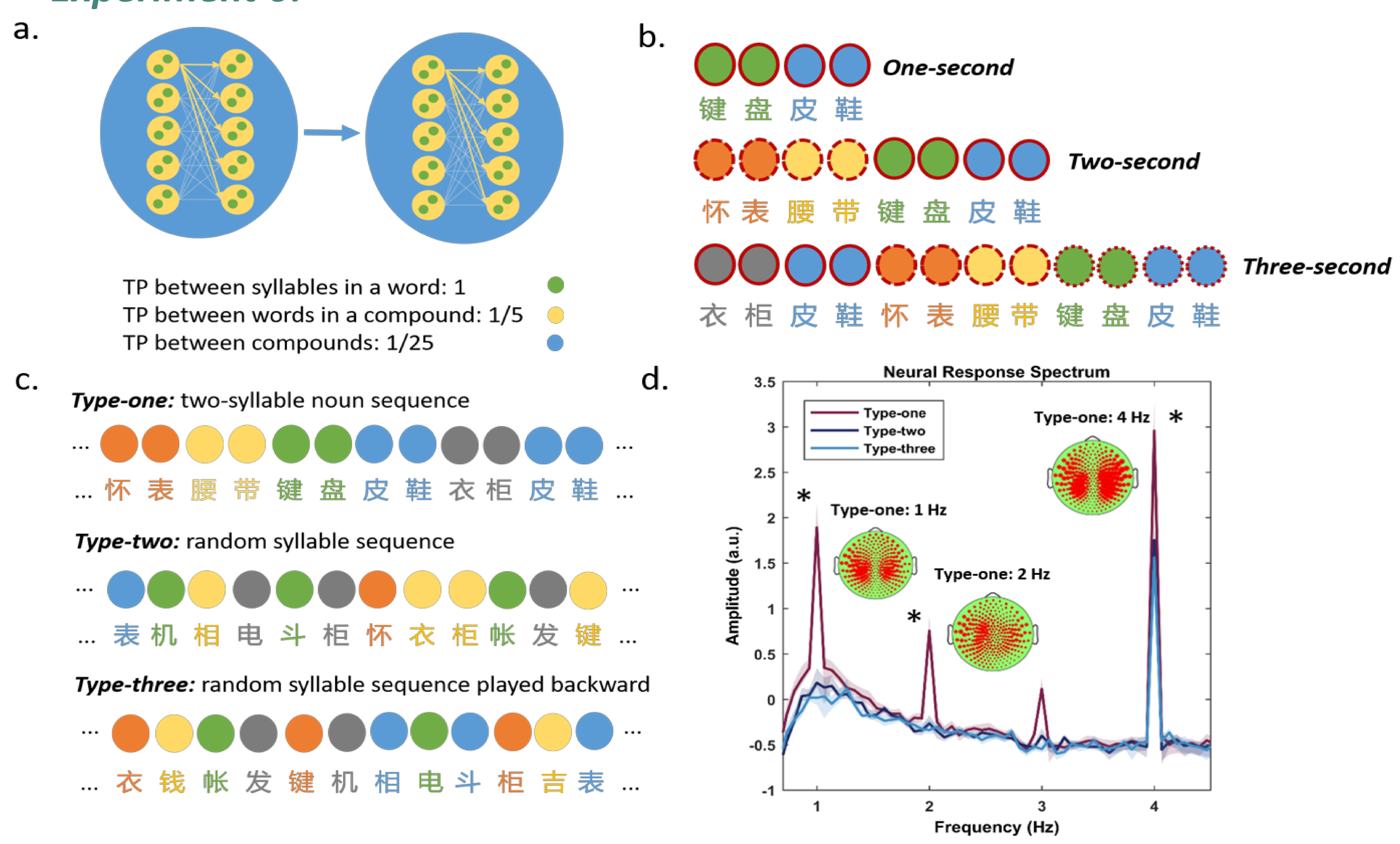
Results

Using Discrete Fourier Transform (DFT) with Generalized Eigen-Decomposition (GED), our analysis indicated that the cortical tracking effect could be induced solely by transitional probabilities, and the cortical tracking effect might not be a pure reflection of units chunking using high-level linguistic knowledge.

Experiment 2:



Experiment 6:



Methods

Six Magnetoencephalography (MEG) experiments were conducted with Dutch native speakers to investigate the role of TPs in the cortical tracking effect.

Experiment 1: Dutch participants listen to Dutch isochronous syllable sequences with syllables and words appear at the rate of 4 Hz and 2 Hz, respectively.

Experiment 2: Dutch participants listen to Chinese syllable sequences with the same structure as in Experiment 1.

Experiment 3: Training Dutch participants to extract Dutch novel compounds (1 Hz) that are built on words.

Experiment 4: Testing whether the rhythm of the trained novel compounds in Experiment 3 could be reflected in the neural activity.

Experiment 5: Training Dutch participants extracting Chinese 1 Hz compounds (removing high-level linguistic information).

Experiment 6: Checking whether the neural activity would reflect the rhythm of the statistically defined compounds in Experiment 5.

Conclusion

Speech segmentation benefits from statistical inference. Cortical activity simultaneously tracks the rhythm of multiple layers of linguistic structures could be induced solely by transitional probability and used as an effective neural readout to reflect linguistic structure extraction.

References

1, Ding, N., Melloni, L., Zhang, H., Tian, X., & Poeppel, D. (2016). Cortical tracking of hierarchical linguistic structures in connected speech. *Nature neuroscience, 19*(1), 158-164.
2, Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science, 274*(5294), 1926-1928.
3, Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition, 70*(1), 27-52.
4, Saffran, J. R., Newport, E. L., & Aslin, R. N. (1996). Word segmentation: The role of distributional cues. *Journal of memory and language, 35*(4), 606-621.

Contacts:

Fan Bai: fan.bai@mpi.nl
Antje Meyer antje.meyer@mpi.nl
Andrea Martin: andrea.martin@mpi.nl

MAX PLANCK

MAX PLANCK INSTITUTE FOR PSYCHOLINGUISTICS

DONDERS INSTITUTE