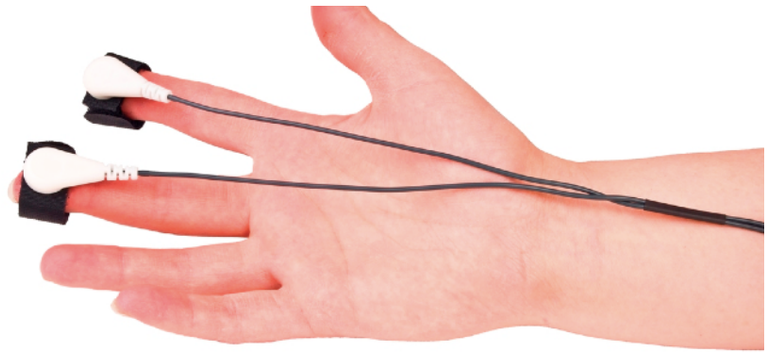

PsPM course session 3: SCR

Dominik R Bach

Wellcome Centre for Human Neuroimaging & Max Planck UCL Centre for Computational Psychiatry and Ageing, University College London
Clinical Research Priority Program "Synapse & Trauma" & Department of Psychiatry, Psychotherapy, and Psychosomatics, University of Zurich

16.04.2020

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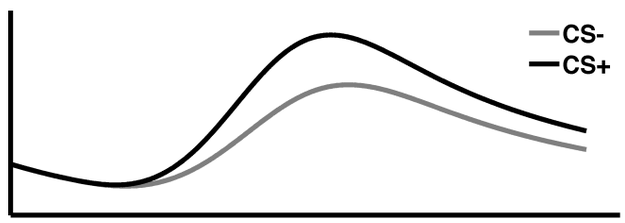
Course overview

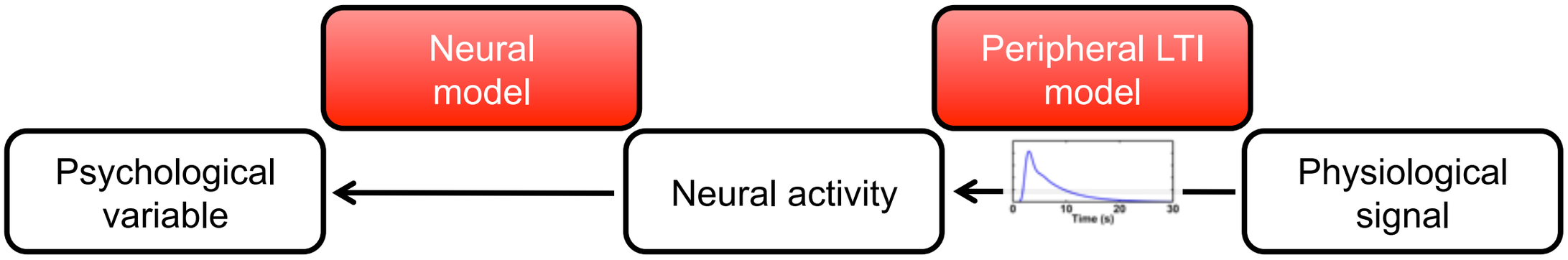
Memory difference between CS+/CS-?

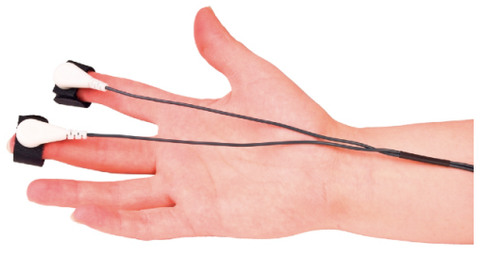
Lecture 7: 14.05.2020



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

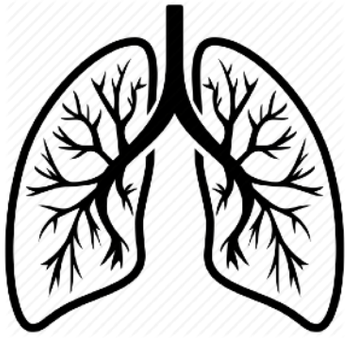
Lecture 2: 09.04.2020



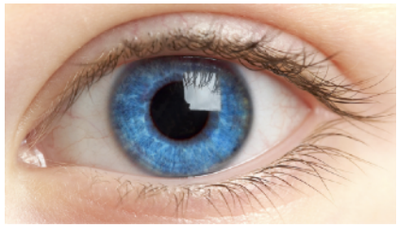


Lecture 3: 16.04.2020

Lecture 5: 30.04.2020



Lecture 6: 07.05.2020



Lecture 4: 23.04.2020

Lecture 6: 07.05.2020

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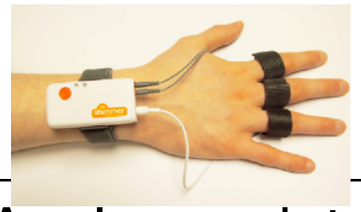
PsPM pipeline overview

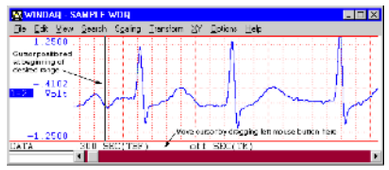


Analogue data recording

If possible, only anti-aliasing filter

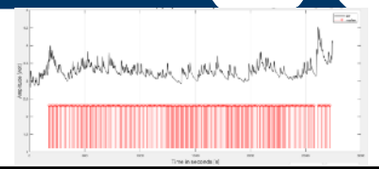
Digitisation

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

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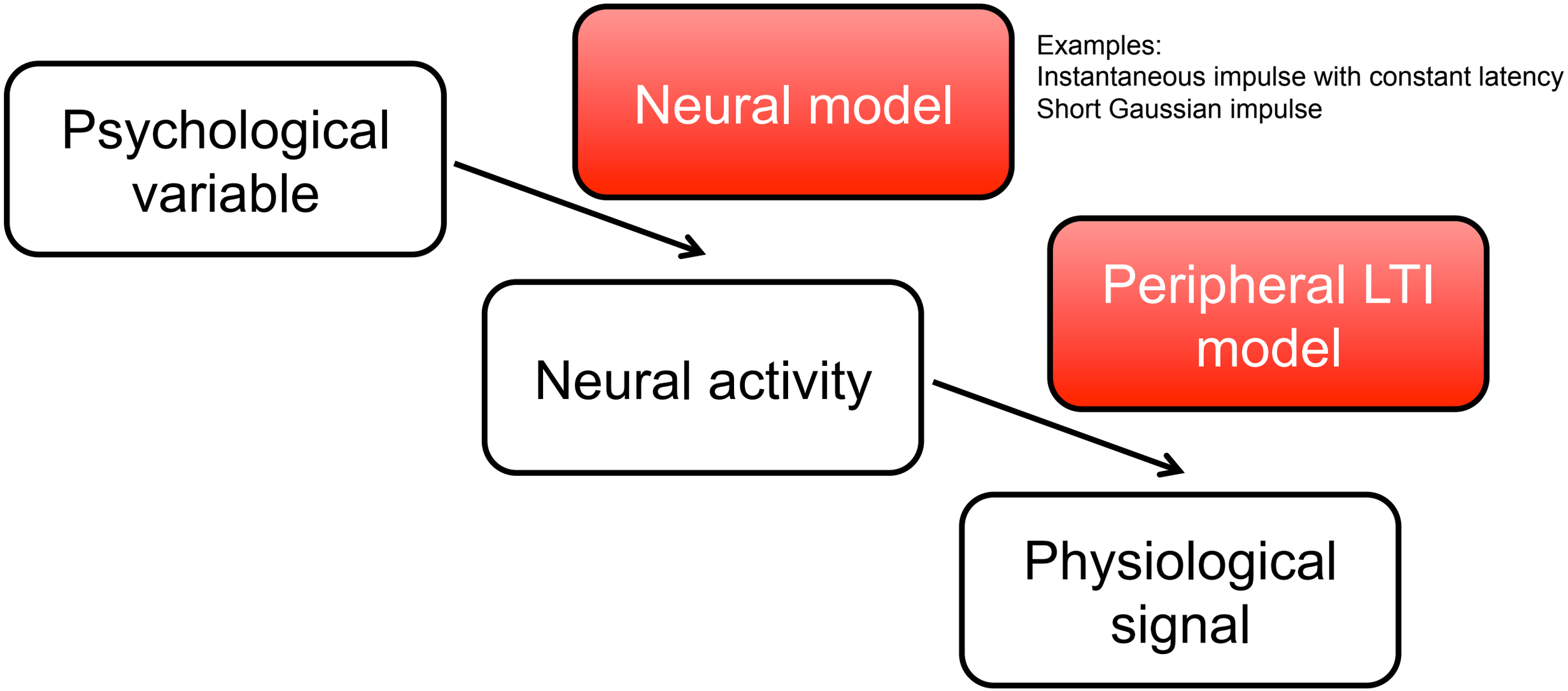
Basic formalism



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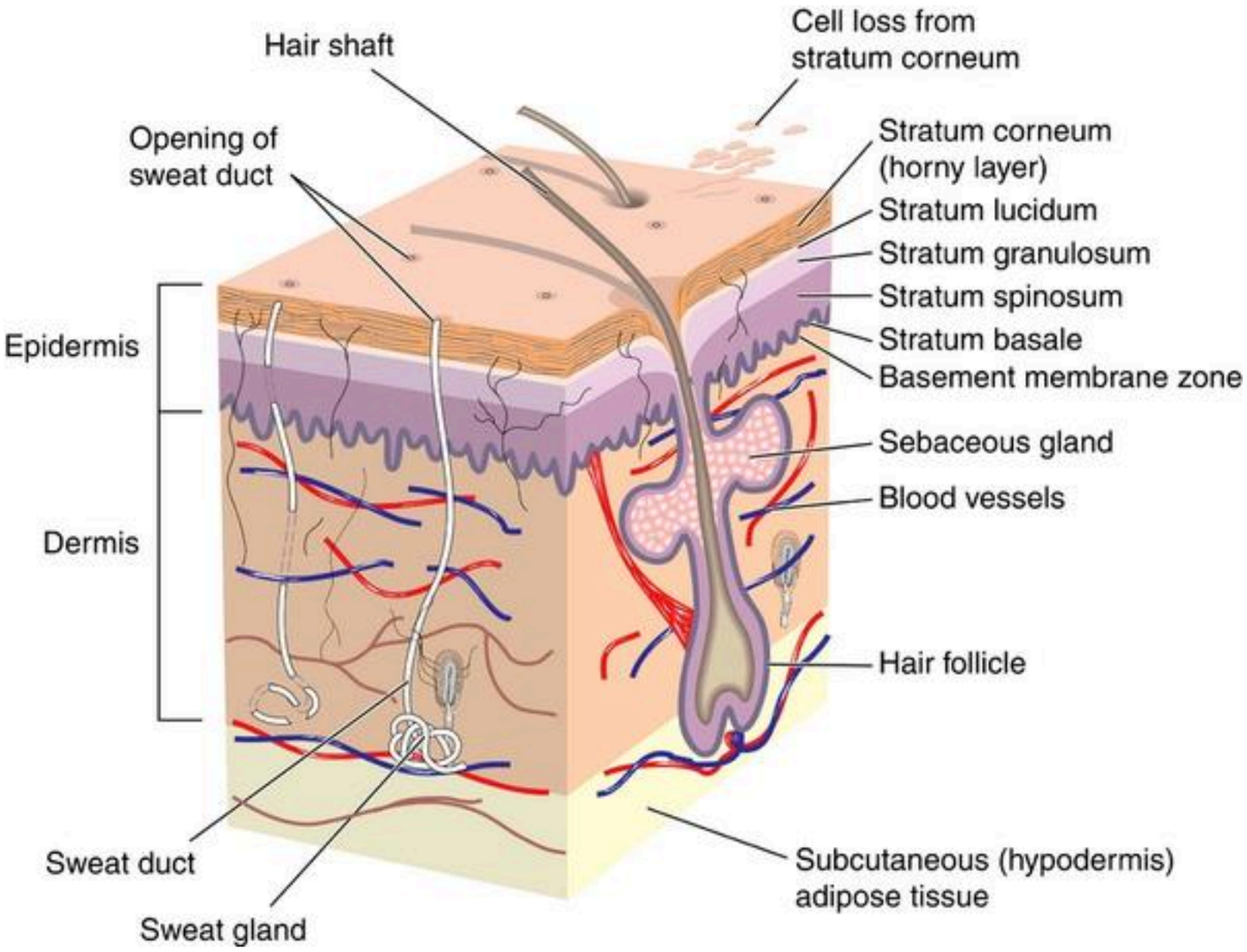
Bach & Friston (2013), Bach et al. (2018)

Skin conductance



Constant voltage (DC) coupler:

$$G = \frac{1}{R} = \frac{I}{U}$$

Applies constant voltage (e.g. 0.5 V), quantifies current via a measured voltage proportional to the current

Measured voltage depends on sensitivity, needs to be transformed to mcS for comparability between subjects & studies

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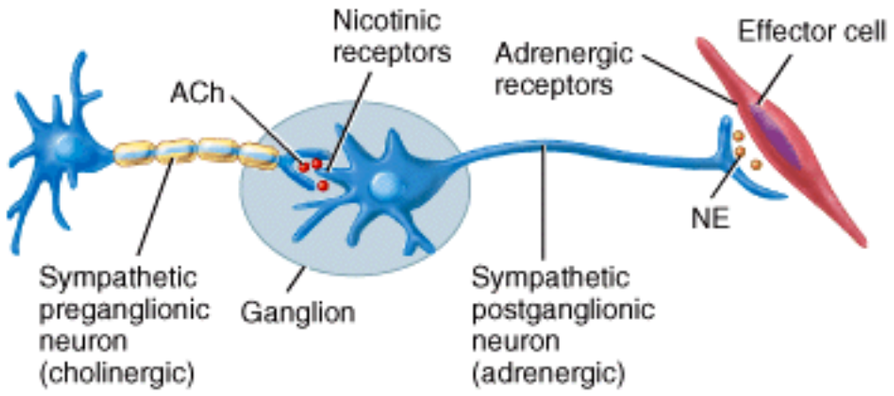
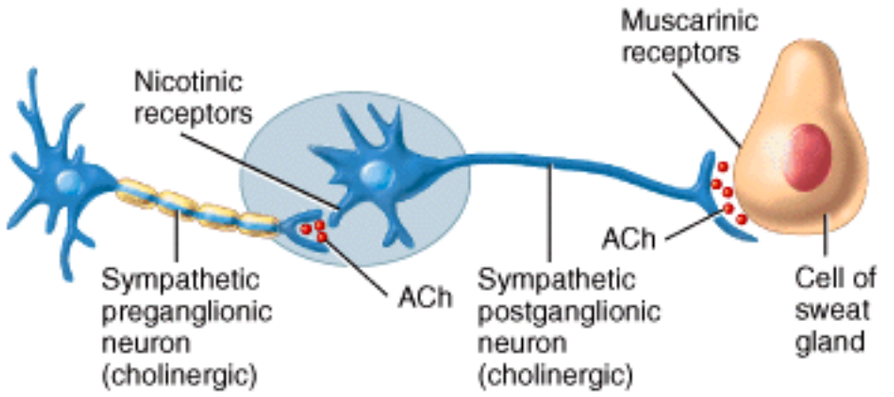
Boucsein (2012) Electrodermal activity

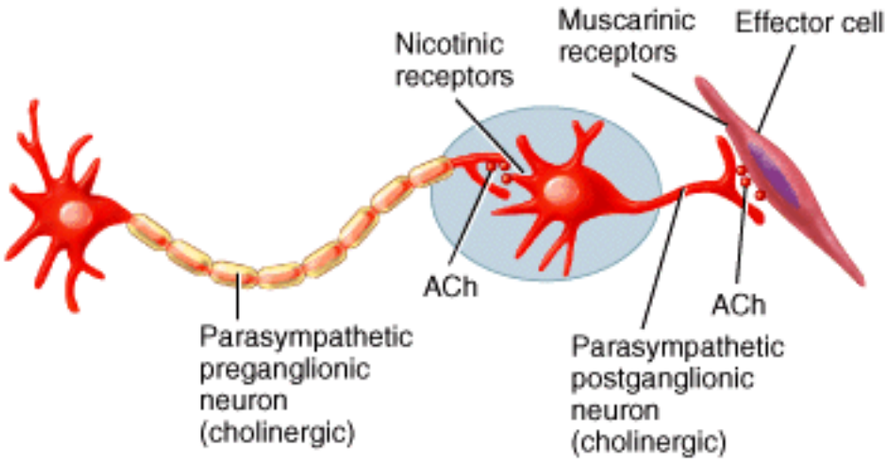
Physiology



(a) Sympathetic division–innervation to most effector tissues



(b) Sympathetic division–innervation to most sweat glands



(c) Parasympathetic division

Thermoregulation

"Emotional sweating": mainly measured on palmar & plantar skin with high sweat gland density, but no positive evidence for regional specificity

"Gustatory sweating"

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Boucsein (2012) Electrodermal activity

Orienting response

- Novelty
- Salience

Fear conditioning

- Debate as to how many componentes: 1-3 depending on ITI, evidence is weak
- Amygdala-dependent threat learning or (hippocampus-dependent?) contingency
- awareness? [1]

Motor action

- Often strongest determinant of SCR

Operant conditioning

- SCR can be reinforced

Information processing

- Cognitive load, decision-making, memory

Tonic arousal

- Anxiety, stress

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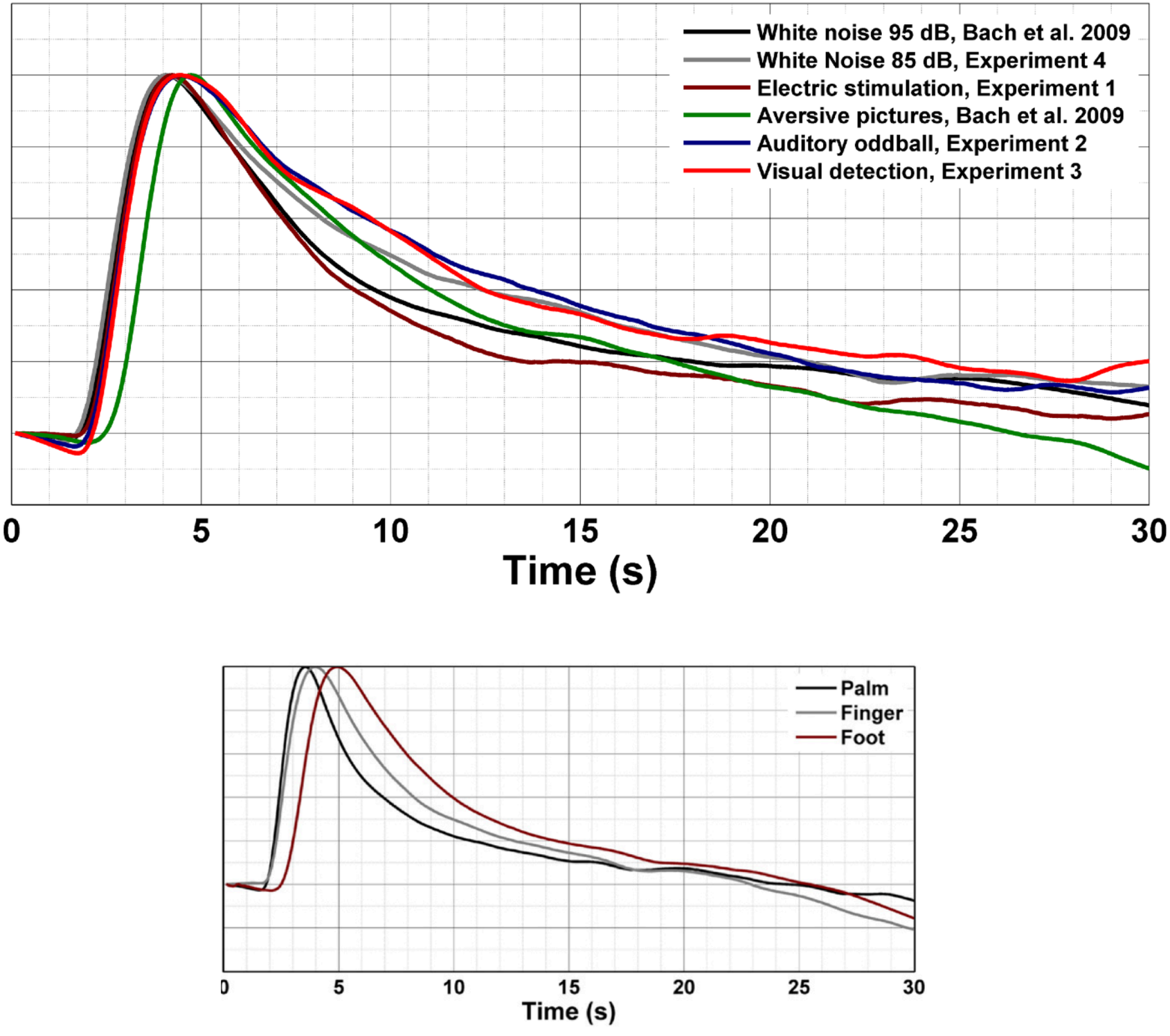
Review: Boucsein (2012) Electrodermal activity, [1] Ojala & Bach (pre-print)

(Un)Specificity



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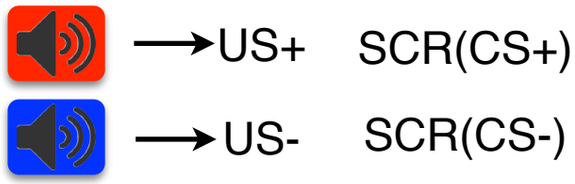
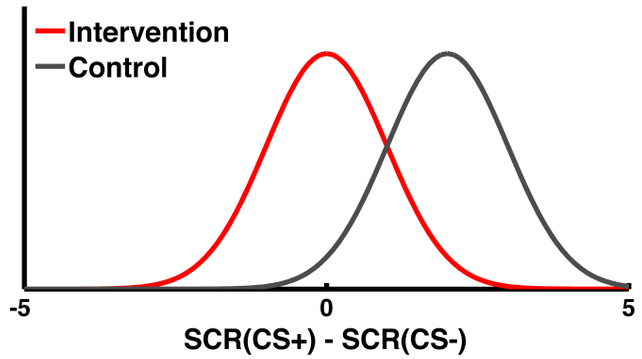
Boucsein (2012), Bach et al. (2009, 2010)

Comparison of measurement models





Measure	d	N*
SCR peak scoring	0.44	514
SCR model-based	0.75	174
HPR model-based	0.97	108
RAR model-based	0.61	268
PSR peak scoring	0.60	278
PSR model-based	0.82	150
SEBR peak scoring	1.00	102
SEBR model-based	1.17	74

*: Sample size required to achieve 80% power at α = .05 in a one-tailed test, if intervention reduces fear memory at least 50% and has no variability (best-case scenario)

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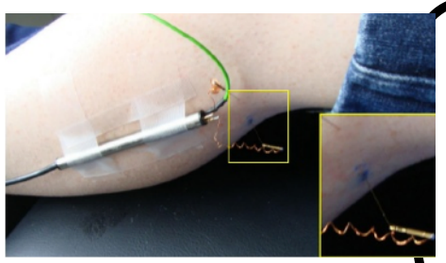
Bach & Melinscak (2020) Beh Res Ther

Basic formalism

Psychological variable

Neural model

Examples:
Instantaneous impulse with constant latency
Short Gaussian impulse



Neural activity

Peripheral LTI model

Physiological signal

SCR data are non-linear due to slow-frequency drifts. These components are removed with high-pass filters in all model-based approaches (including Ledalab: allows visualising these tonic components, but they are not part of the model).

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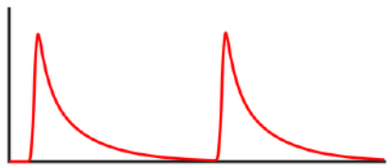
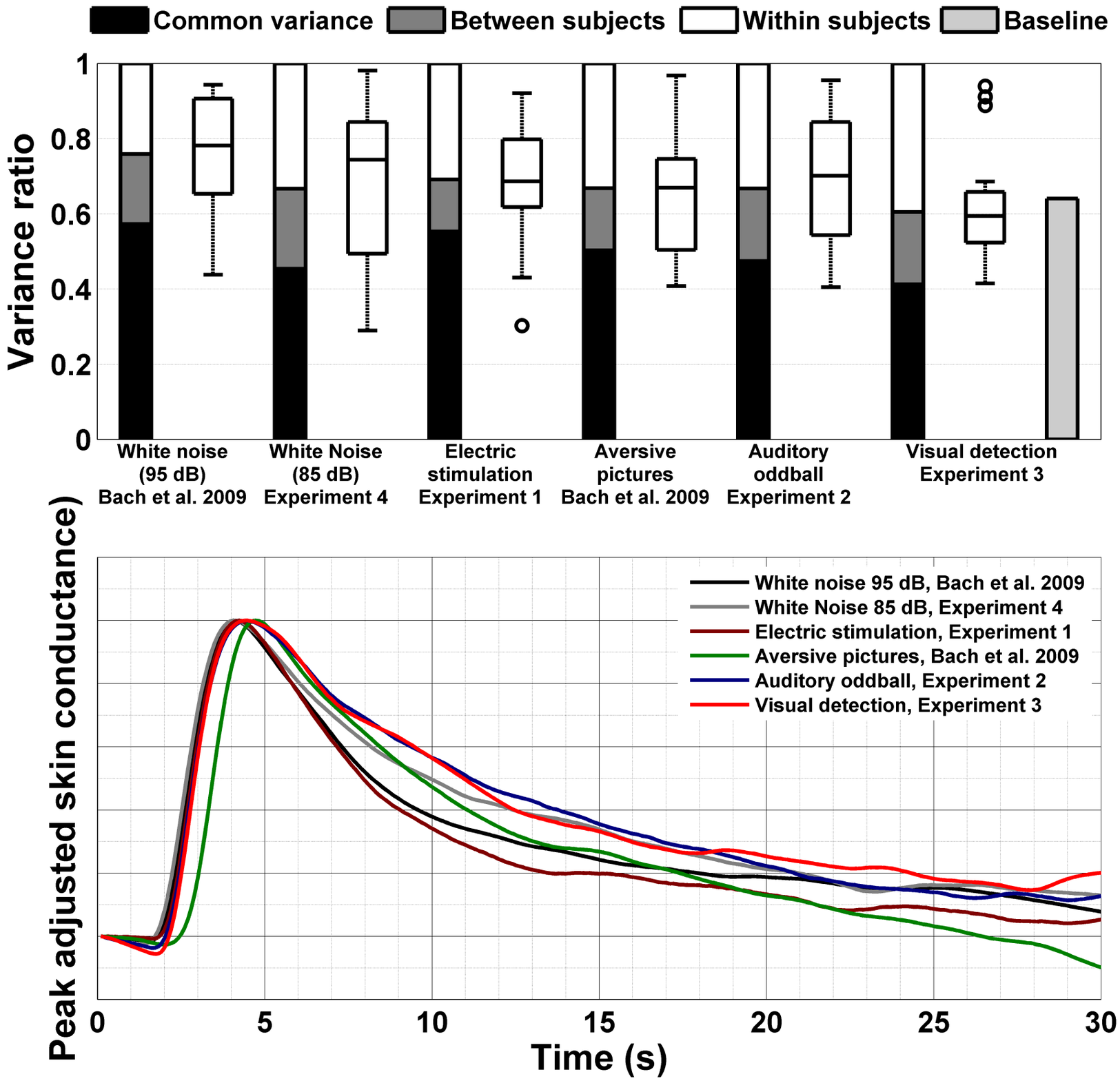
Bach & Friston (2013) Psychophysiology

Indirect tests: time invariance





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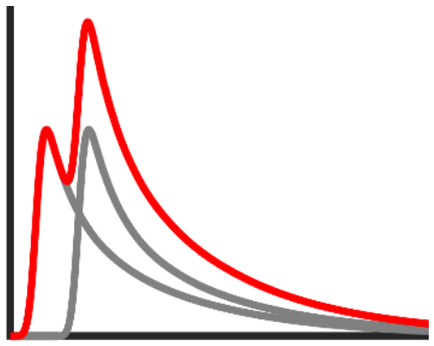
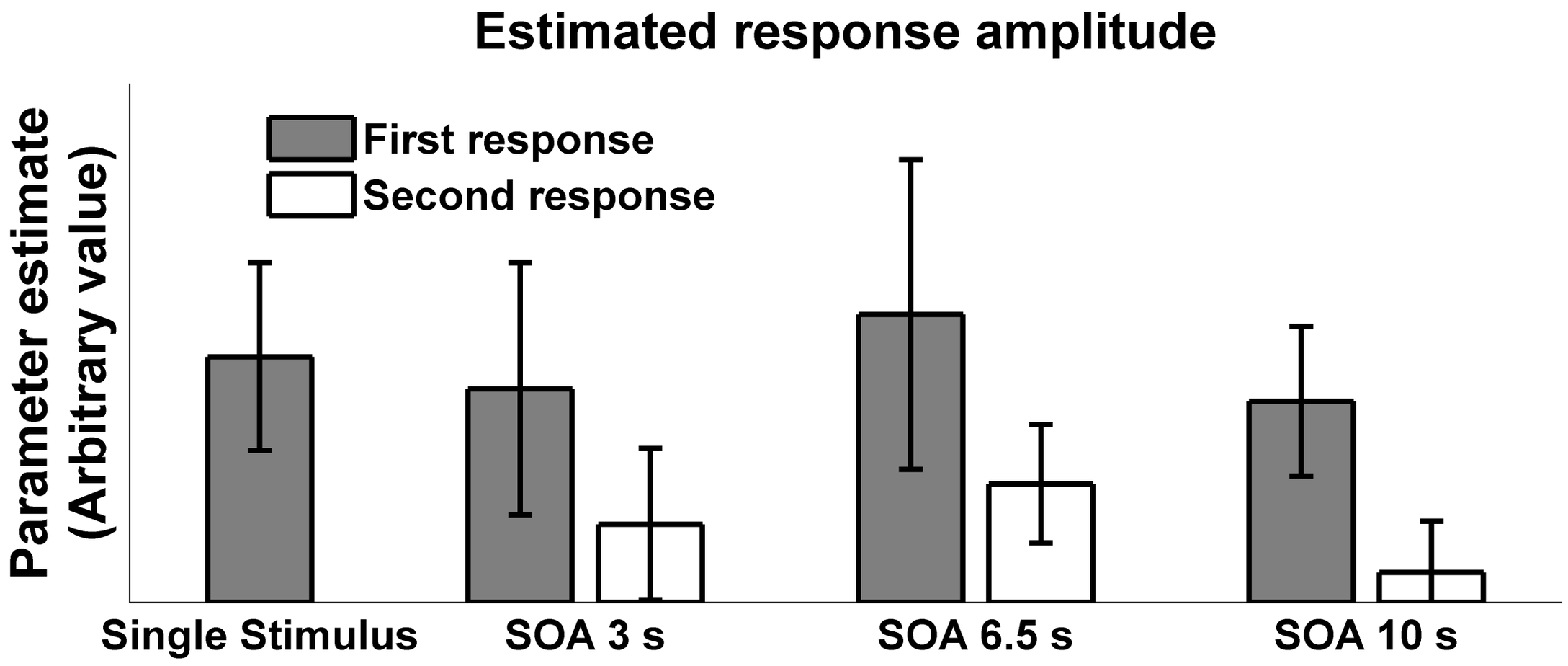
Bach et al. (2009) J Neurosci Methods, Bach et al. (2010) Int J Psychophysiology

Indirect tests: linearity





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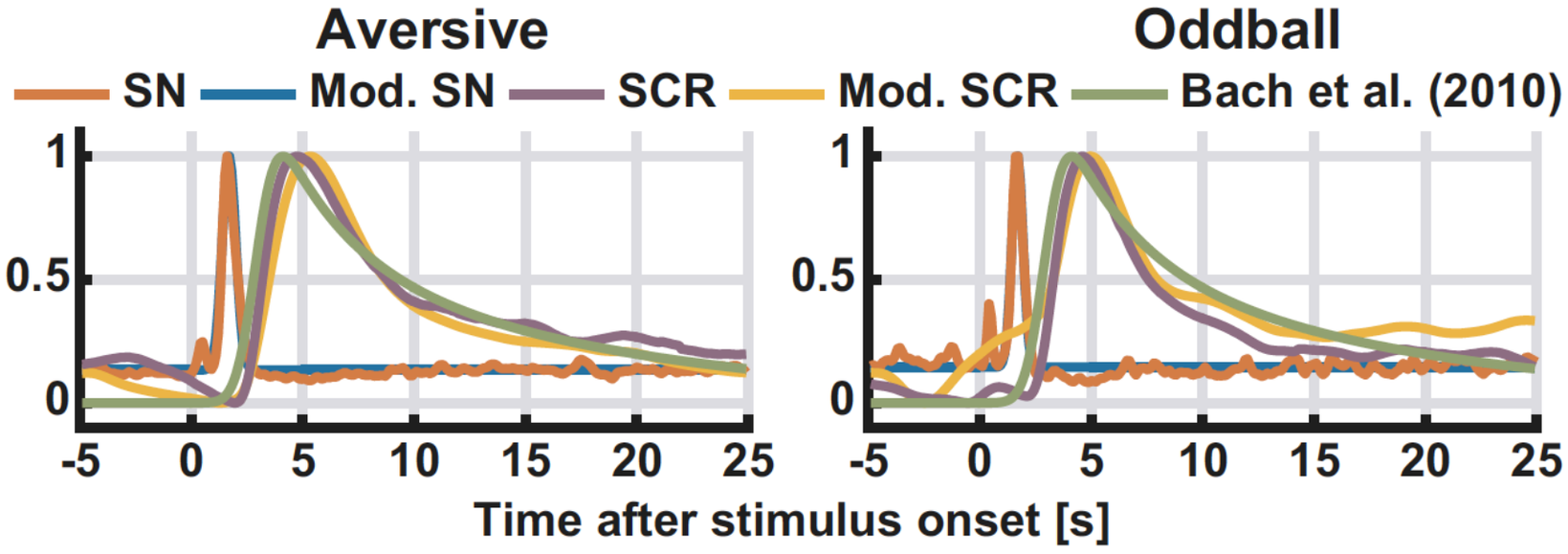
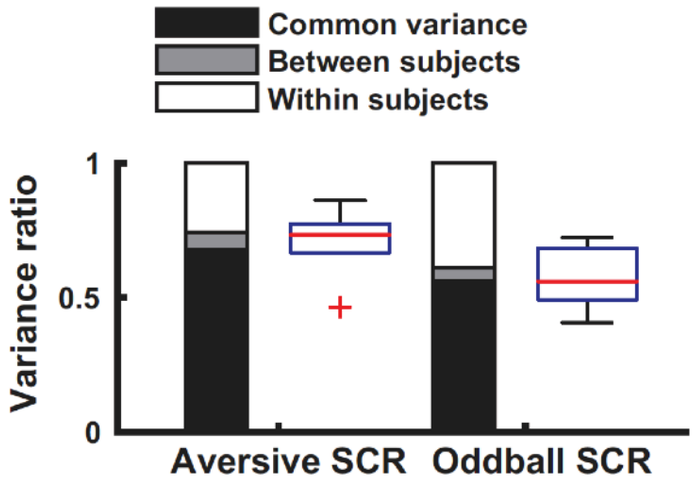
Bach et al. (2010) Int J Psychophysiology

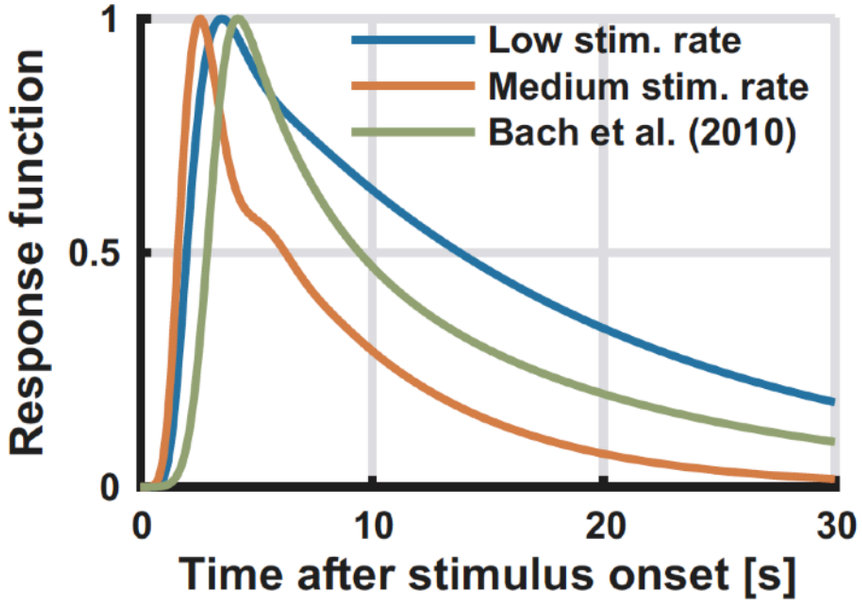
Direct tests of LTI assumptions

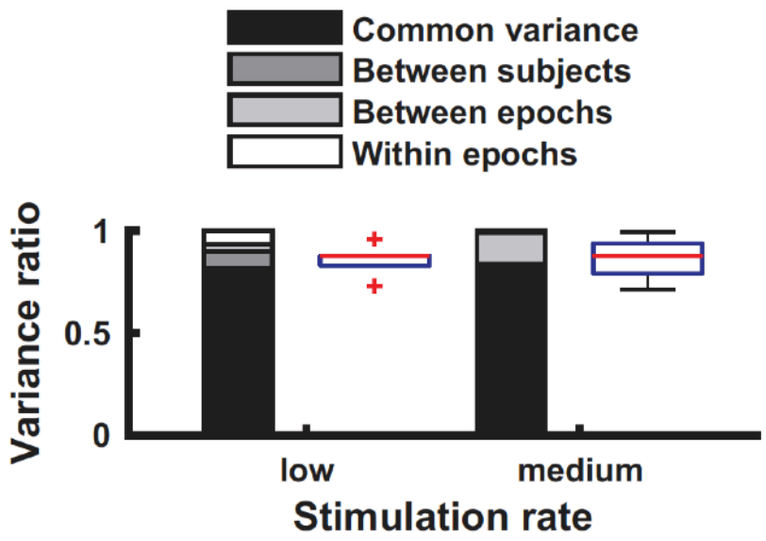
Intraneural recordings





Intraneural stimulation (under peripheral anesthesia): results for frequencies below 0.6 Hz





High trial-by-trial variability in gain factor, but no evidence for peripheral habituation

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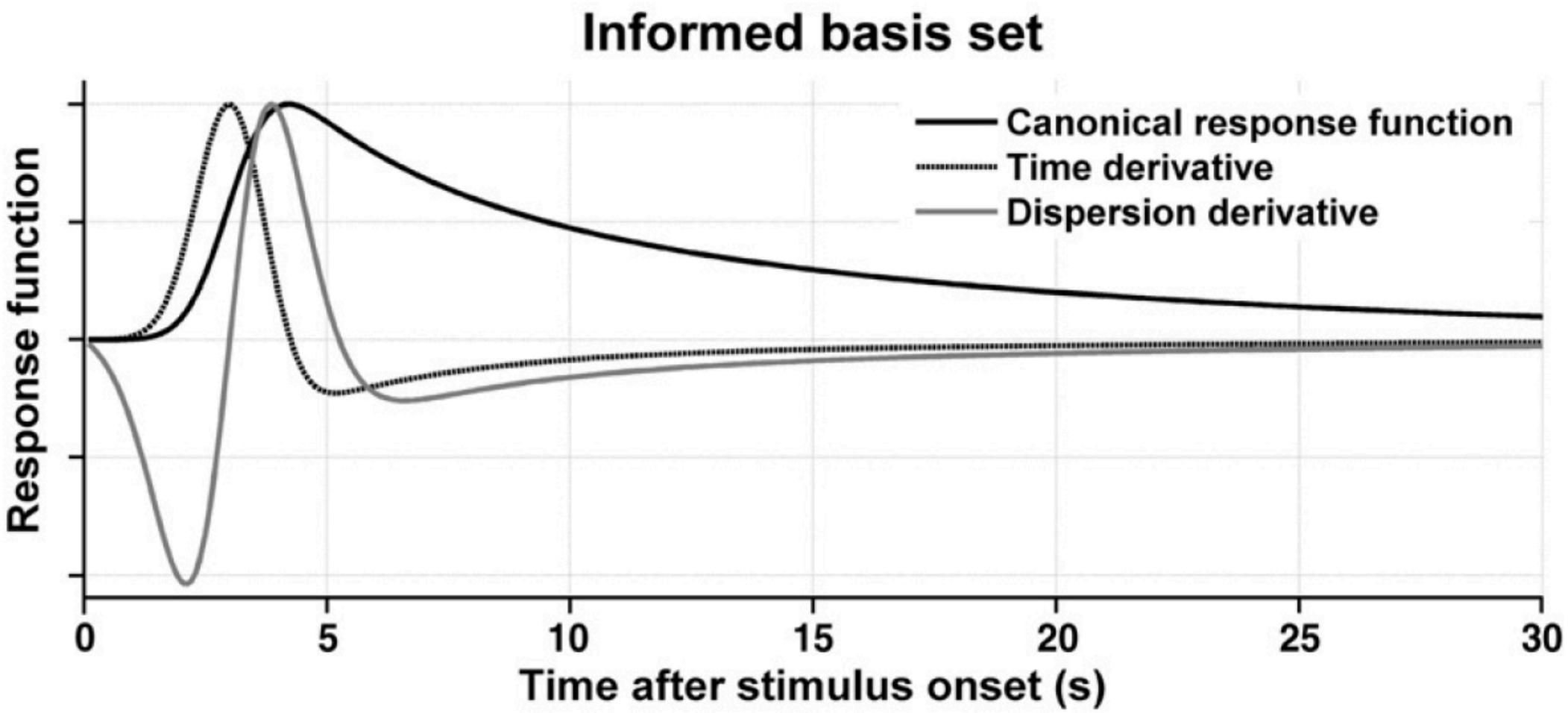
Gerster et al. (2018) Psychophysiology

Peripheral model(s)



$$h(t) \propto \int_0^t N(t-\tau)\left(E_1(\tau) + E_2(\tau)\right) d\tau \;,\; t \geqslant 0,$$

$$N(t) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(t-t_0)^2/2\sigma^2},$$

$$E_i(t) = e^{-\lambda_i t},$$

$$\dddot{y} + \vartheta_1 \ddot{y} + \vartheta_2 \dot{y} + \vartheta_3 y - u(t - \vartheta_4) = 0$$

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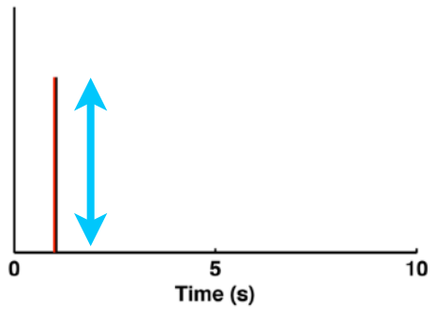
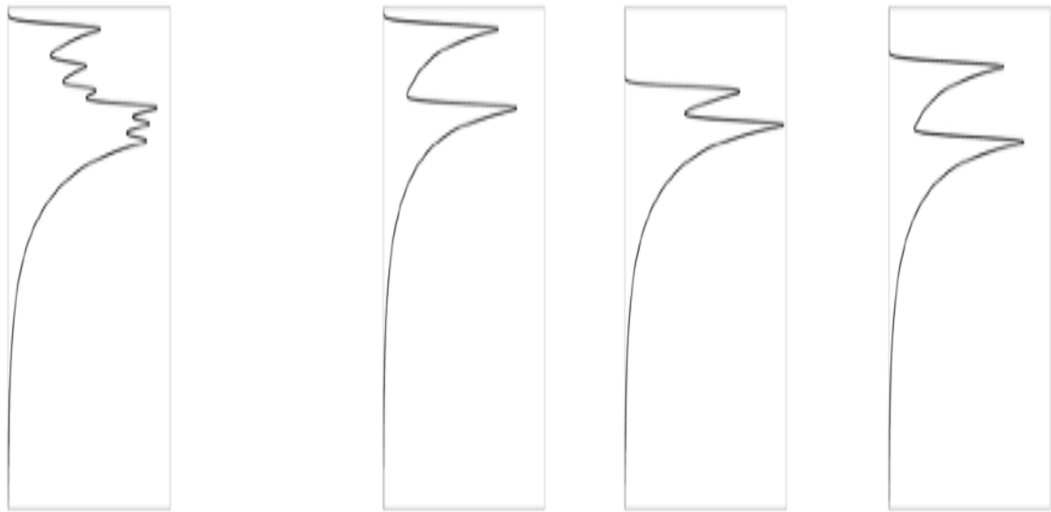
Model inversion

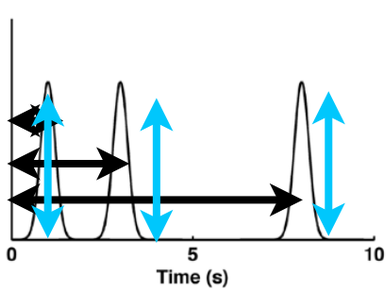


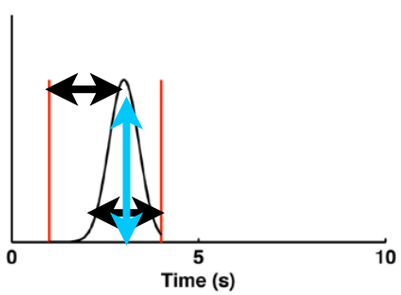
General Linear Model

$$\hat{\beta} = \arg\max L\left(SCR|\beta\right)$$

$$SCR = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$







Non-linear methods:

- maximum-a-posteriori estimation using Variational Bayes ("DCM")
- for SF also: approximation using Matching Pursuit (100 x faster)

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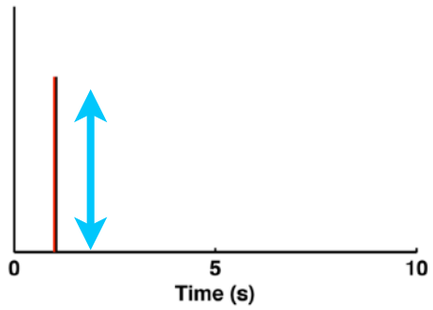
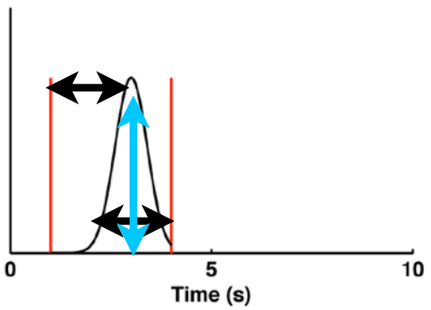
Bach et al. (2009) J Neurosci Meth, Bach et al. (2010) Biological Psychology, Bach et al. (2011) Psychophysiology, Bach & Staib (2015) Psychophysiology

Neural model(s)



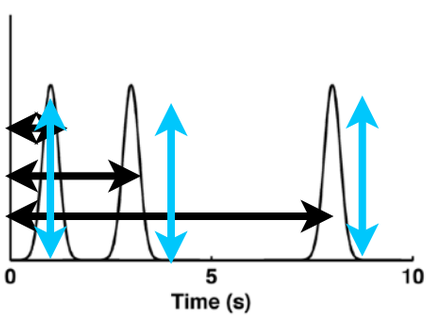
$$SN = \begin{cases} a & t = 0 \\ 0 & \text{otherwise} \end{cases}$$

evoked SCR:
constant-latency input



event-related SCR:
constrained-latency input

$$SN = a \exp \frac{-(t-\mu)^2}{2\sigma^2},\ 0 < \mu < \mu_{max},\ \sigma_{min} < \sigma < \sigma_{max}$$



$$SN = a \exp \frac{-(t-\mu)^2}{2\sigma^2},\ \sigma = \sigma_0$$

spontaneous
fluctuations (SF):
input at unknown time points

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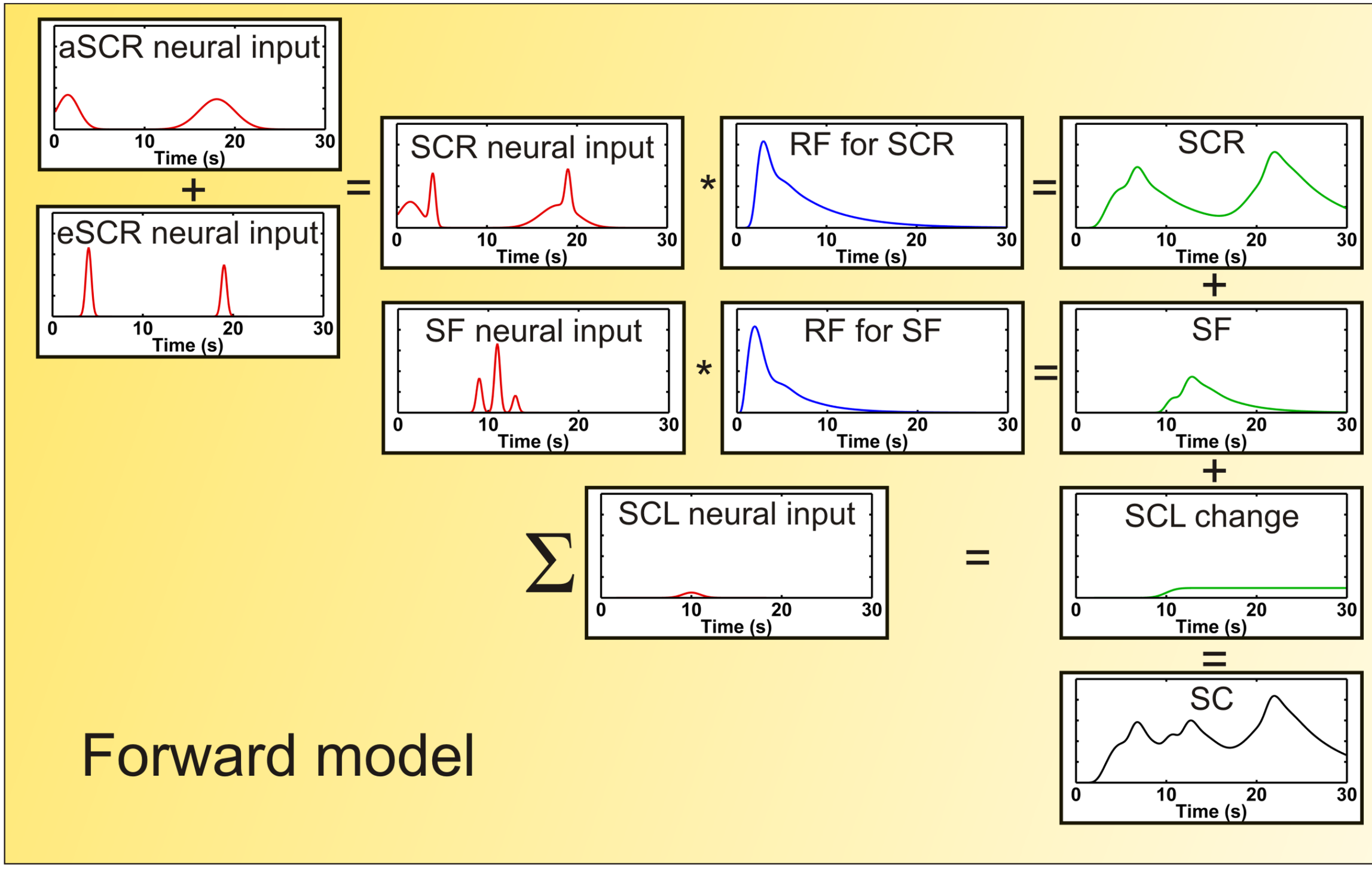
Bach et al. (2009) J Neurosci Methods, Bach et al. (2010) Biological Psychology, Bach et al. (2011) Psychophysiology

Non-linear model inversion



Forward model

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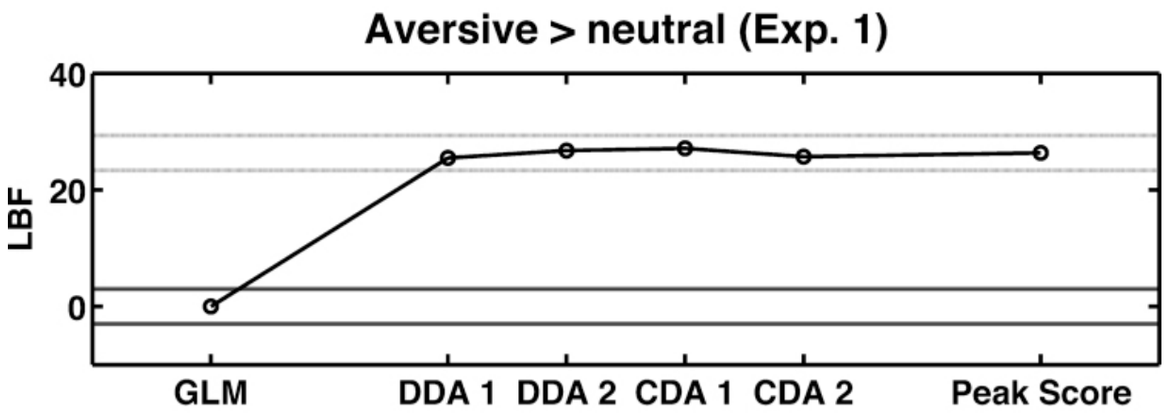
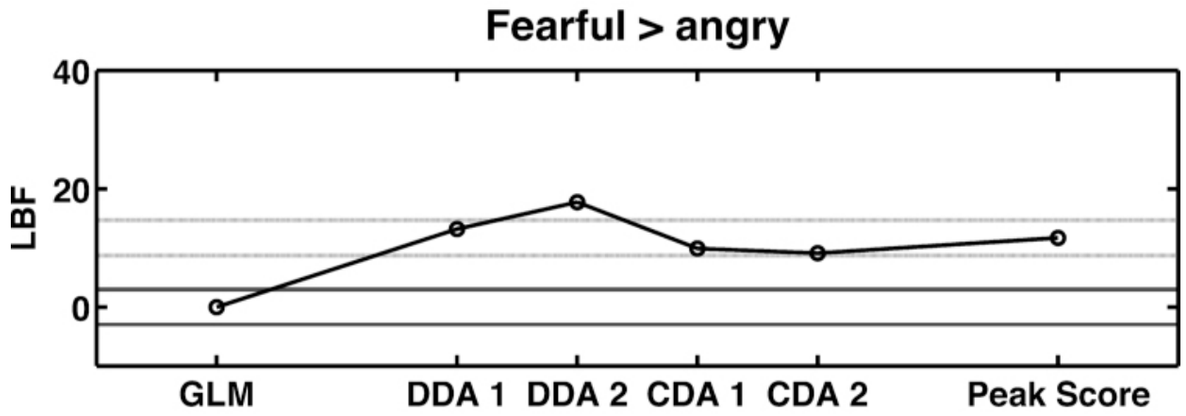
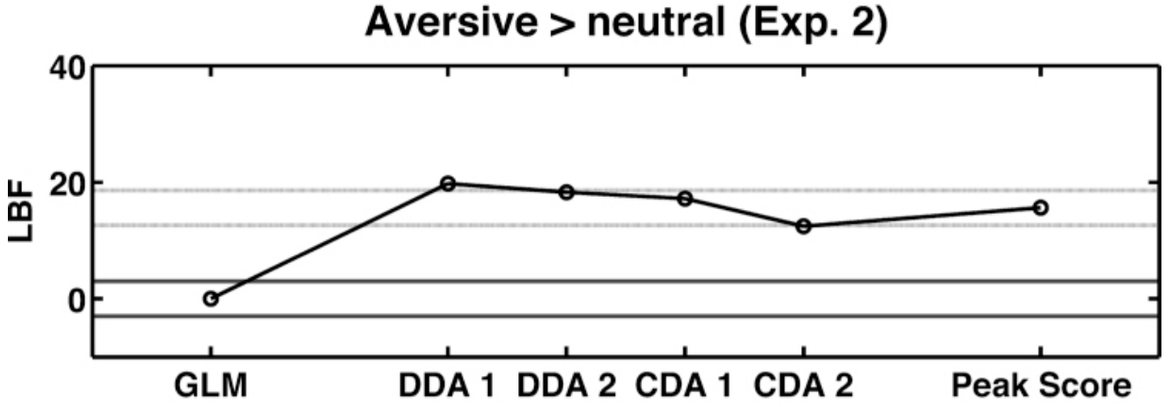
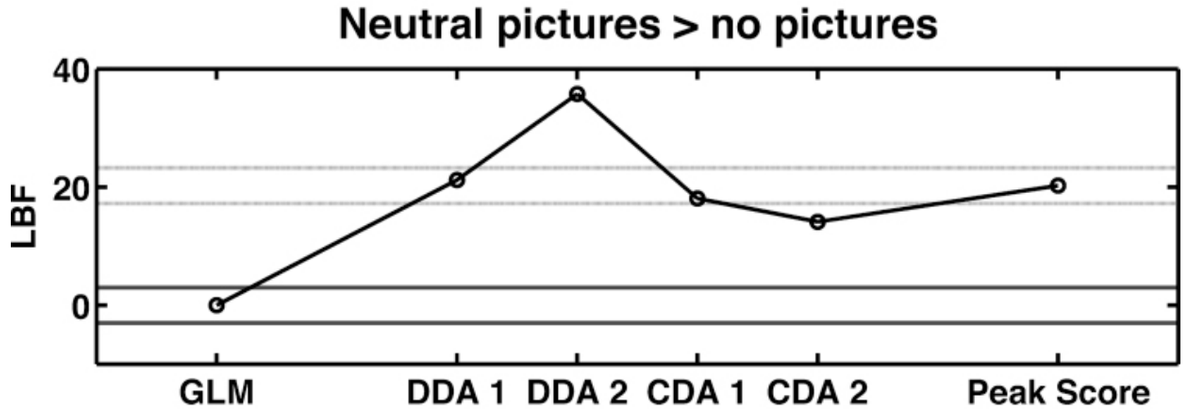
Bach et al. (2010) Biological Psychology

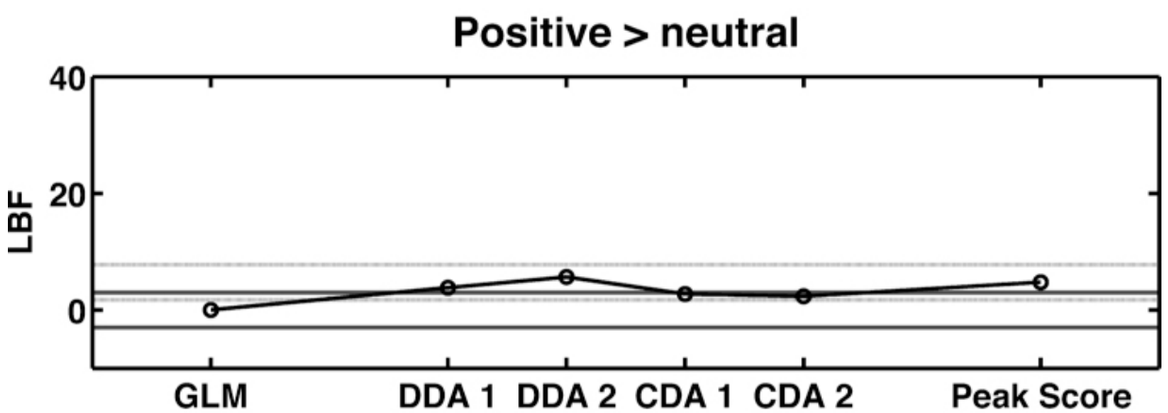
Evaluation of retrodictive validity: evoked SCR











Model evidence (LBF)

- smaller is better
- decisiveness threshold 3

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Bach et al. (2014) Biological Psychology

Evaluation of retrodictive validity: anticipatory SCR

	Experiment 1		
	CS+ > CS−		Comparison with default DCM:
	t(19)	*p*	LBF (smaller is better)
Default DCM	3.88	0.001	
Peak	1.99	0.062	18
CDA ('AmpSum')	2.39	0.027	15
CDA ('SCR')	2.56	0.019	13
DCM (z-standard)	4.31	<0.001	−2
Peak (z-standard)	2.12	0.047	17
CDA ('AmpSum') (z-standard)	2.59	0.018	13
CDA ('SCR') (z-standard)	2.92	0.009	10

	Experiment 2		
	CS+ > CS−		Comparison with default DCM:
	t(29)	*p*	LBF (smaller is better)
Default DCM	3.55	0.001	
Peak	2.32	0.027	11
CDA ('AmpSum')	2.77	0.010	08
CDA ('SCR')	2.64	0.013	09
DCM (z-standard)	3.64	0.001	−1
Peak (z-standard)	2.64	0.013	09
CDA ('AmpSum') (z-standard)	2.95	0.006	06
CDA ('SCR') (z-standard)	2.94	0.006	06

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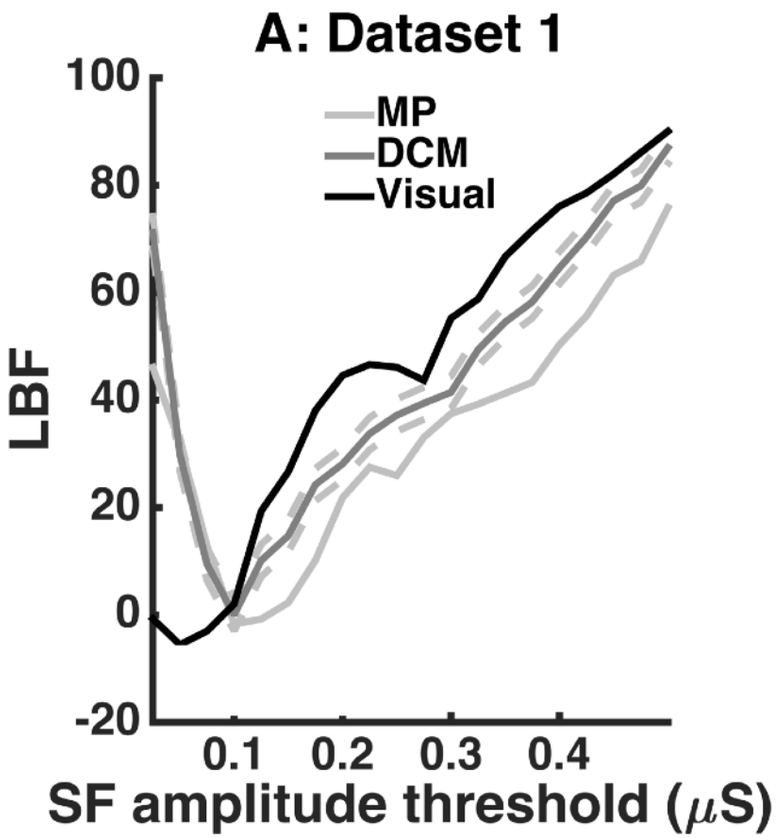
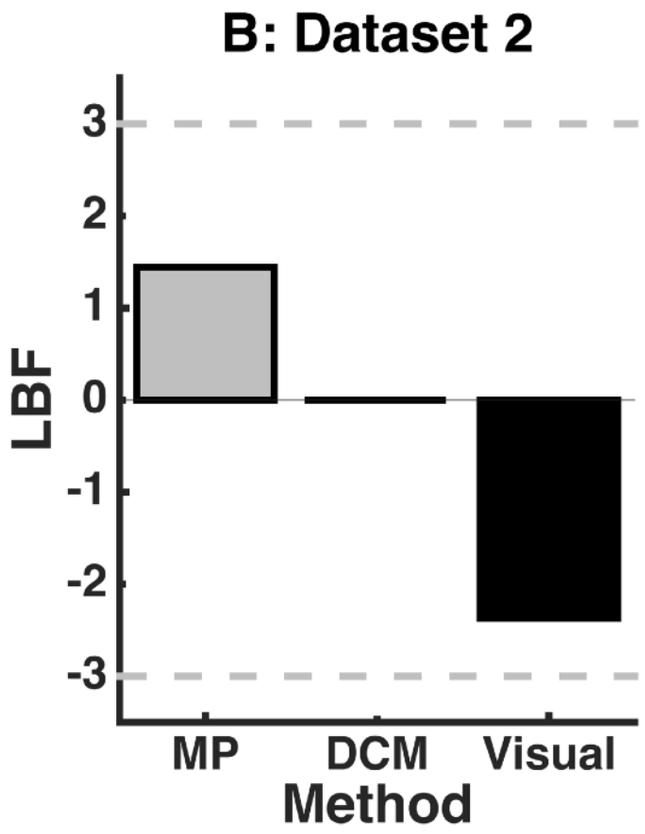
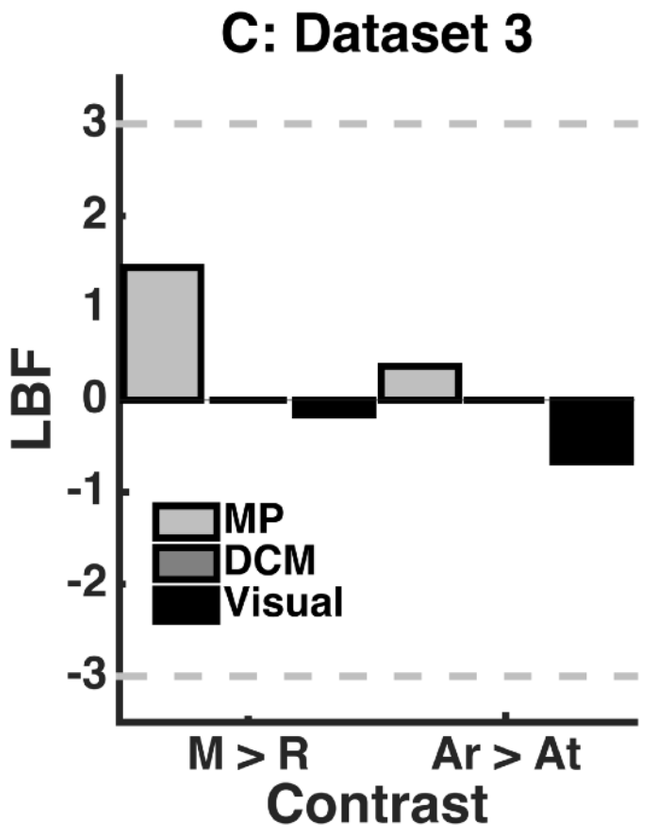
Staib, Castegnetti, Bach (2015) Psychophysiology

Evaluation of retrodictive validity: SF







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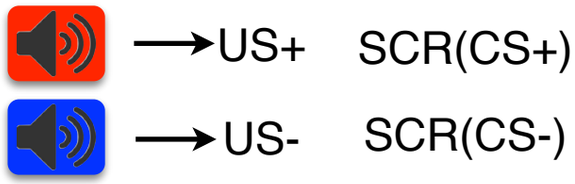
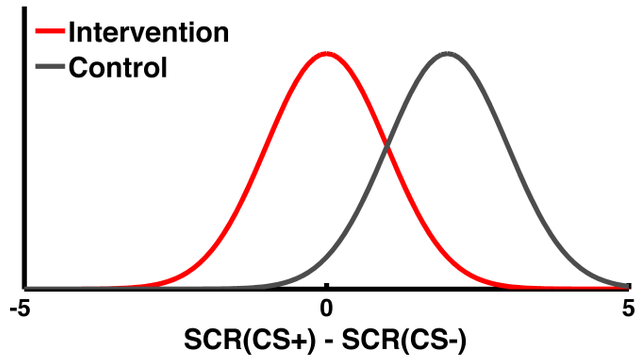
Bach & Staib (2015) Psychophysiology

Comparison of measurement models





Measure	d	N*
SCR peak scoring	0.44	514
SCR model-based	0.75	174
HPR model-based	0.97	108
RAR model-based	0.61	268
PSR peak scoring	0.60	278
PSR model-based	0.82	150
SEBR peak scoring	1.00	102
SEBR model-based	1.17	74

*: Sample size required to achieve 80% power at α = .05 in a one-tailed test, if intervention reduces fear memory at least 50% and has no variability (best-case scenario)

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Bach & Melinscak (2020) Beh Res Ther

Data pre-processing and implementation

Filtering (done on-the-fly)

- Low-pass 5 Hz, downsampling to 10 Hz
- Optimal high-pass filters (empirically determined): 0.05 Hz unidirectional (GLM), 0.0159 Hz bidirectional (non-linear model), 0.0159 Hz unidirectional (SF model, not optimised)

Response function

- Canonical SCRF, applies to all manipulations/conditions
- Interpret parameter estimates for individual conditions and trials
- GLM: constrained RF with canonical RF + time derivative is best [1]
- non-linear model: no benefit from IRF if estimated from short ITI data (7-11 s, Staib et al. 2015) but could be beneficial if estimated from external data set with long ITI

Conclusion & open questions

- GLM: fairly mature model, optimised preprocessing and RF
- DCM:
  - best neural forward model for fear conditioning with different SOAs
  - global optimisation as a faster and more precise inversion algorithm

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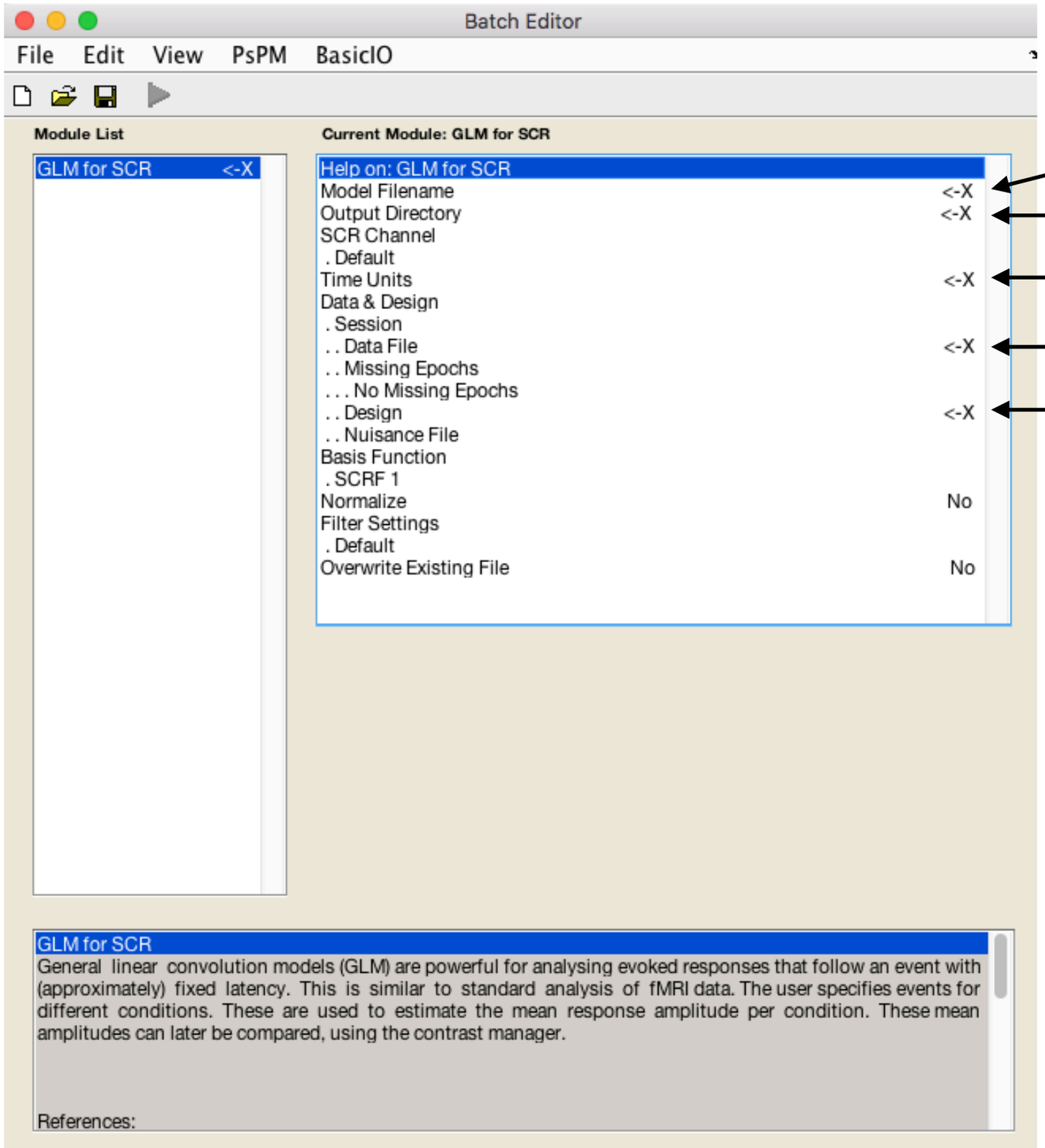
[1] Bach et al. (2013) Biological Psychology

GUI implementation: GLM



Name for 1st level model file ...

... and directory

Seconds, samples, markers?

Data file (1 per session)

Timings (specify in GUI or 1 file per session)

SPM style timing files:

```
names = {'Neutral', 'Aversive'};
onsets = {[1, 5], [2, 3, 4]};

pmod(1).name{1} = 'Arousal_rating';
pmod(1).param{1} = [0.1 1.3];

pmod(2).name{1} = 'Arousal_rating';
pmod(2).param{1} = [4.7, 8.3, 7.0];
```

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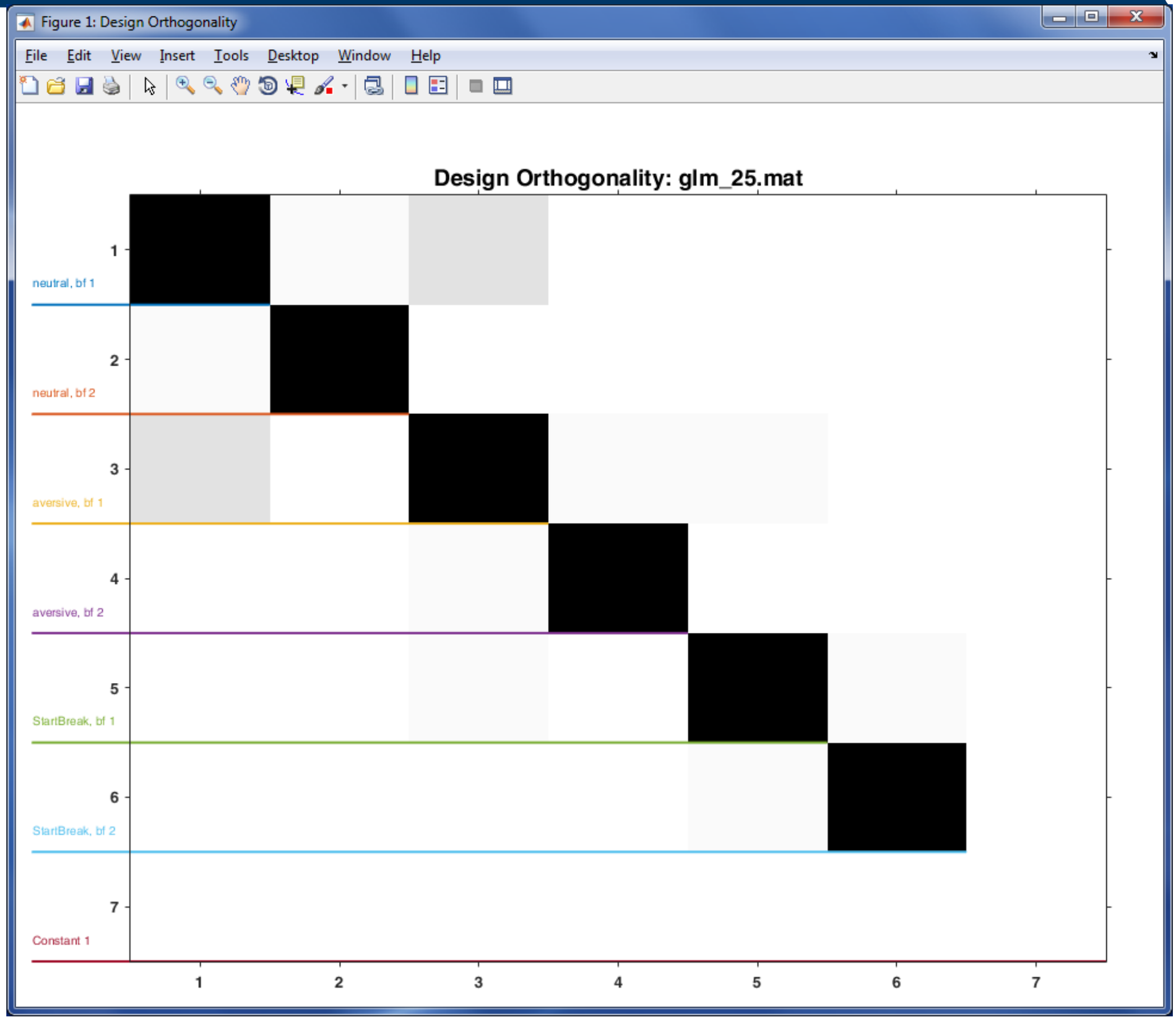
Design orthogonality



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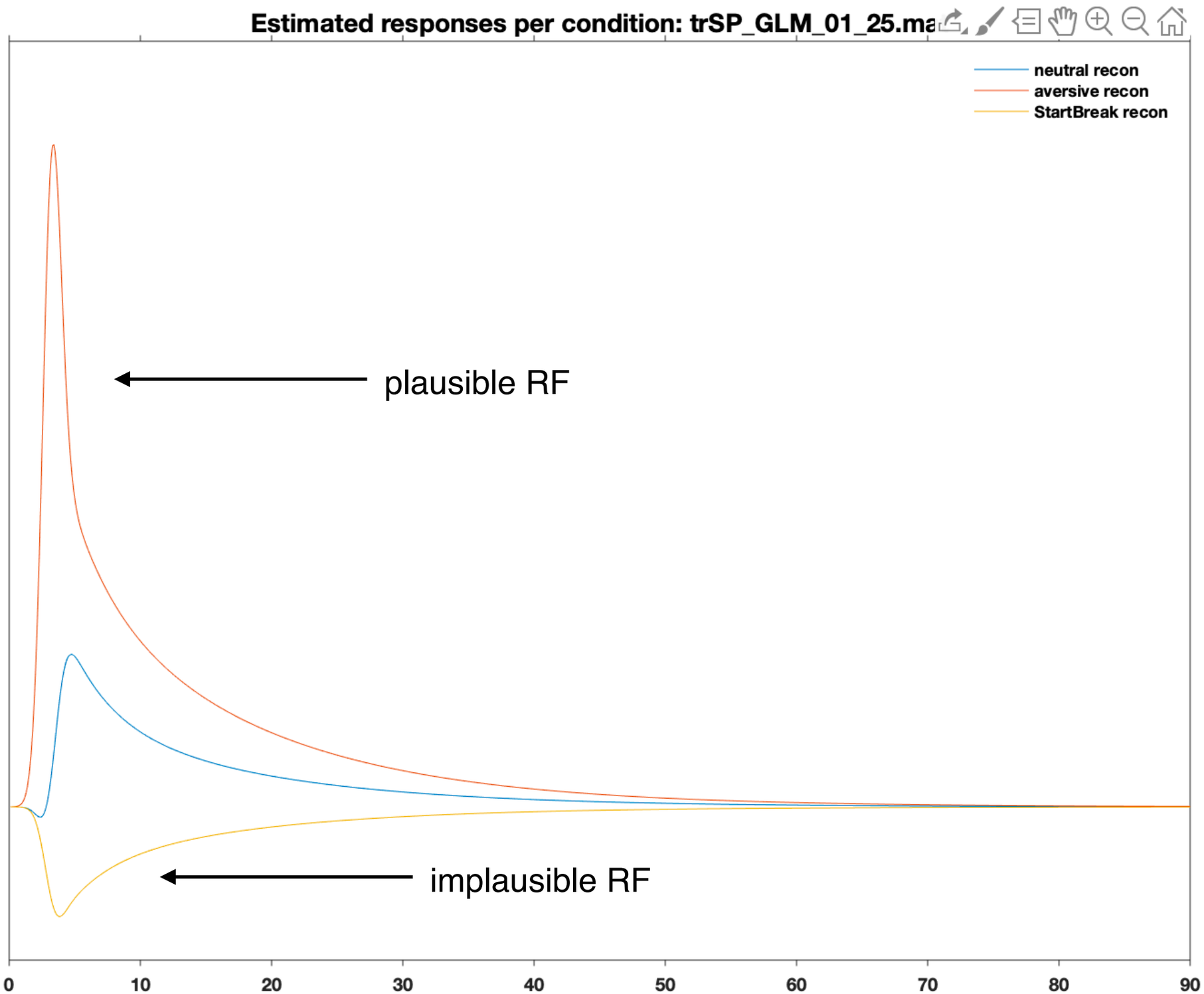
Estimated RF



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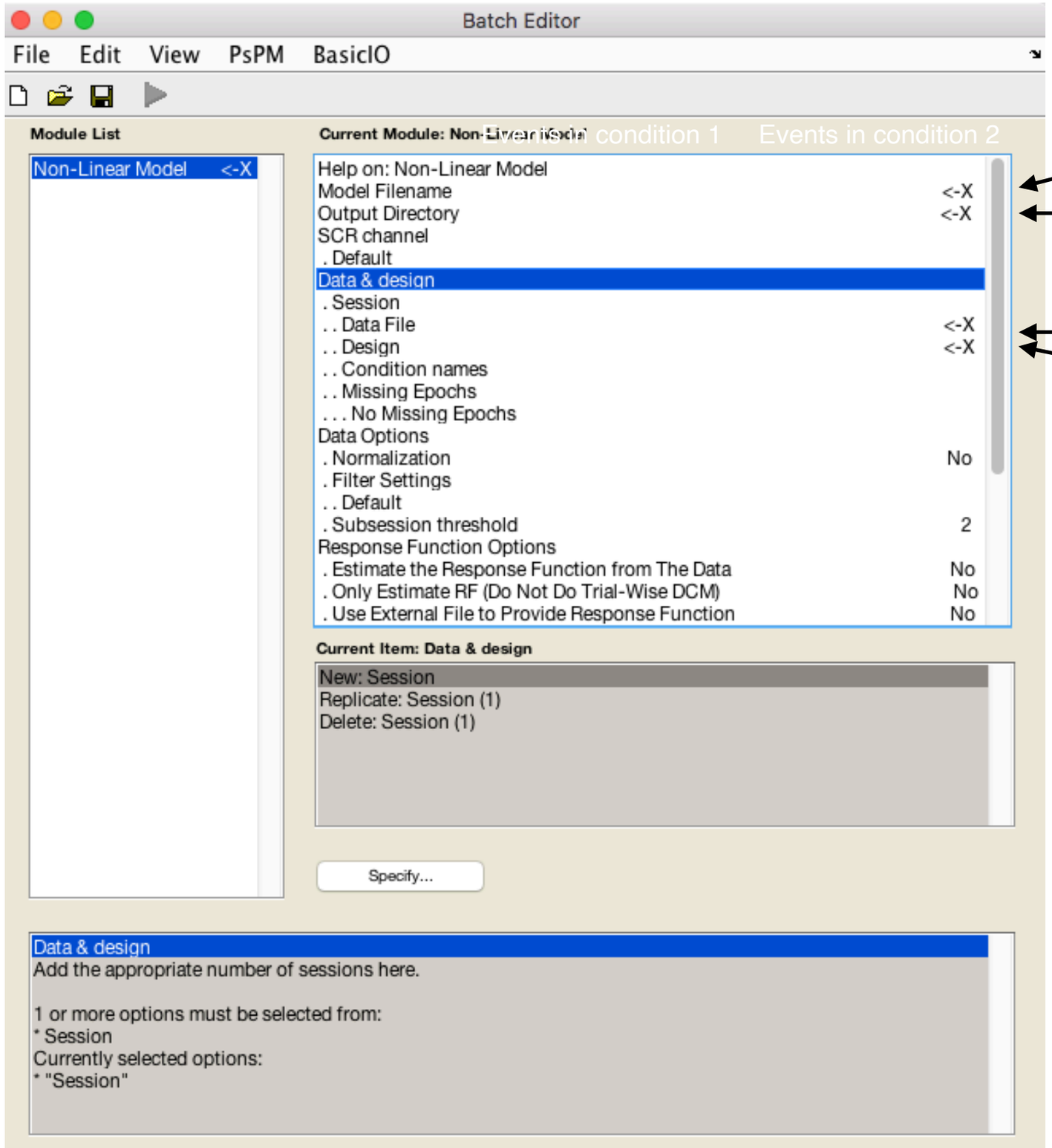
GUI implementation: non-linear model



Name for 1st level model file ...

... and directory

Timing always in seconds!

Data file (1 per session)

Timings (specify in GUI or 1 file per session)

Specific conventions, different from GLM timing files.

Flexible responses (constrained latency & dispersion):

```
events{1} =   [1 4;
              10 14];
```

Fixed responses (constant latency & dispersion):

```
events{2} =   [5;
               15];
```

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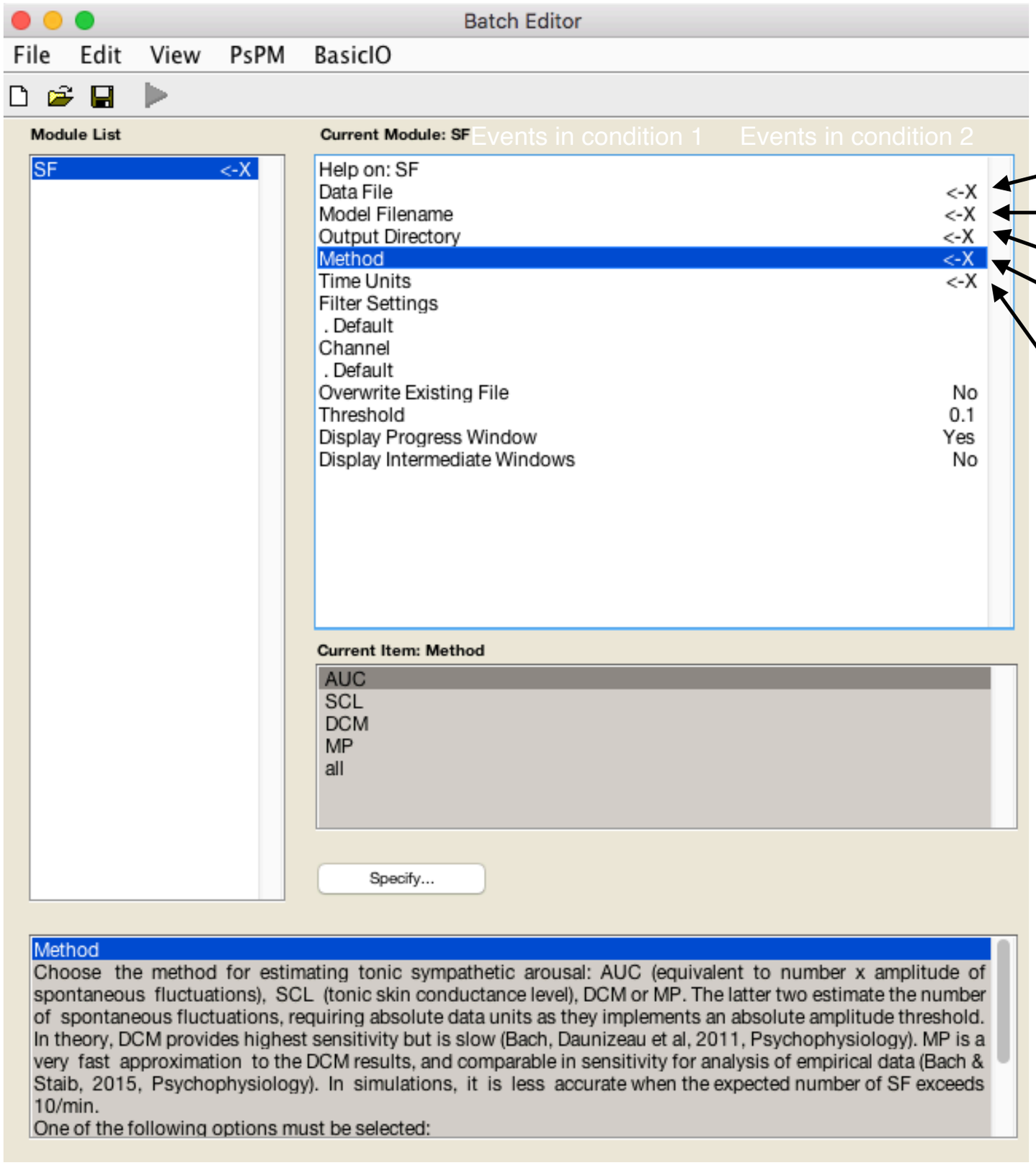
GUI implementation: SF



Data file (1 per session)

Name for 1st level model file ...

... and directory

AUC (mean-baseline), SCL (mean), DCM (number of responses), MP (number of responses), all

Timings: seconds, samples, markers (provide epochs) or entire file

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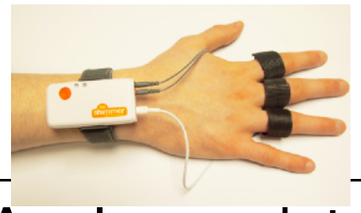
PsPM pipeline overview: today's tutorial

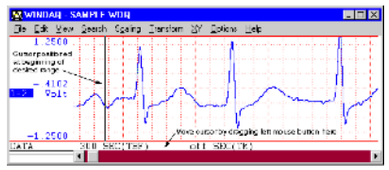


Analogue data recording

If possible, only anti-aliasing filter

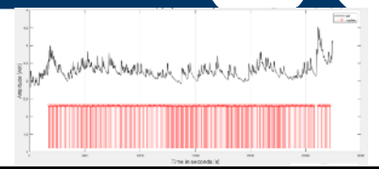
Digitisation

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

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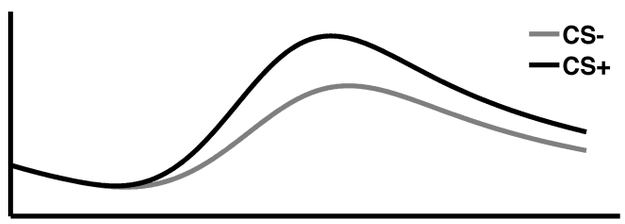
Next lecture: Pupil responses (Christoph Korn)

CS+/CS- → US → Memory

Memory difference between CS+/CS-?

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

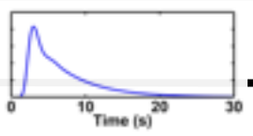
Lecture 7: 14.05.2020



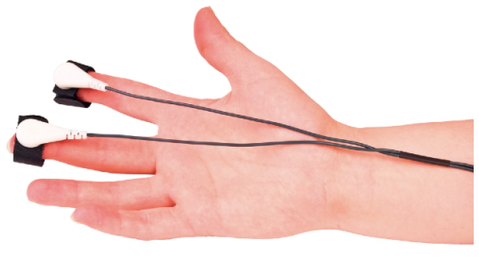
Lecture 2: 09.04.2020

Neural model

Peripheral LTI model

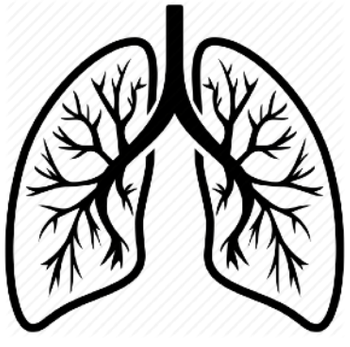
Psychological variable ← Neural activity ← 

— Physiological signal

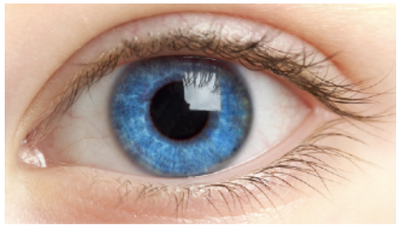


Lecture 3: 16.04.2020

Lecture 5: 30.04.2020



Lecture 6: 07.05.2020



Lecture 4: 23.04.2020

Lecture 6: 07.05.2020

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Thank you!

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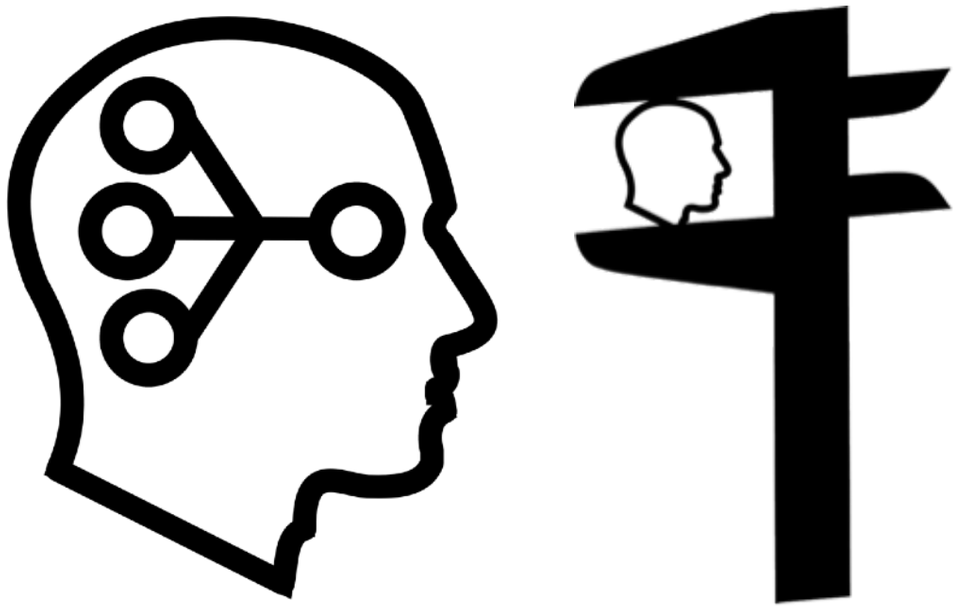

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