

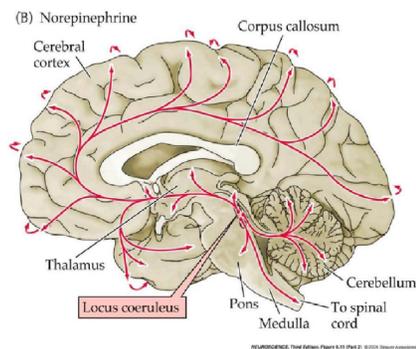
Pupil dilation in natural story listening during fMRI

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Introduction

- Pupil diameter in language processing is sensitive to cognitive load [4] and surprisal effects [2].
- The neurobiological basis of pupil dilation is the release of norepinephrine (NE) from the Locus Coeruleus (LC) [1]; this leads to better task performance.



- In discourse, passive voice: a syntactic factor for forming discourse predictions on the topic of the upcoming sentence [3] (after passive voice, reference to the subject is more predictable than after active voice).
- predictions of semantic nature, as i.e. after high causality events both sentence participants are foregrounded equally highly compared to low causal events (e.g. *hitting* vs. *seeing* [5]).

Methods

Participants. Twenty monolingual native speakers of German, all right-handed (Edinburgh Inventory of Handedness) (age mean = 24.3 years, sd = 2.1 years, male N = 6).

Design.

- **Voice (V):** active (A) vs. passive (P),
- **Causality (C):** high (H) vs. low (L),
- **Position of measurement (P):** *sentence* vs. *referent*.

Hypotheses.

1. Stronger effects for the referent in contrast to the sentence, if pupillary responses in auditory comprehension capture surprisal effects.

2. Passive would increase future predictability of the referent, as manifested in a change in pupil size compared to processing the referent after active voice.
3. Causality would interact with voice in the pupil measurements.

C. Stimuli

- AH *The engineer pushed the pharmacist quickly back into the car, because due to the traffic... **The engineer** sped off immediately.*
 PH *The engineer was pushed quickly into the car by the pharmacist because due to the traffic... **The engineer** sped off immediately.*
 AL *The pharmacist held the engineer in very high esteem They knew each ... **The pharmacist** was waiting ...*
 PL *The pharmacist was held in very high esteem by the engineer They knew each ... **The pharmacist** was waiting ...*

Table 1: Example stimuli, C. for condition.

Stimuli. Conditions embedded in 20 two-minute long stories:

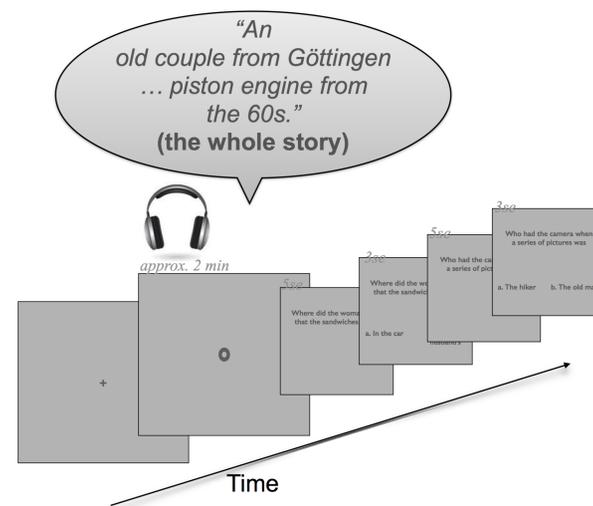


Figure 1: One story trial.

Analysis.

- **Blink correction:** rejected all data points during each blink and 5 data points before and after it.
- **Slow drifts:** modelled a baseline event within the intervening context sentence and subtracting the event from the baseline pupil sizes.
- modelled the previous 2x2x2 design plus maximal random effects structure, which allowed the model to converge.

Results

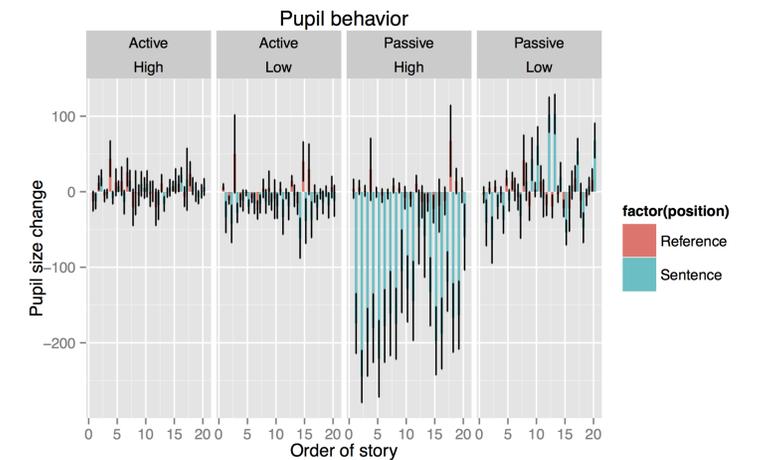


Figure 2: Baseline corrected differences from mean pupillary radius.

- no significant effects on the referent in comparison to the sentence,
- a significant two-way interaction of voice and causality for sentence, mainly driven by pupil dilation during processing of Pass-low (estimate 182, std.error=30, t-value=6), and
- increased pupil dilation for passive voice in interaction with causality of the event (e.g. *hitting* vs. *seeing*).

Conclusion

- LC-NE activity is sensitive to the match between the semantic properties of an event and how it is expressed grammatically

References

[1] Wolfgang Einhäuser, James Stout, Christof Koch, and Olivia Carter. Pupil dilation reflects perceptual selection and predicts subsequent stability in perceptual rivalry. *Proceedings of the National Academy of Sciences*, 105(5):1704–1709, 2008.
 [2] Stefan L Frank and Robin L Thompson. Early effects of word surprisal on pupil size during reading. 2012.
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 [5] Pirita Pyykkönen, Danielle Matthews, and J Järvi. Three-year-olds are sensitive to semantic prominence during online language comprehension: A visual world study of pronoun resolution. *Language and Cognitive ...*, (909926360), 2010.