Markov-Switching Models of Trial-level EEG & Pupil Dilation

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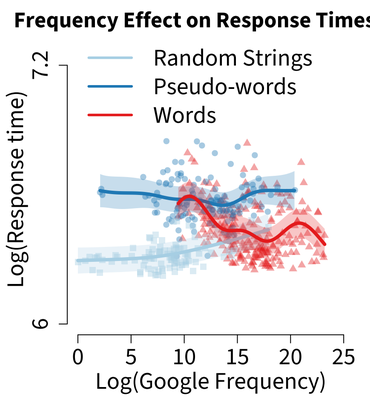
Introduction

- **ERPs** are commonly used to study word processing[1]
- **Pupil** dilation indirectly reflects cognitive events[2]
  > Do the same events leave a **trace in both signals?**
- **NEW:** To recover events we generalize EEG Markov models[3] to **deconvolve the pupil** on the trial level
  > Markov models have recovered cognitive stages from EEG[3], here we compare stages from the pupil **and** EEG
  > Conventional deconvolution approaches[4-7] neglect trial and event-level variability in event onset and response

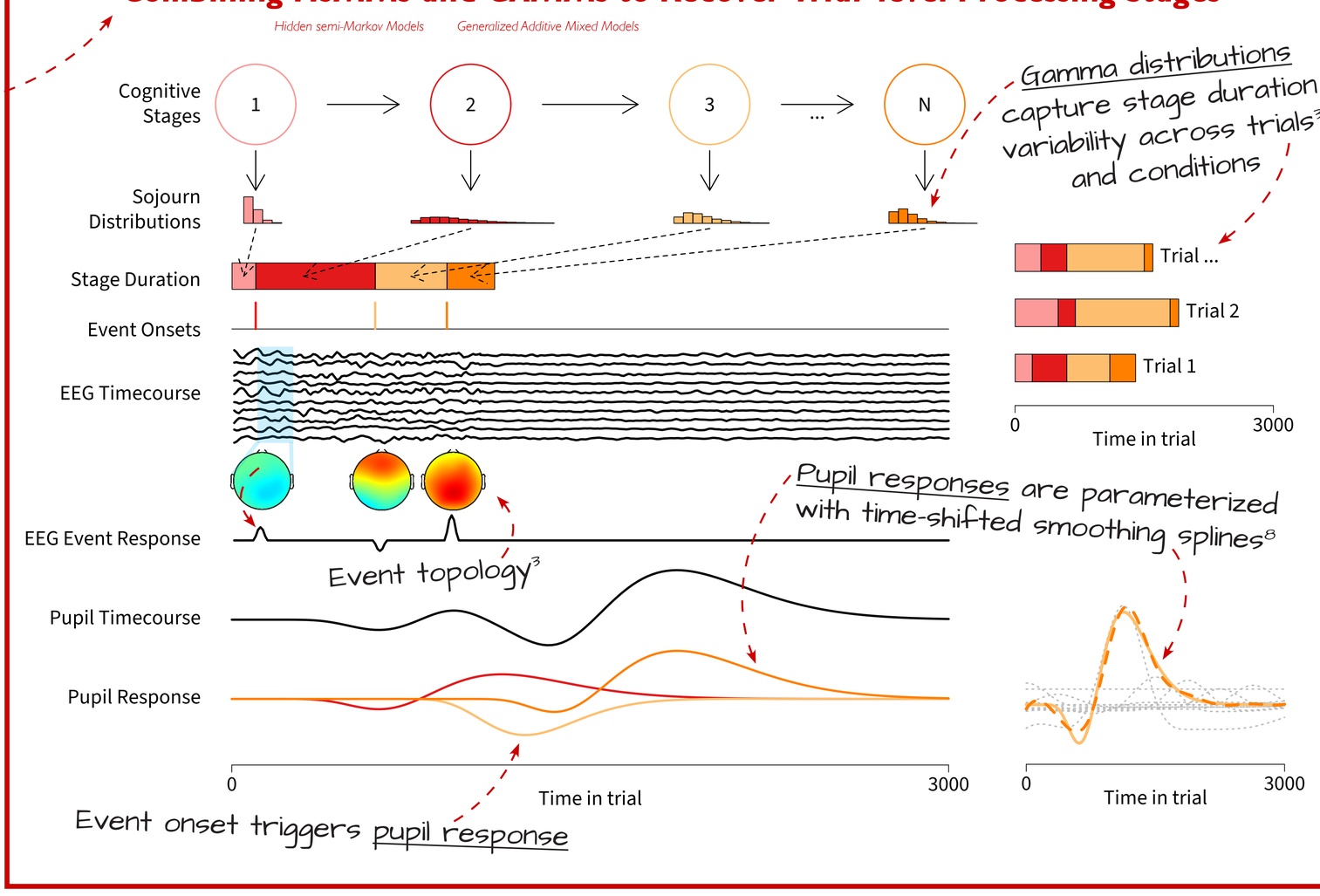
Experiment

- 26 native Dutch speakers performed 500 lexical decision (LD) trials
- 125 pseudo-words, 125 random strings, 250 words
- Google result count[9] was used as frequency measure for all stimuli

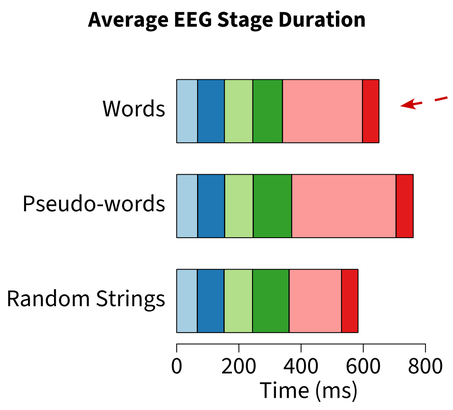


What can Markov models of EEG and Pupil reveal about LD processes?

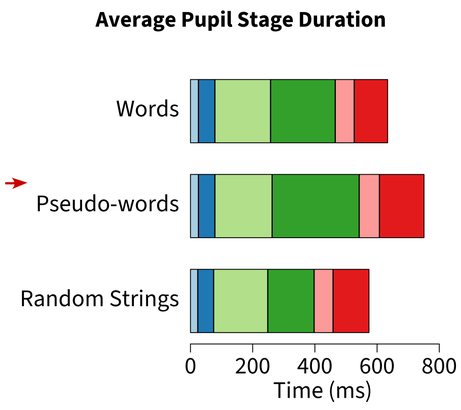
New method: Semi-Markov-Switching Models

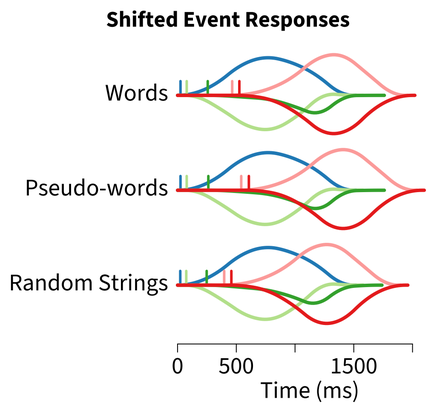


Preliminary Results



- Six stages best explain the **EEG** data, stages four and five differ significantly between conditions
- Six stages best explain the **pupil** data, only stage four differs significantly between conditions
- Stage onset timings and durations in the **pupil** model are significantly different from the **EEG**:
  > The first stage in the **pupil** model is much shorter and stage four seems to match stage five in the **EEG**



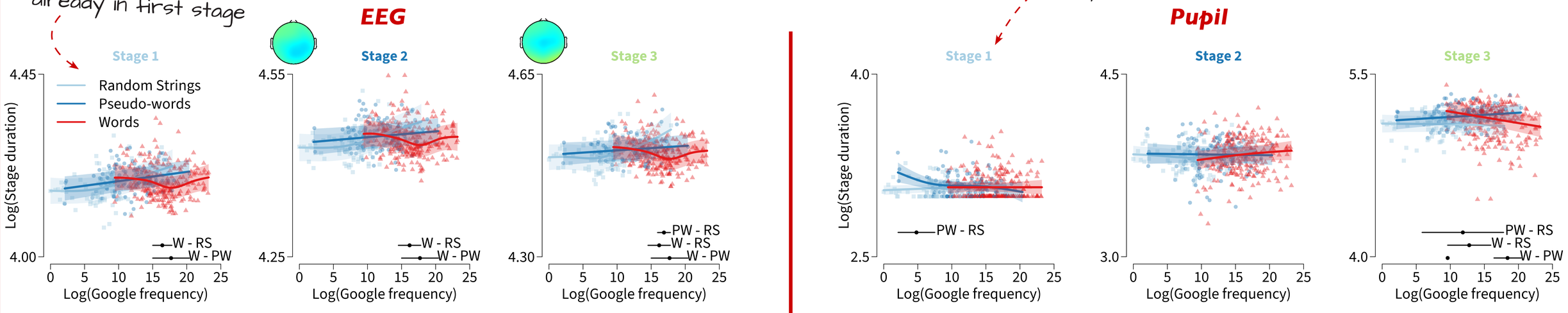


Orthographic encoding and visual processing[1]

Early Lexical Decision Processes

Frequency effects visible already in first stage

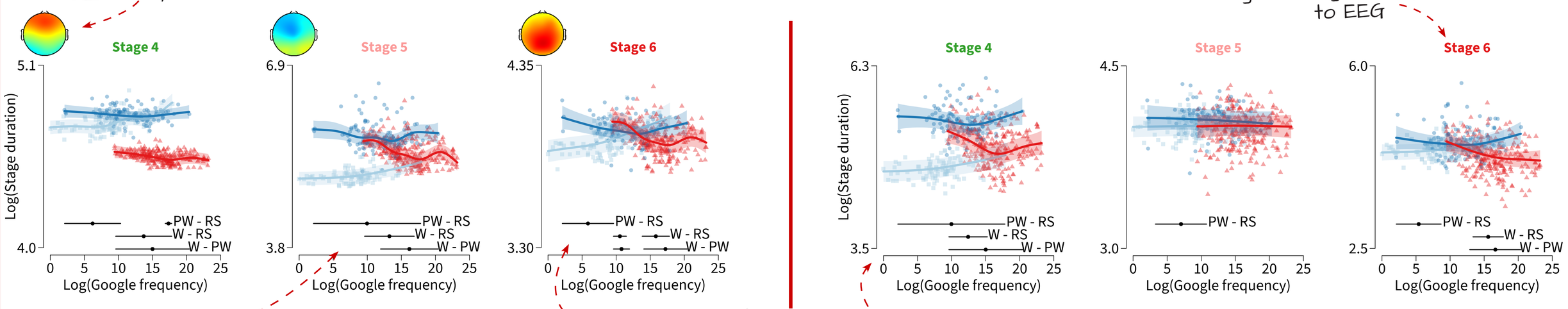
First event shifts to stimulus onset - maybe a stage is missing?



Mid-frontal "old/new effect"[10] suggests familiarity-driven word identification!

Late Lexical Decision Processes

Stage 6 is again very similar to EEG



Strong frequency effects hint at a decision stage[11-12]!

Response preparation speed dependent on decision confidence[13]?

Stage 4 is similar to stage 5 recovered from EEG - but too early?

References:

[1] Segalowitz & Zheng, "An ERP study of category priming: Evidence of early lexical semantic access.", Bio. Psychol., 2009
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[6] Willems et al., "Training-induced Changes in the Dynamics of Attention as Reflected in Pupil Dilation.", J Cogn Neurosci., 2015
[7] Denison et al., "Modeling pupil responses to rapid sequential events.", Behav. Res. Methods, 2020
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[9] Hendrix & Sun, "A word or two about nonwords: Frequency, semantic neighborhood density, and orthography-to-semantics consistency effects for nonwords in the lexical decision task", J. Exp. Psychol.: Learn. Mem. Cogn., 2020
[10] Rugg & Curran, "Event-related potentials and recognition memory.", TiCS, 2007
[11] Balota & Chumbley, "Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage.", J Exp Psychol Hum Percept Perform., 1984
[12] Ratcliff et al., "A Diffusion Model Account of the Lexical Decision Task.", Psychol Rev., 2004
[13] Ratcliff & Murdock, "Retrieval processes in recognition memory.", Psychol Rev., 1976

Discussion

- Both models suggest similar stages, but also **similar processes**?
  > Differences in stage timings could result from specific events (stimulus) affecting the pupil differently or from less precise onset recovery!
- Different advantages of EEG and pupil: EEG provides event topologies but studying pupil responses might reveal **how effortful** different events are!

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