

Robust Predictive Mechanisms in Natural Language Processing across the Adult Lifespan

Preprint



MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES

Sandra Martin¹, Merle Schuckart², Jonas Obleser², Gesa Hartwigsen^{1,3}

¹Max Planck Institute for Human Cognitive and Brain Sciences, Germany; ²Department of Psychology, University of Lübeck, Germany; ³Wilhelm Wundt Institute for Psychology, Leipzig University, Germany

martin@cbs.mpg.de
@drsandramartin.
bsky.social

Introduction

- Language prediction is crucial for understanding and enhancing everyday communication. For instance, during reading, upcoming linguistic input is predicted, leading to higher surprisal for unpredicted words [1].
- Cognitive aging offers an intriguing context to explore the interplay of language prediction and cognitive control due to age-related sensory and executive decline [2].
- It is unclear to what extent age moderates the construction of internal linguistic predictions.

Research questions

What are the cognitive costs of language predictions?

What impact does cognitive aging have on the generation and use of language predictions?

Methods

Participants

Original sample

- 175 adults (M 45, SD 18, 18-85 years)

Replication sample

- 96 adults (M 40, SD 14, 18-70 years)

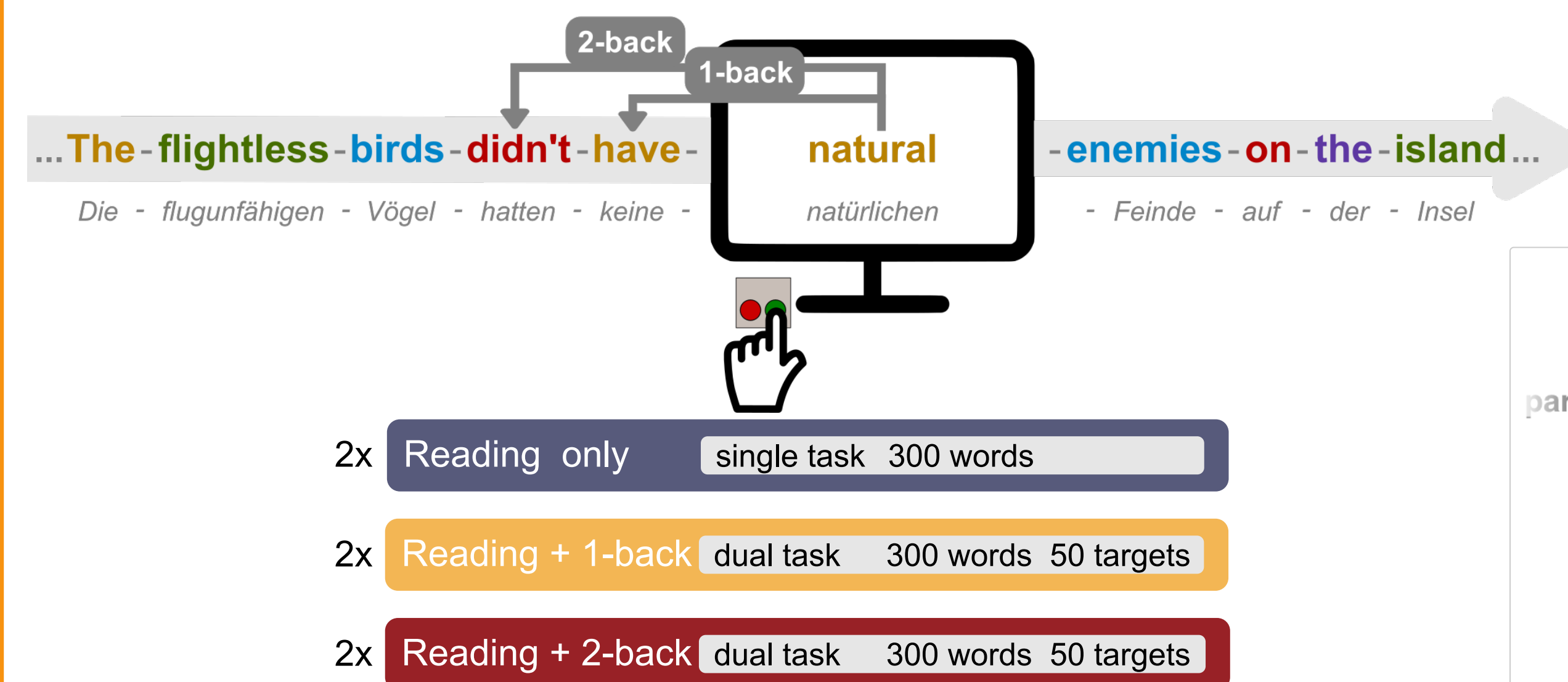
Design

- One session (online or in lab)
- Nine newspaper articles (300 words)
- Blocks of single task and dual-task

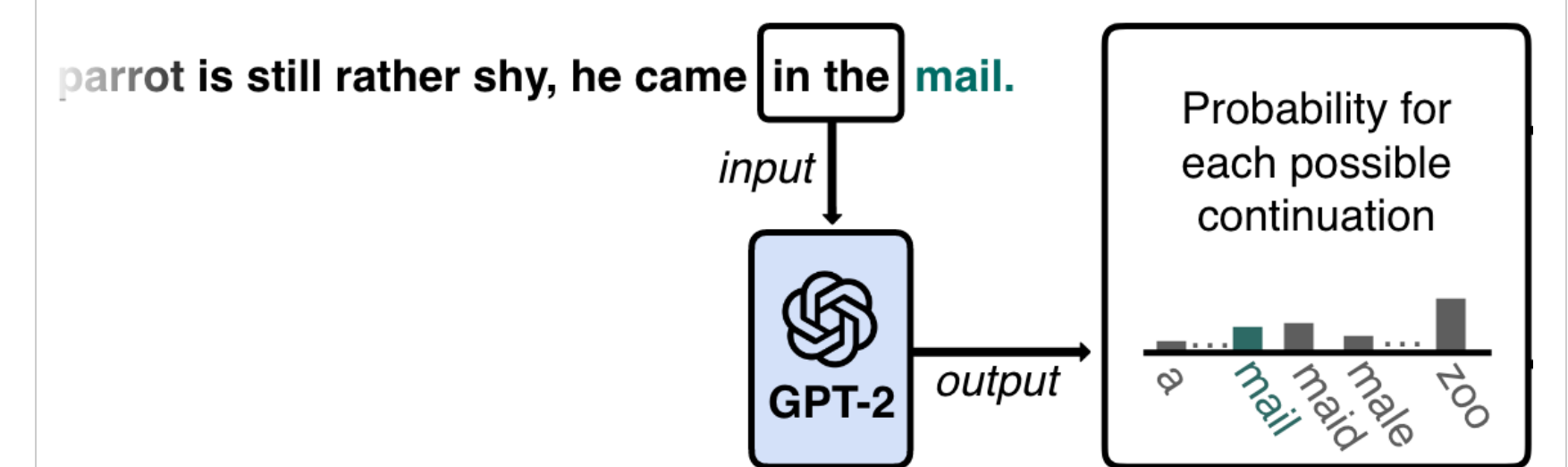
Data analysis

- Linear and non-linear mixed-effects models for reaction time and accuracy (D-prime)
- Surprisal scores (word probability) on time scale 2 for texts generated in GPT-2 [3]

Reading task (single and dual-task design)

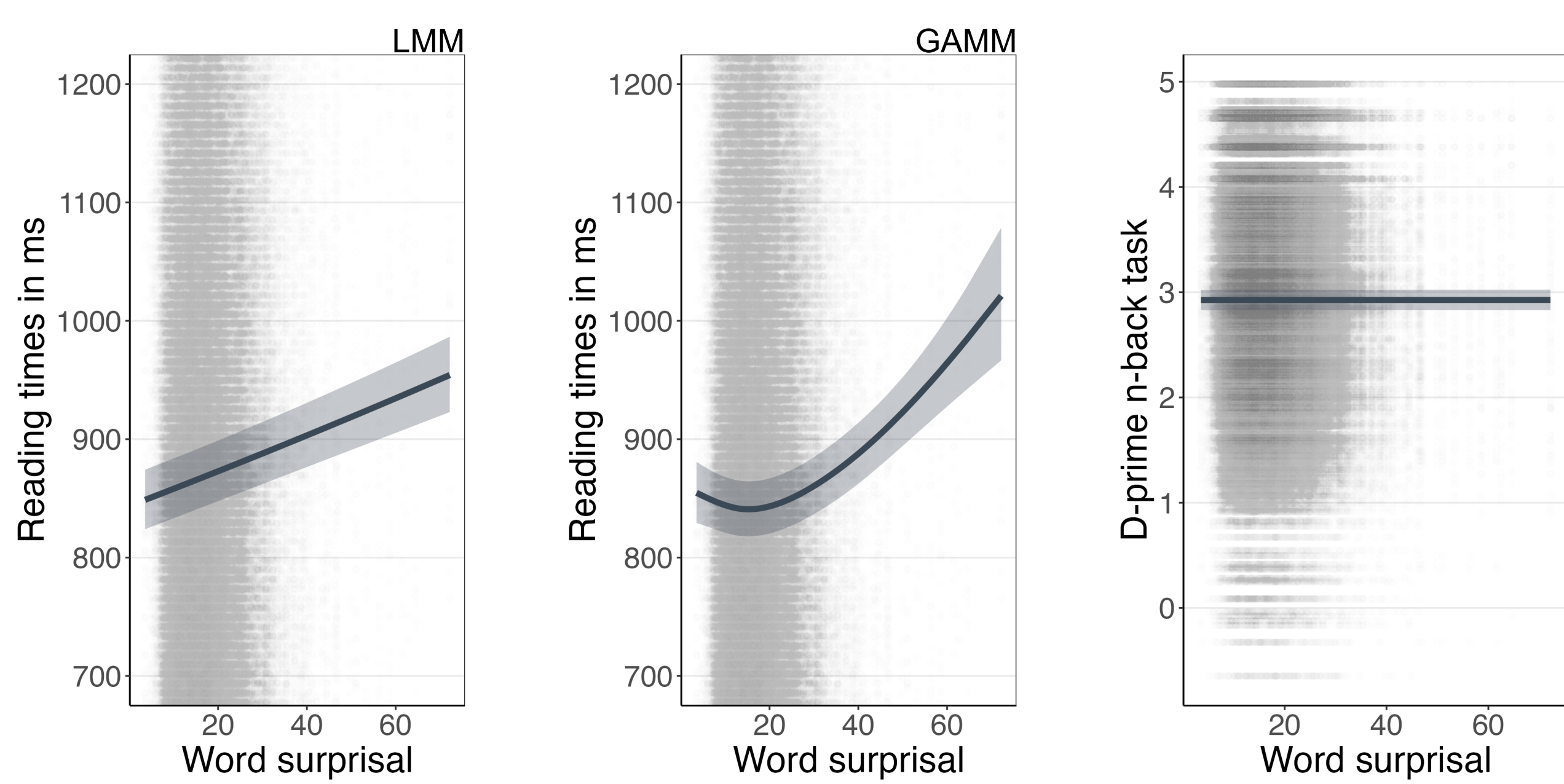


Generation of Word Surprisal



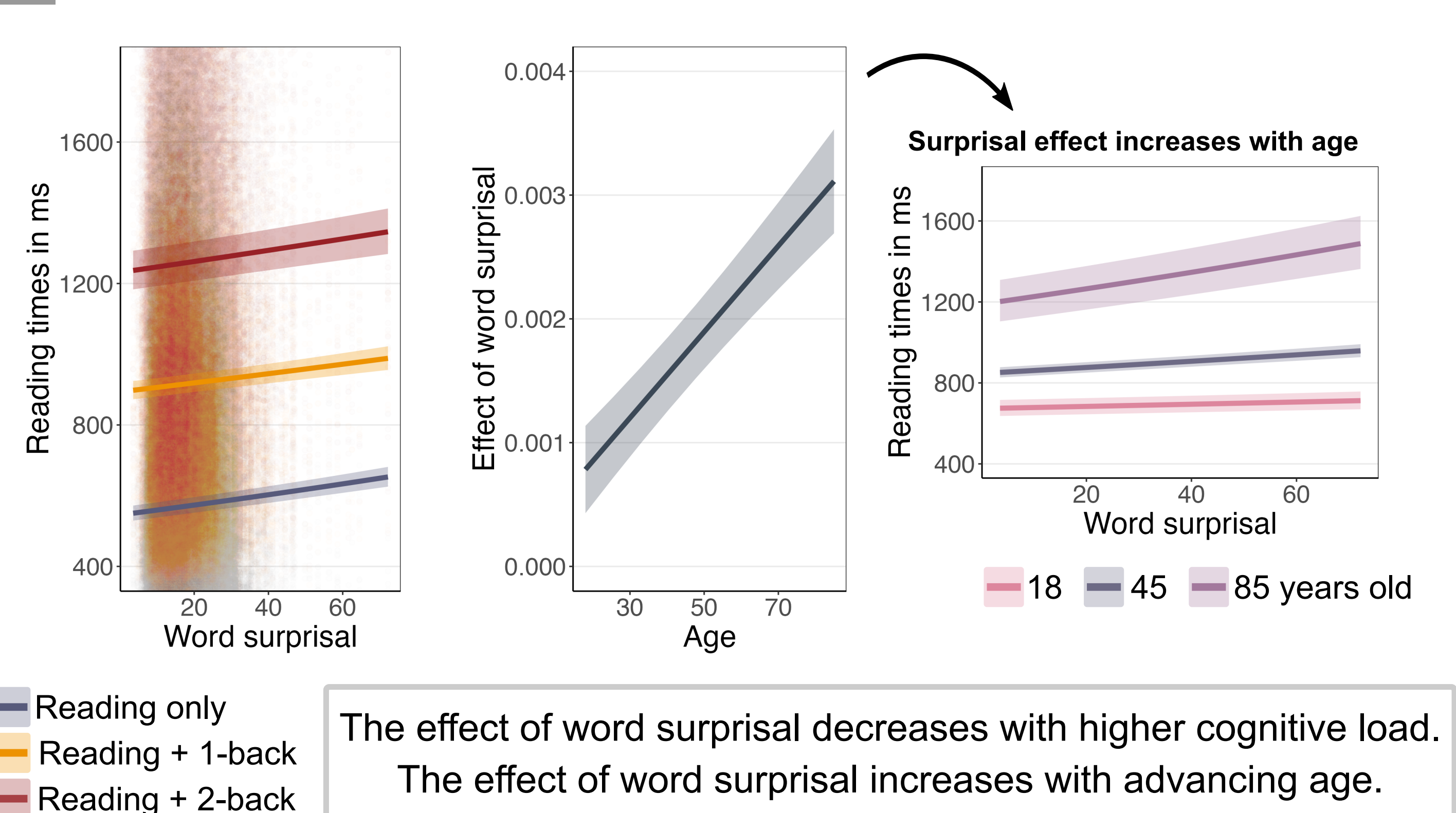
Results

1 The Effect of Word Surprisal on Reading Times and N-back Accuracy



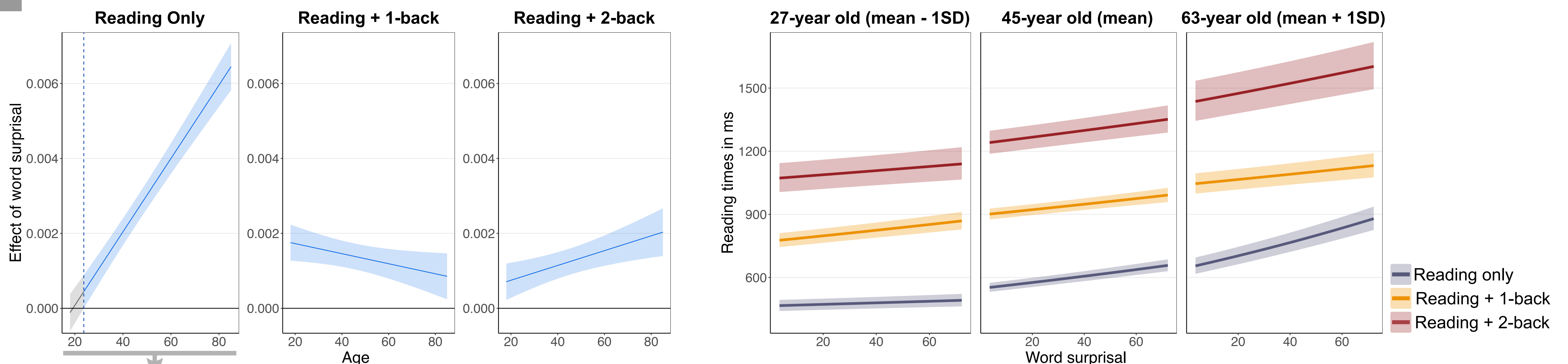
Lower predictability increases reading times in a non-linear fashion [4] but does not have a strong effect on accuracy in a concurrent n-back task.

2 The Effect of Cognitive Load and Age on Language Predictions



The effect of word surprisal decreases with higher cognitive load. The effect of word surprisal increases with advancing age.

3 The Interaction of Age, Cognitive Load, and Surprisal

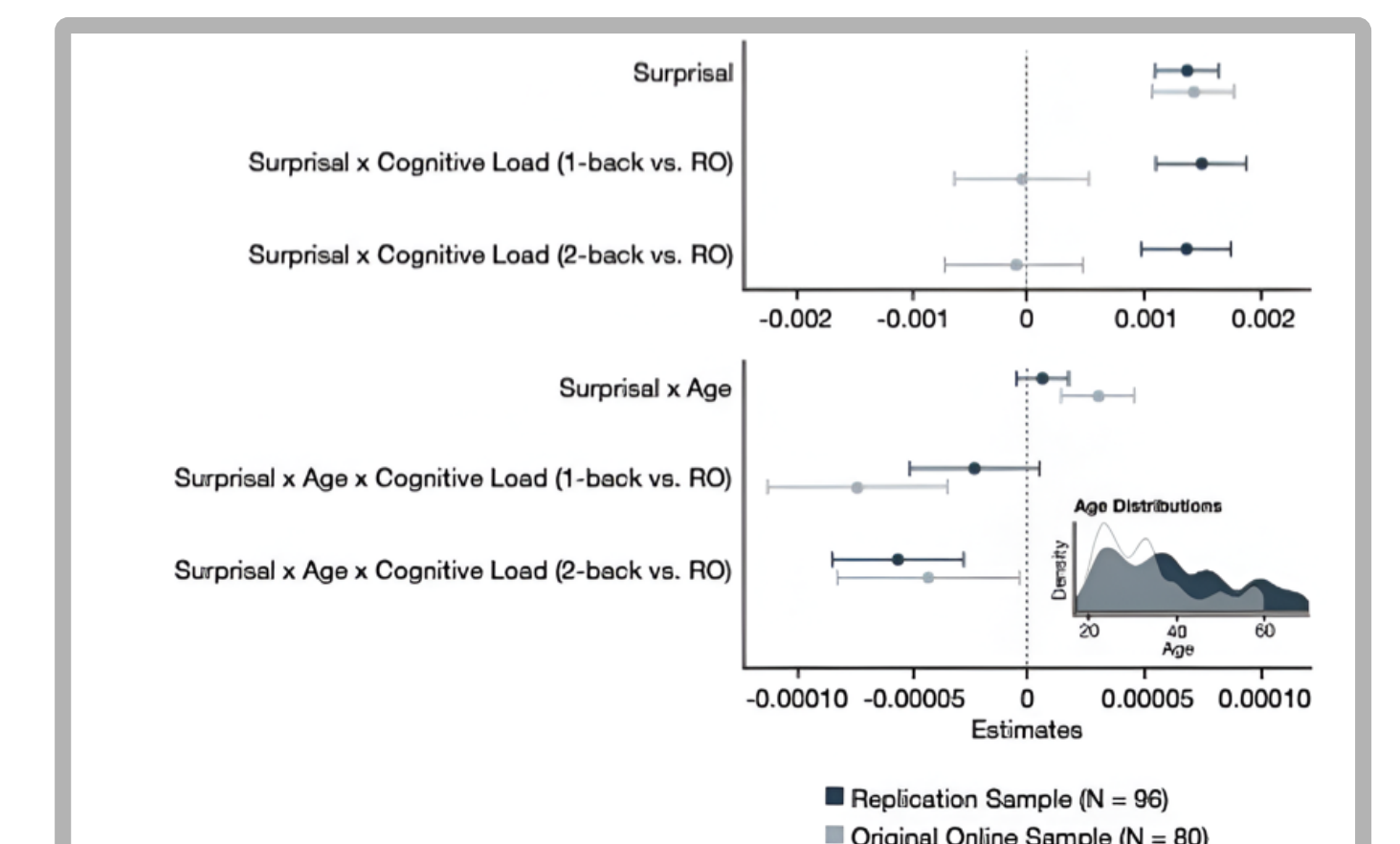


Significant three-way interaction of age, cognitive load, and word surprisal:

Strongest effect of surprisal is observed in reading baseline and effect declines with increasing cognitive load.

Interaction with age shows largest effects of surprisal in older adults: in reading only and reading + 2-back tasks.

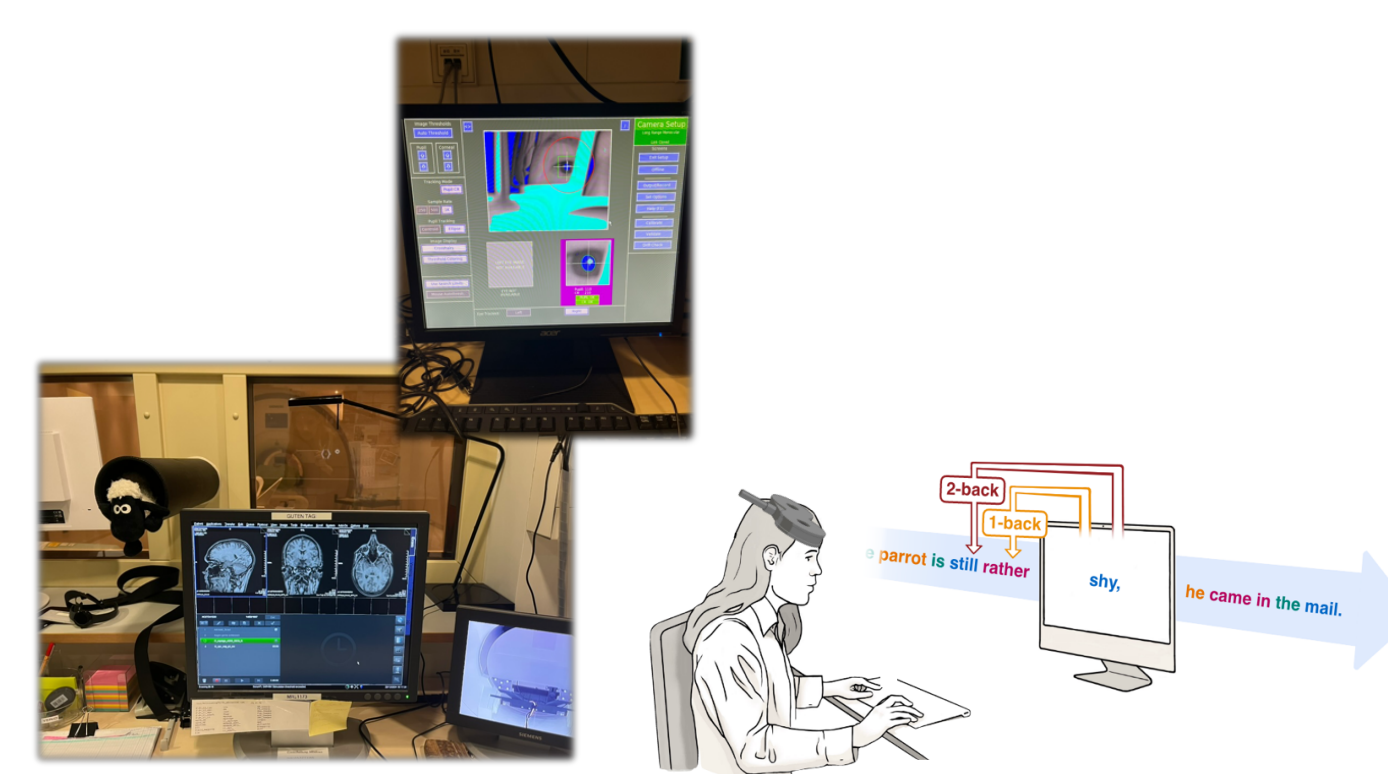
Effects replicate in independent sample assessed online.



Discussion

- Interaction of cognitive load and word surprisal suggests that executive resources beyond attention are integral to language prediction.
- The effect of surprisal increases with advancing age, suggesting greater reliance on intact vocabulary and world knowledge – possibly also due to sensory decline with age? This may lead to more fine-tuned predictions, which are more vulnerable to unexpected information.
- Aging mediates the effect of cognitive load on surprisal: Strongest effects are observed in reading only and reading + 2-back conditions. This suggests a CRUNCH point in the 1-back condition leading to longer reading times but stronger reliance on predictions in 2-back condition.

Ongoing fMRI and TMS Studies



References

- [1] Schmitt, L.-M., et al. (2021). Sci Adv.
- [2] Hedden T., & Gabrieli J.D.E. (2004). Nat Rev Neurosci.
- [3] Hugging Face (2023). GPT-2 [dbmdt/german-gpt-2].
- [4] Shain, C., et al. (2022). J Neurosci.

@copla.bsky.social