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course materials at:
www.sfs.uni-tuebingen.de/~jvanrij/LSA2015

Analyzing time series data using GAMs

Jacolien van Rij & Martijn Wieling | LSA 2015, Chicago

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Day 2 • July 10

1) Short **summary** of smooths
2) Intro **pupil dilation data**
3) Lab session: smooths and pupil dilation data

Generalized Additive Models

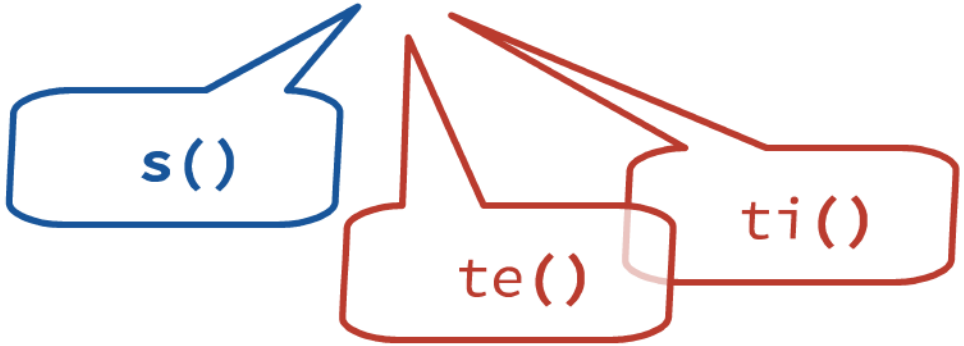
(Lin & Zhang, 1999; Wood, 2006; 2011)

Nonlinear regression

- Relaxing assumption of linear relation between dependent variable and predictor

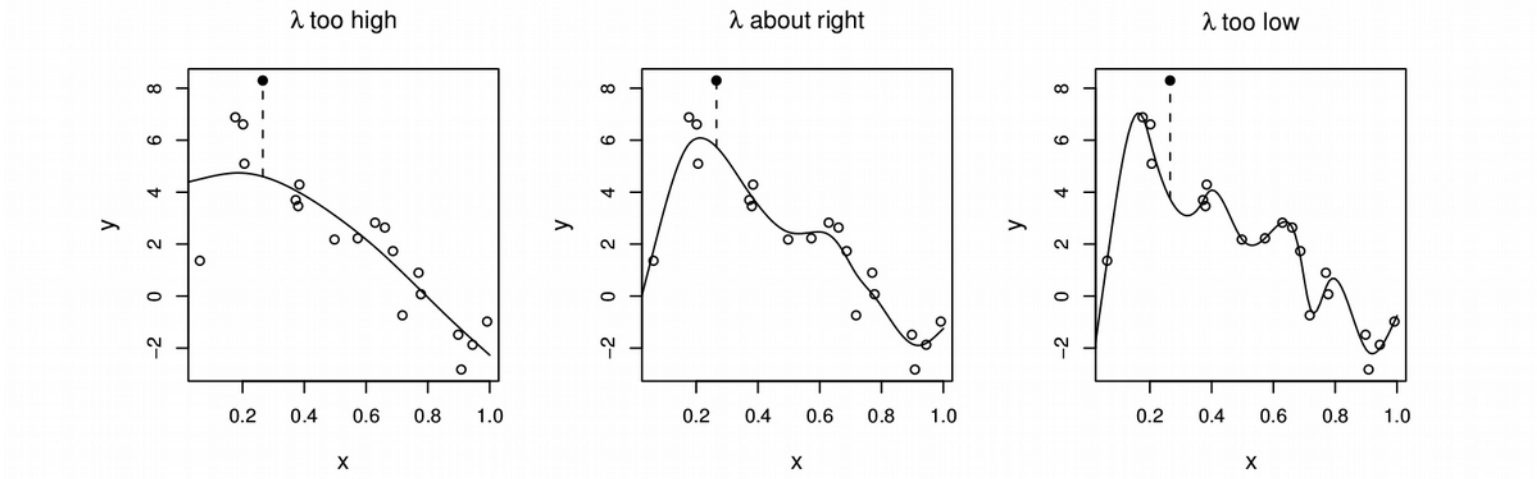
- Regression formula: $y = \beta_0 + \beta_1 * x_1 + \beta_2 * x_2 + \epsilon$

becomes: $y = \beta_0 + f(x_1) + f(x_2) + \epsilon$



Base functions

- `s(X, k=10, bs='tp')`
  - Arguments
  - `help(s)`
- Cross-validation



(Wood, 2006, p. 130, fig. 3.9)

Use of function `s()`

- For 1-dimensional smooths, e.g. `s(Time)`
  - Split smooths by categorical predictors:
    `Group + s(Time, by=Group)`

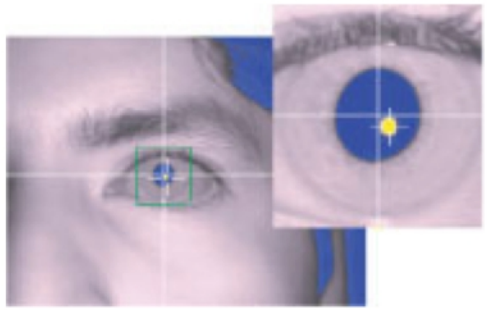
- For random effects
  - Random intercepts: `s(Item, bs="re")`
  - Random slopes: `s(Item, logFreq, bs="re")`
  - Random smooths:
    `s(logFreq, Item, bs="fs", m=1)`

- For isotropic interactions, e.g. `s(Xgaze, Ygaze)`

Pupillometry

Eye-tracking

- Camera to measure gaze position
  - Used for usability and applied research…
  - …but also cognitive science



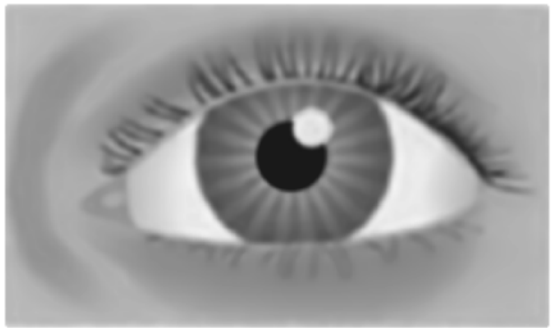
(Eye Link 1000, SR Research)

Eye-tracking data

TIMESTAMP	GAZE_X	GAZE_Y	PUPIL_SIZE	SAMPLE_MESSAGE
1823674	84.6	387.7	890	!MODE RECORD P 500 2 1
1823676	84.4	387.8	890	.
1823678	84.3	387.4	890	.
1823680	84.3	387.1	890	.
1823682	84.4	387.2	891	.
1823684	84.4	387.4	891	.
1823686	84.5	387.2	894	.
1823688	84.4	387.2	894	.
1823690	84.3	387.3	894	.
1823692	84.3	387.2	894	.
1823694	84.5	387.7	894	.
1823696	84.4	387.7	895	.

1825848	.	.	0	.
1825850	.	.	0	.
1825852	.	.	0	.
1825854	.	.	0	.
1825856	.	.	0	.

Pupil dilation



- Primarily determined by light and accommodation reflexes
- Also '*psychophysiological index of dynamic brain activity in human cognition.*' (Beatty & Lucero-Wagoner, 2000)
  - slow movements
  - small scale movements, about .5 mm in pupillary diameter
- First reports from 1875 in Germany, rediscovered in 1960s
- Triggered by attention, effort, processing load, working memory load, emotion, ...

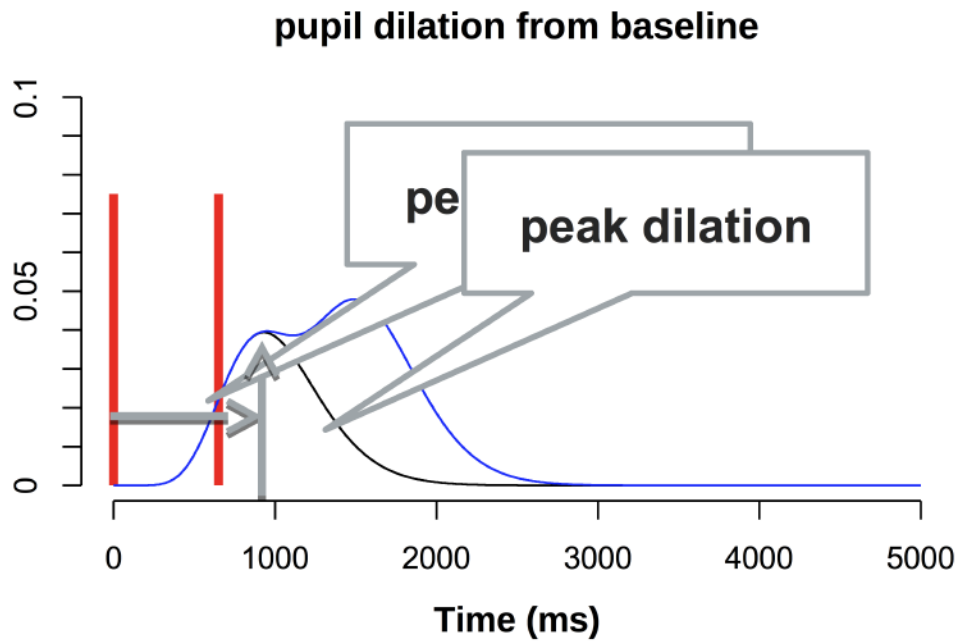
Pupillometry in language processing research

- Pupil dilation is a precise and consistent measure of processing activity during on-line language processing

- Sensitive to (among others):
  - grammatical complexity (Just & Carpenter, 1993)
  - integration of prosodic information and visual context (Engelhardt et al., 2010)
  - focus prosody (Zellin et al., 2011)

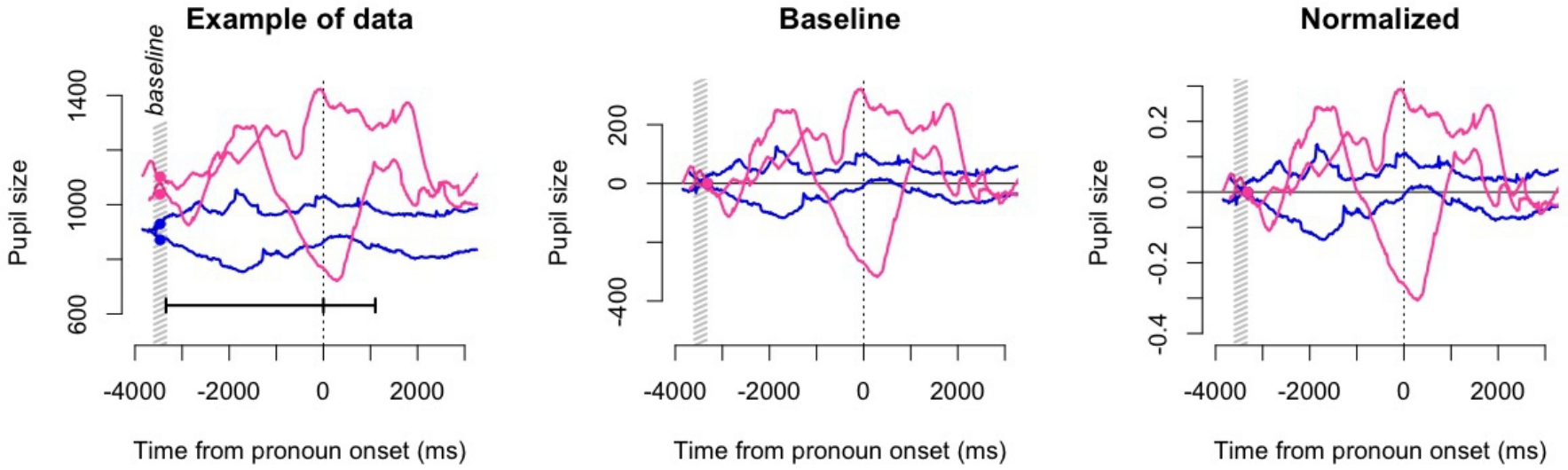
Characteristics

- Hoeks & Levelt (1993): Estimation of pupil dilation response by mathematical function
  - peak around 930 ms after trigger



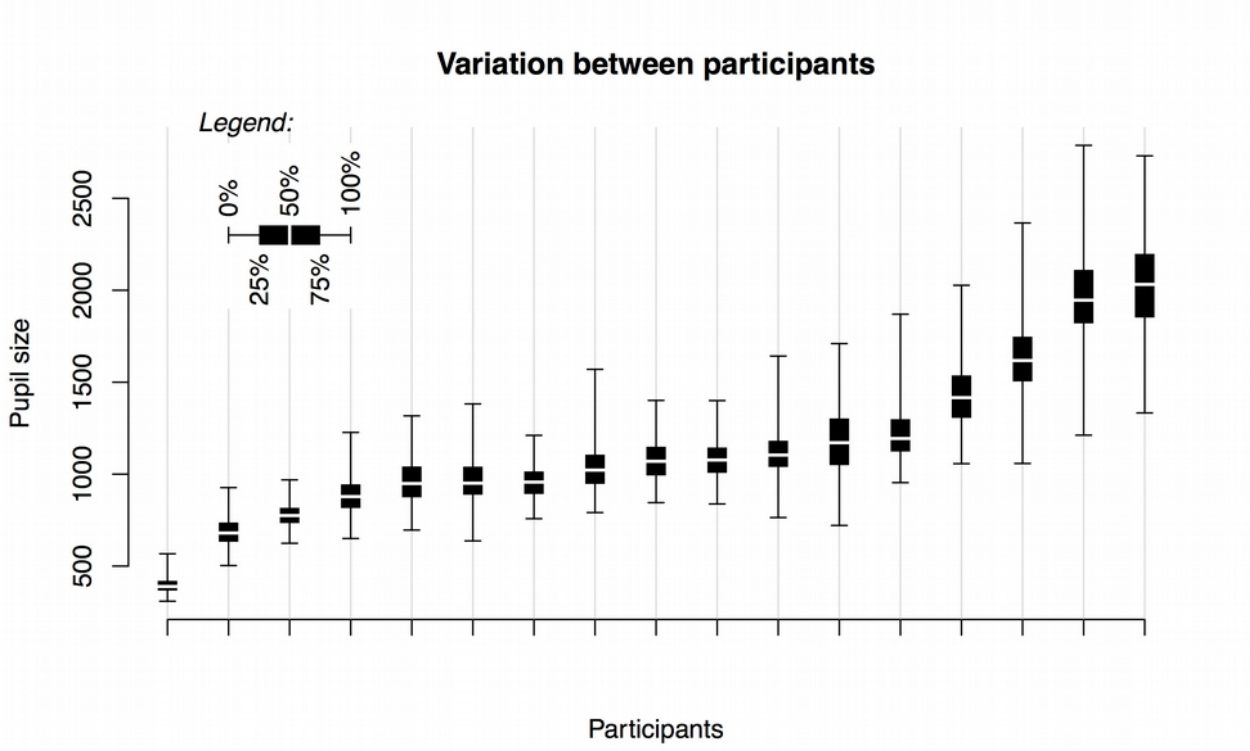
In practice:

- Lots of variation between participants and items

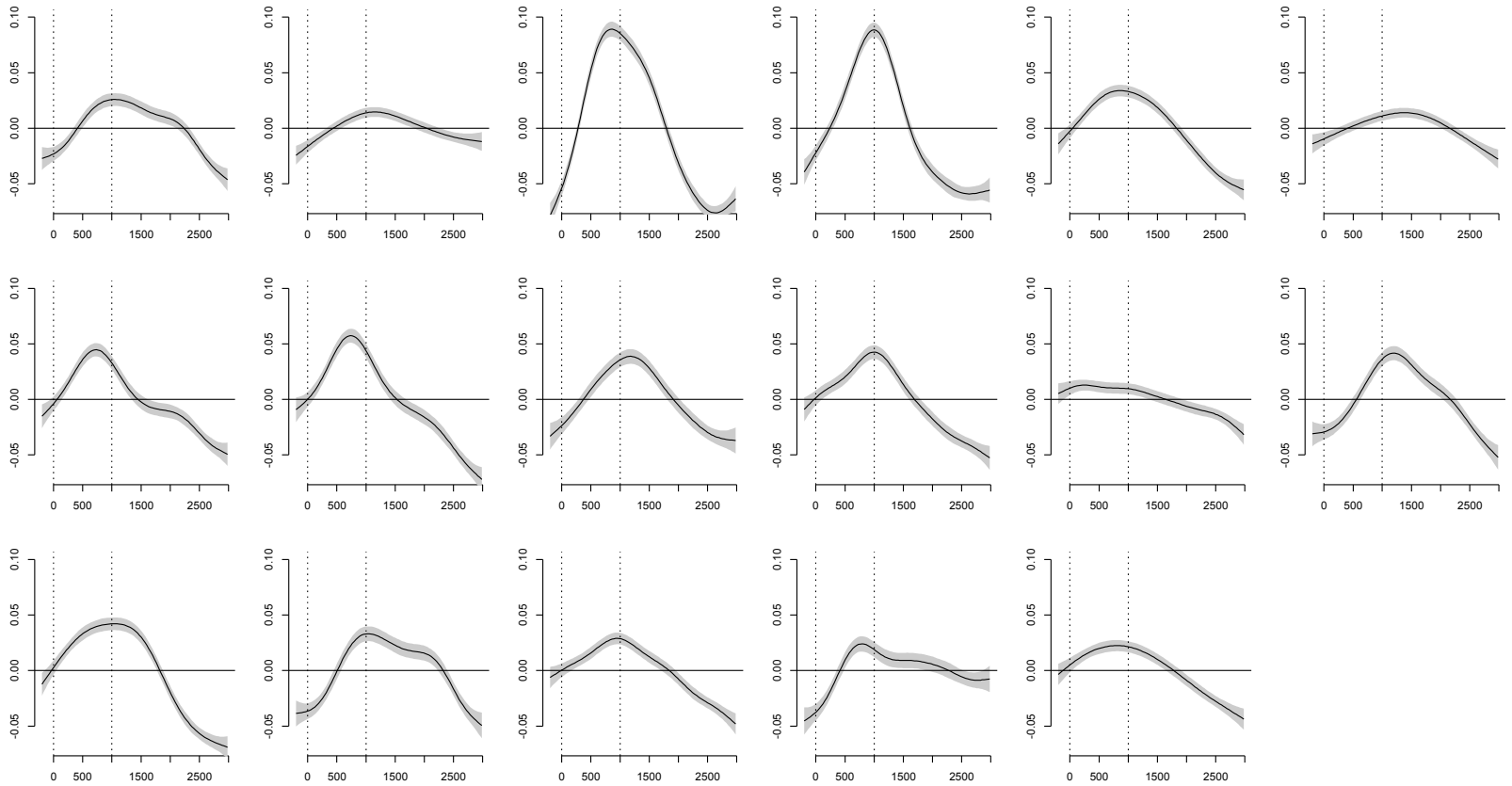


Characteristics

- Large individual differences in pupil size

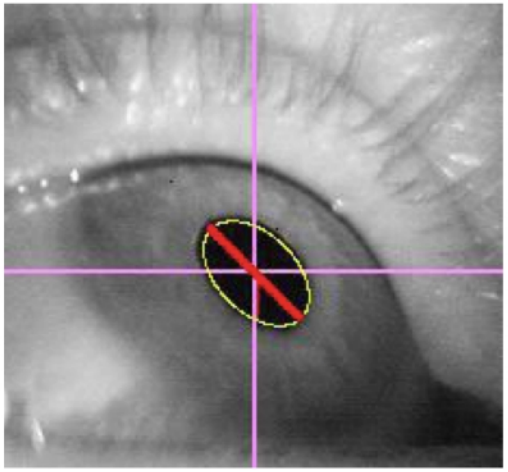


Characteristics



Characteristics

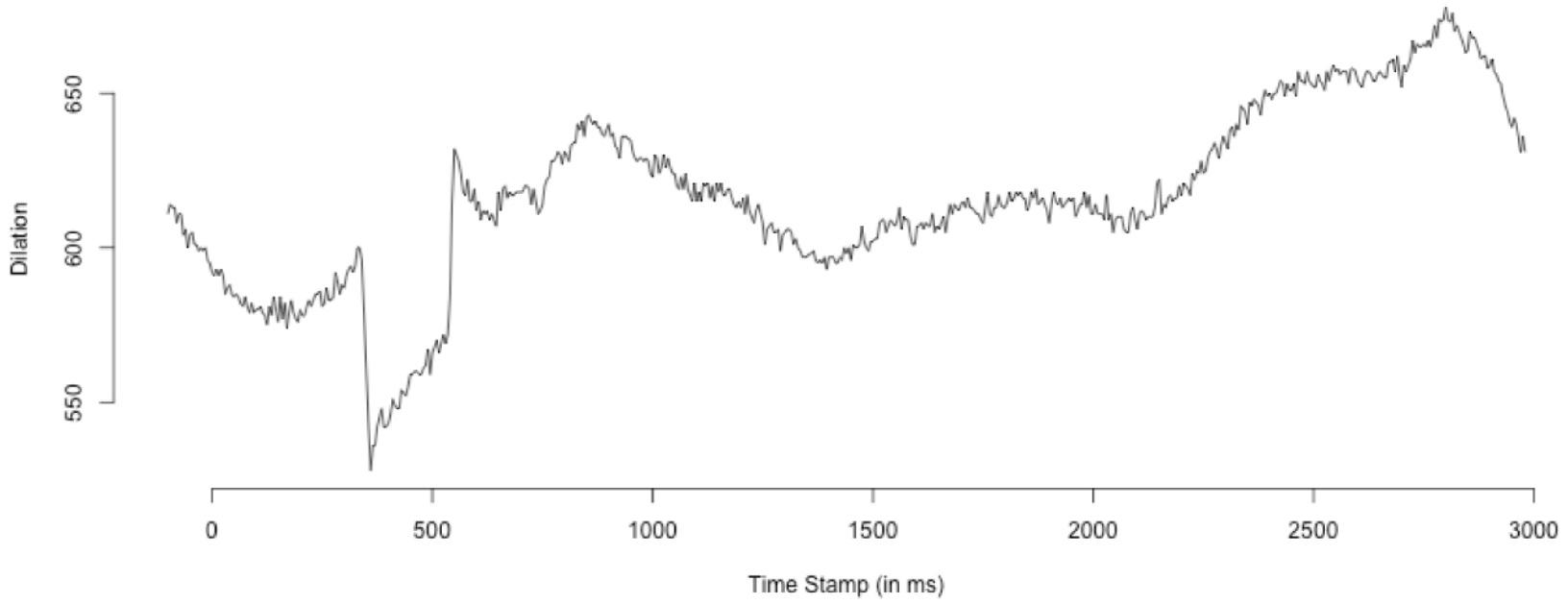
- Pupil size is influenced by gaze position



www.arringtonresearch.com

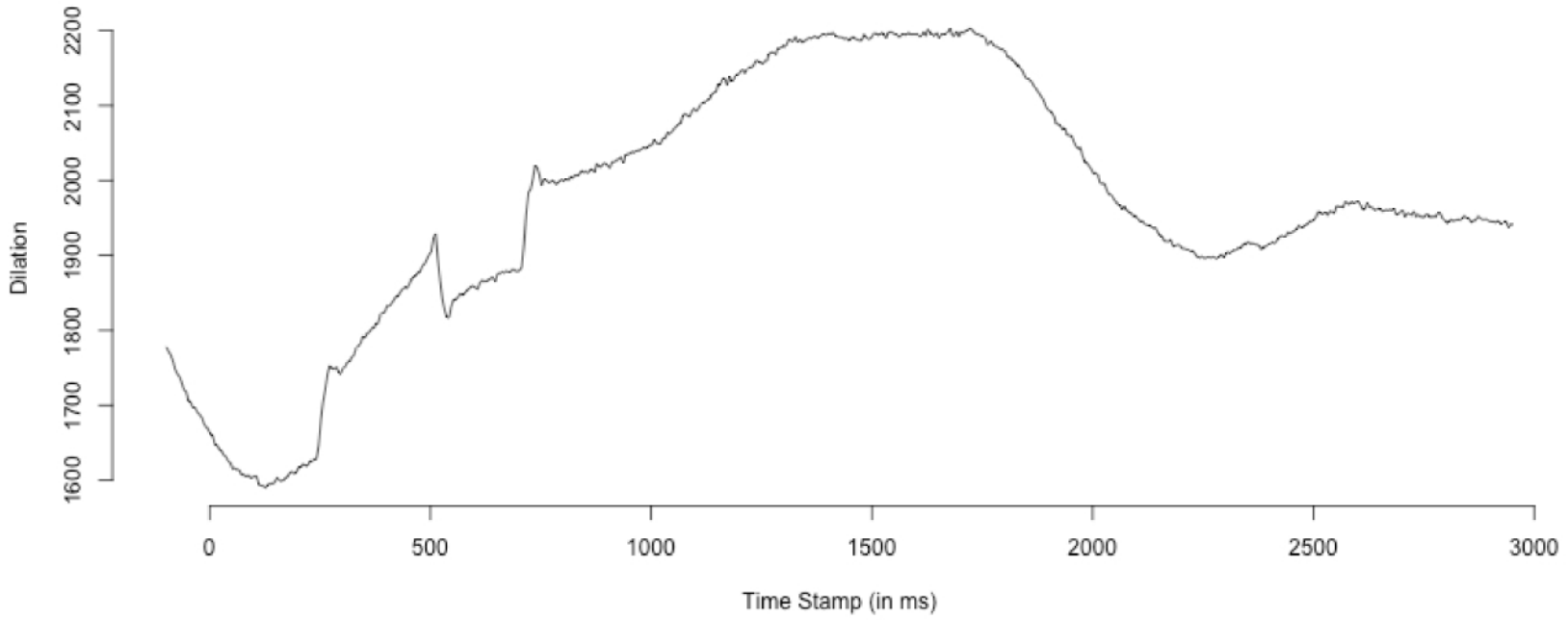
Characteristics

- Saccades



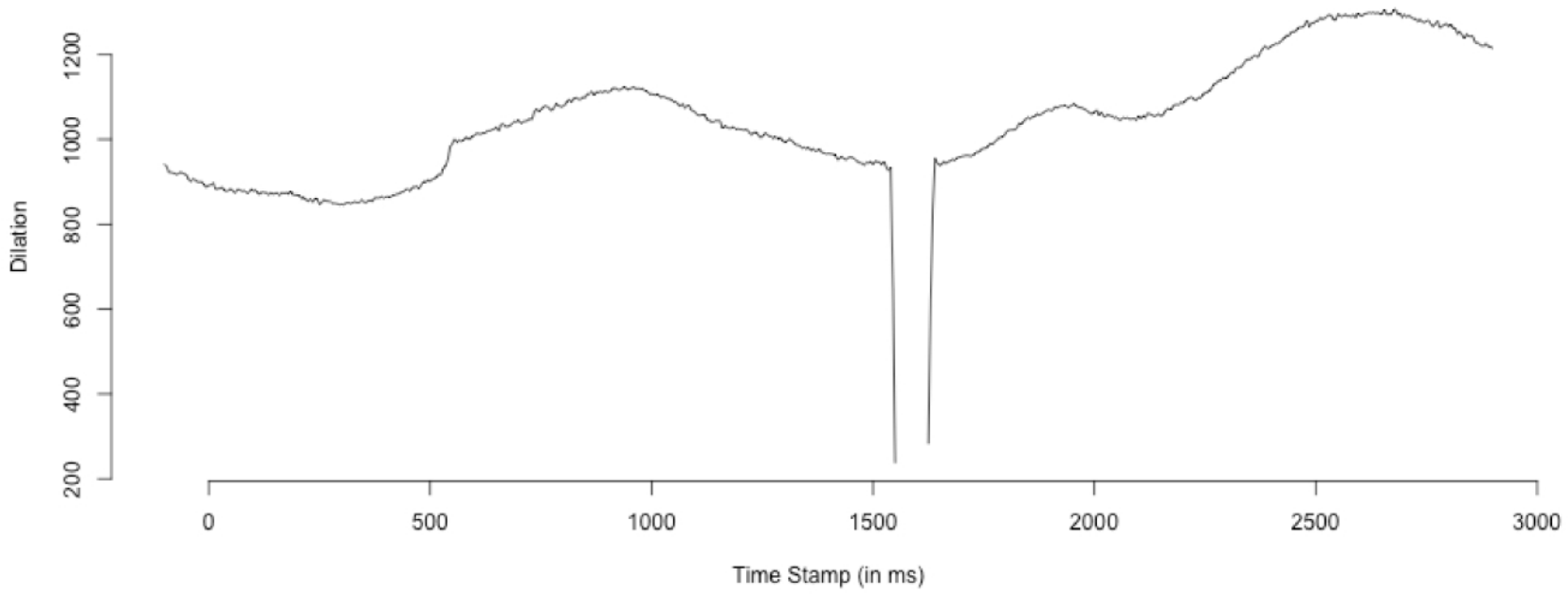
Characteristics

- Saccades



Characteristics

- Other artifacts



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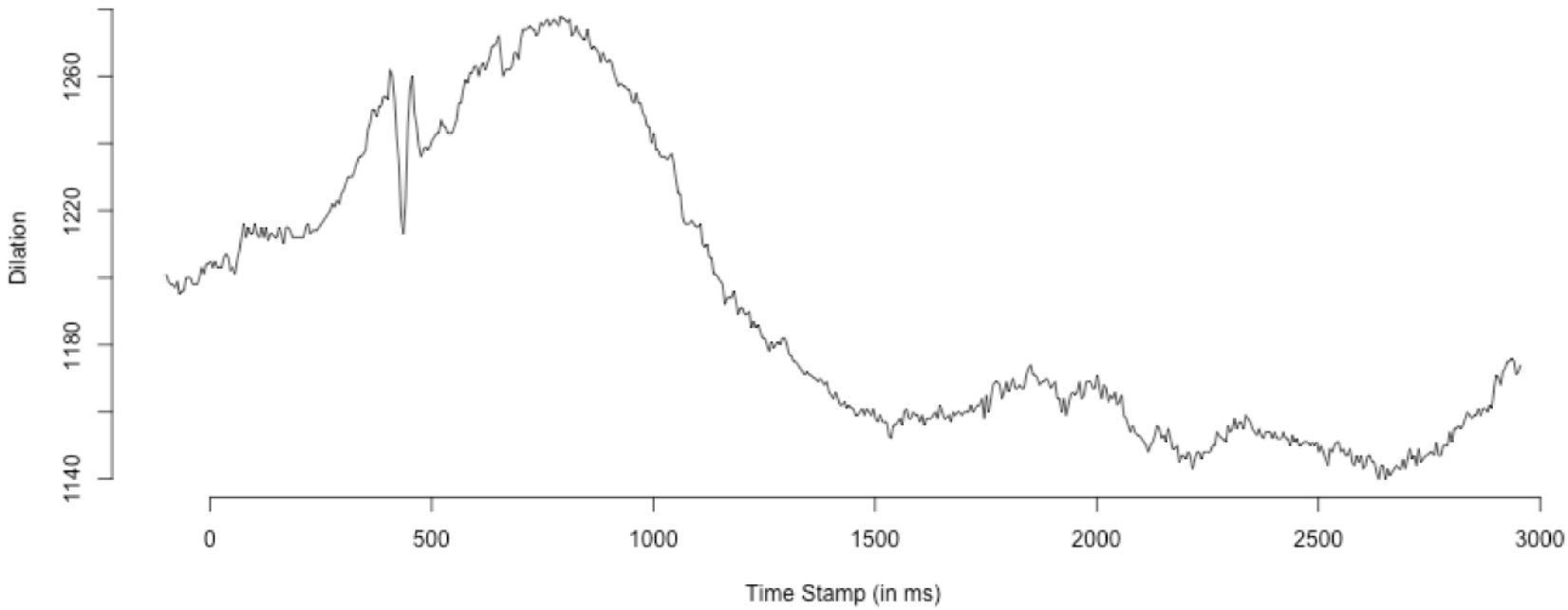
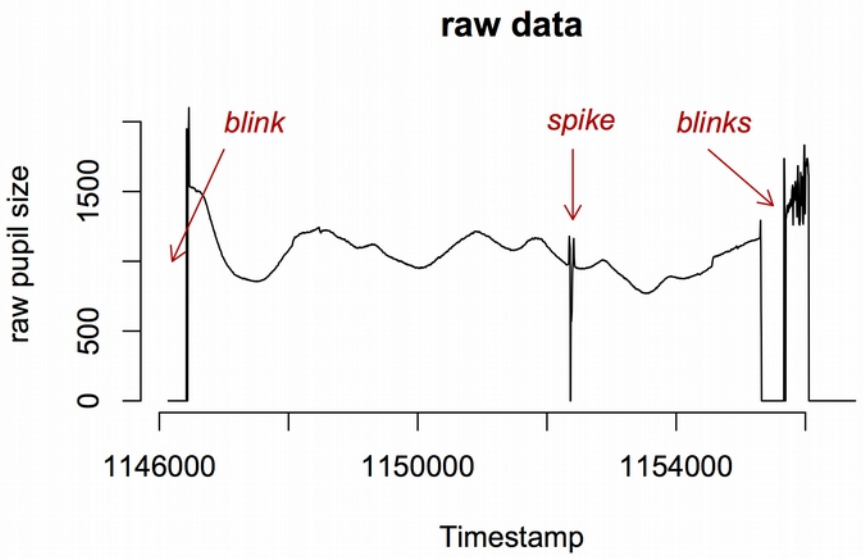
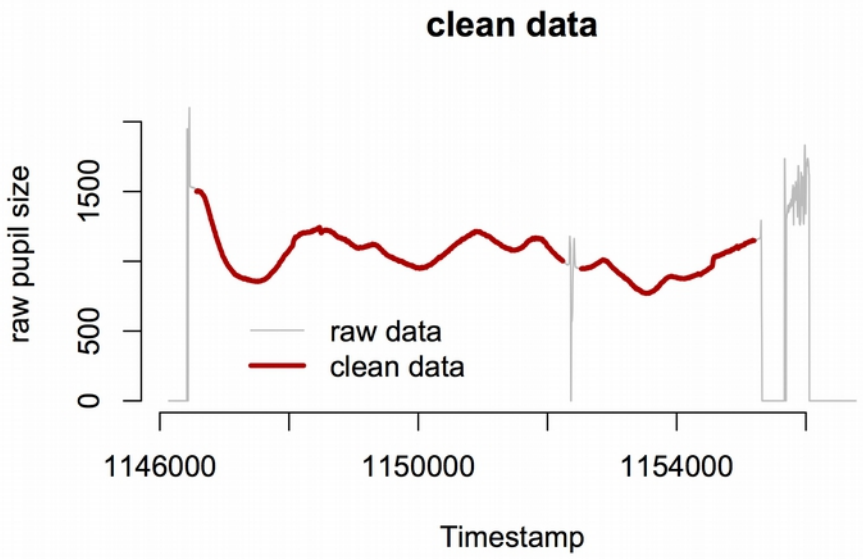


Preprocessing

- Remove blinks and artifacts
- Downsampling (filtering not necessary)
  - For example to 50Hz ≈ time bins of 20 ms
- Calculating baseline
  - For example, 100 ms before stimulus onset

Preprocessing





Baseline & normalization

- Pupil size can be measured in different units: area, diameter, or arbitrary unit - depends on eye tracker / camera

- Convert to pupil dilation for plotting:
  - `pupil <- (pupil_size - baseline)`
  - baseline: average pupil size 100 ms before onset pronoun
  - Normalization (not preferred):
    `pupil <- (pupil_size - baseline) / baseline`

Experiment

- Visual World Paradigm
  - Visual pictures on the screen
  - Auditory signal

- **Linking hypothesis:** the listener's attention will shift to potential referents in the display as they become relevant

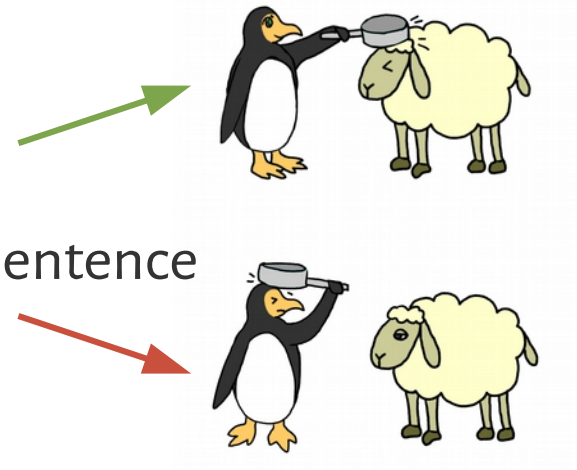
  (Allopenna et al, 1998; Cooper, 1974; Tanenhaus et al., 1995)

2x2 within-subject design

- Manipulating **linguistic context**:
  - AP (agent-patient): Here you see a penguin and a sheep.
  - PA (patient-agent): Here you see a sheep and a penguin.

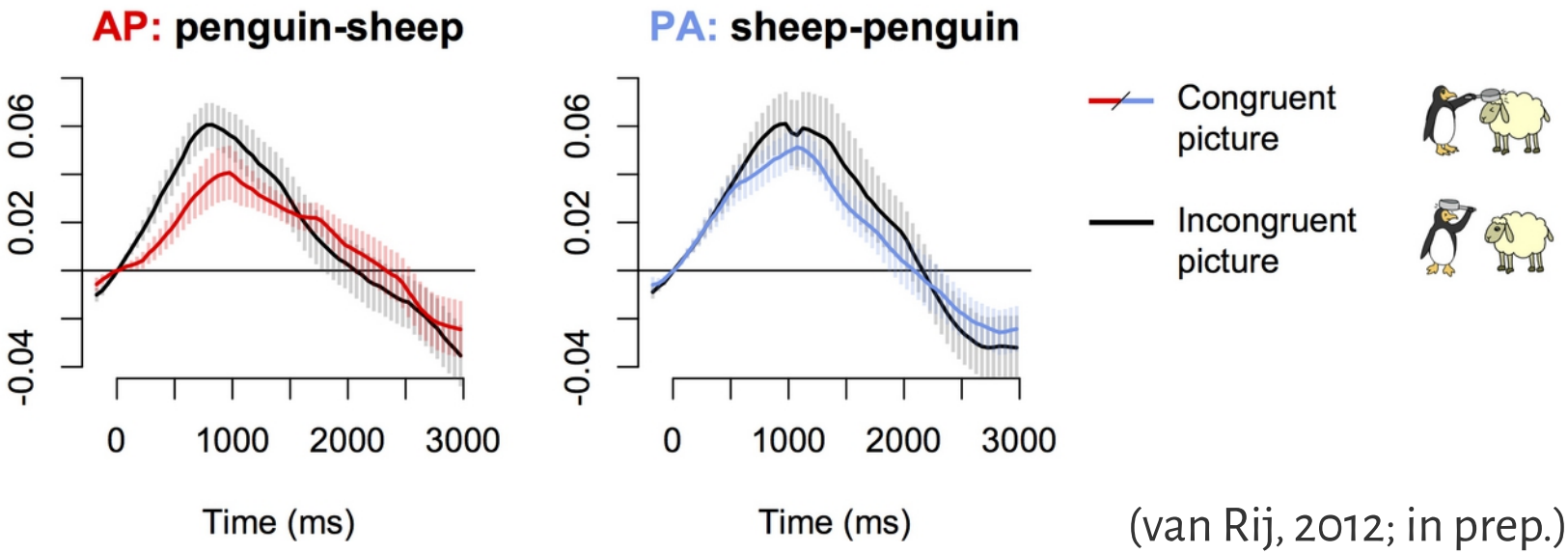
- Test sentence: The penguin is hitting HIM with a pan.

- Manipulating **visual context:**
  - **Congruent:** picture matches sentence
  - **Incongruent:** picture does not match sentence



Results

- With AP context (penguin - sheep) effect of visual context,
  but not / less so with PA context (sheep - penguin)
- Visual context influences interpretation (c.f., Knoeferle et al, 2005)



(van Rij, 2012; in prep.)