

# Robust Predictive Mechanisms in Natural Language Processing across the Adult Lifespan



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## 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)

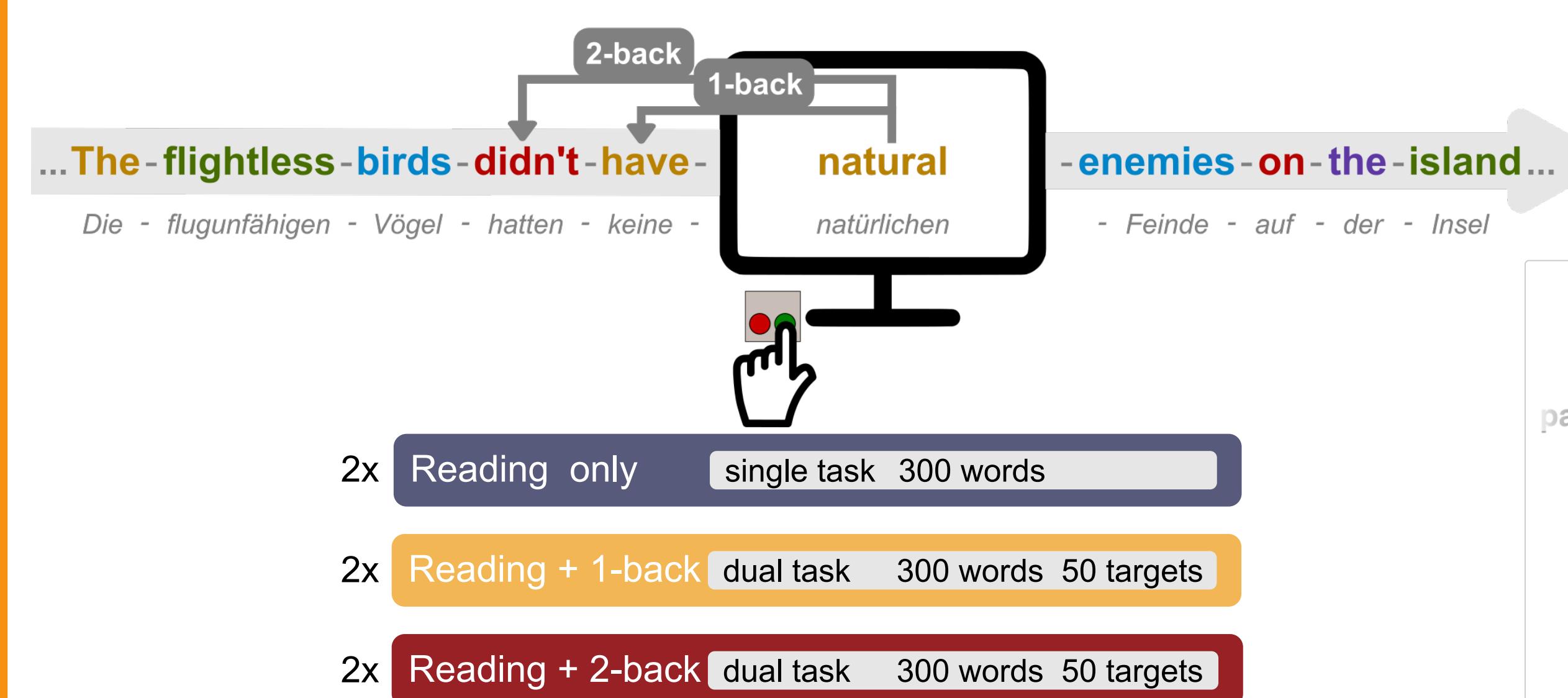
### Design

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

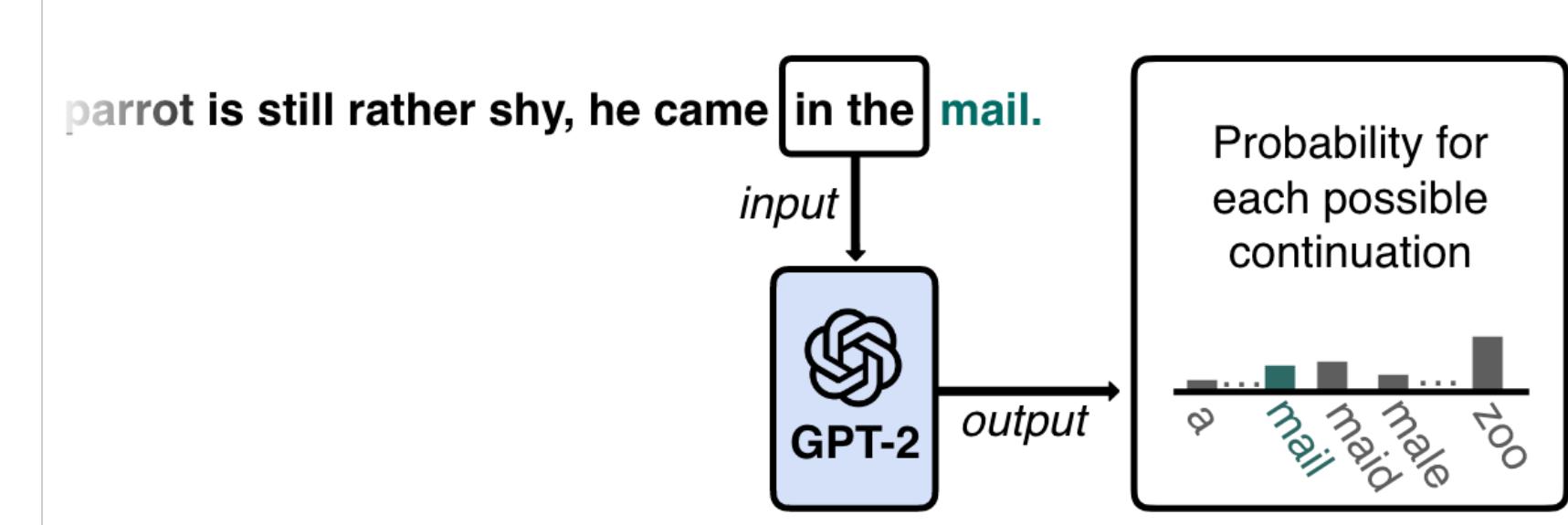
### Data analysis

- 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)

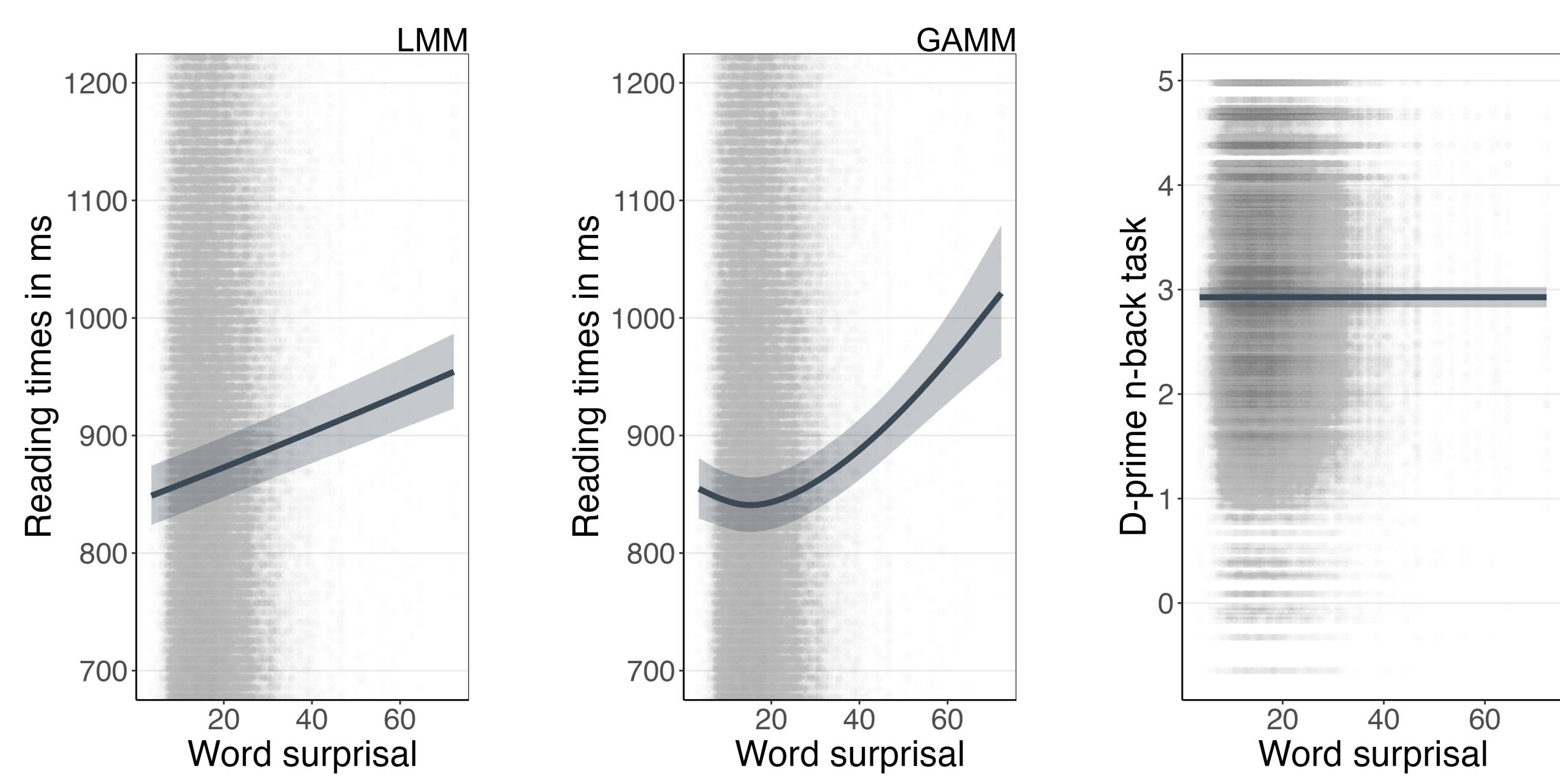


### Generation of Word Surprisal



## Results

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

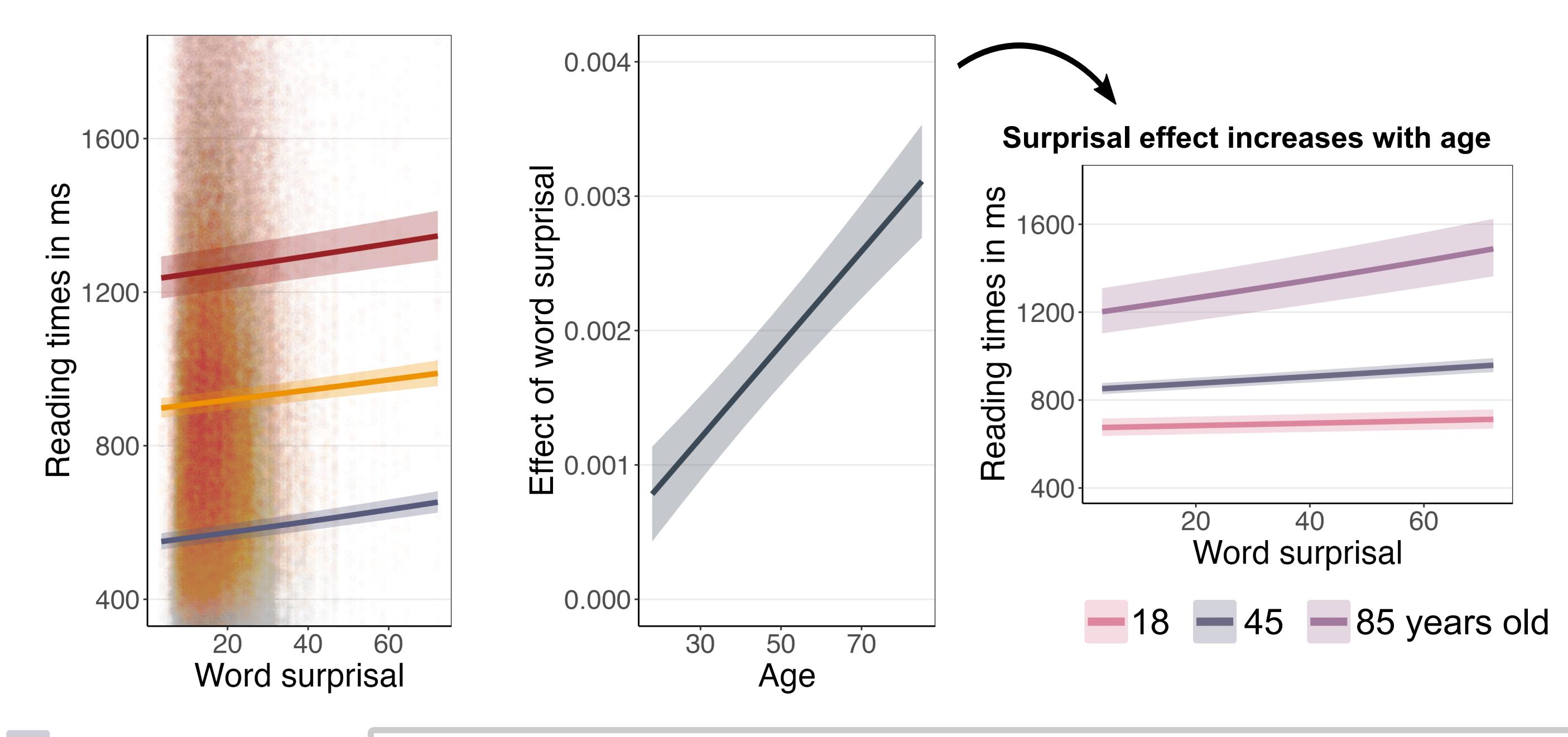


Lower predictability increases reading times in a non-linear fashion [4] but does not have a strong effect on accuracy in a concurrent n-back task.

1

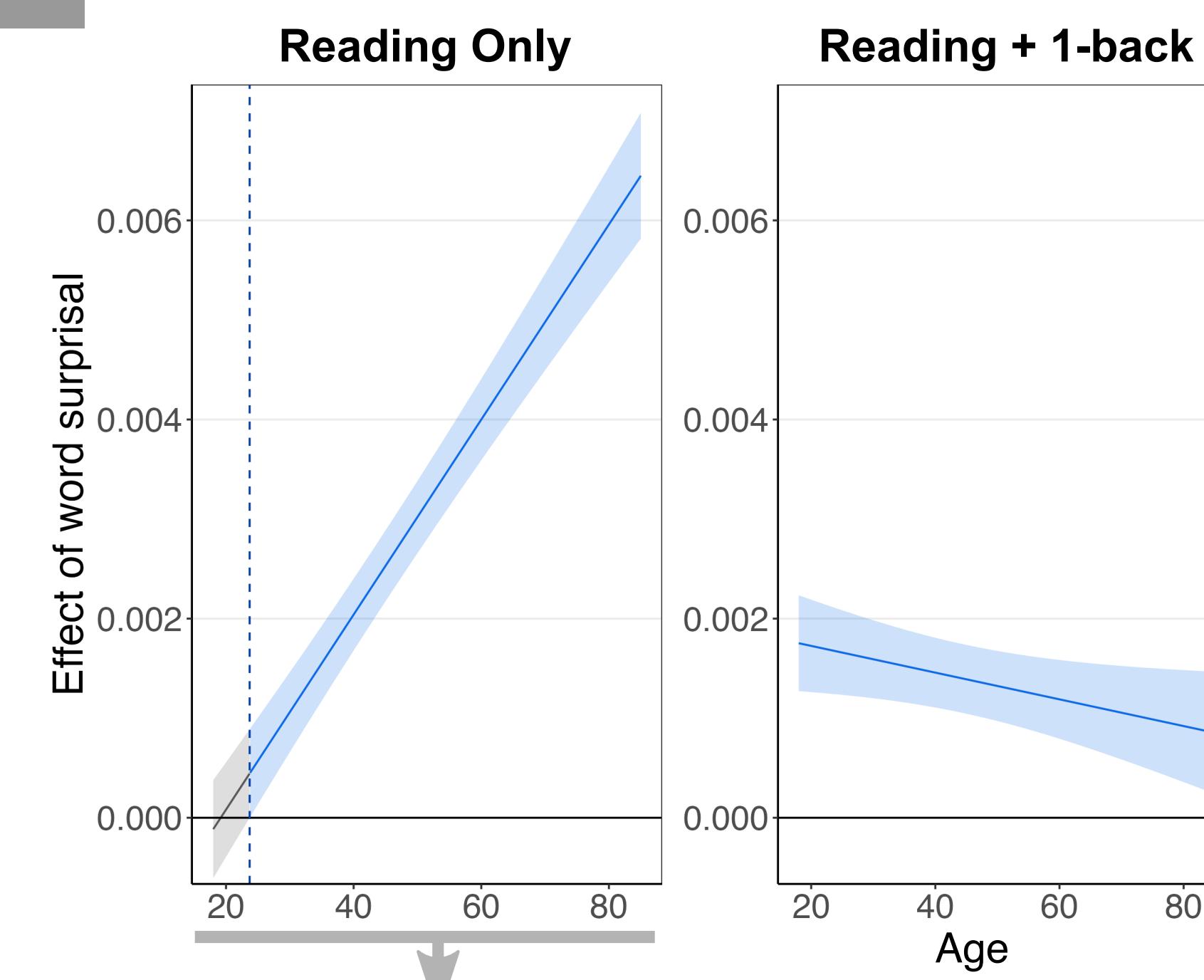
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### The Effect of Cognitive Load and Age on Language Predictions



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

3



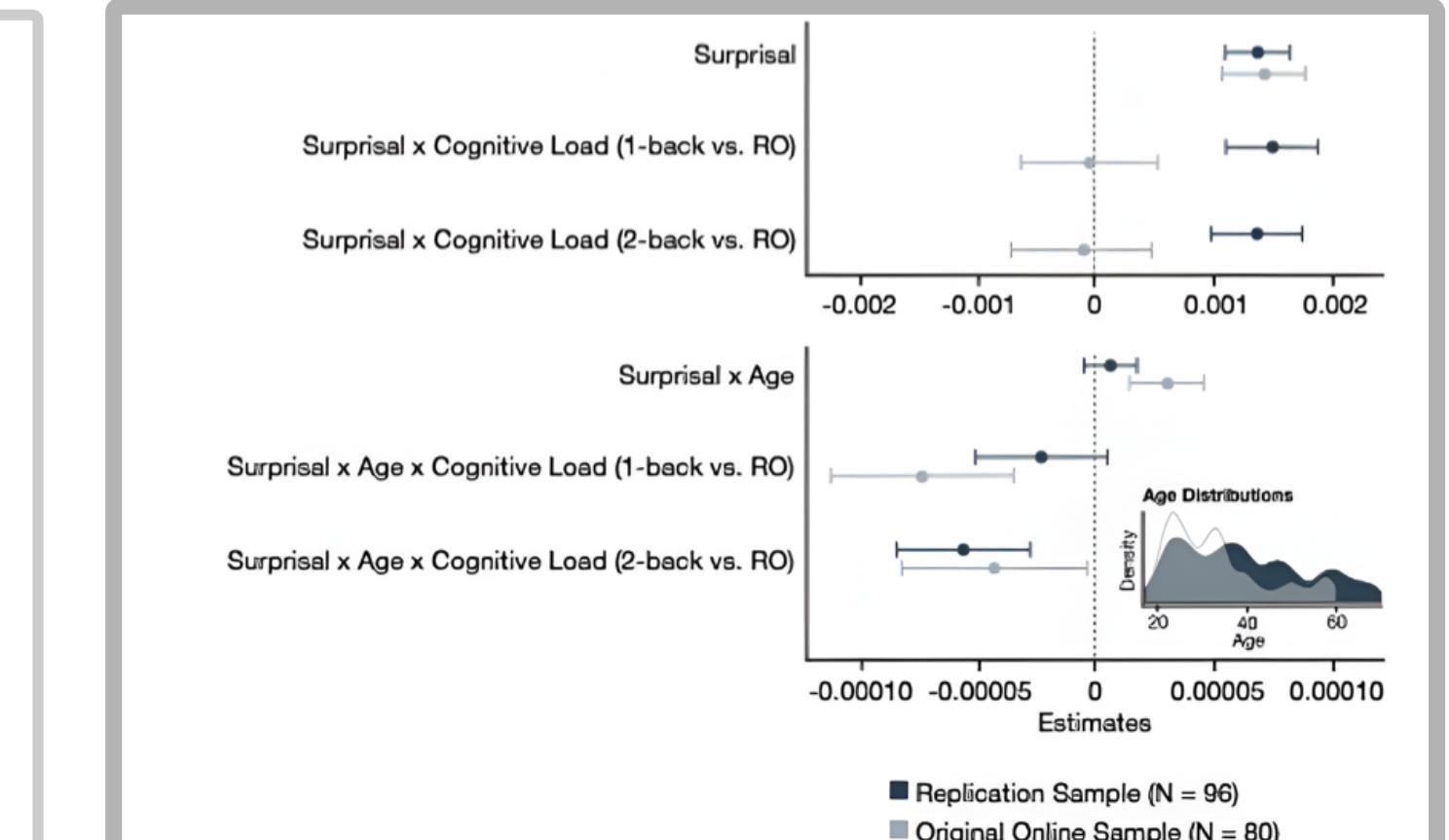
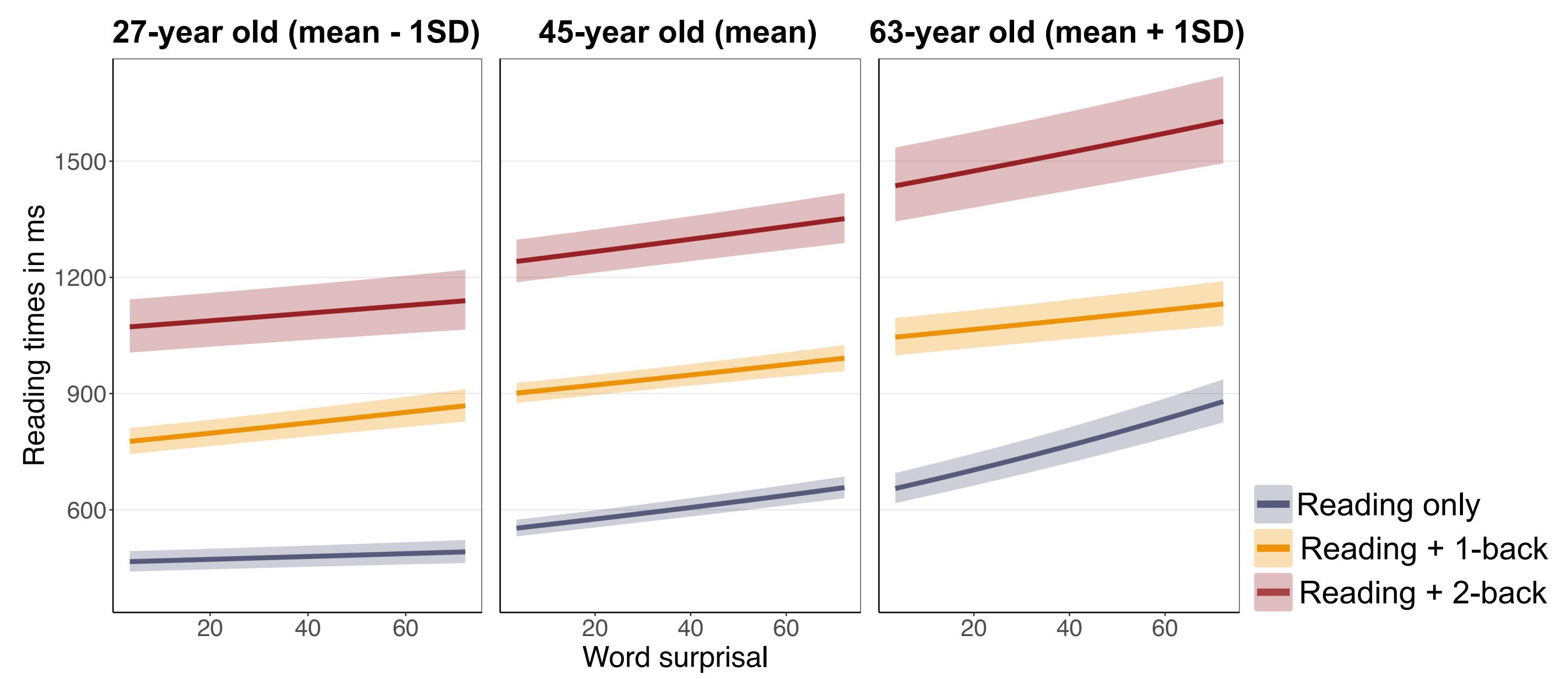
### The Interaction of Age, Cognitive Load, and Surprisal

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.

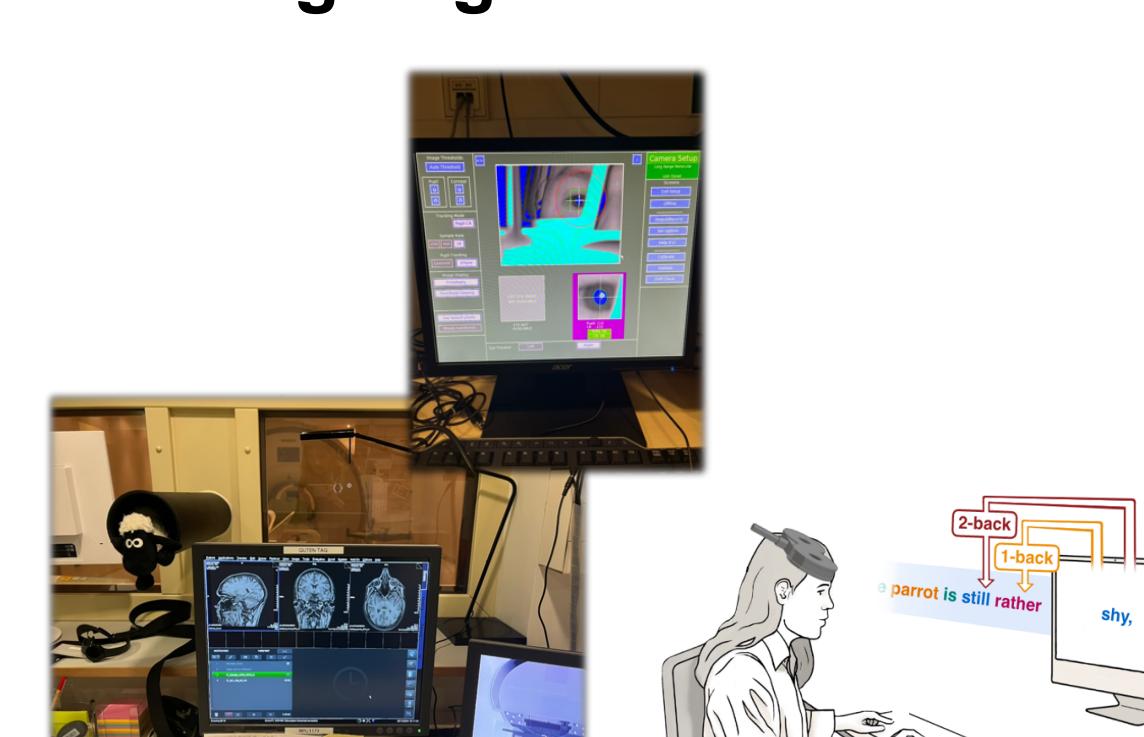
Effects replicate in independent sample assessed online.



## 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 [dbmtd/german-gpt-2].
- [4] Shain, C., et al. (2022). J Neurosci.