Pupil models

Christoph Korn, 23.04.2020

Questions

Have you **acquired** pupil or eye gaze data?

Never

Often

Questions

Have you **analyzed** pupil data?

Never Often

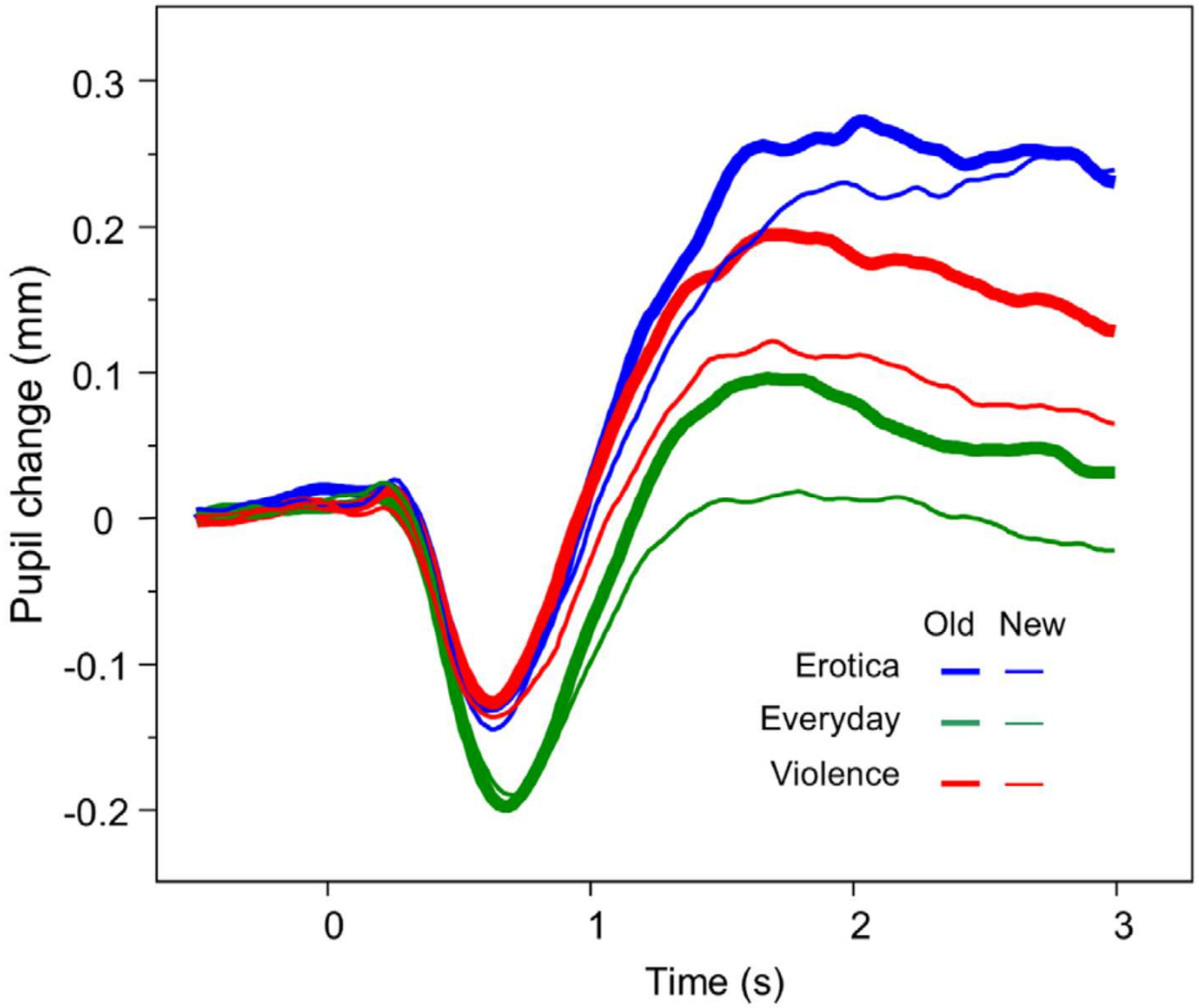
Questions

Do you have experience with models of physiological data?

No A lot

Pupil in psychology and cognitive (neuro)science

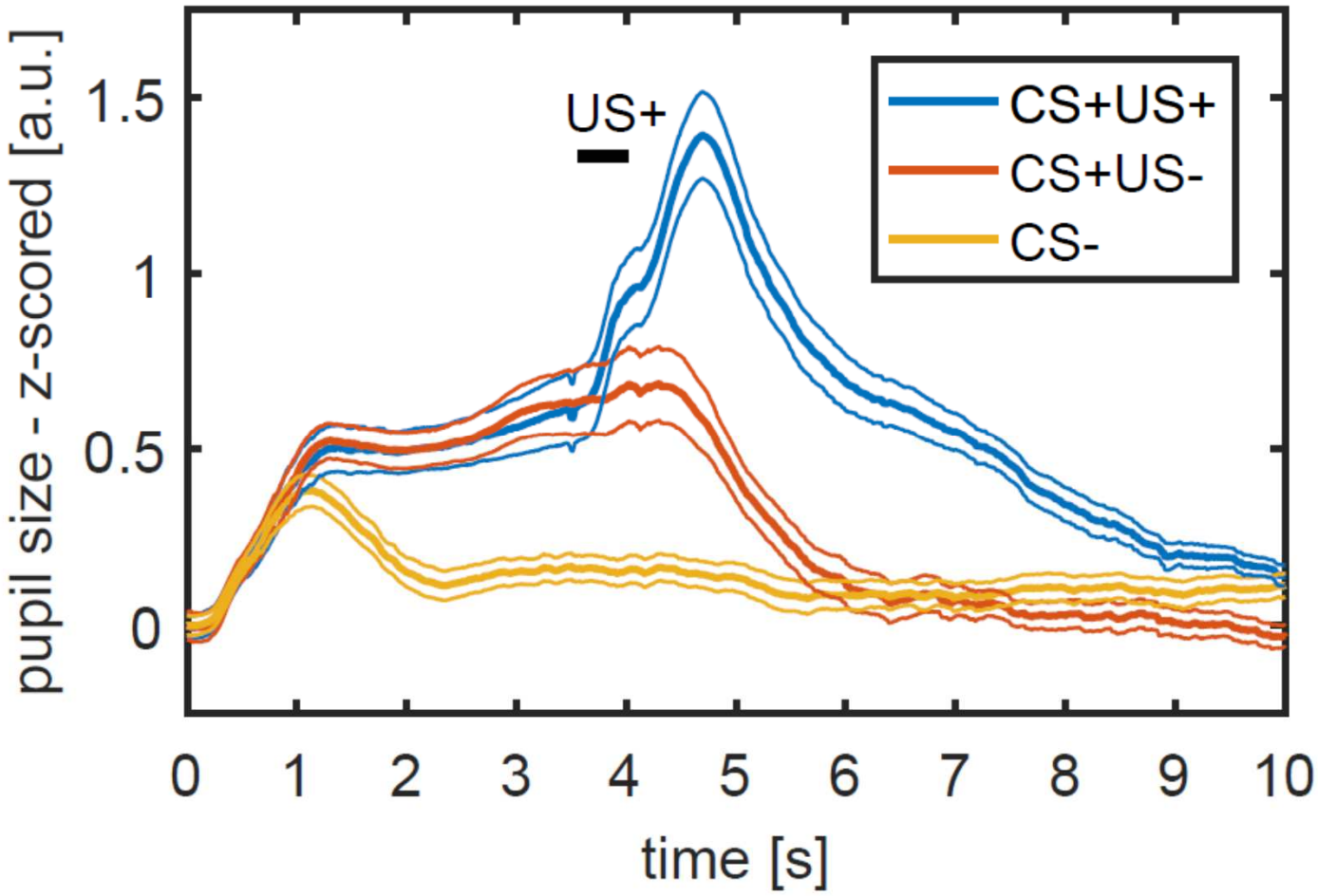
- Emotions & memory



Bradley & Lang, 2015

Pupil in psychology and cognitive (neuro)science

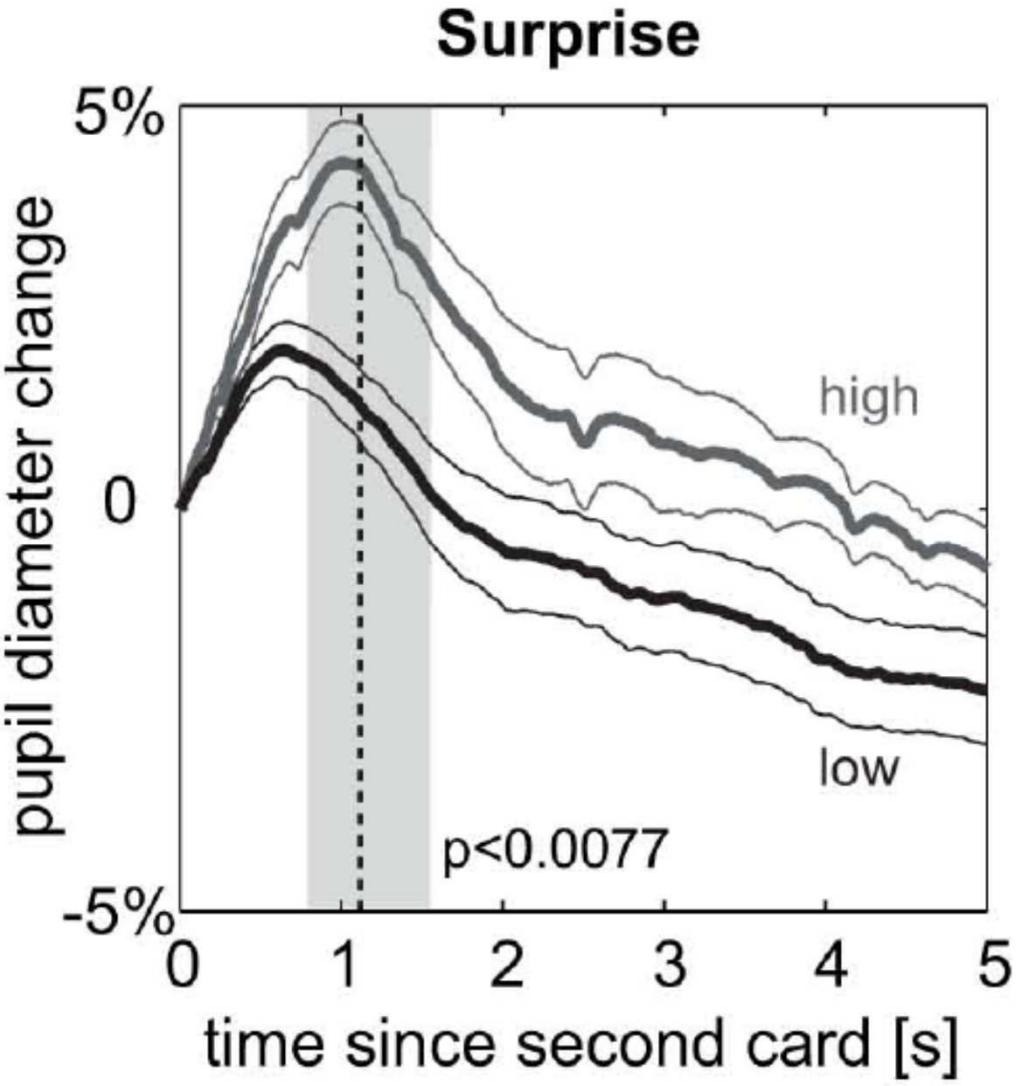
- Fear conditioning



Korn et al., 2016

Pupil in psychology and cognitive (neuro)science

- Different types of uncertainty

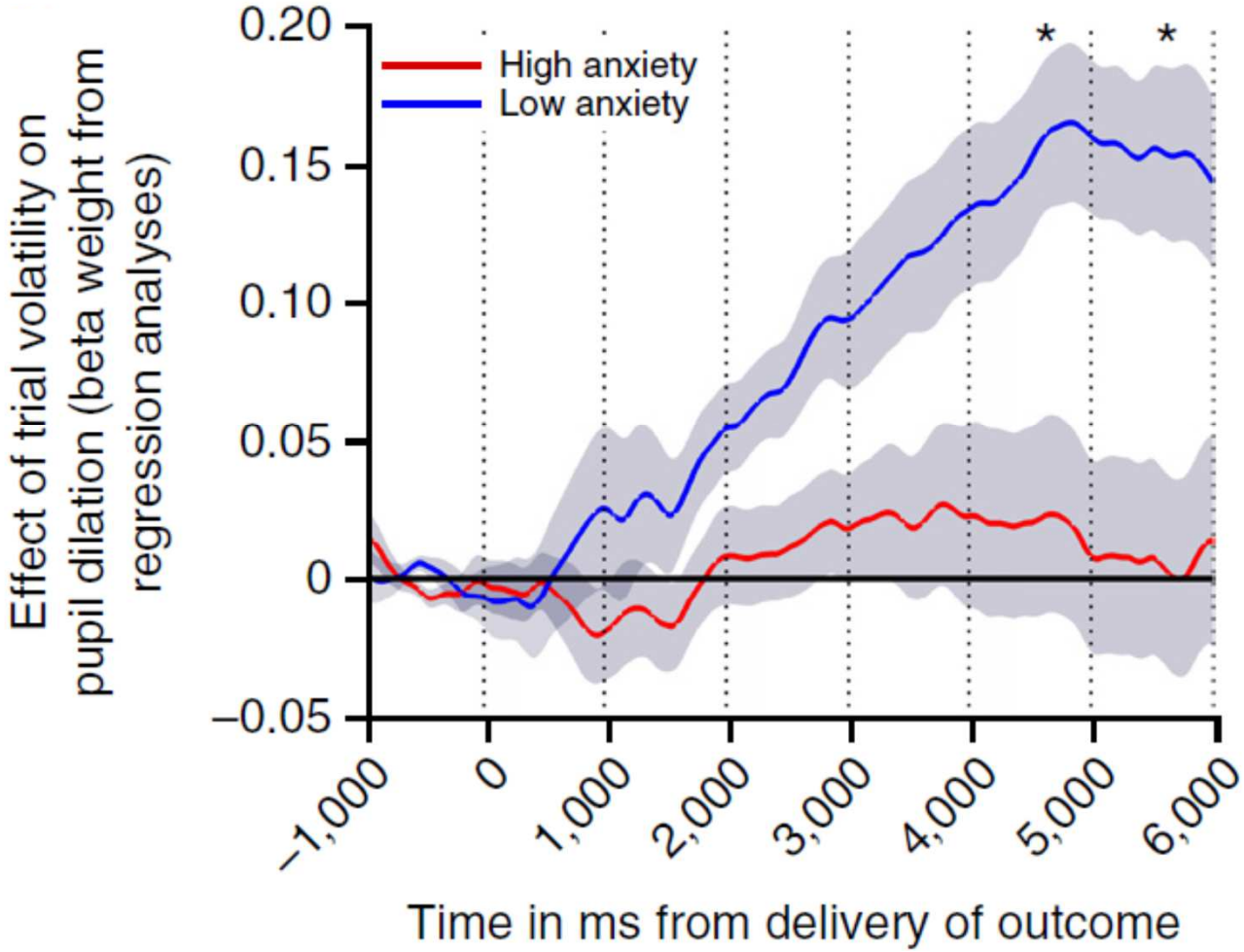


Preuschoff et al., 2011

See also
Nassar et al., 2012
Eldar et al., 2013
O'Reilly et al., 2013

Pupil in psychology and cognitive (neuro)science

- Individual differences in anxiety score

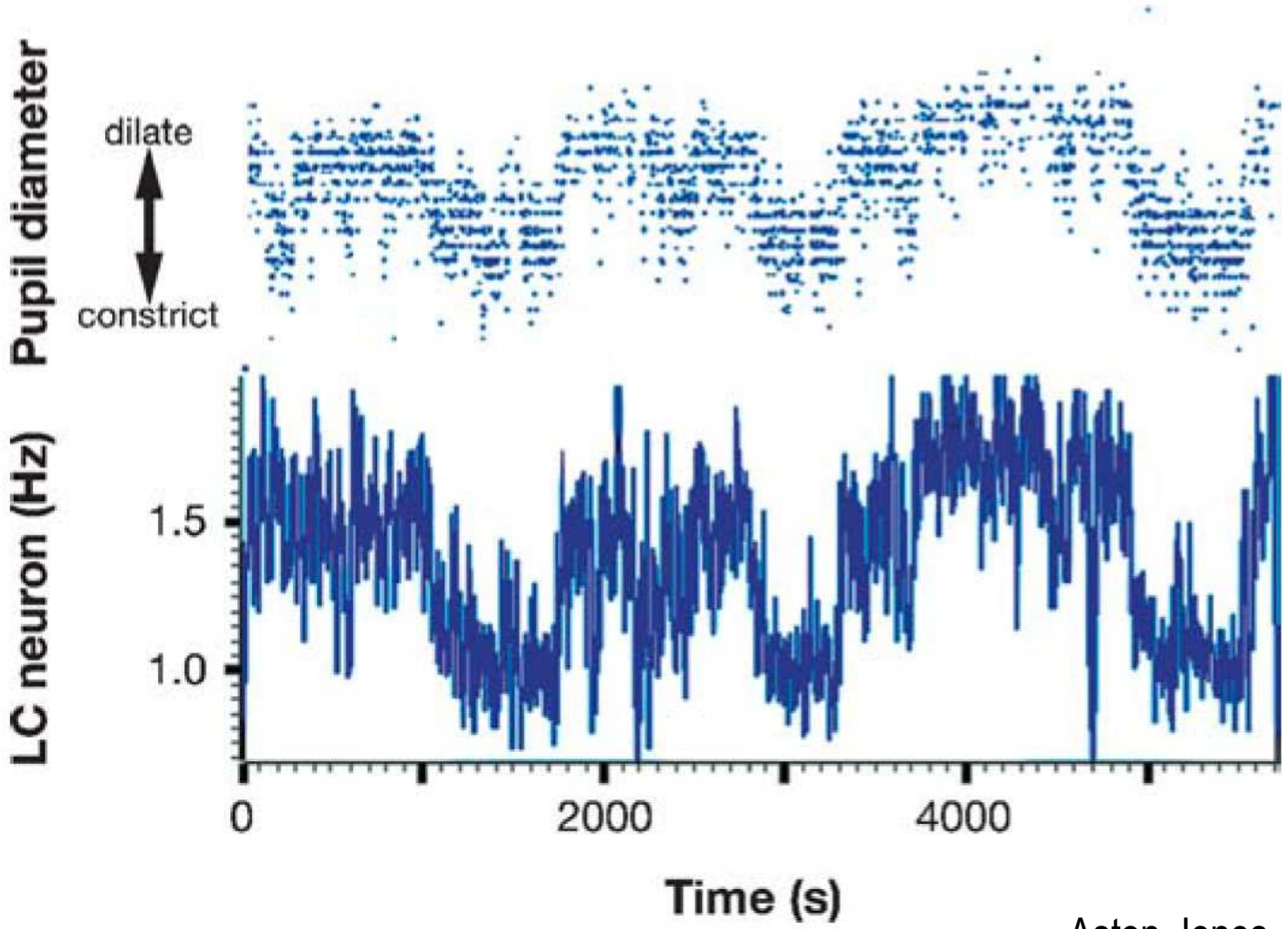


Browning et al., 2015

See also
Preller et al., 2013
Steidtmann et al., 2010
Siegle et al., 2001

Pupil in psychology and cognitive (neuro)science

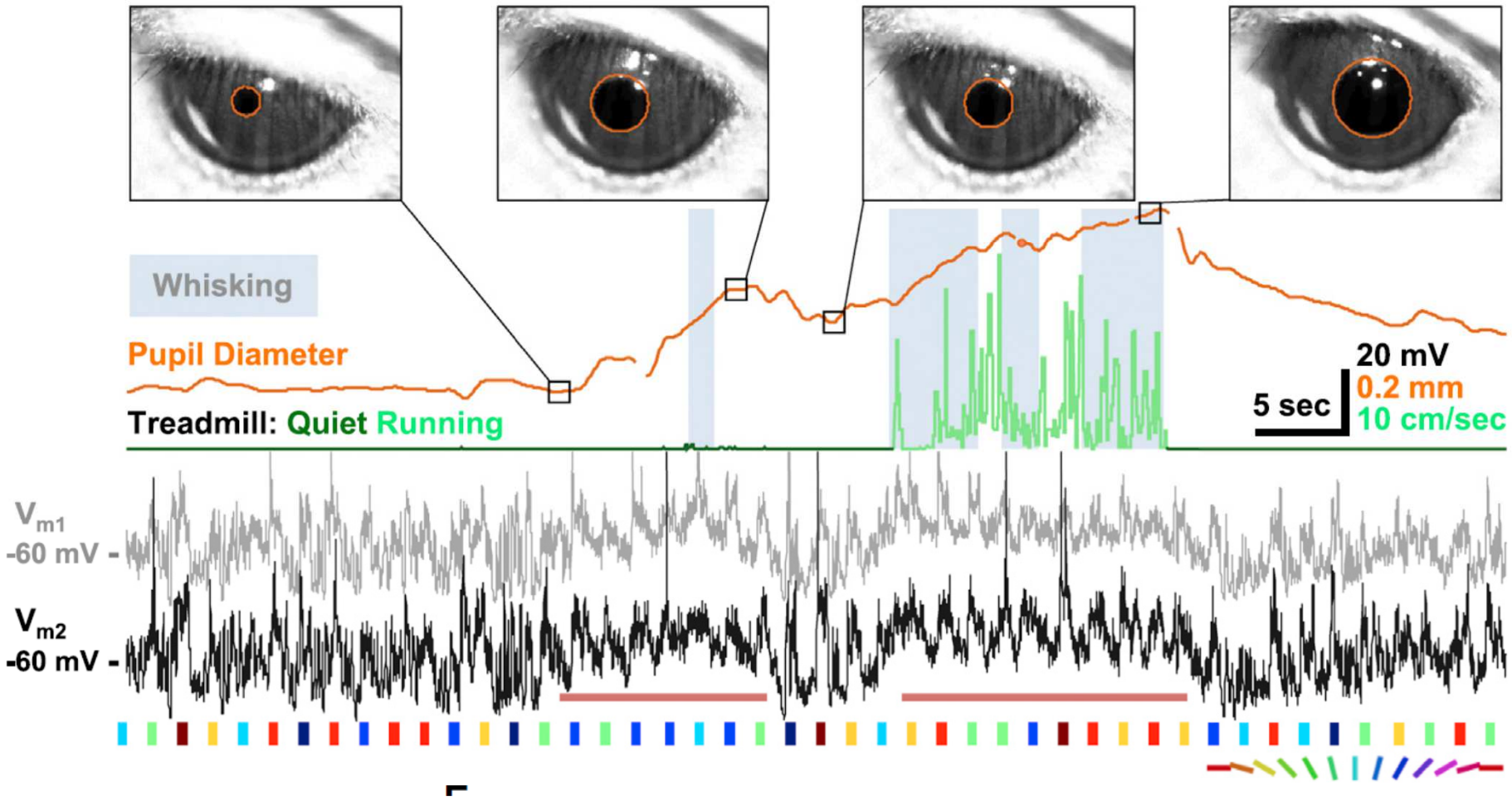
- Noradrenaline & locus coeruleus



Aston-Jones, Cohen, 2005
See also Joshi et al., 2015

Pupil in psychology and cognitive (neuro)science

- Cortical states in rodents

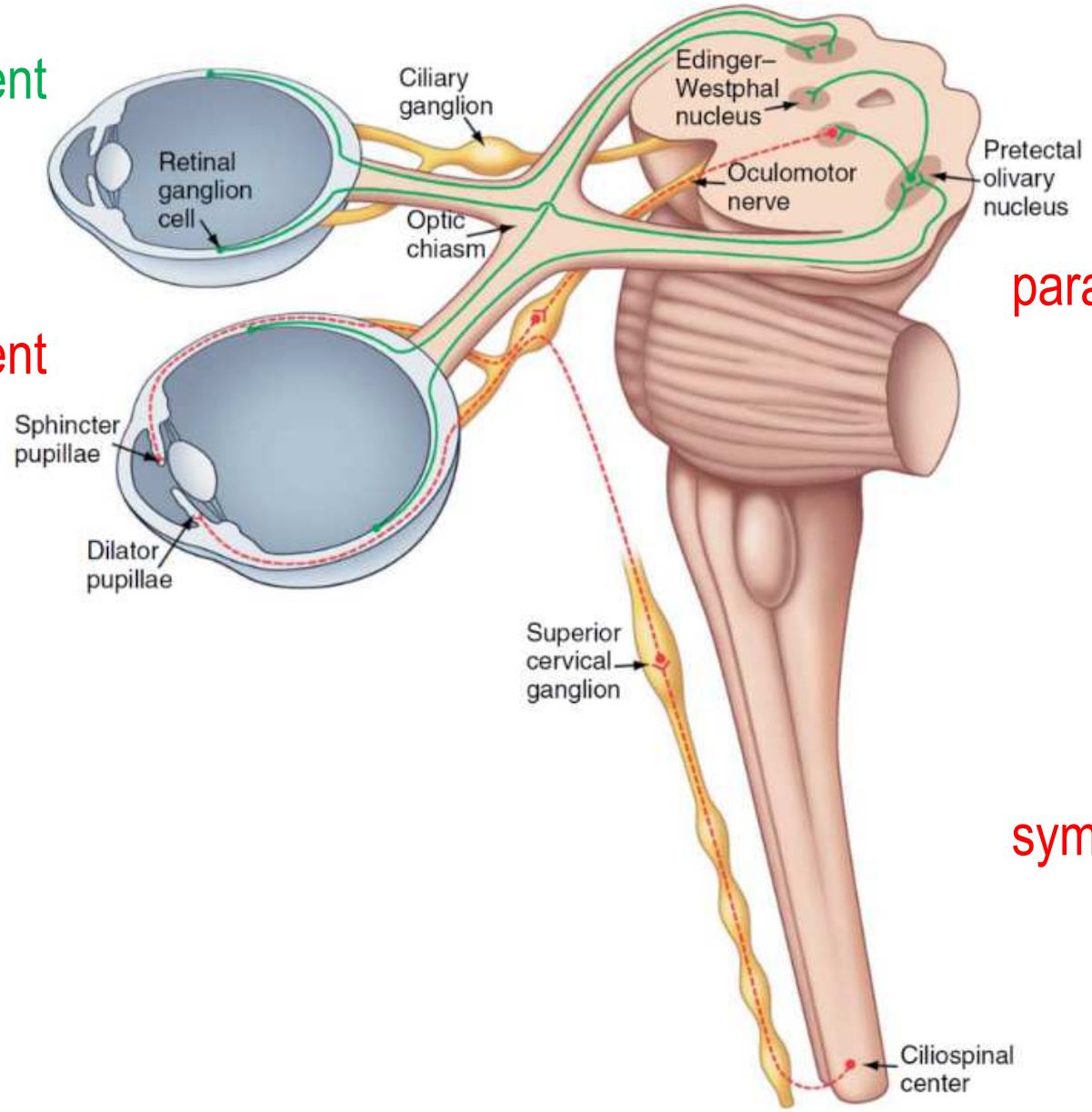


Reimer et al., 2014

Pupil physiology

afferent

efferent



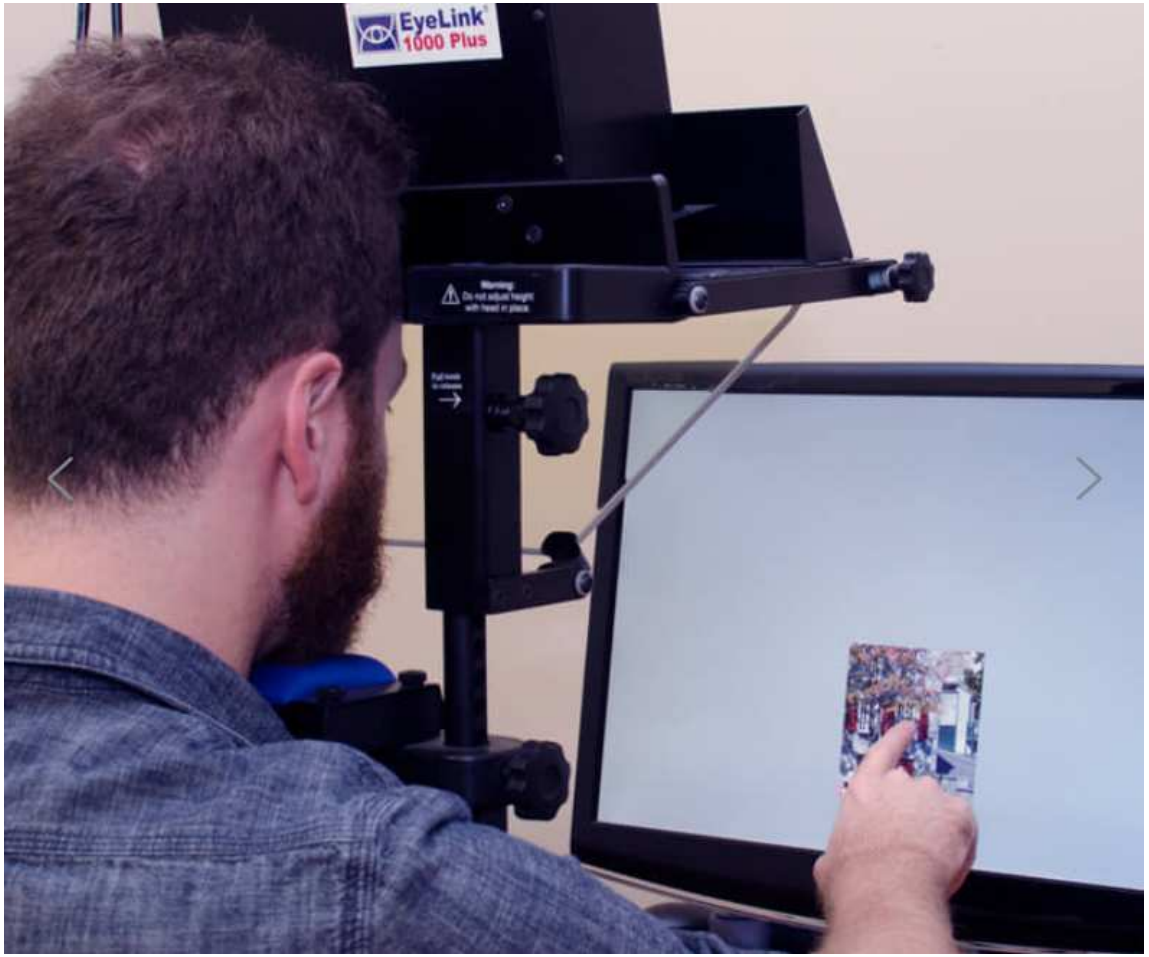
parasympathetic

sympathetic

McDougal, 2008

Data acquisition

Data acquisition



Data acquisition

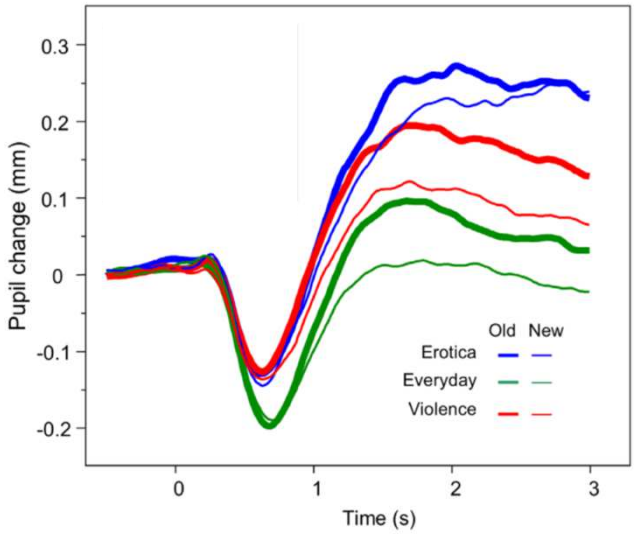
- Illumination:
  - Room
  - Stimuli (and background screen)
- Positioning:
  - Distances between screen, eyes, & eye tracker
  - Calibration of eye positions
  - Eccentricity of stimuli & gaze angle
  - Absolute or relative pupil size
  - Chin rest
- Participants:
  - Glasses
  - Eye problems
  - Drugs
- Pauses for blinking
- Etc.

Data preprocessing

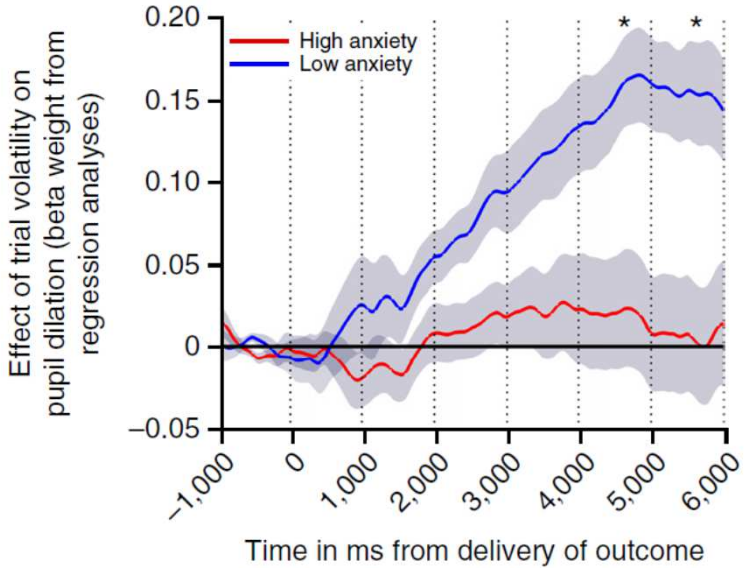
- Import
- Trimming
- Interpolation of missing data points
  - detection of saccades, blinks, & head movements often during acquisition
- Filtering
- Normalization

Model-free analyses

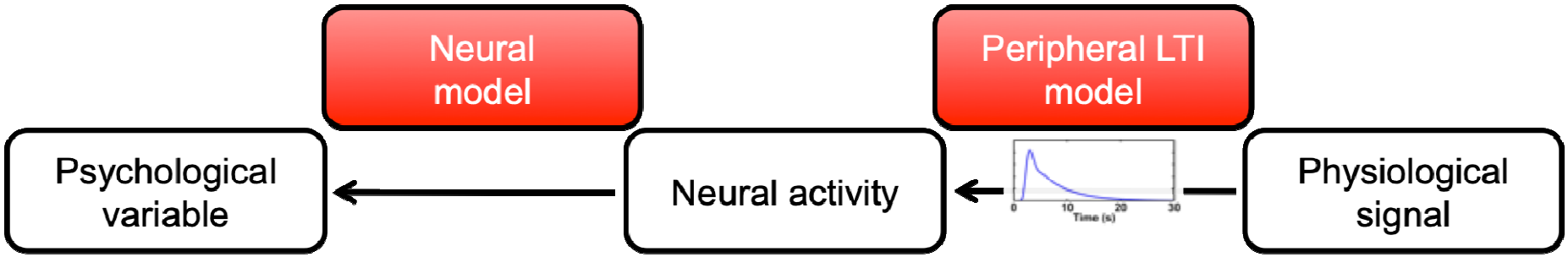
Comparison of grand means in time window



Regression of variables of interest onto time series



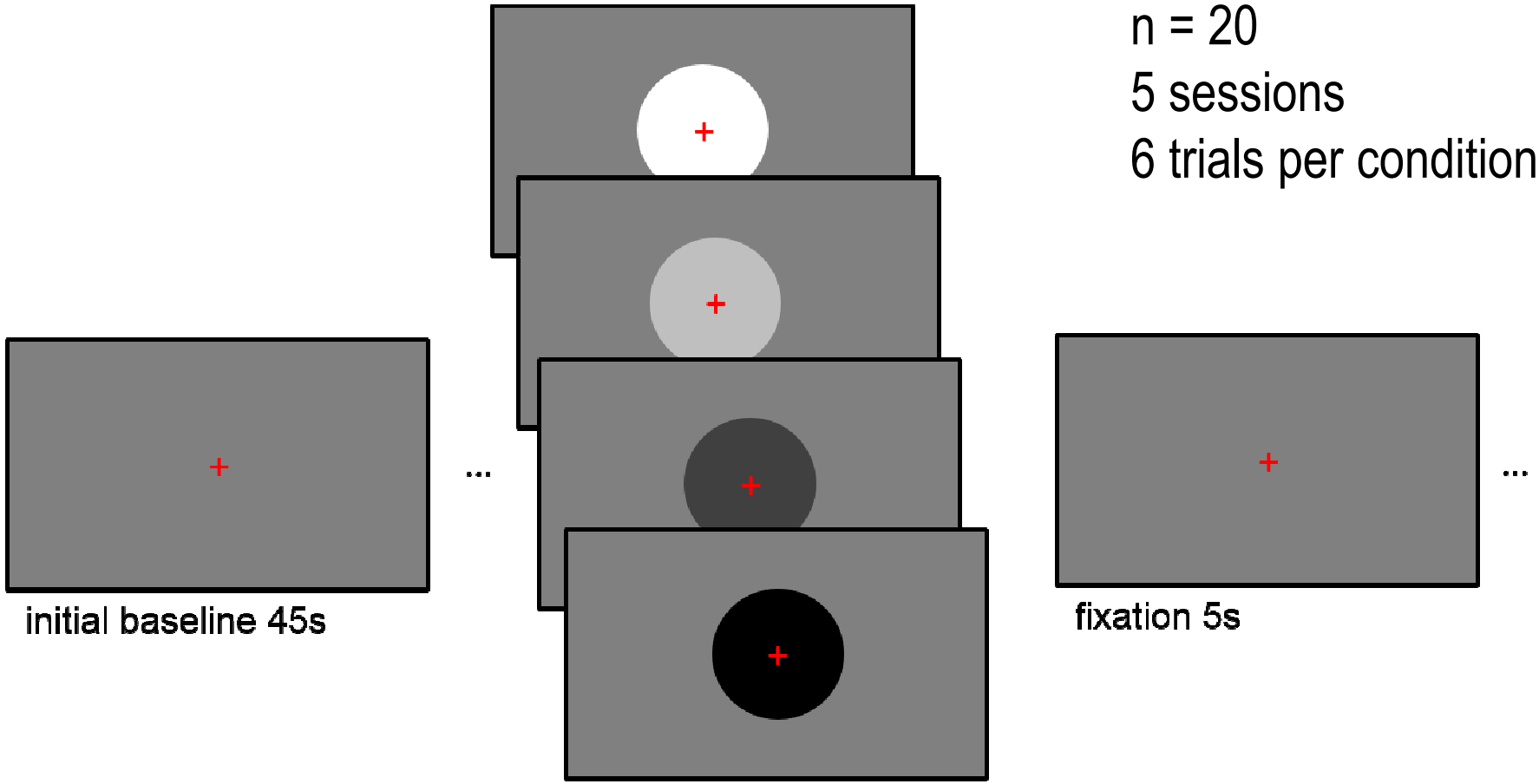
Model-based analyses



Model-based analyses

1. Illuminance
   - Steady-state model
   - Dynamics (LTI model)
2. Cognitive processes
   - Estimation of inputs
   - Condition differences (GLM)

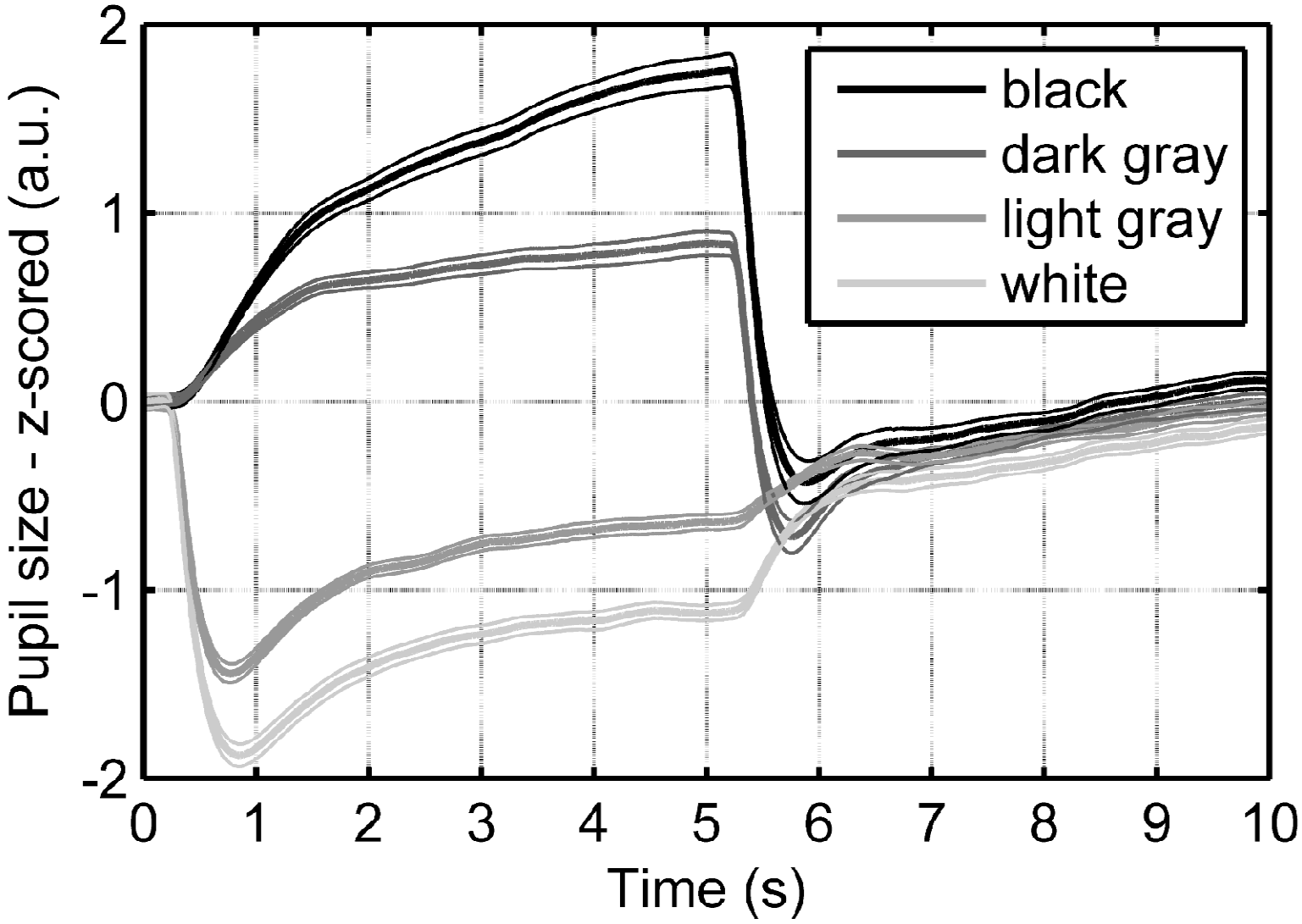
Illuminance task



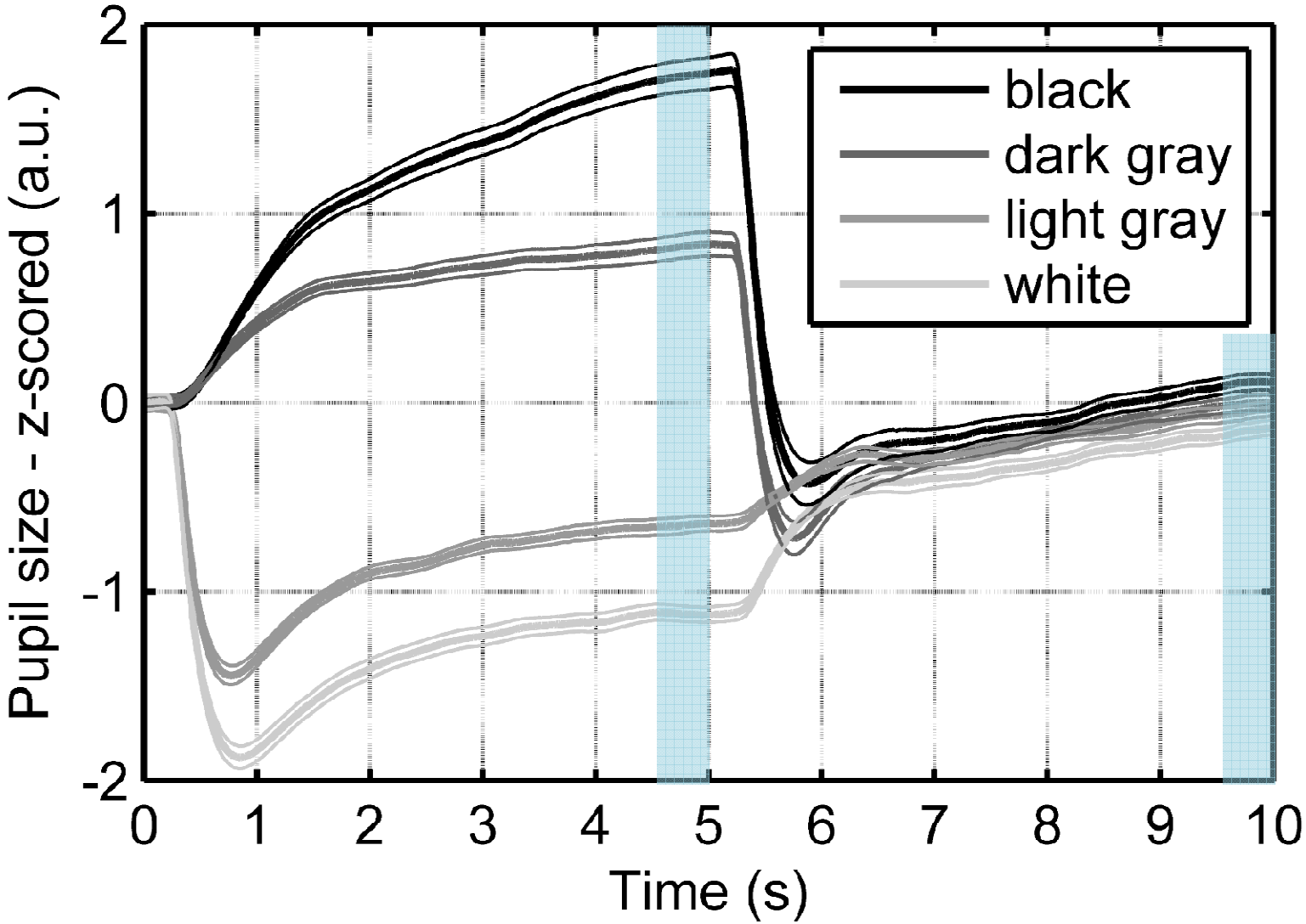
n = 20
5 sessions
6 trials per condition

Korn & Bach, 2016

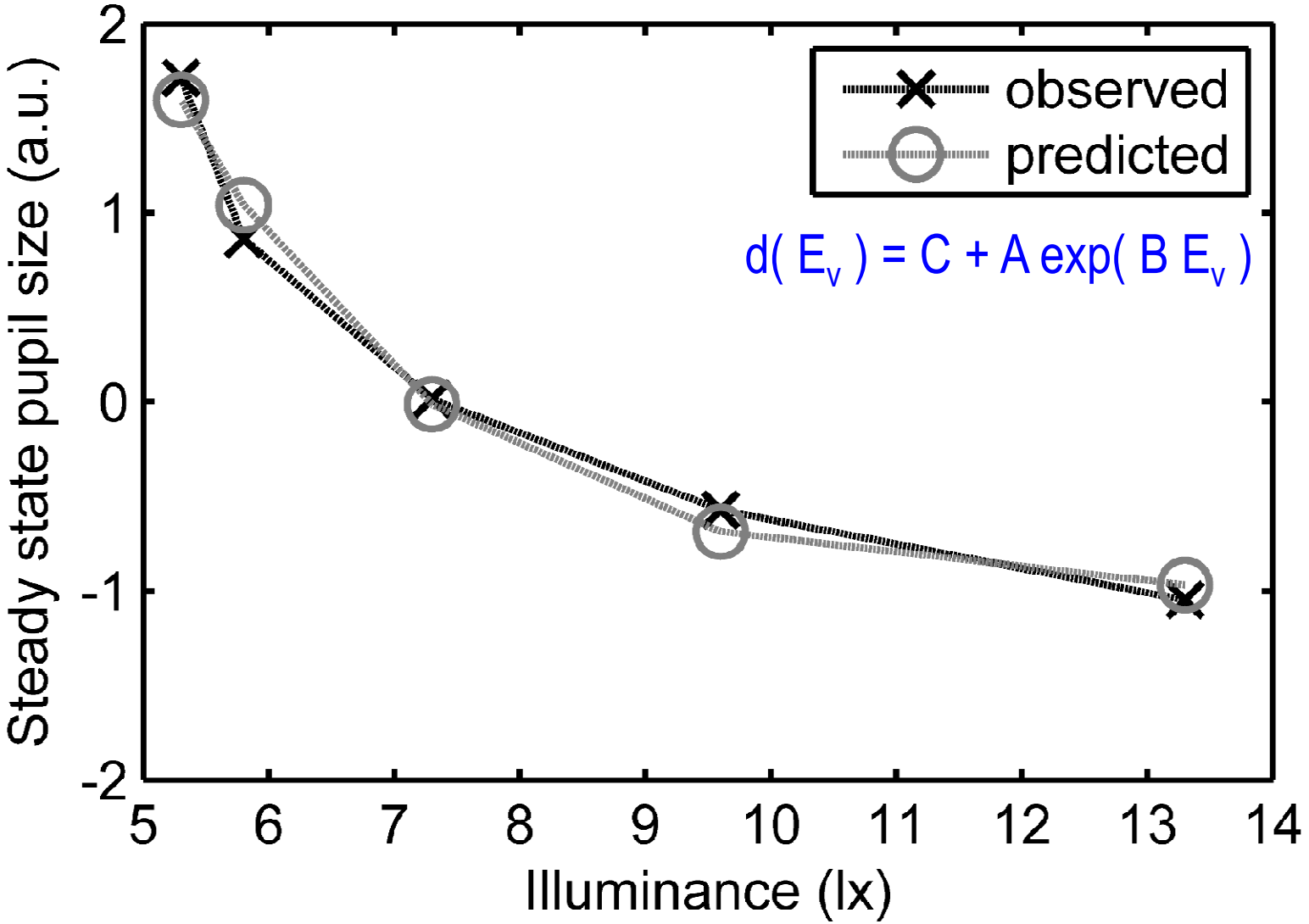
Illuminance task: Grand means



Illuminance steady-state pupil model



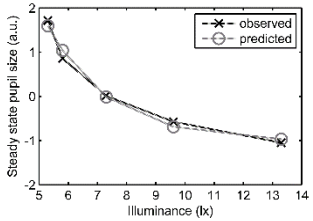
Illuminance steady-state pupil model



Model-based analyses

1. Illuminance

   – Steady-state model



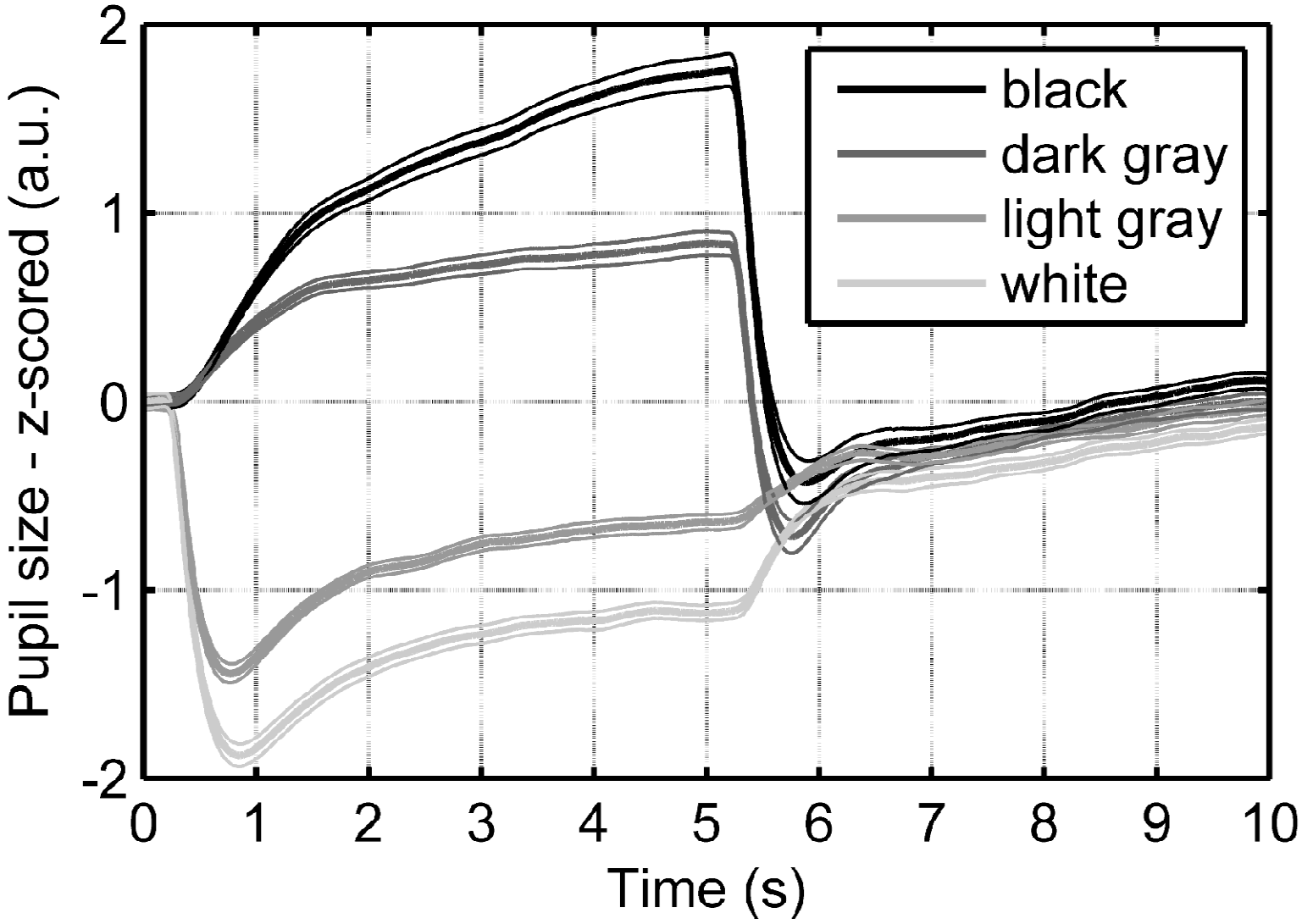
   – Dynamics (LTI model)

2. Cognitive processes

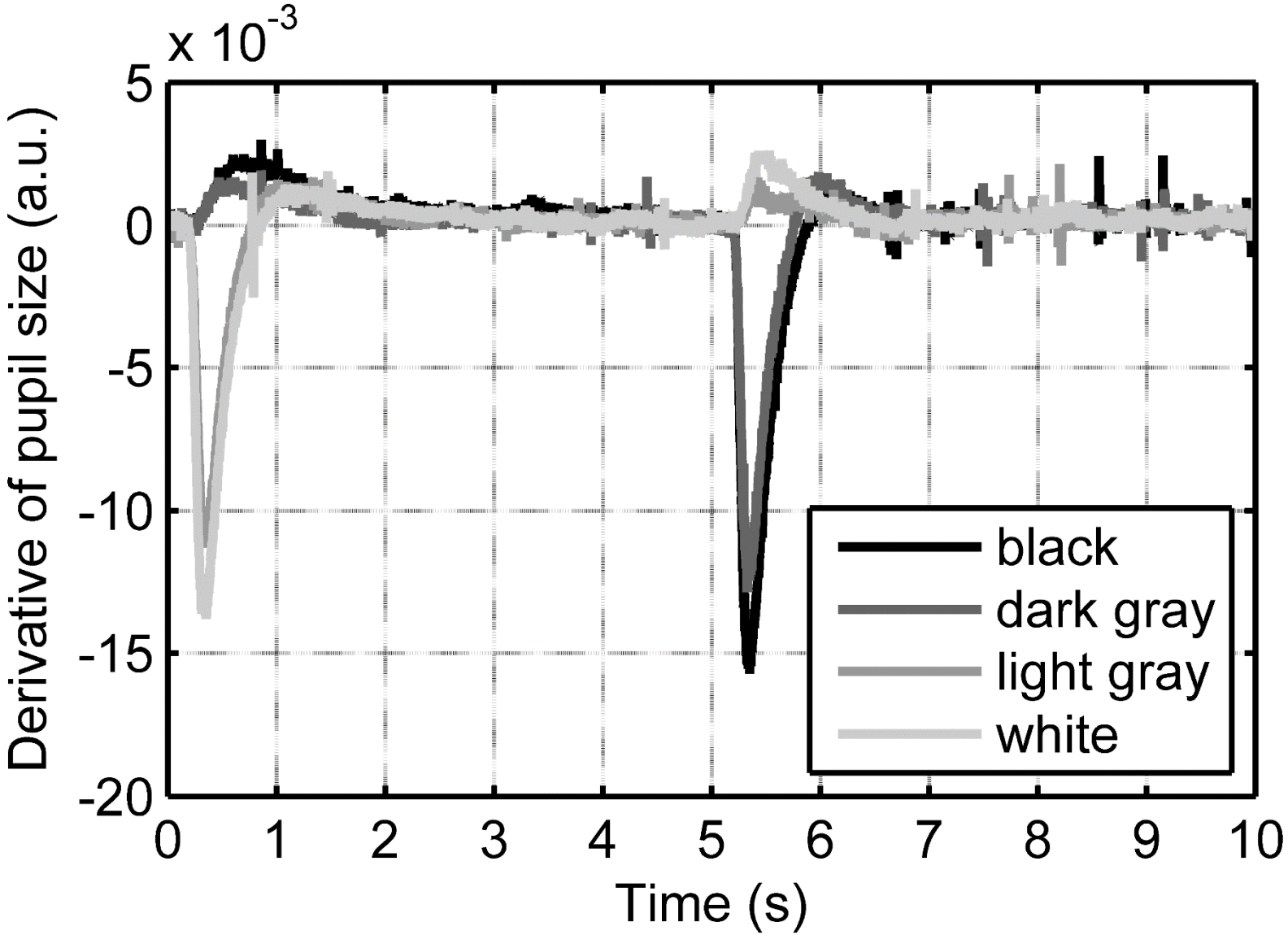
   – Estimation of inputs

   – Condition differences (GLM)

Illuminance task: Grand means

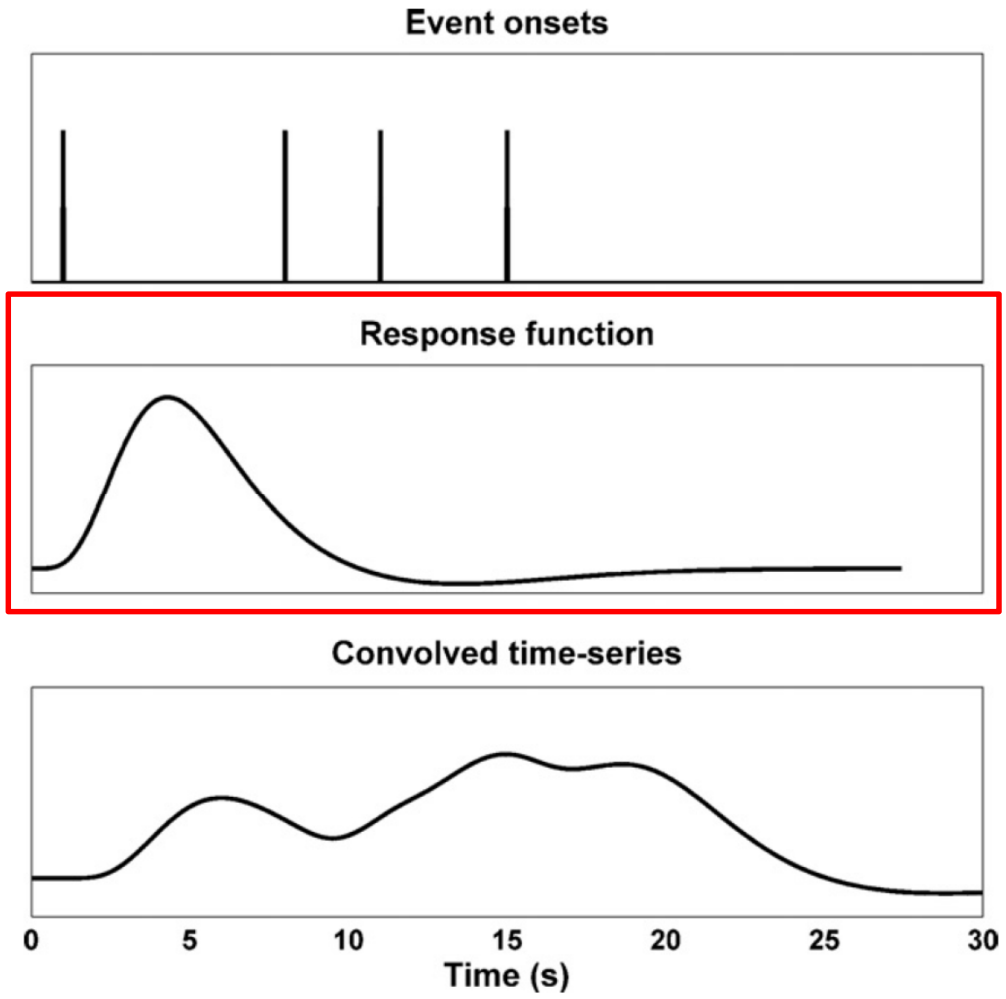


Illuminance task: Grand means – time derivatives



Reminder: LTI

- LTI linear time invariant system

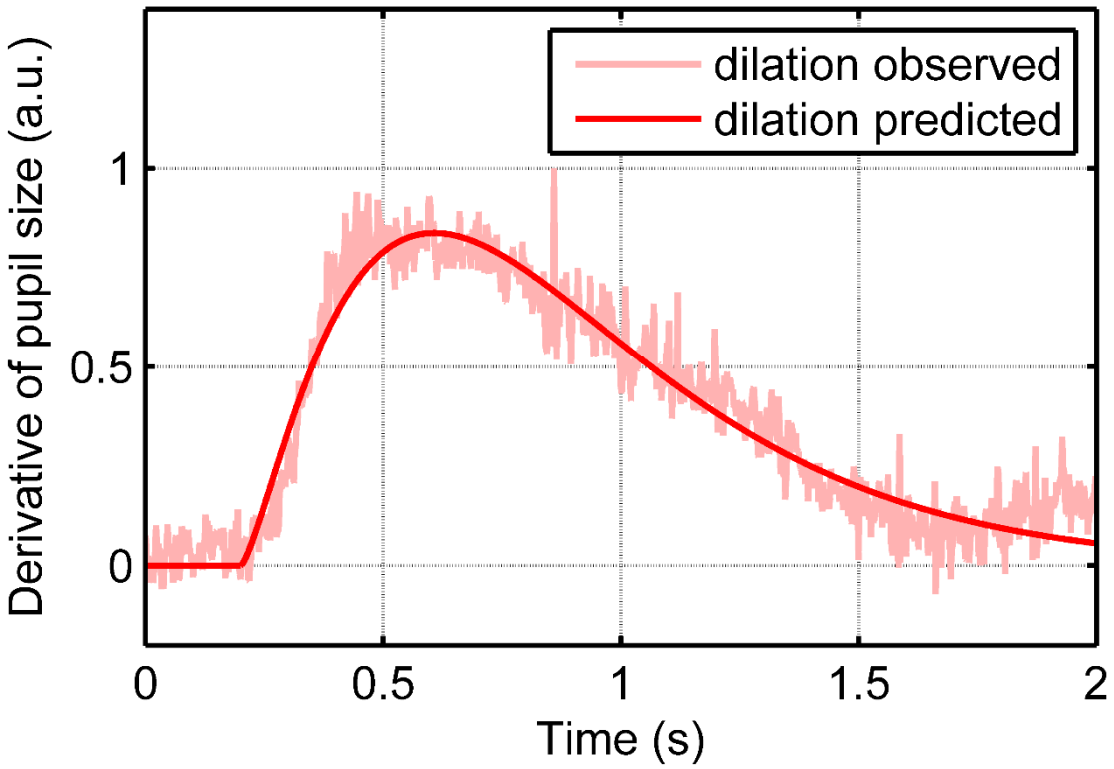


Bach et al., 2009

Illuminance dynamics: Response functions (1)

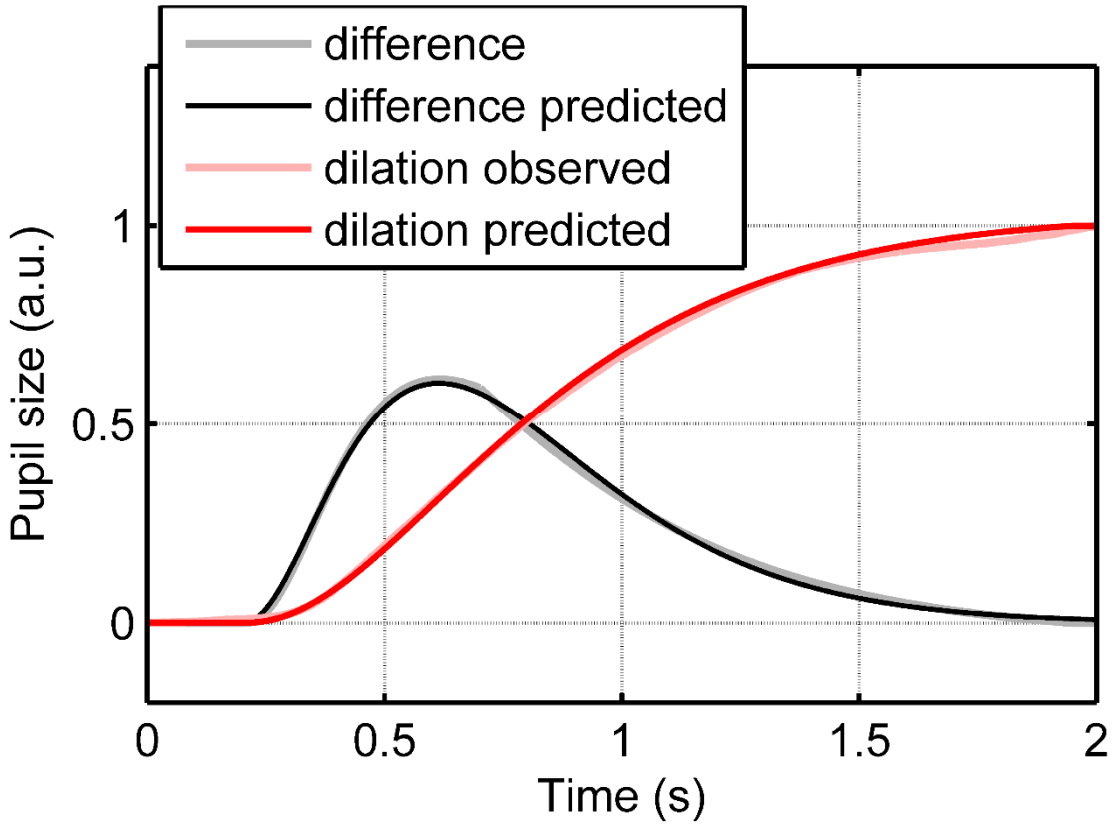
- Scaling of grand means using steady-state pupil model
- Time derivatives of dilation
- Approximation of derivative with gamma function

$$d(t) = c / (\theta^k \Gamma(k)) \, t^{k-1} \exp(-t / \theta)$$



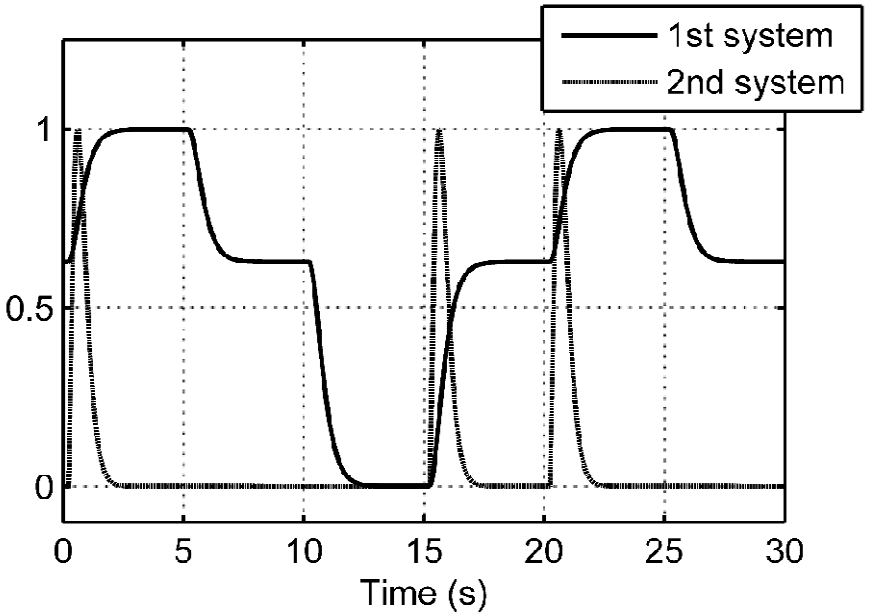
Illuminance dynamics: Response functions (2)

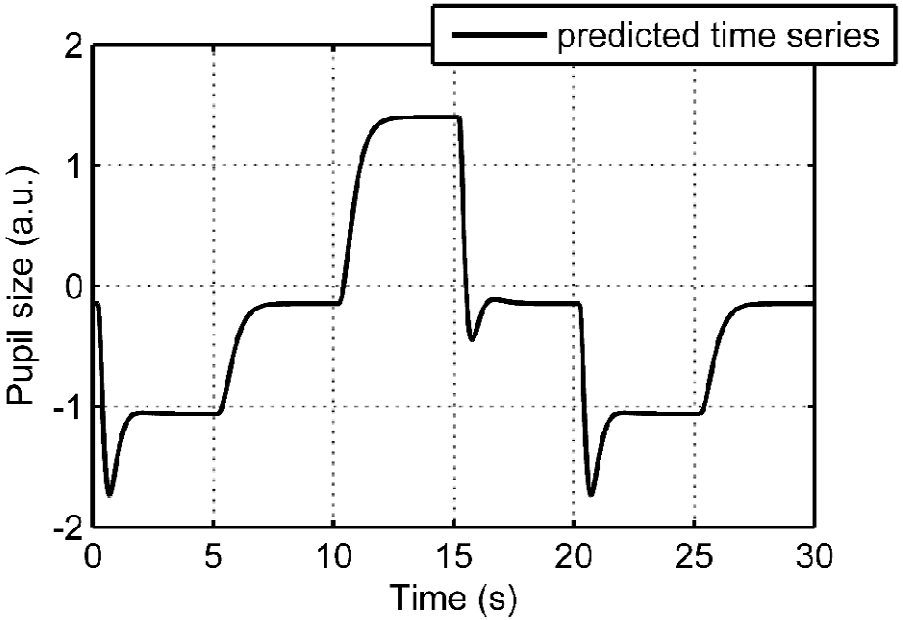
- Difference between predicted constriction and dilation
- Approximation with gamma function



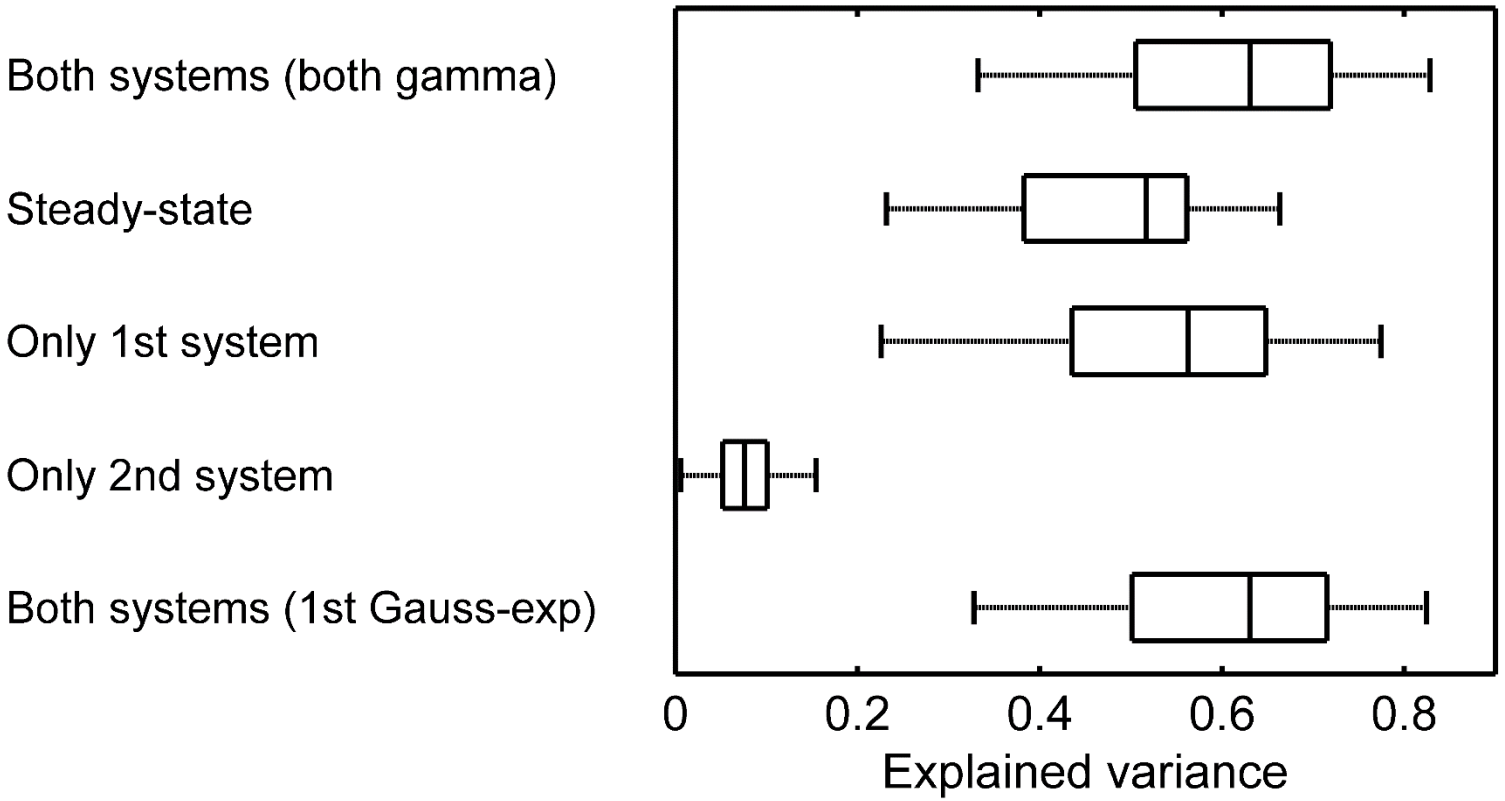
Illuminance dynamics: Illustration of LTI model

- 1st system: Dilation & constriction
- 2nd system: Constriction only





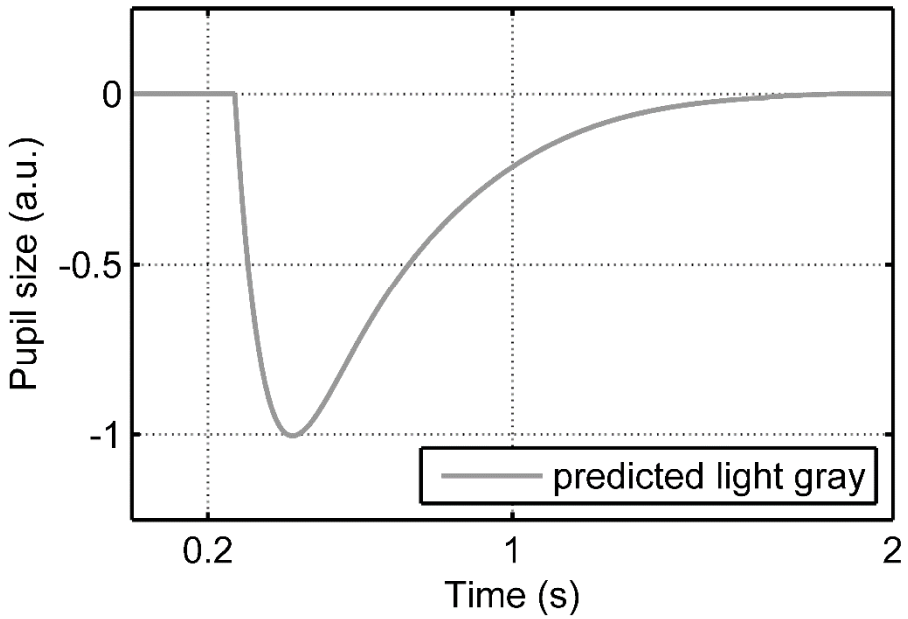
Illuminance dynamics: Model accuracy

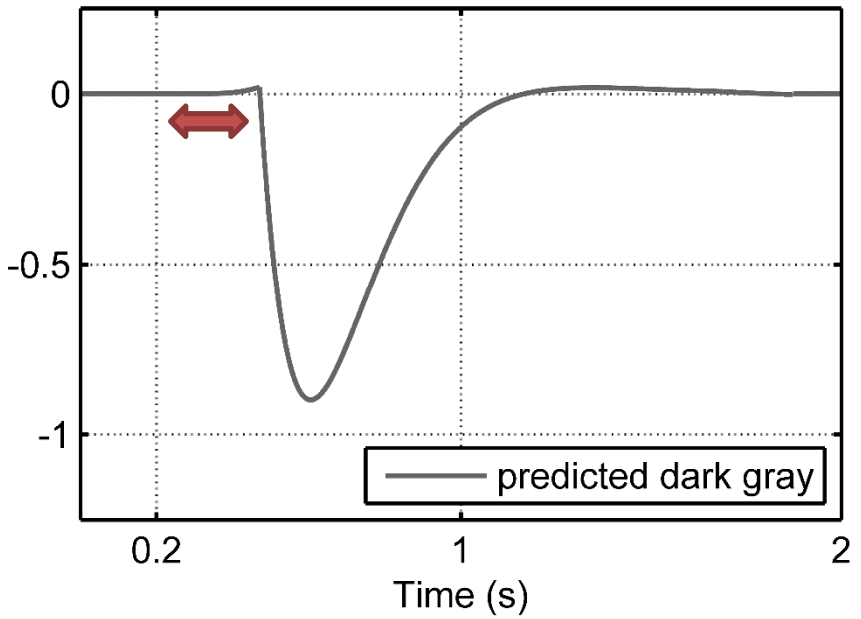


- Variance during 45 s baseline period: 0.41 ± 0.15

Illuminance dynamics: Model validation

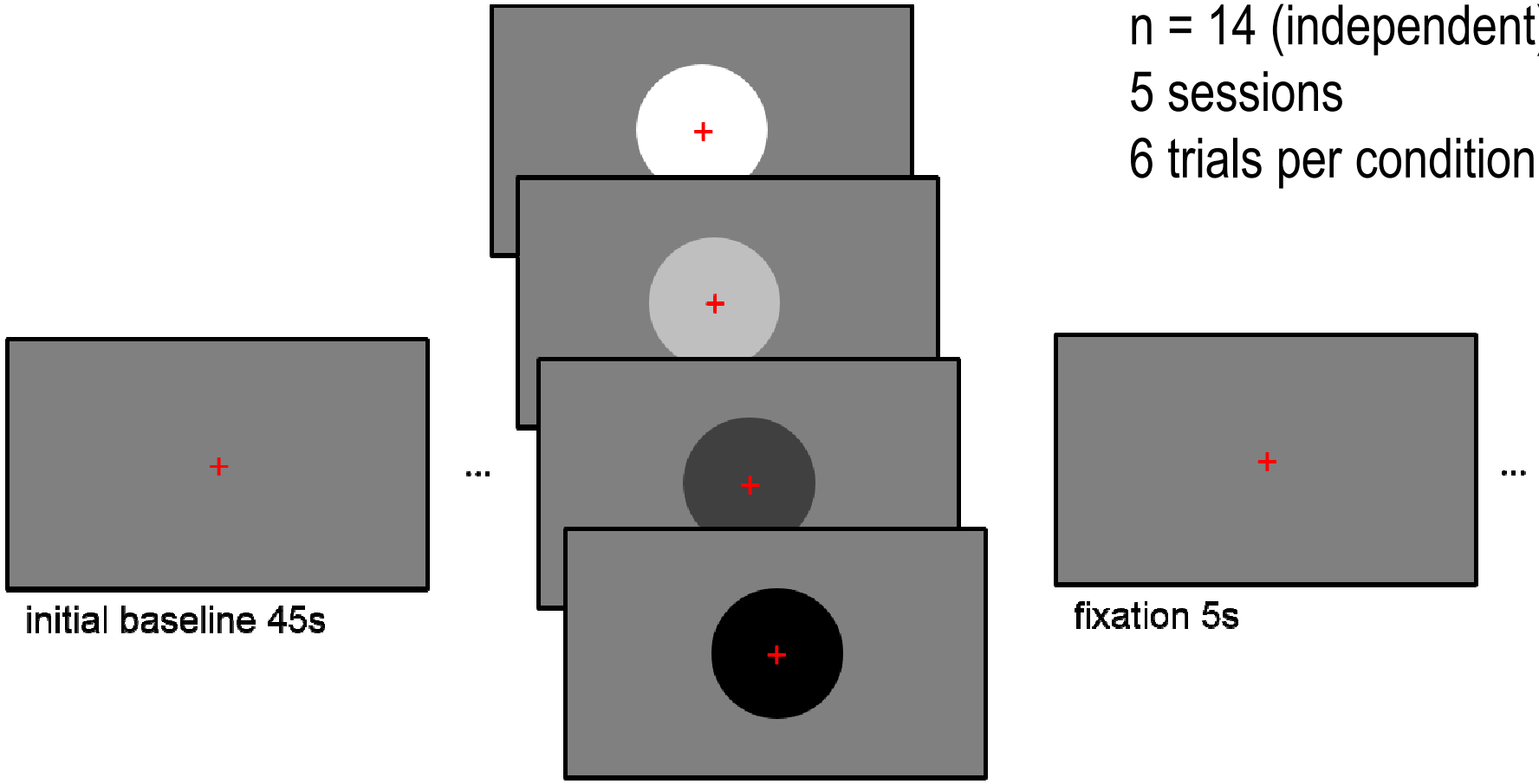
- Counter-intuitive prediction for brief illuminance inputs of **200 ms**





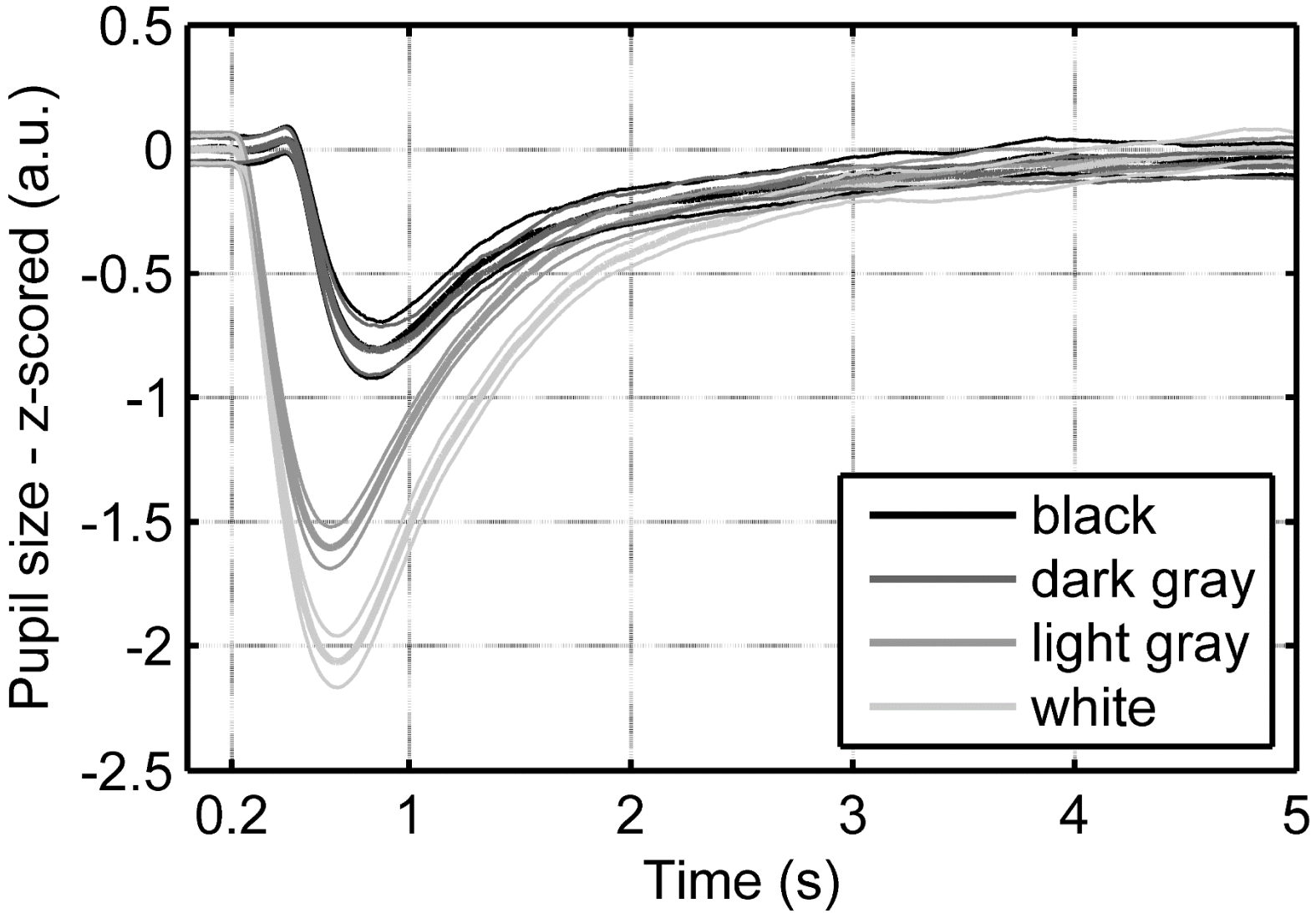
Barbur et al., 1992

Illuminance flashes task

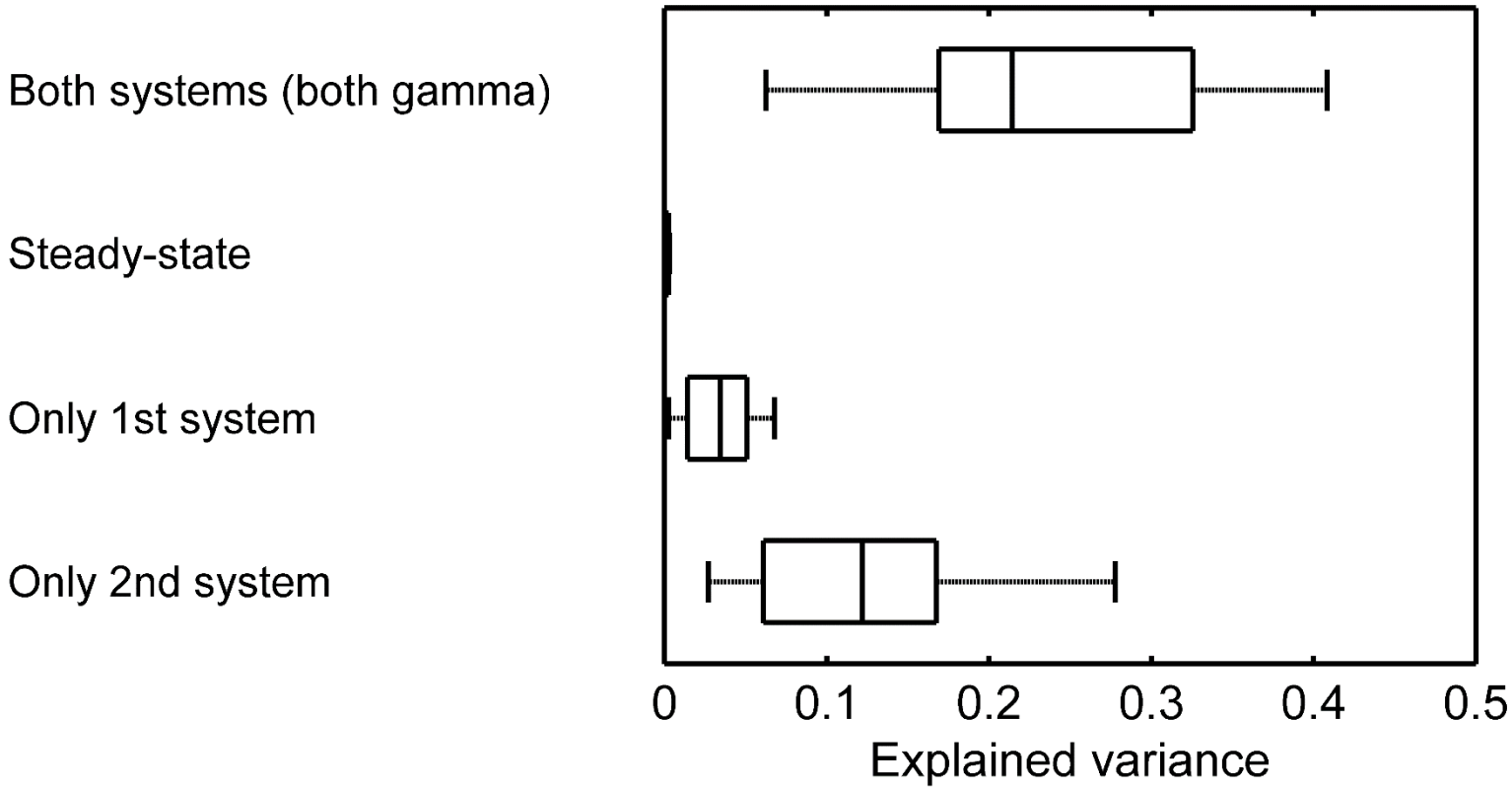


n = 14 (independent)
5 sessions
6 trials per condition

Illuminance flashes task: Grand means



Illuminance dynamics: Model accuracy for flashes

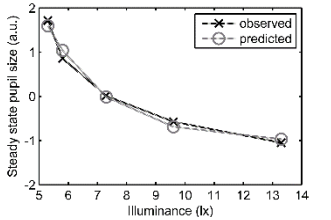


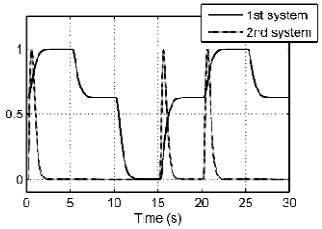
Model-based analyses

1. Illuminance

   – Steady-state model

   – Dynamics (LTI model)





2. Cognitive processes

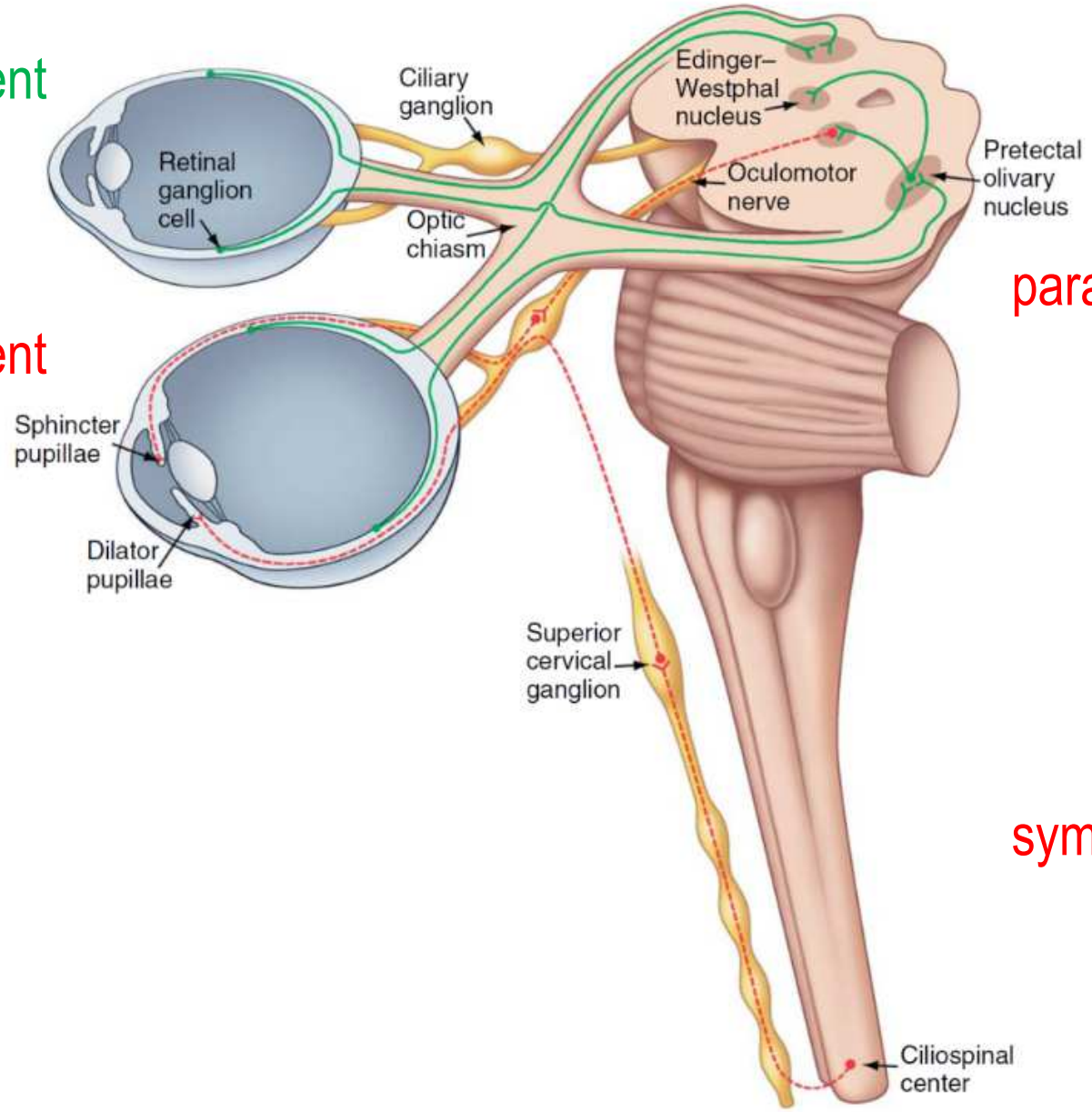
   – Estimation of inputs

   – Condition differences (GLM)

Reminder: Pupil physiology

afferent

efferent

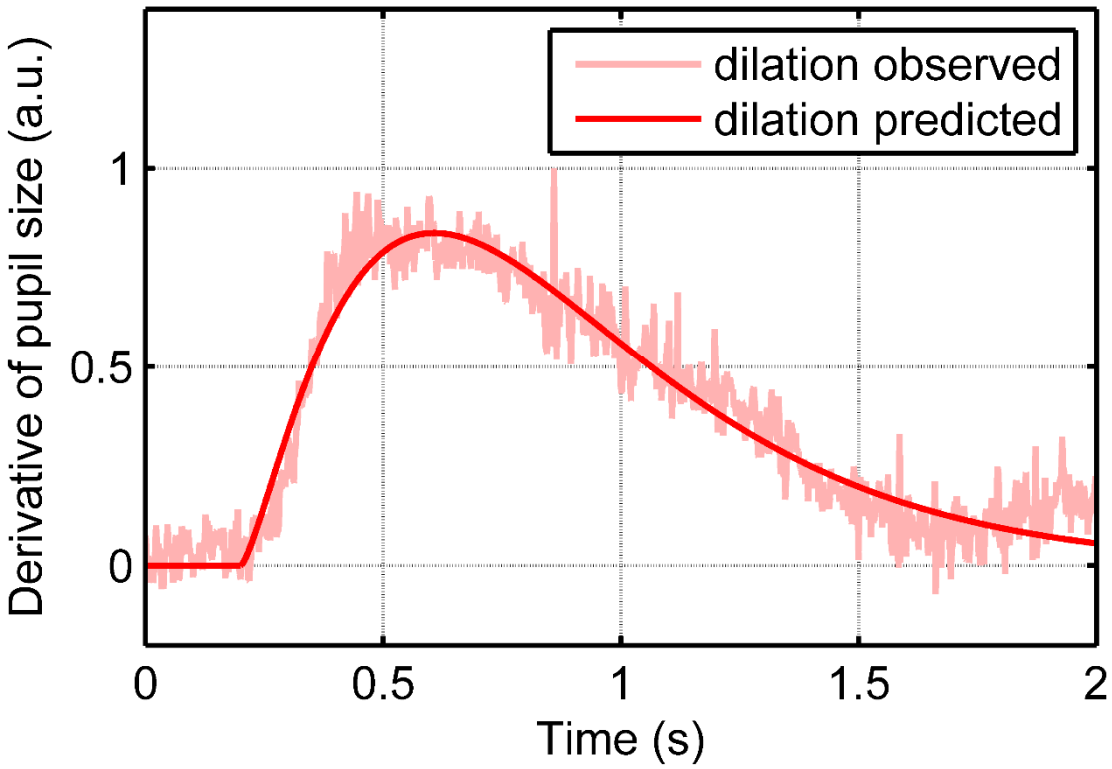


parasympathetic

sympathetic

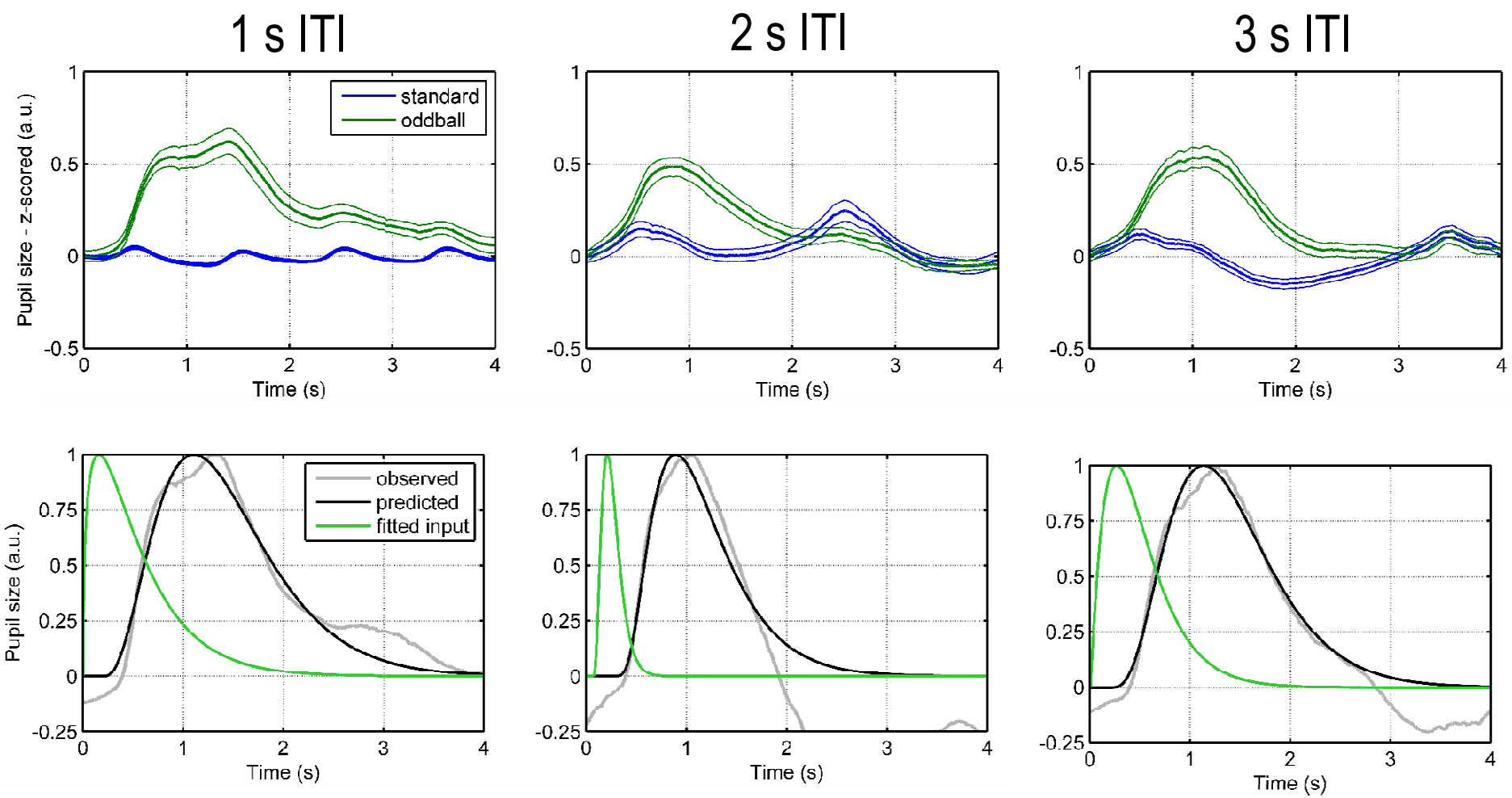
McDougal, 2008

Reminder: Response functions (1)



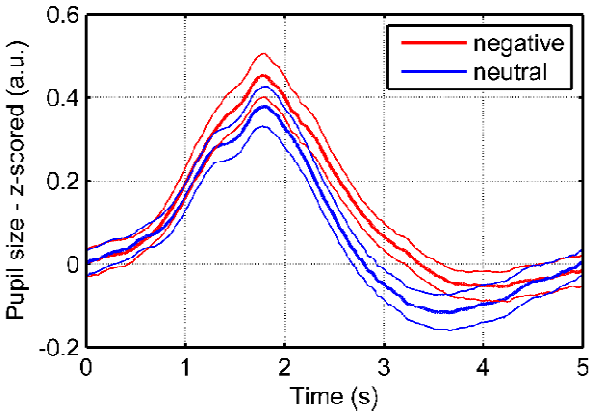
Estimation of inputs: Auditory oddball task

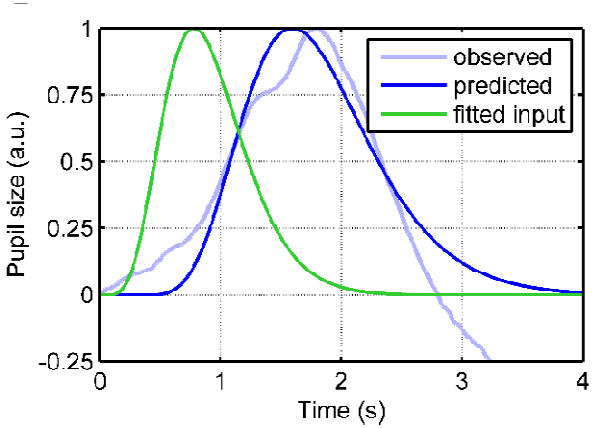
n = 69; 1 session

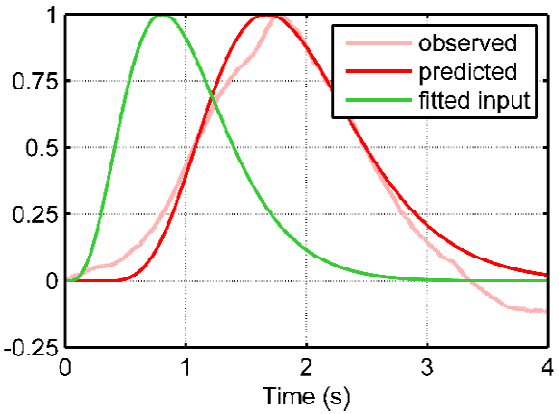


Estimation of inputs: Emotional words task

n = 27; 2 sessions





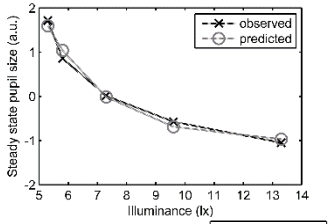


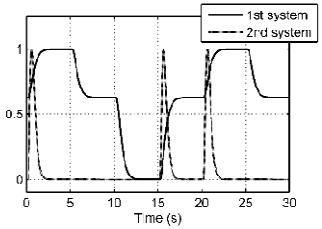
Model-based analyses

1. Illuminance

   – Steady-state model

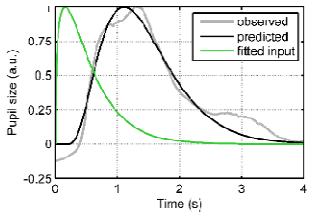
   – Dynamics (LTI model)





2. Cognitive processes

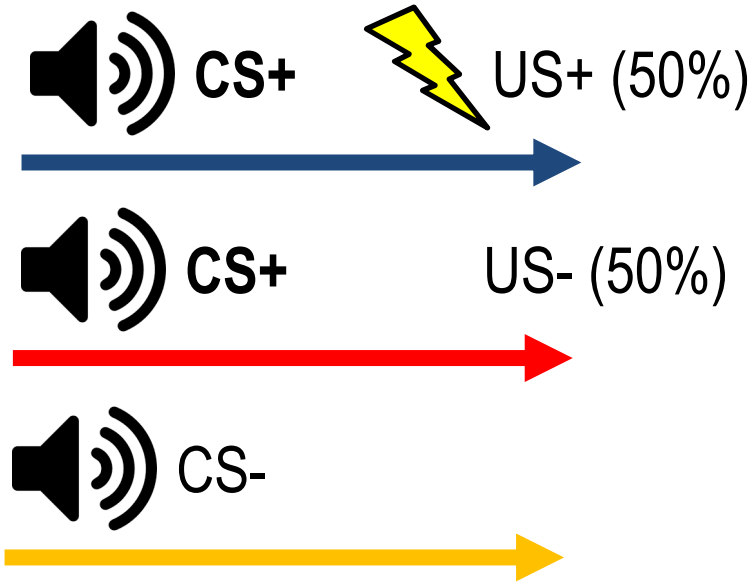
   – Estimation of inputs

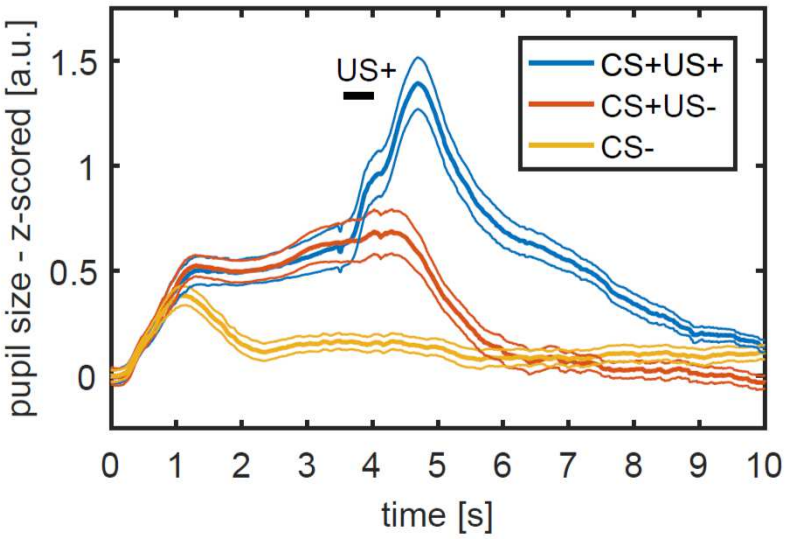


   – Condition differences (GLM)

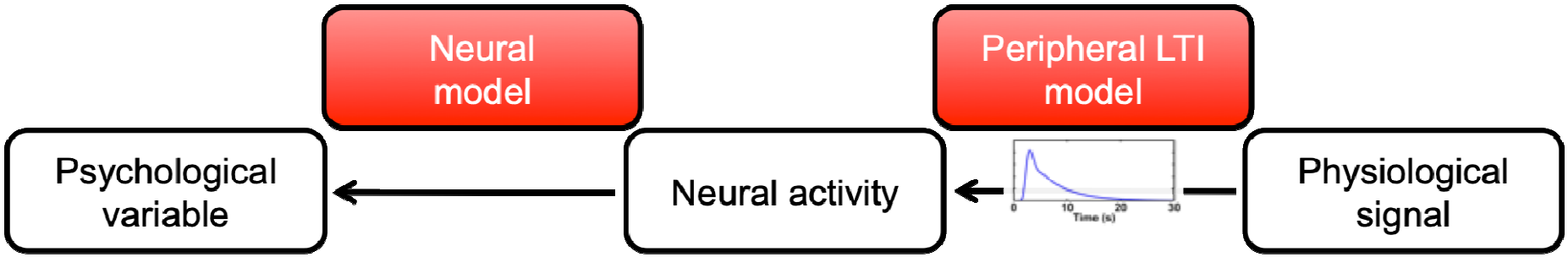
Condition differences: Fear conditioning

Auditory CS



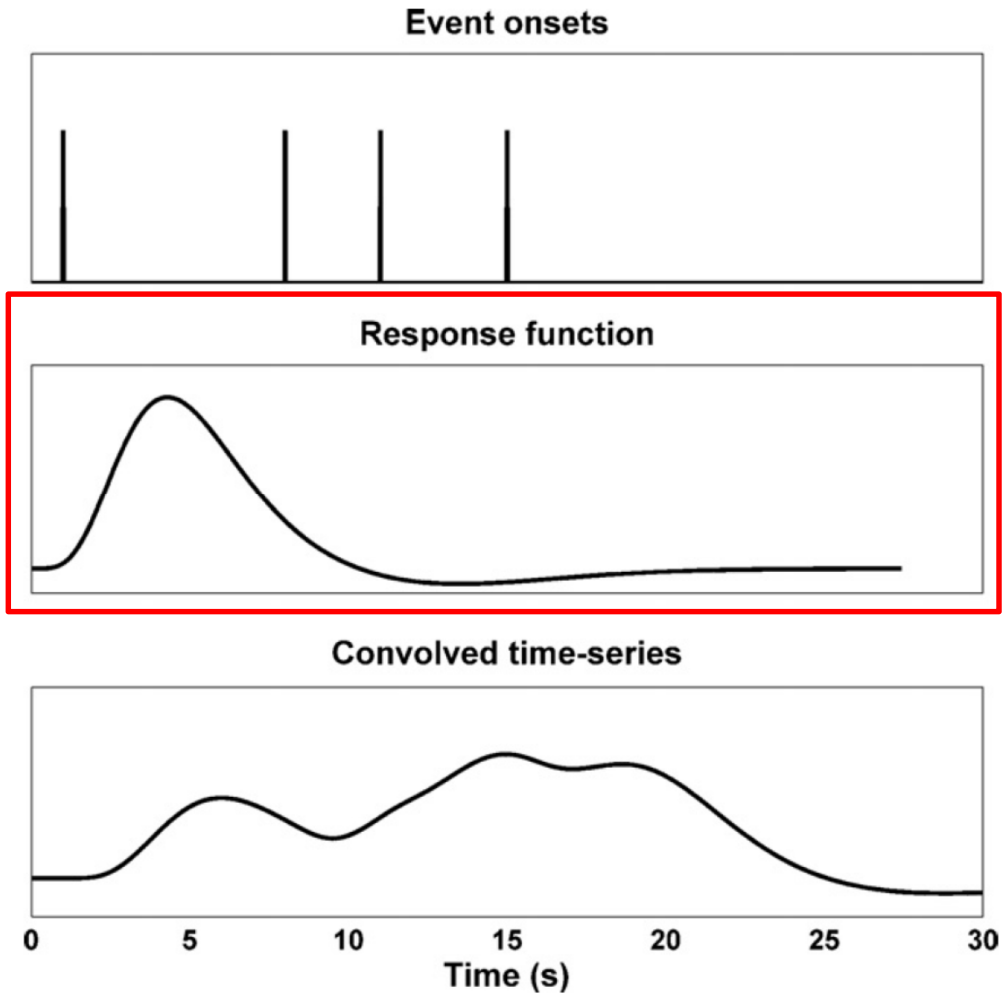


Model-based analyses



Reminder: LTI

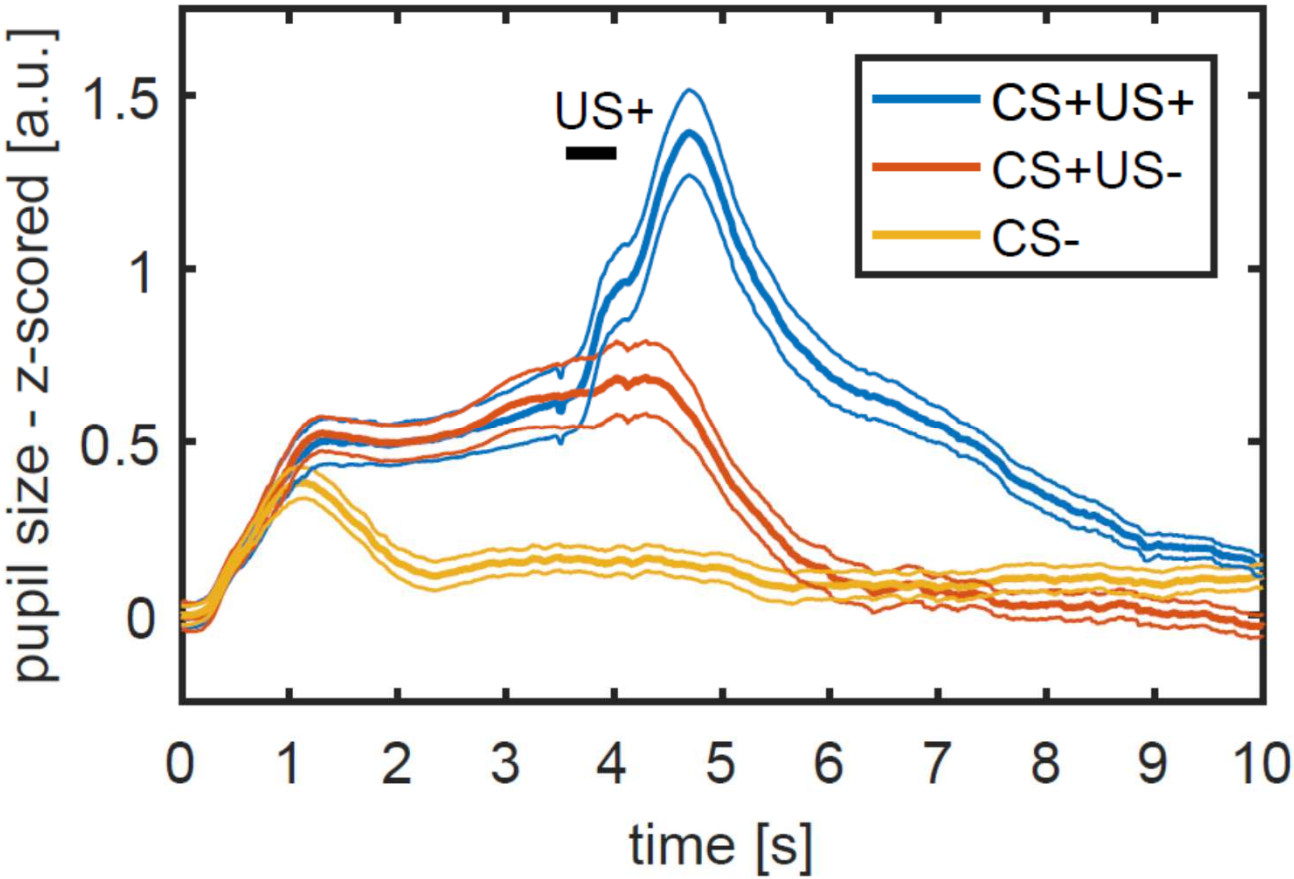
- LTI linear time invariant system



Bach et al., 2009

Condition differences: Fear conditioning

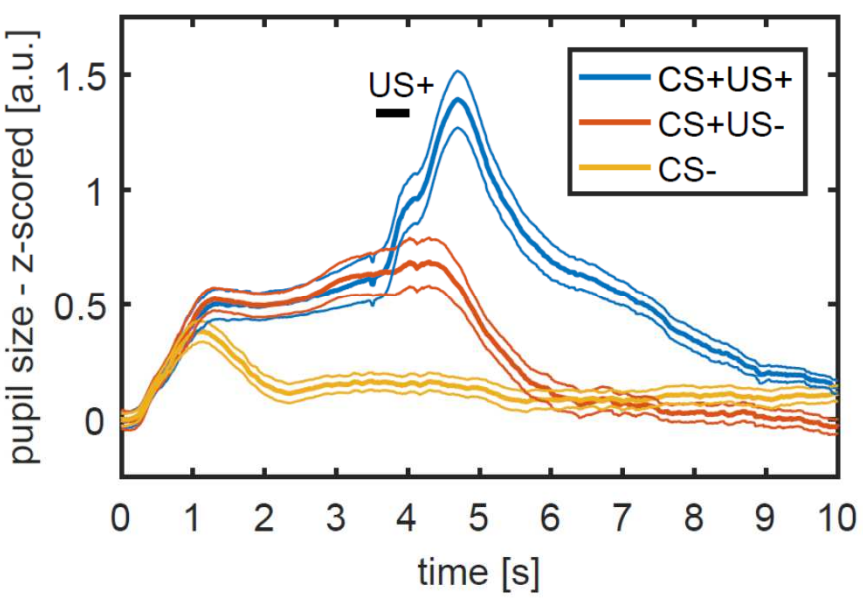
Auditory CS; n = 19

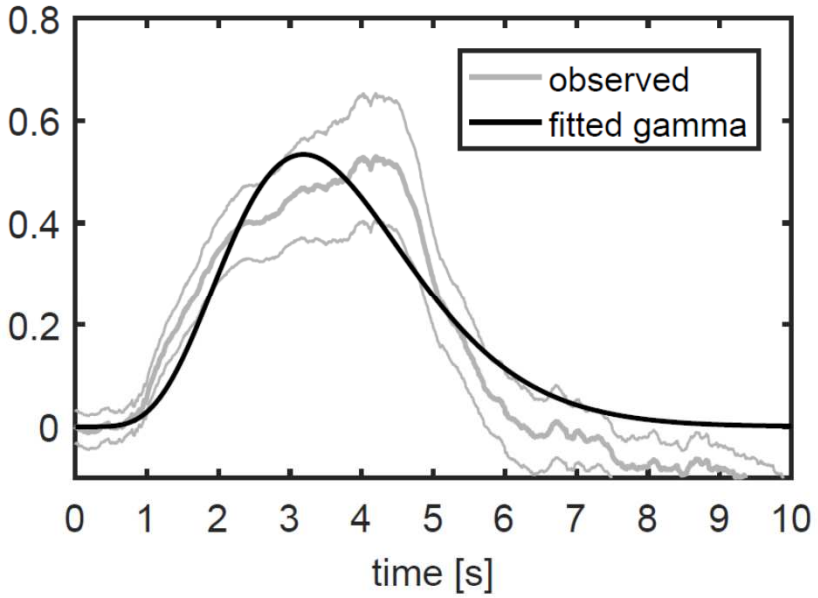


Korn et al, 2016

Condition differences: Fear conditioning

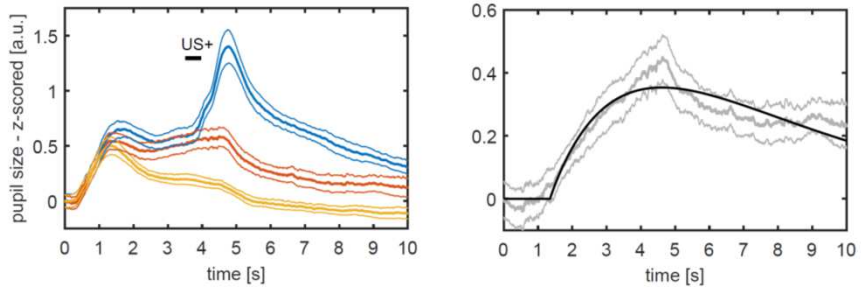
Auditory CS; n = 19



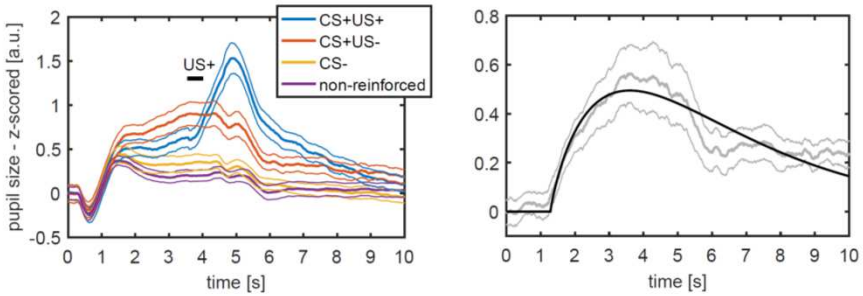


Korn et al, 2016

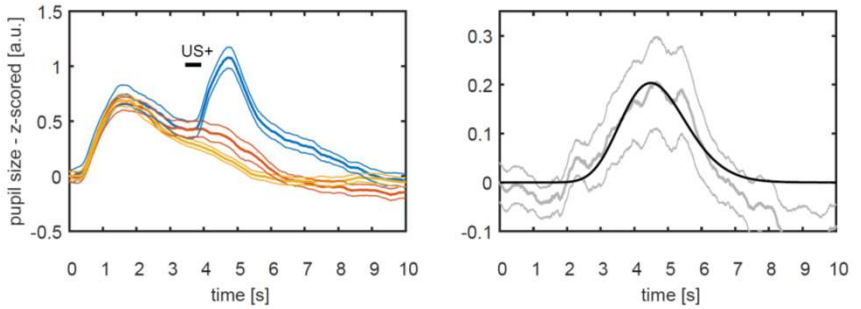
Condition differences: Fear conditioning



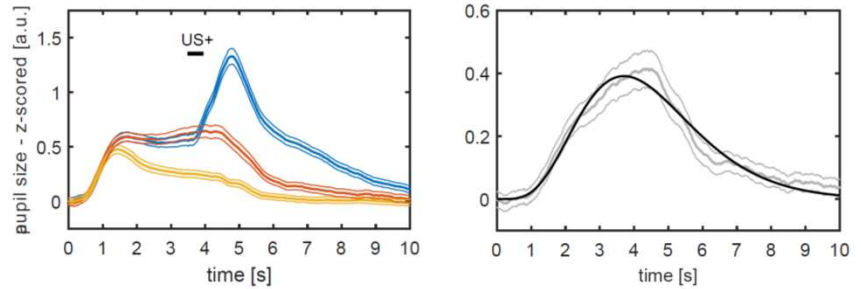
Auditory CS, n = 12



Visual CS, n = 17



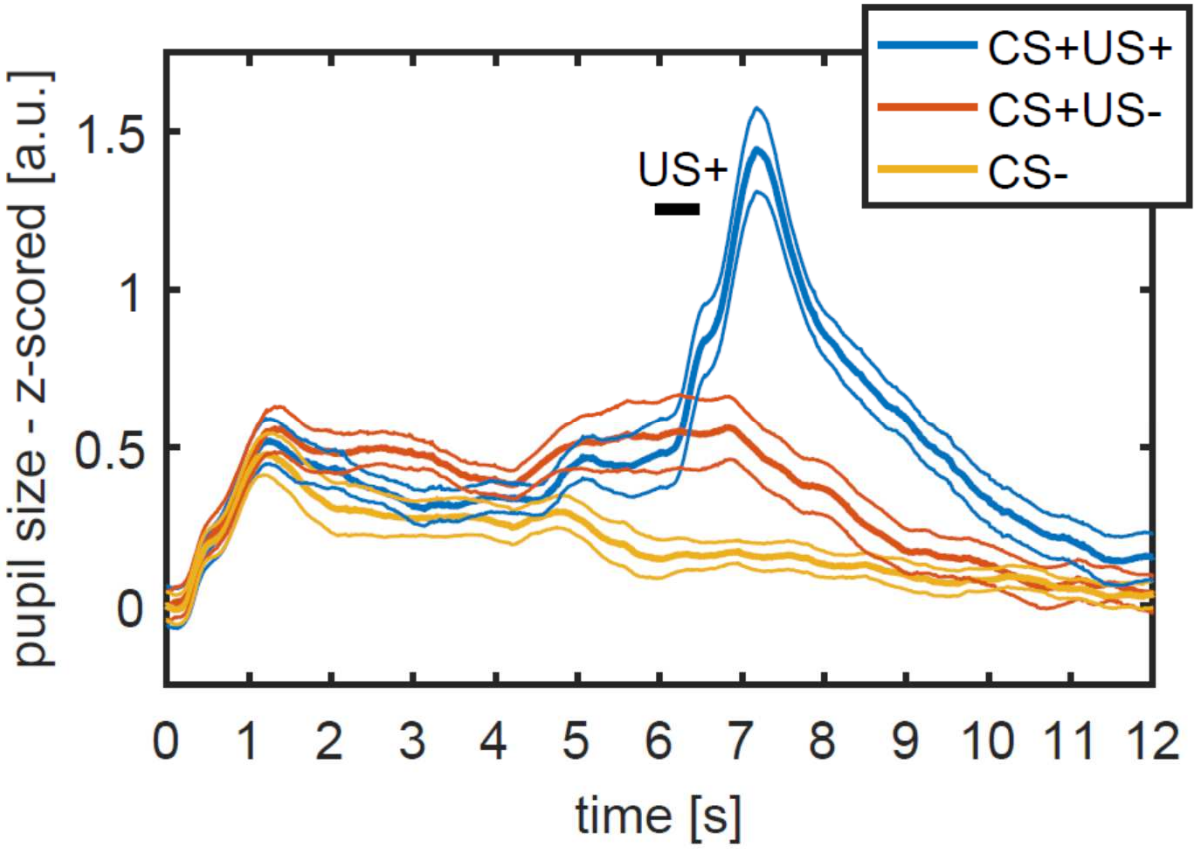
Somatosensory CS, n = 18



All combined

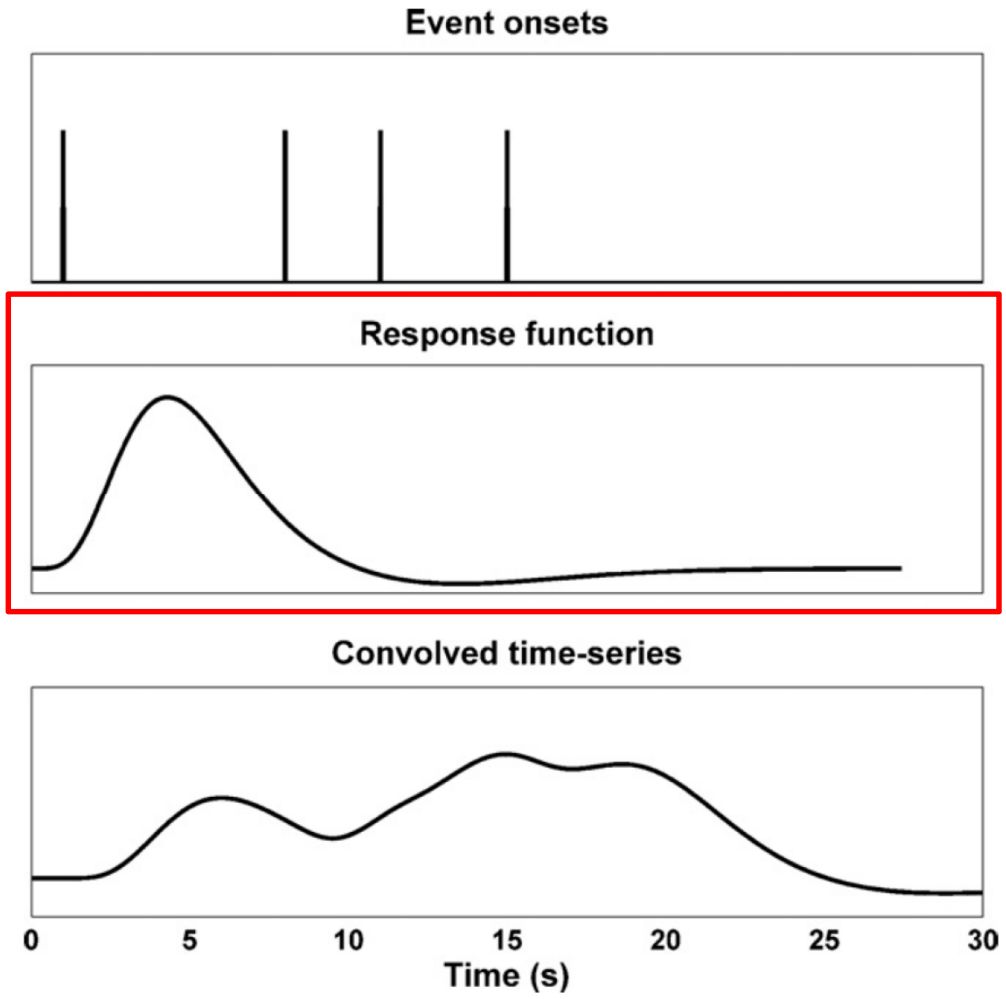
Condition differences: Fear conditioning

Long Auditory CS, n = 15



Reminder: LTI

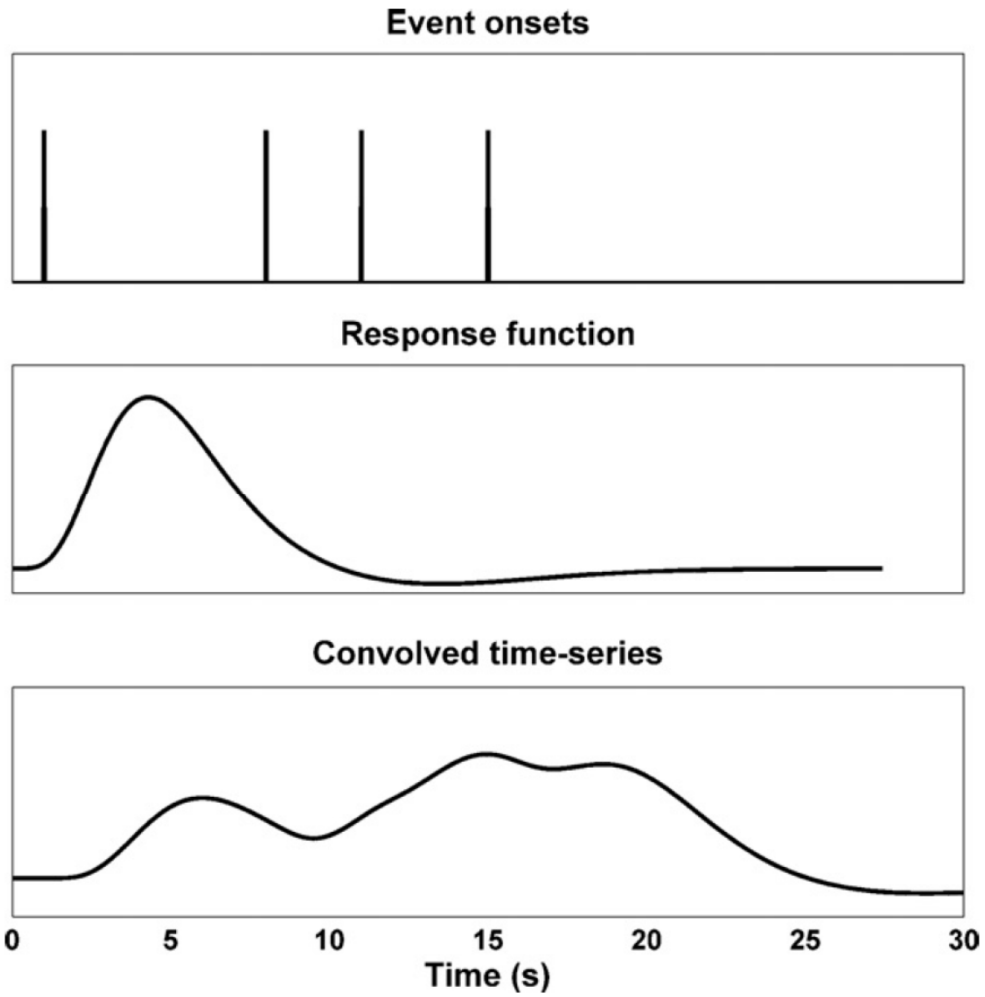
- LTI linear time invariant system

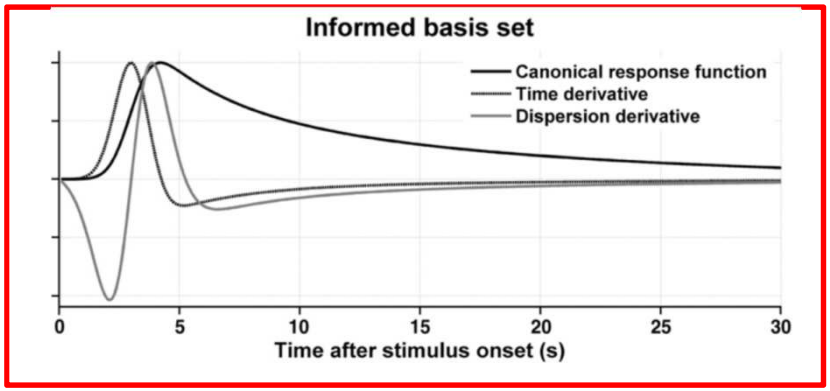


Bach et al., 2009

Response function with derivatives

- LTI linear time invariant system

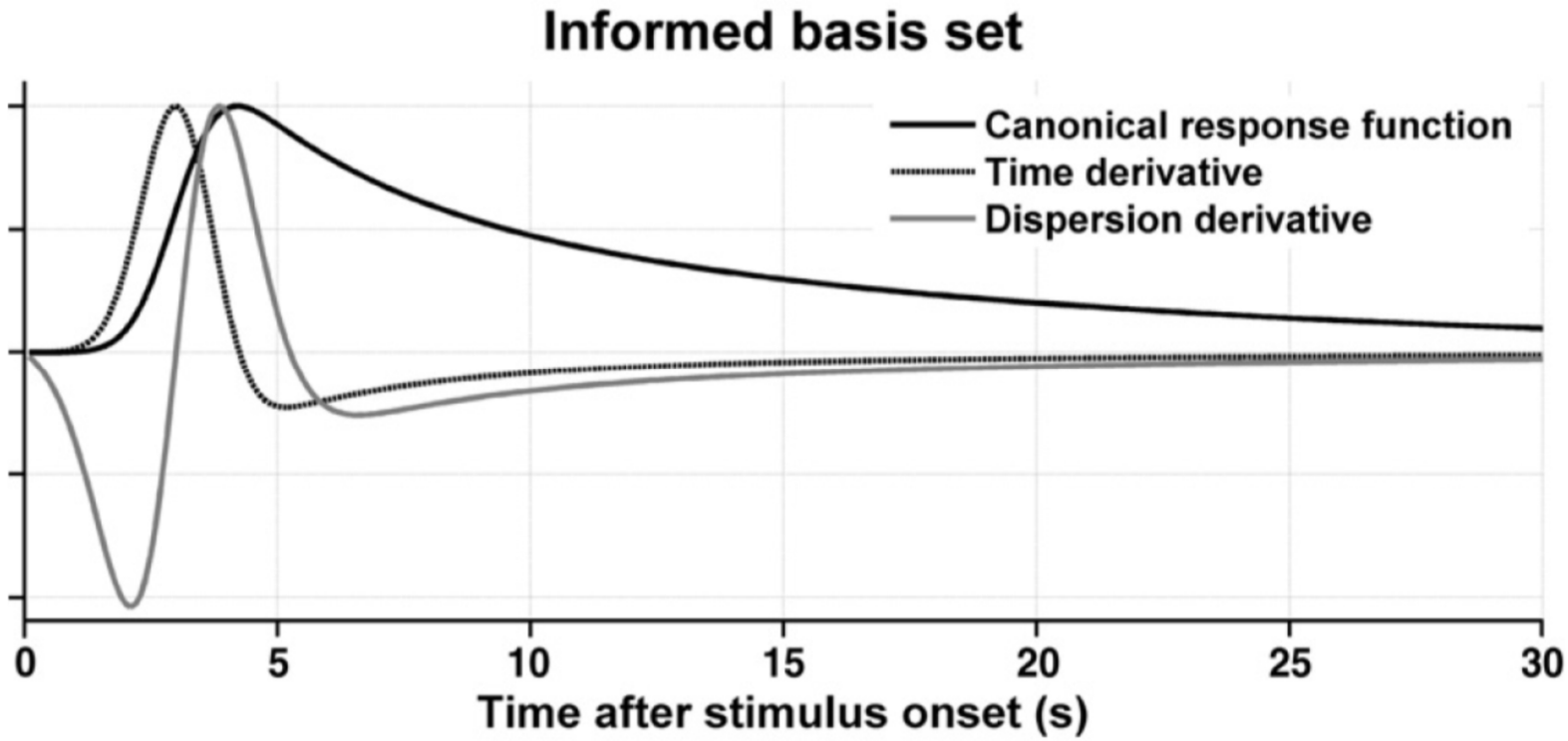




Bach et al., 2009

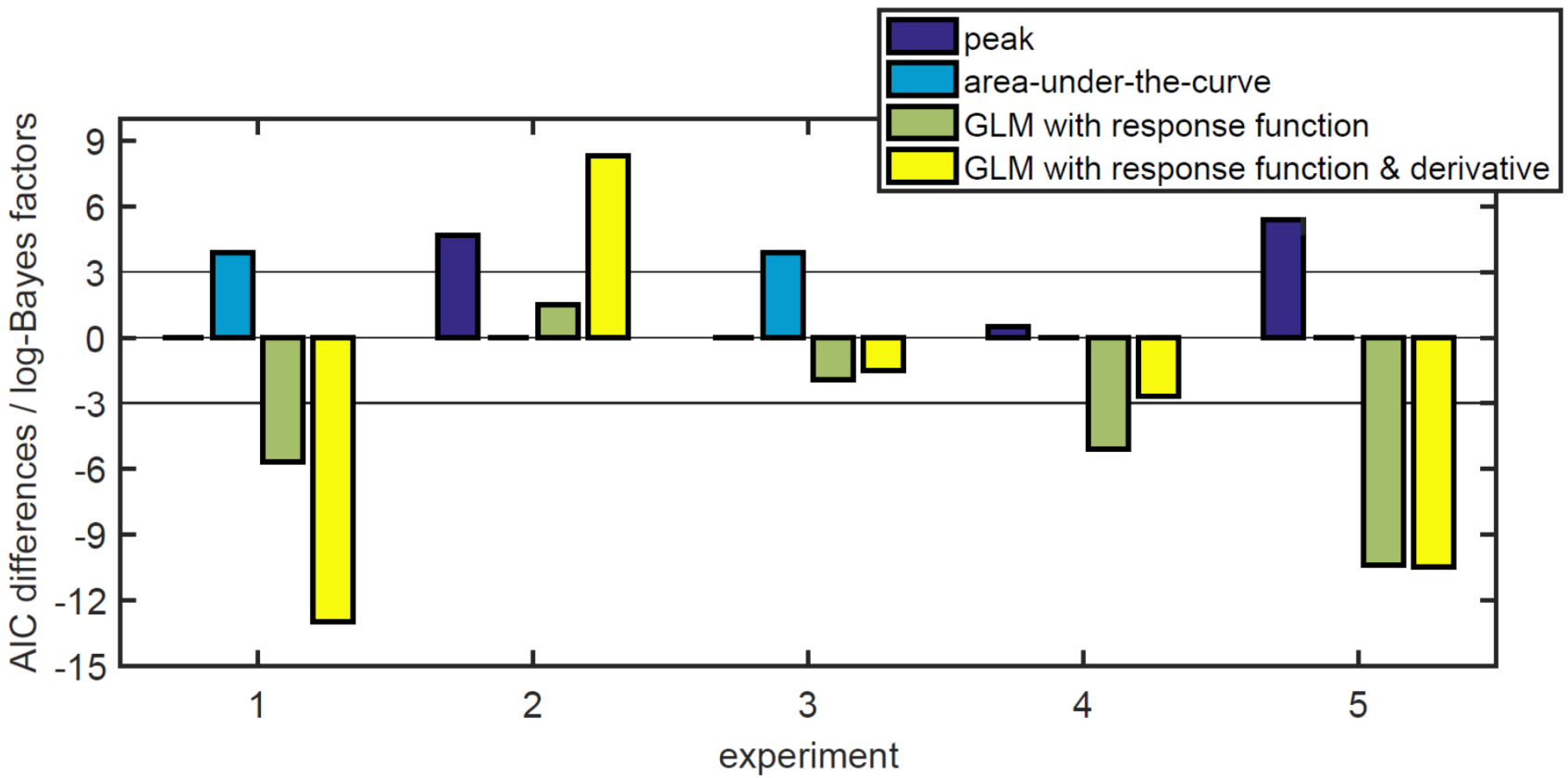
Response function with derivatives

- LTI linear time invariant system

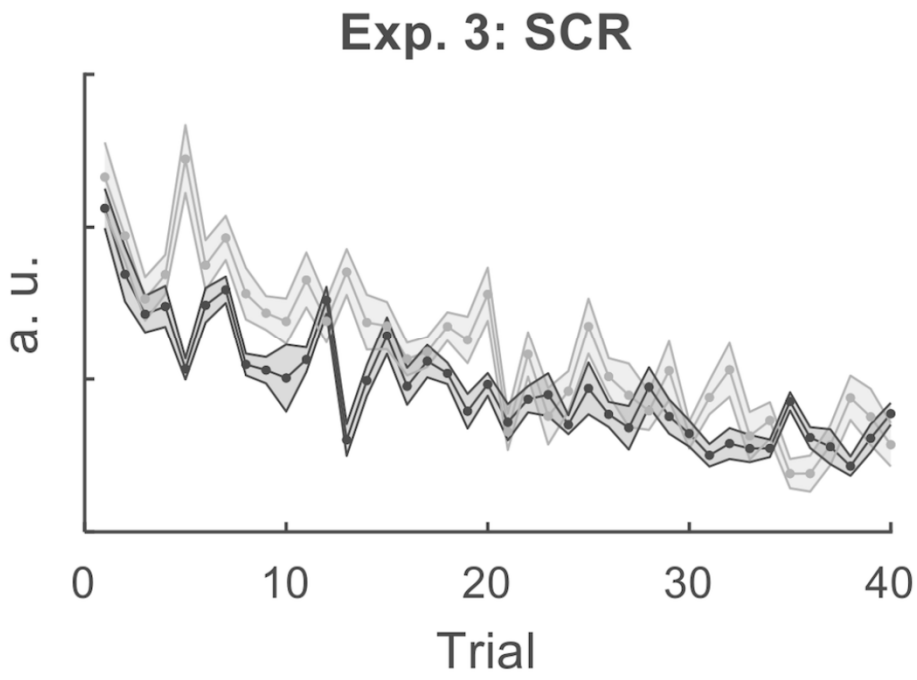


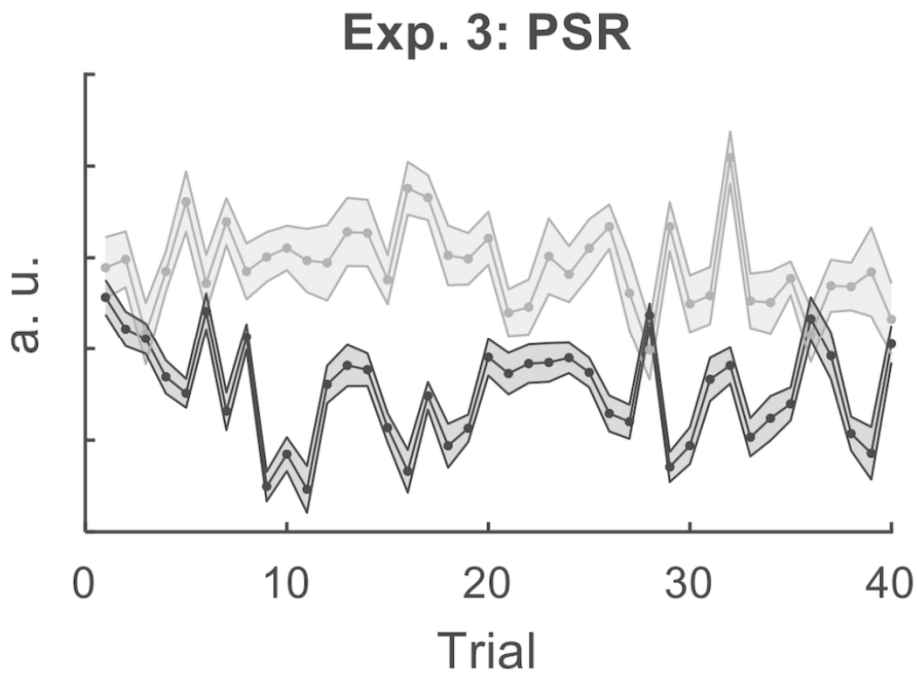
Bach et al., 2009

Condition differences: Model comparison



Condition differences: Fear conditioning & learning models

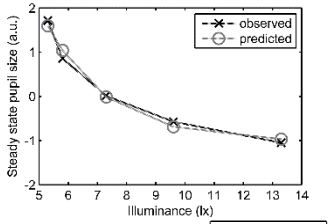


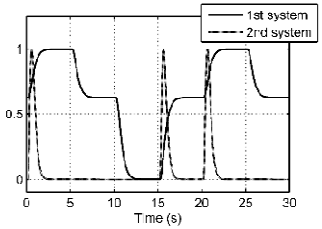


Tzovara, Korn, Bach., 2018

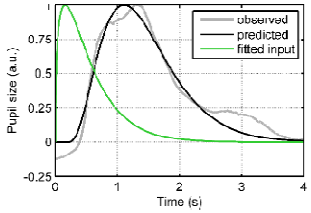
Model-based analyses

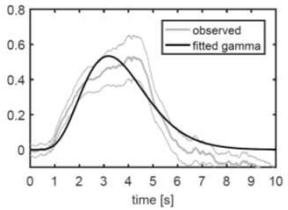
1. Illuminance
   - Steady-state model
   - Dynamics (LTI model)





2. Cognitive processes
   - Estimation of inputs
   - Condition differences (GLM)



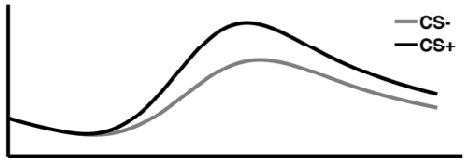


Course overview

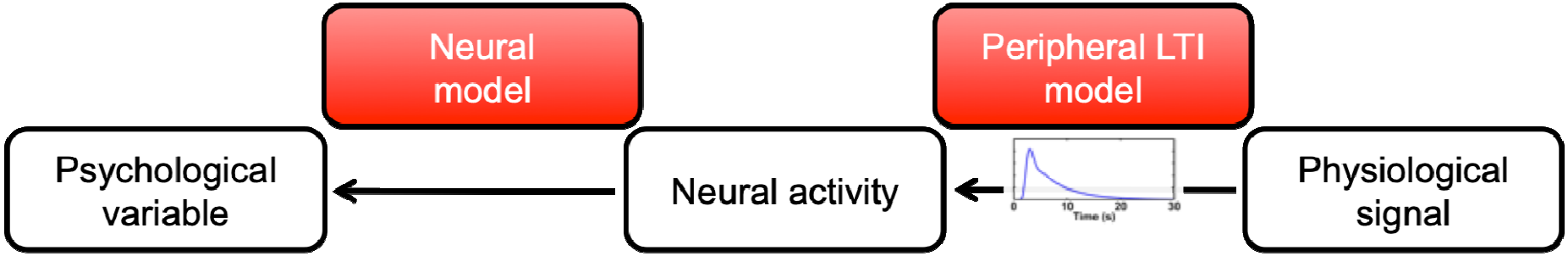
Memory difference between CS+/CS-?

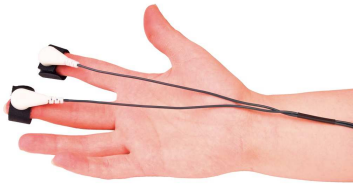
Lecture 7: 14.05.2020

The "best possible" approximation to the true psychological variable.

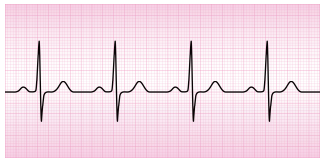


Lecture 2: 09.04.2020

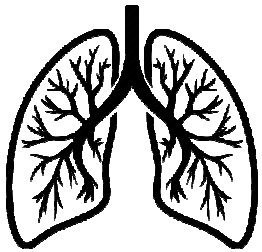




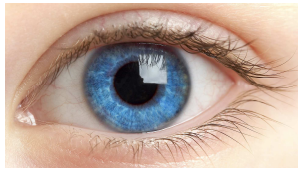
Lecture 3: 16.04.2020



Lecture 5: 30.04.2020



Lecture 6: 07.05.2020



Lecture 4: 23.04.2020

Lecture 6: 0 7.05.2020

Thanks to Dominik Bach

Funders

FNSNF
Swiss National Science Foundation

erc

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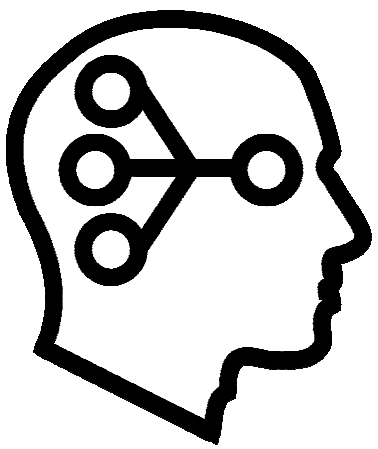
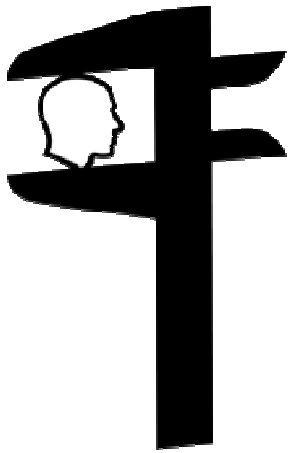




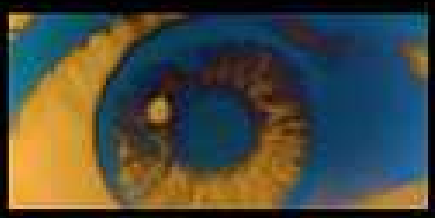
Thanks to

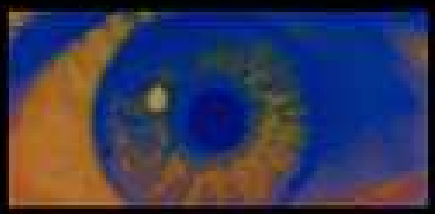
European Meeting of Human Fear Conditioning

Valerie Jentsch

Thank you very much for your attention!

Questions?





PsPM tutorial for pupil models

Christoph Korn, 23.04.2020

Questions

Have you worked with **Matlab** (or a similar program?

Never Often

Questions

Have you worked with **SPM**?

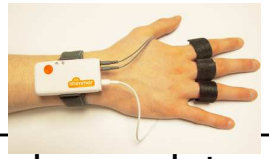
Never Often

Questions

Have you worked with **PsPM**?

Never Often

PsPM pipeline overview

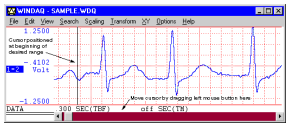


Analogue data recording

If possible, only anti-aliasing filter

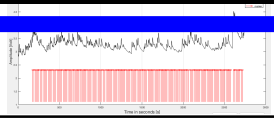
Digitisation

High sampling rate if no anti-aliasing filter



Recorded file

Import



PsPM file:
Data time-series
(Marker time stamps)

Preprocessing:
Trim unnecessary data
Detect missing fixation and exclude/(correct) pupil size
Heart beat detection & interpolation
Respiration cycle detection & interpolation
Startle eyeblink EMG filtering and rectification

Each step usually generates a new file with a prefix (SPM-style)

Model inversion:
GLM, non-linear models

All necessary filters applied on-the-fly during model inversion

1st (participant) level model files

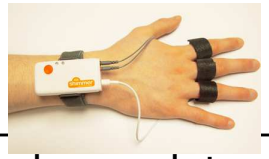
Export parameters to SPSS, R, ...

Group-level model (t-test, ANOVA, LME, ...)

2nd-level t-test

2nd (group) level model file

PsPM pipeline overview



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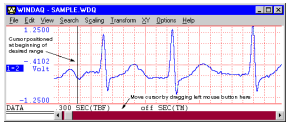

Recorded file

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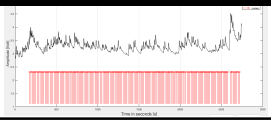

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