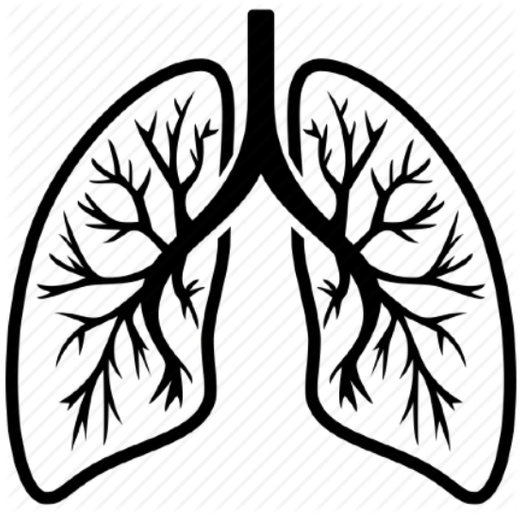
WELLCOME CENTRE FOR HUMAN NEUROIMAGING
MAX PLANCK UCL CENTRE FOR COMPUTATIONAL PSYCHIATRY AND AGEING RESEARCH



PsPM course session 6: Respiration & startle eyeblink

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07.05.2020

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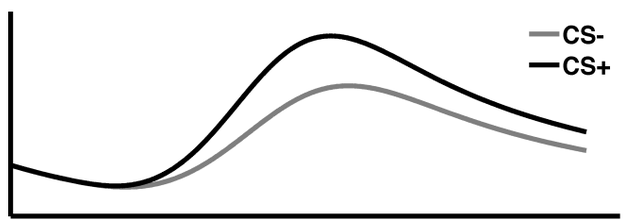
Course overview

CS+/CS- → US → Memory

Memory difference between CS+/CS-?

Lecture 7: 14.05.2020

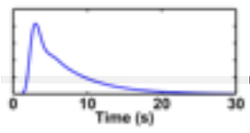


The "best possible" approximation to the true psychological variable.

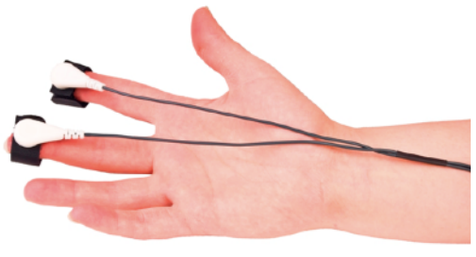
Lecture 2: 09.04.2020

Neural model

Peripheral LTI model

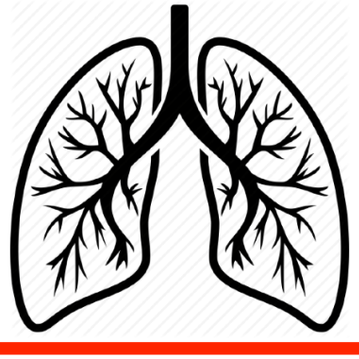
Psychological variable ← Neural activity ← 

— Physiological signal

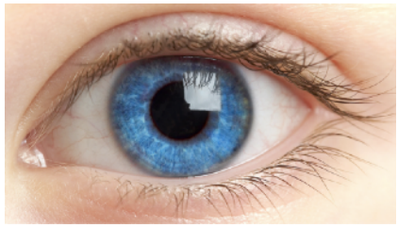


Lecture 3: 16.04.2020

Lecture 5: 30.04.2020



Lecture 6: 07.05.2020



Lecture 4: 23.04.2020

Lecture 6: 07.05.2020

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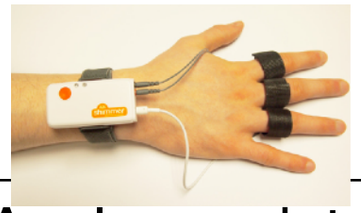
PsPM pipeline overview

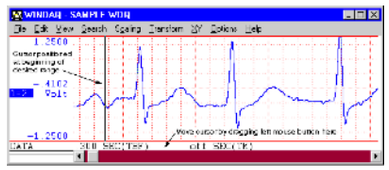


Analogue data recording

If possible, only anti-aliasing filter

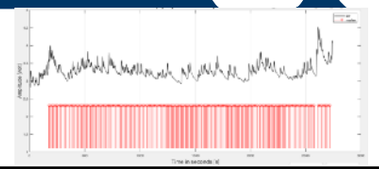
Digitisation

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

From now on really only a "cognitive" model: a representation of external stimulation

Psychological variable

Neural model

Not really a pure peripheral model anymore ... collapses all sort of central/ neural/peripheral processes

Peripheral LTI model

Neural activity

Physiological signal

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

Interest overview

Respiration

Startle

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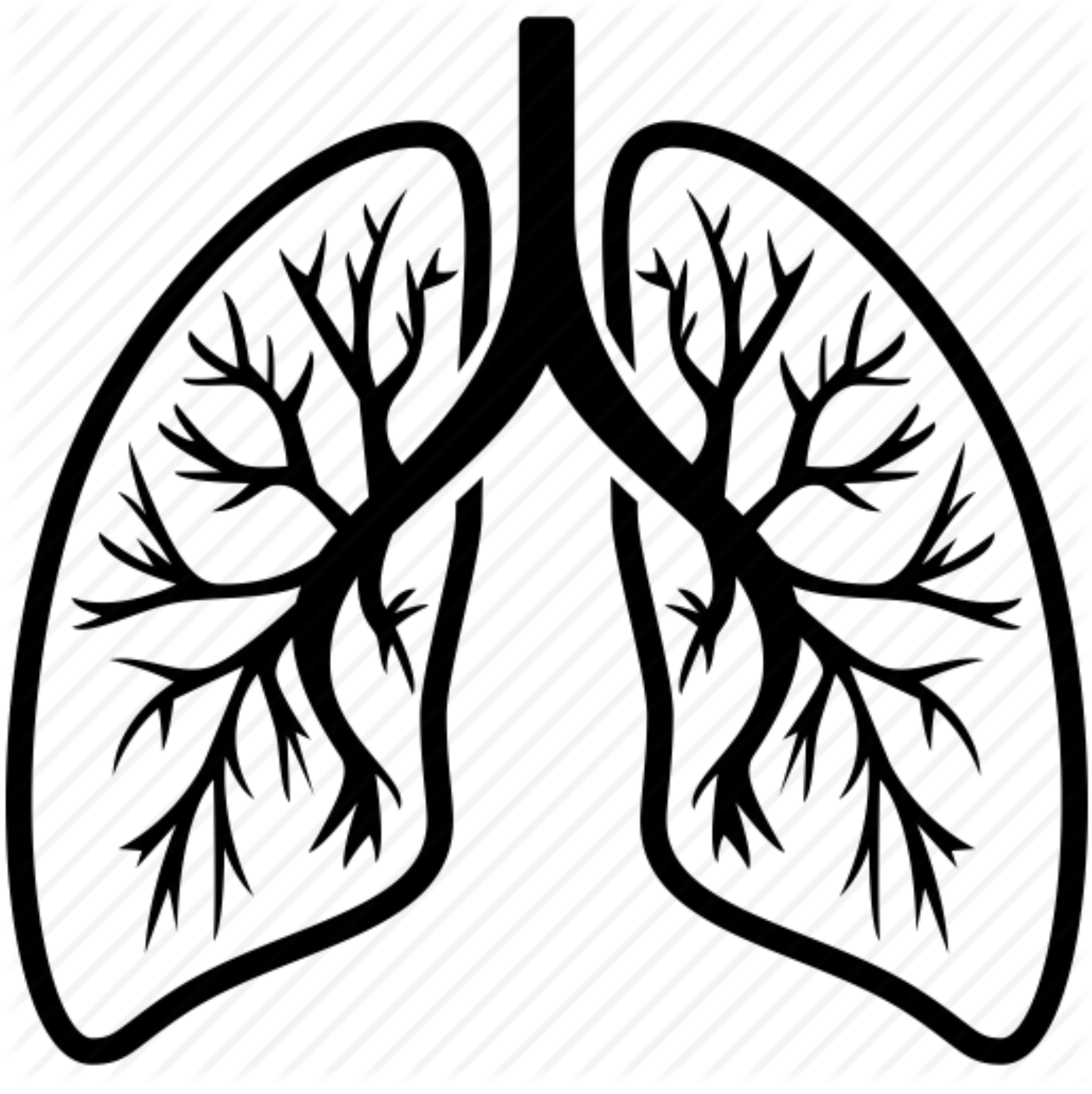
Respiratory responses



Bach et al. (2016), Castegnetti et al. (2017)

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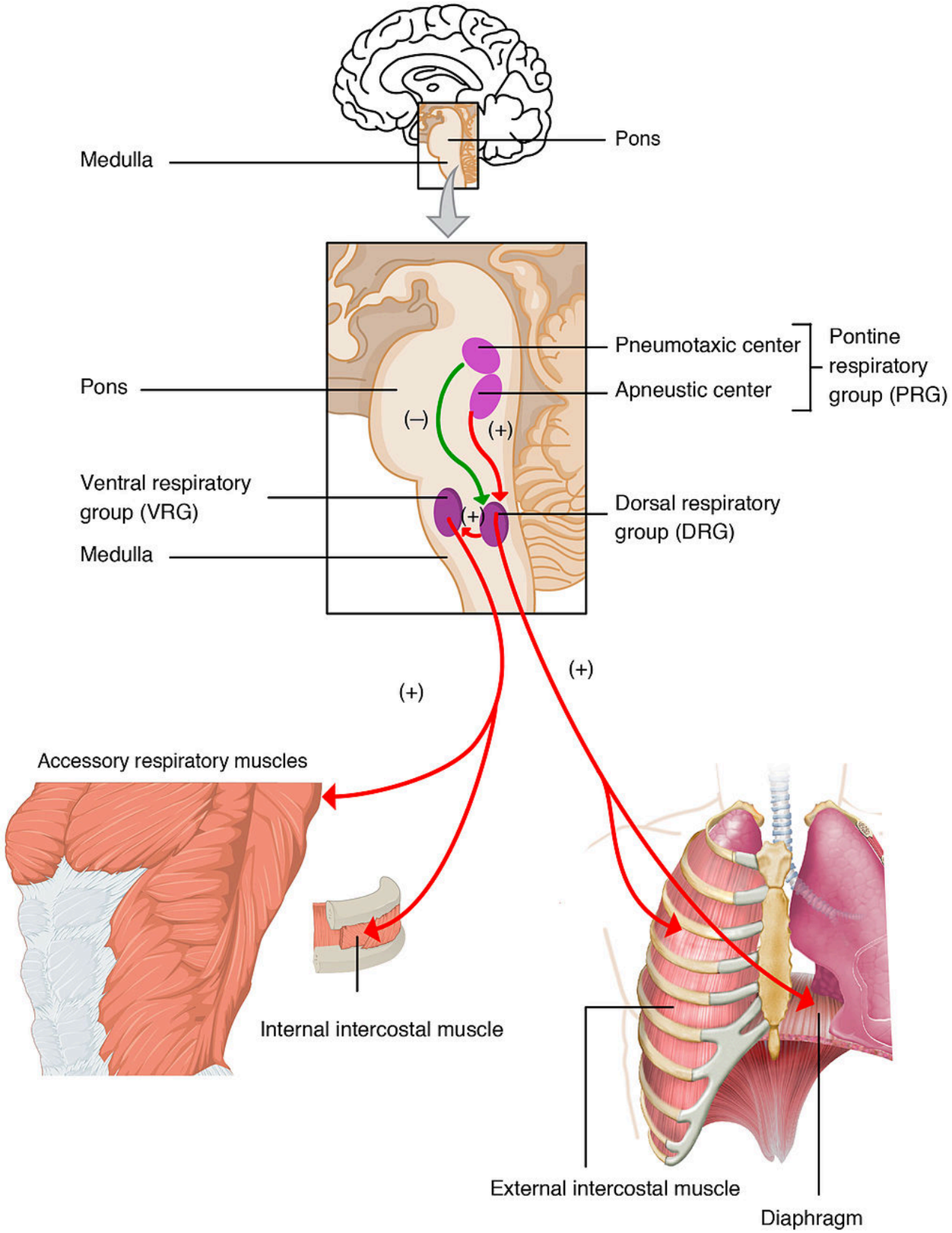
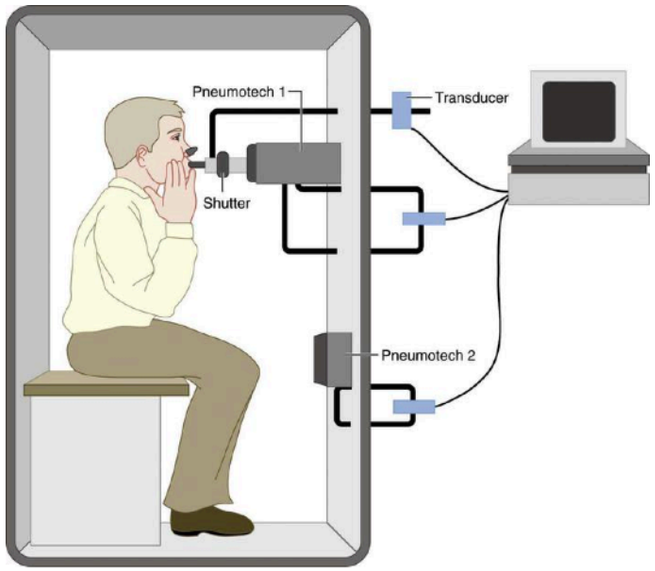
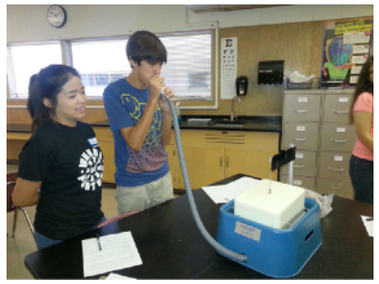
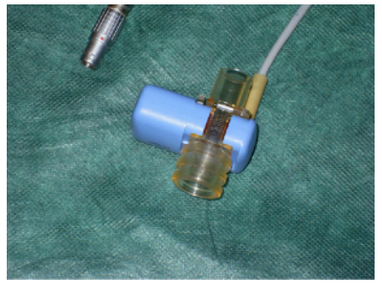
Respiratory physiology



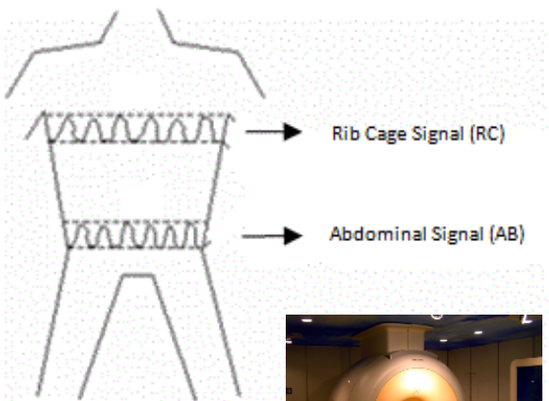




Spirometry



Capnography



Plethysmography via single- or double-belt (chest & abdominal) system (pressure, airflow, frequency modulation)

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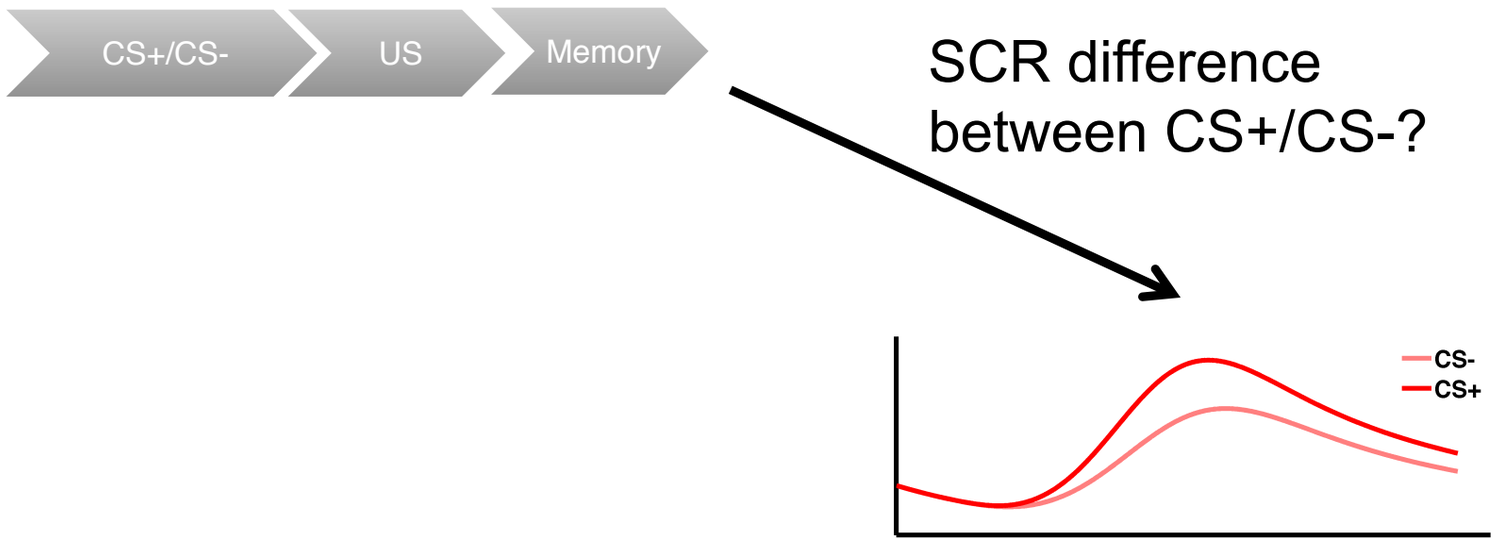
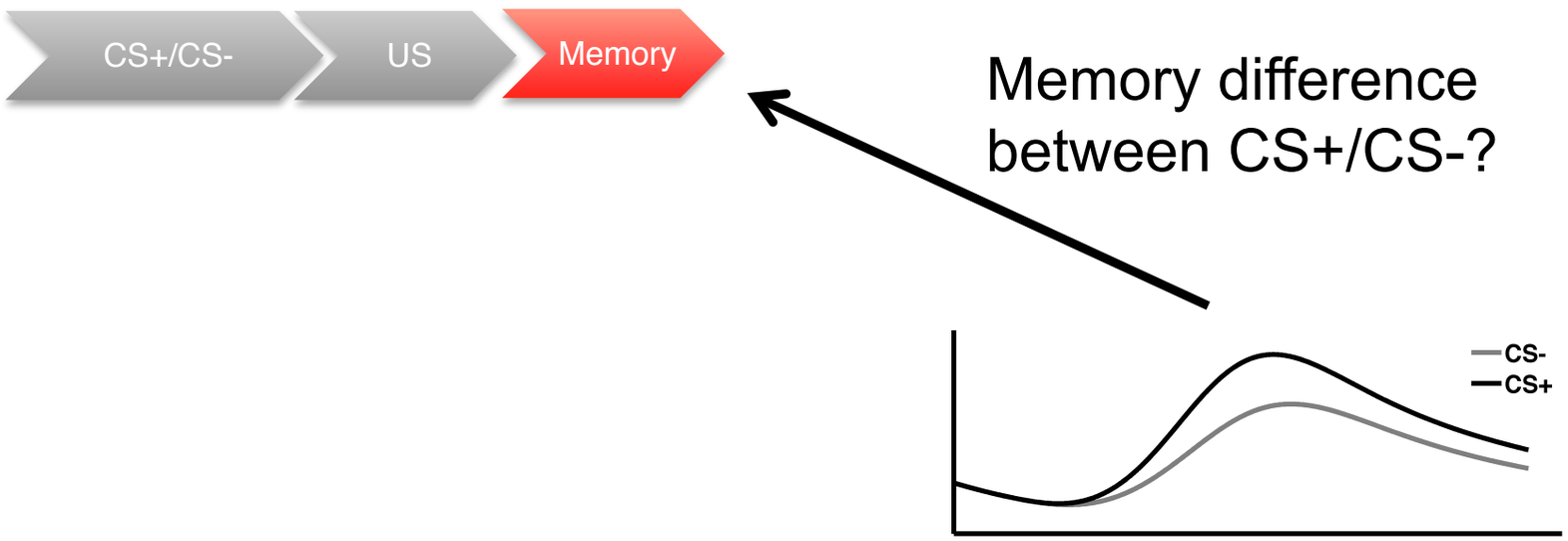
Bach et al. (2016) Journal of Neuroscience Methods

Forward and inverse perspective



Forward perspective: does aversive memory influence SCR?



Inverse perspective: does my procedure establish aversive memory (measured by SCR)?

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Respiratory responses over seconds to minutes

- Respiration patterns, gas exchange parameters, airway responses

Orienting response

- Conjecture: respiratory component specifically related to stimulus novelty [1]
- Measured by inspiratory pauses
- Termed "surprise" in [2]
- Empirical evidence weak

Respiratory startle

- “a short-latency [inspiratory] startle response, followed by a delayed phasic increase in depth and rate of breathing“ [2]

Respiration line length (RLL)

- Total length of the respiratory trace over 15 s
- Conjectured to discriminate between crime-relevant and -irrelevant items in concealed information test

Fear conditioning

- Respiratory period and end-tidal CO2 pressure [3]

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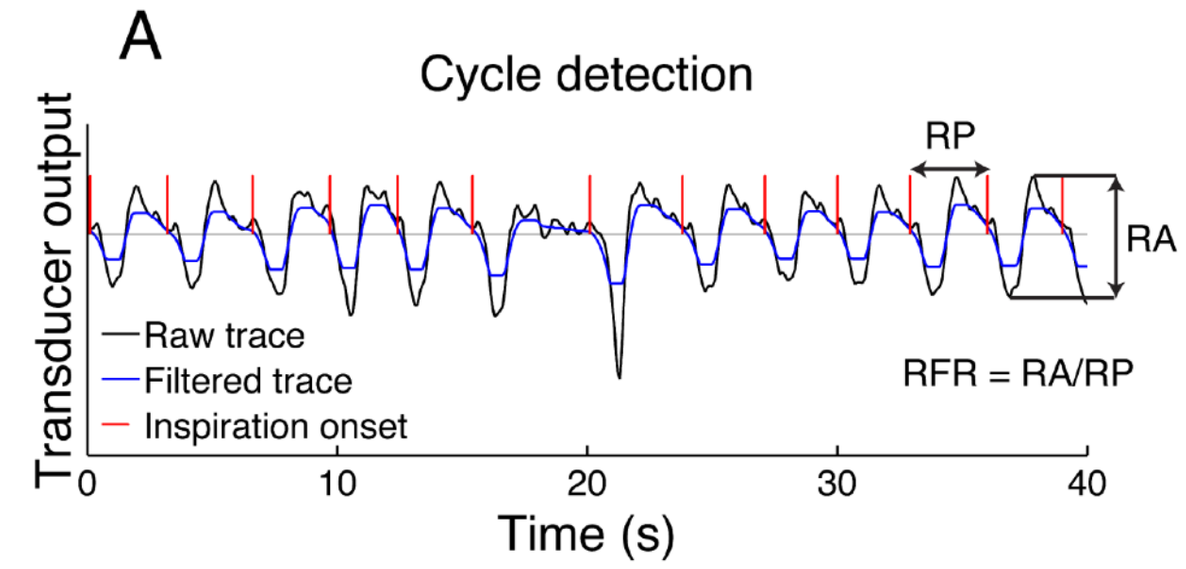
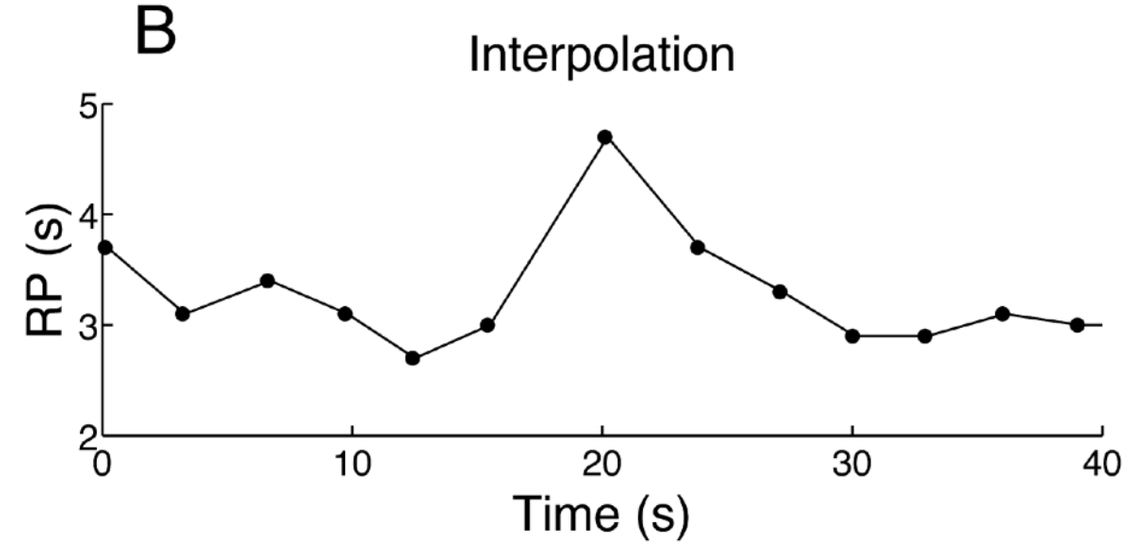
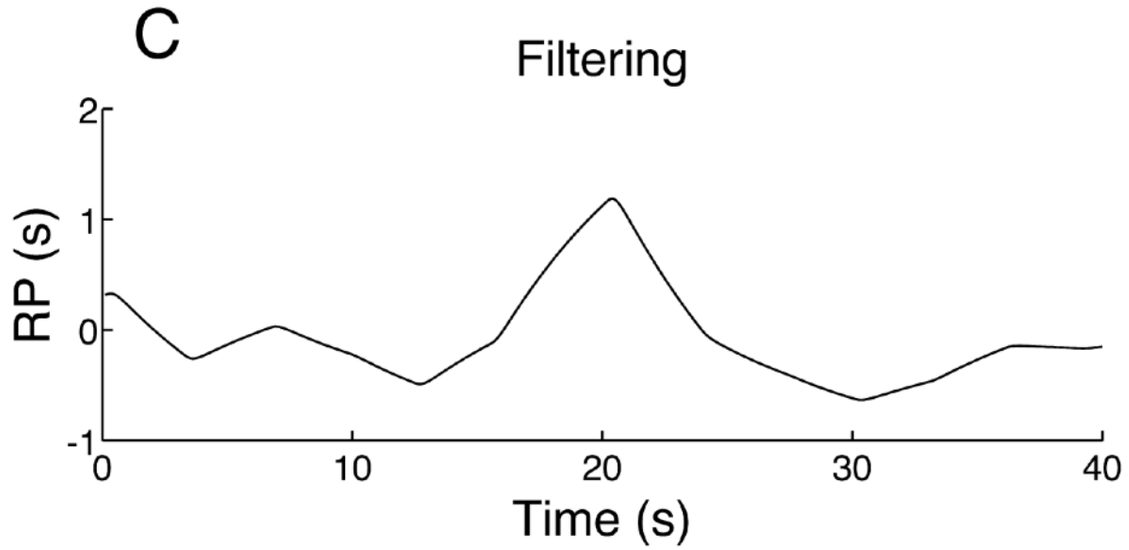
[1] Barry et al. (1977); [2] Boiten et al. (1994); [3] van Diest et al. (2009)

Data pre-processing







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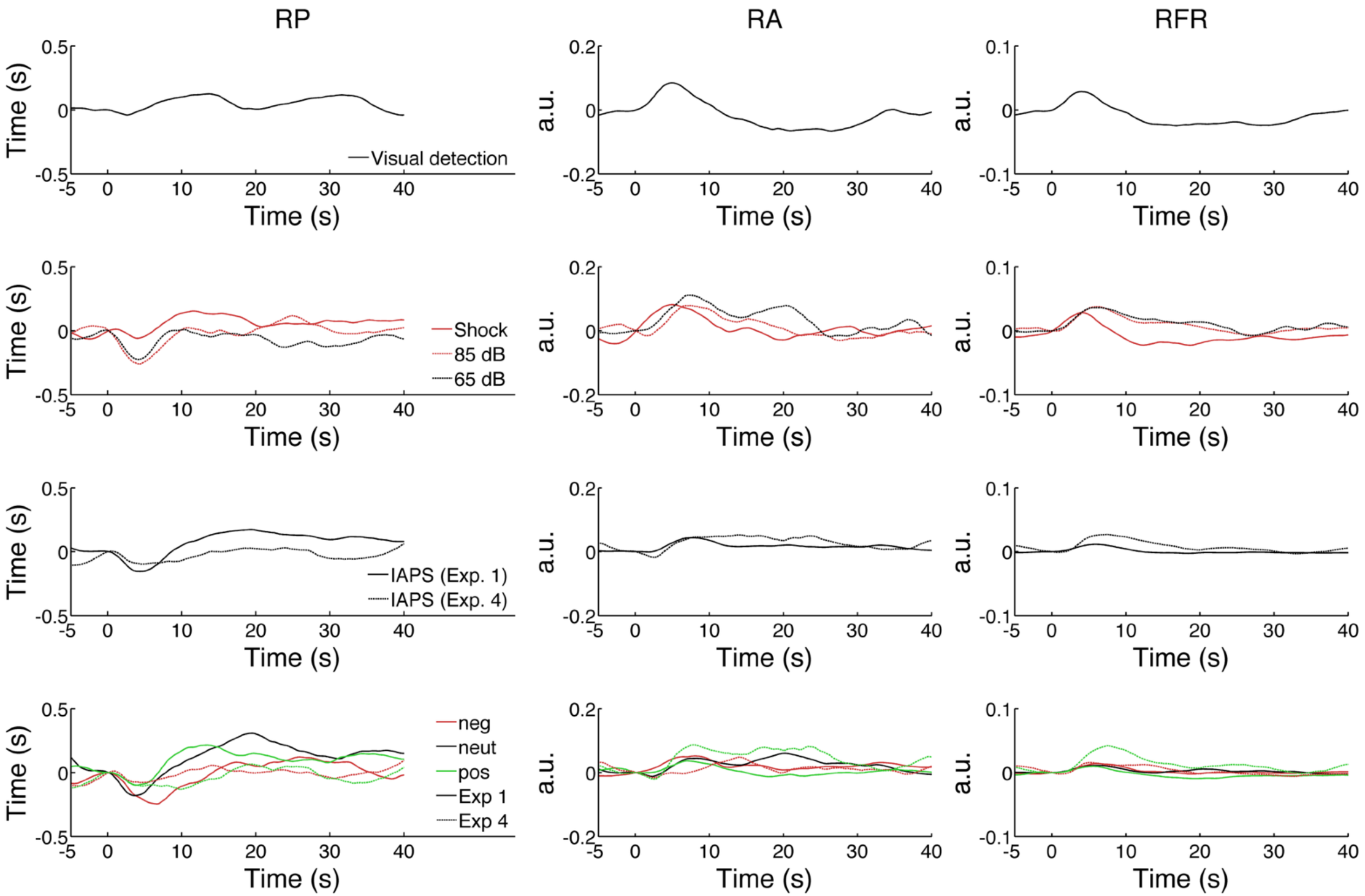
Bach et al. (2016) Journal of Neuroscience Methods

Evoked respiratory responses



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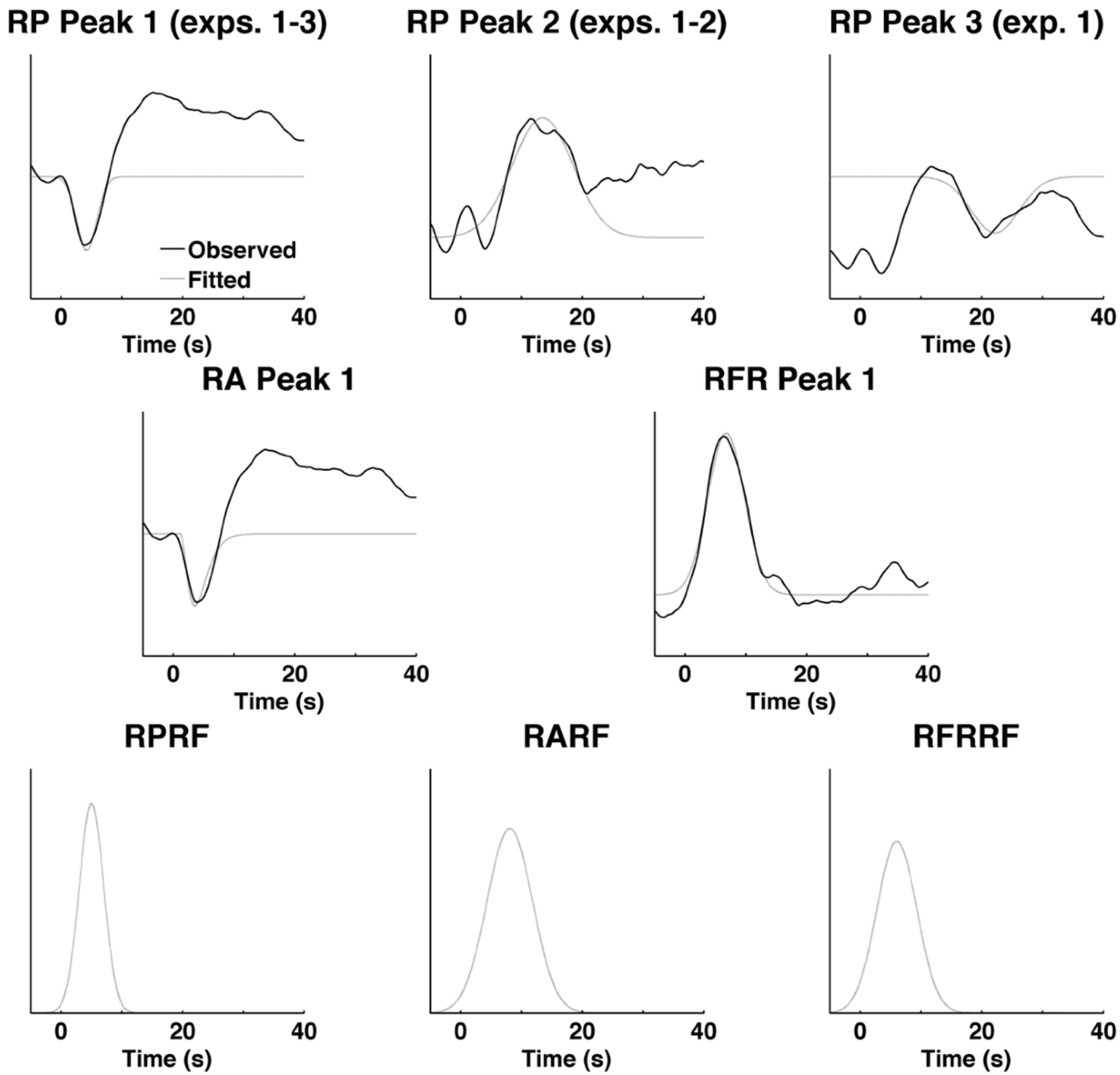
Forward model (evoked)



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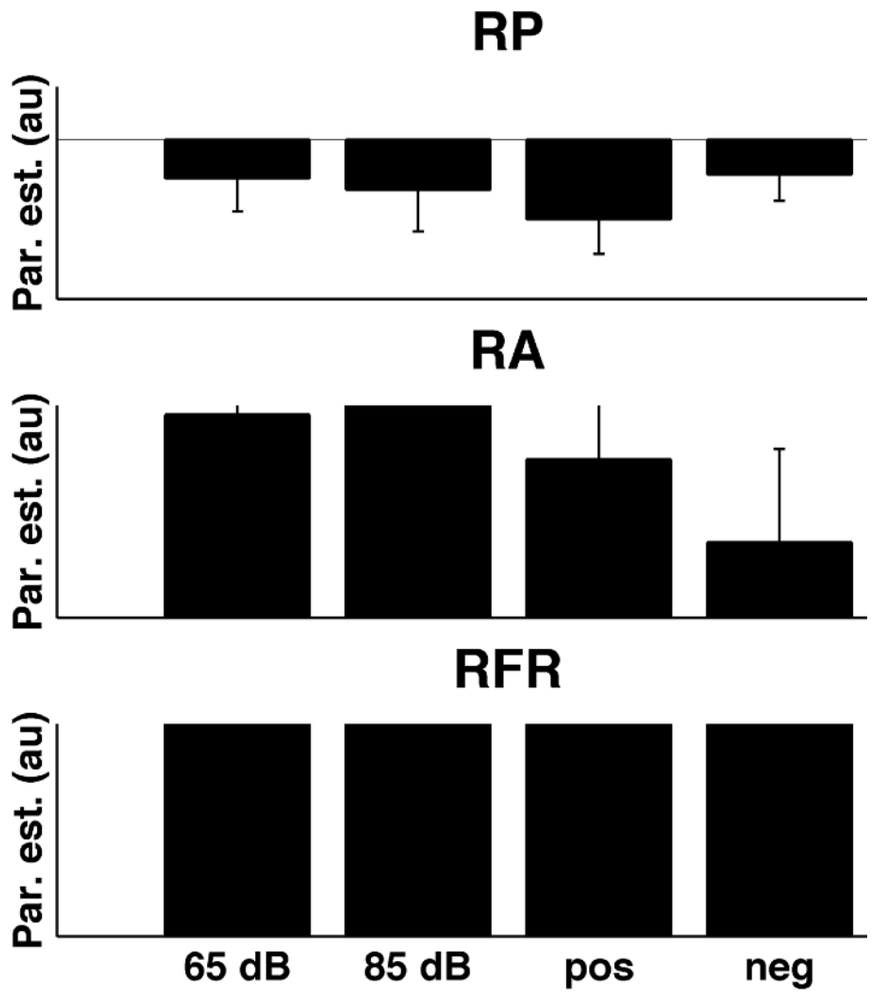
Bach et al. (2016) Journal of Neuroscience Methods

Evoked respiratory responses: validation

	Overall effect (intercept)	Aversive sounds vs. pictures	Aversive vs. non-aversive sounds	Events vs. non-events
Raw data				
RP	t(19) = -2.68 p = .015	t(19) = -0.65 n. s.	t(19) = -0.71 n. s.	t(19) = -.2.26 p = .036
RA	t(19) = 1.89 p = .074	t(19) = 2.85 p = .010	t(19) = .0.88 n. s.	t(19) = 2.11 p = .048
RFR	t(19) = 4.91 p < .001	t(19) = 2.29 p = .034	t(19) = 1.31 n. s.	t(19) = 3.67 p = .002
Z-scored data				
RP	t(19) = -3.11 p = .006	t(19) = -0.83 n. s.	t(19) = -0.53 n. s.	t(19) = -2.68 p = .015
RA	t(19) = 2.74 p = .013	t(19) = 2.78 p = .012	t(19) = 1.18 n. s.	t(19) = 2.62 p = .017
RFR	t(19) = 5.17 p < .001	t(19) = 2.35 p = .030	t(19) = 1.35 n. s.	t(19) = 4.05 p < .001



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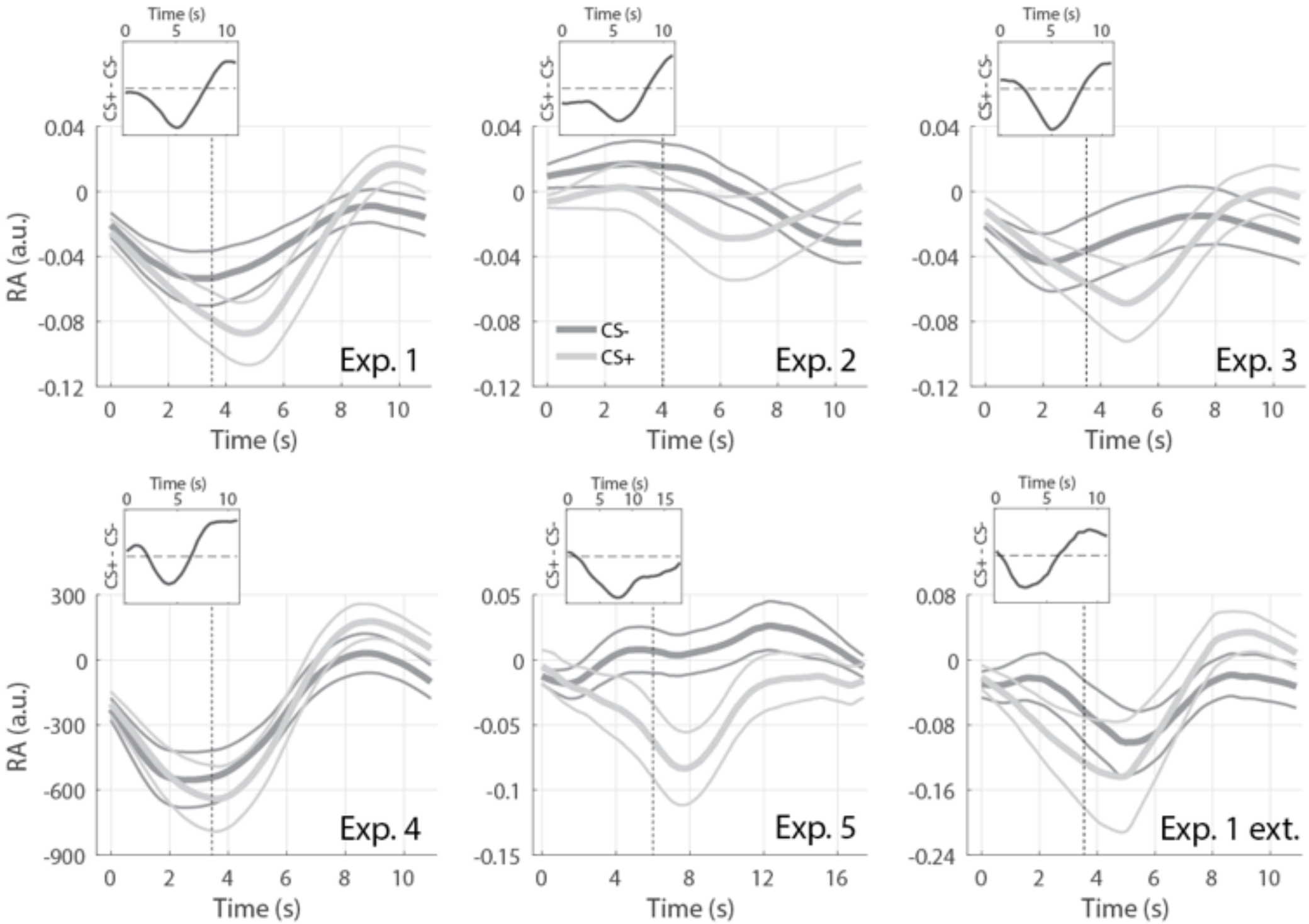
Bach et al. (2016) Journal of Neuroscience Methods

Fear-conditioned RAR: data



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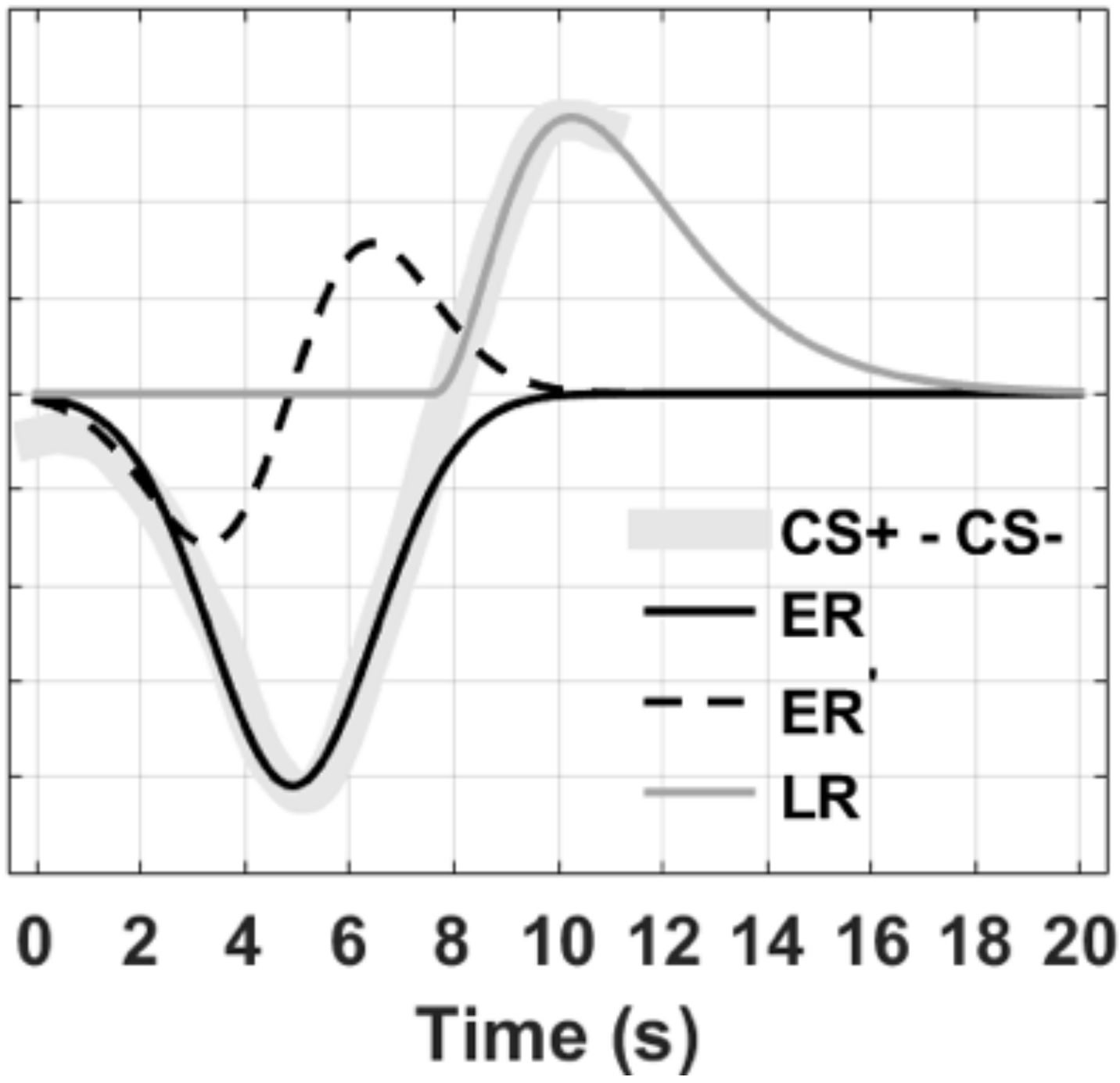
Castegnetti et al. (2017) Psychophysiology

Fear-conditioned RAR: forward model



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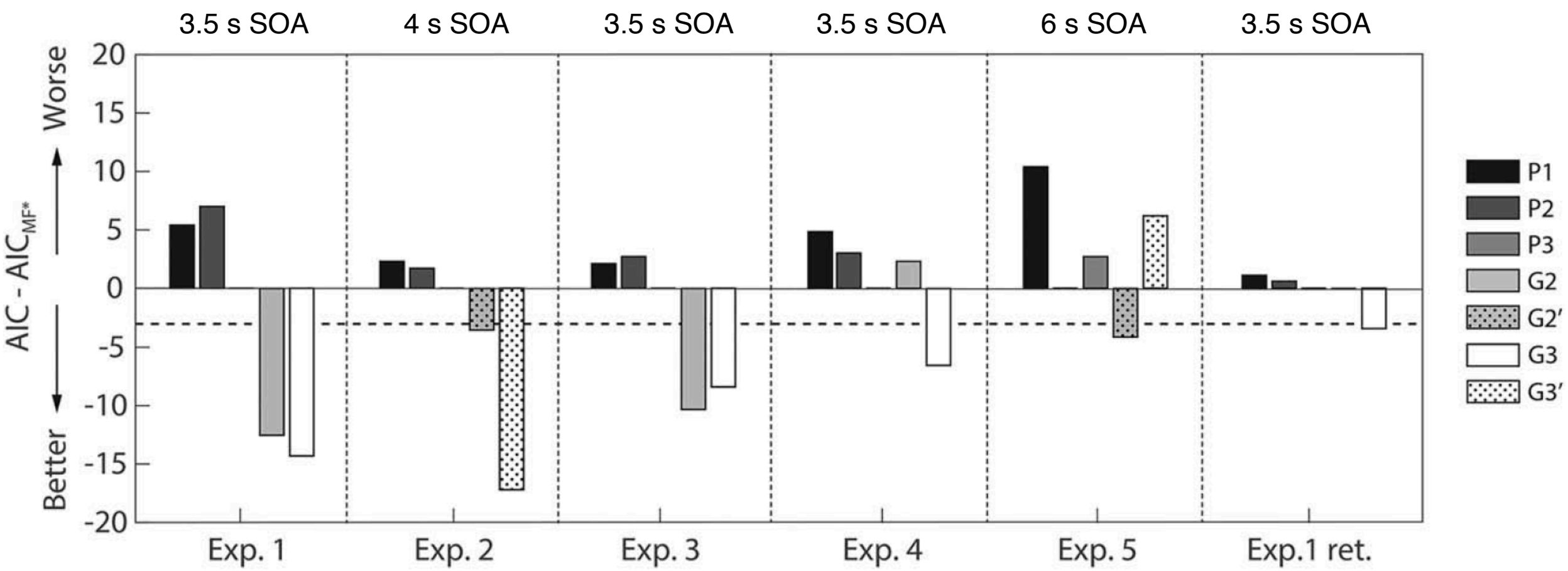
Validation



#	Model description
P1	Maximum variation from baseline
P2	Peak scoring
P3	Average in the 2–7 s window
G1	Canonical response
G2	$ER + \frac{dER}{dt}$
G3	$ER + LR$
G4	$ER + \frac{dER}{dt} + LR$

← Best models in Experiment 1

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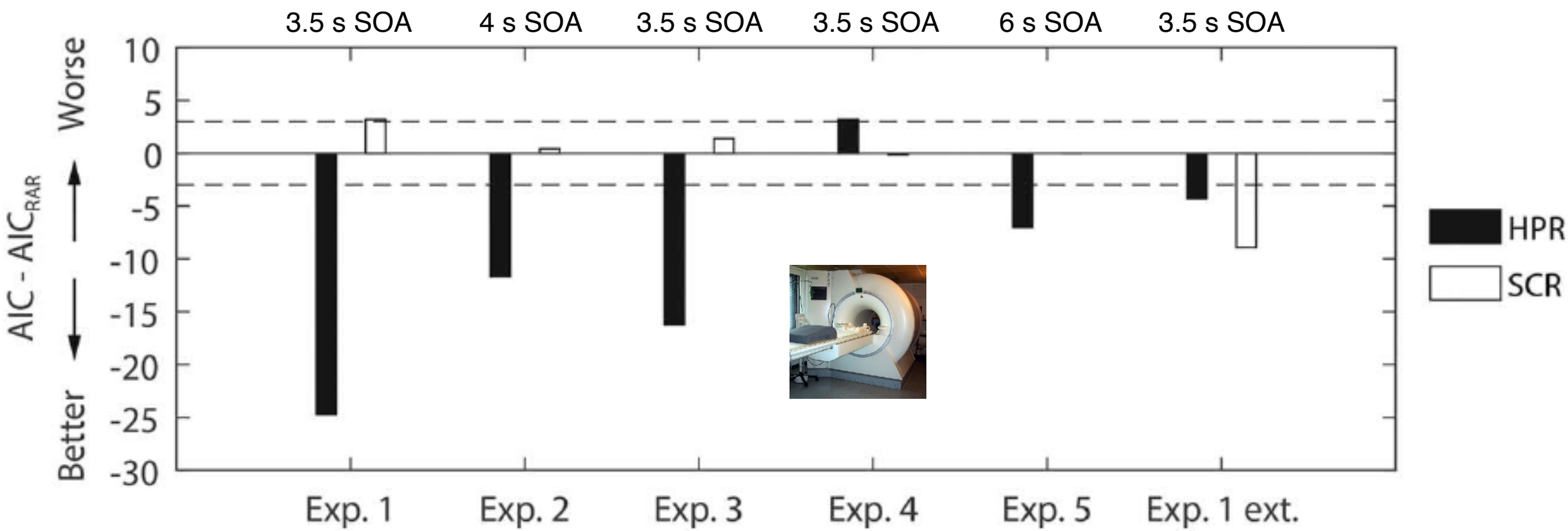
Castegnetti et al. (2017) Psychophysiology

Comparison to SCR and HPR



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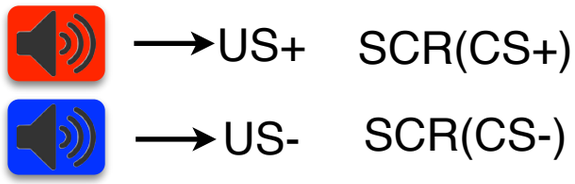
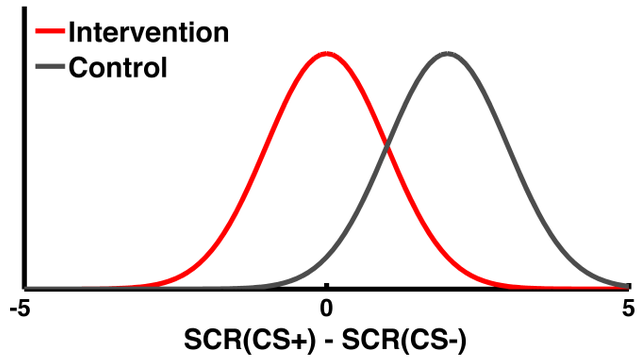
Castegnetti et al. (2017) Psychophysiology

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

Filtering (done on-the-fly)

- Low-pass 1 Hz (evoked) or 2 Hz (FC), downsampling to 10 Hz
- High-pass filters not yet empirically optimised on independent data:
  evoked RP: 0.01 Hz unidirectional
  evoked RFR: 0.001 Hz unidirectional
  evoked RA: 0.001 Hz unidirectional
  fear-conditioned RA: 0.01 Hz bidirectional

Response function

- Canonical RF for evoked RP, RFR, RA, interpretable for individual conditions (possibly best with time derivative for RA & RFR)
- Canonical RF for fear-conditioned RA, interpretable for condition differences, no obvious relation to RF for evoked RA
- Best RF for short SOA fear-conditioned RA: early+late component, possibly US-locked, but needs more testing for long SOAs

Conclusion & open questions

- Inference on psychological variables still unclear for evoked responses
- Fear-conditioned RA model requires independent optimisation and validation

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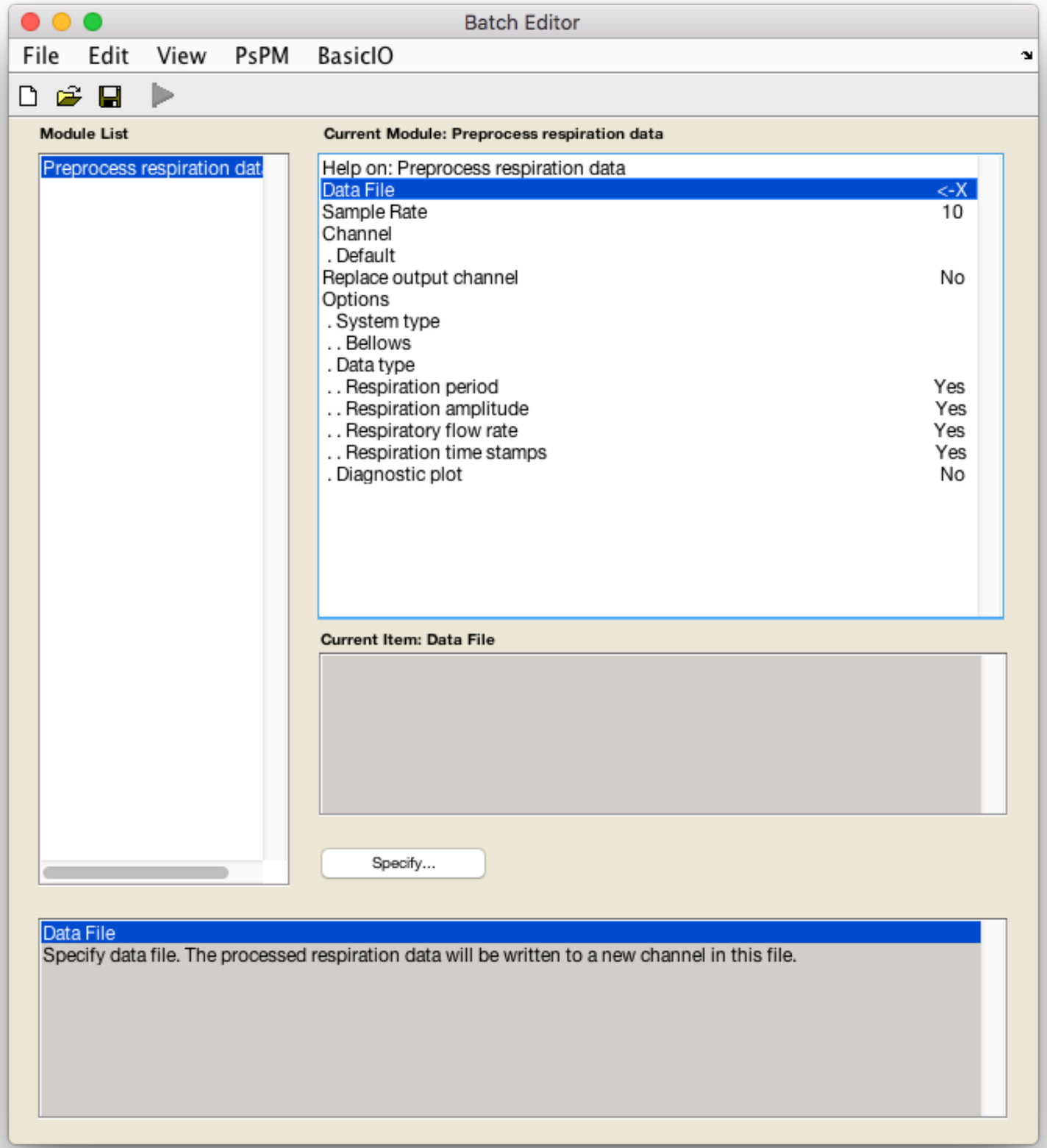
GUI: Preprocessing



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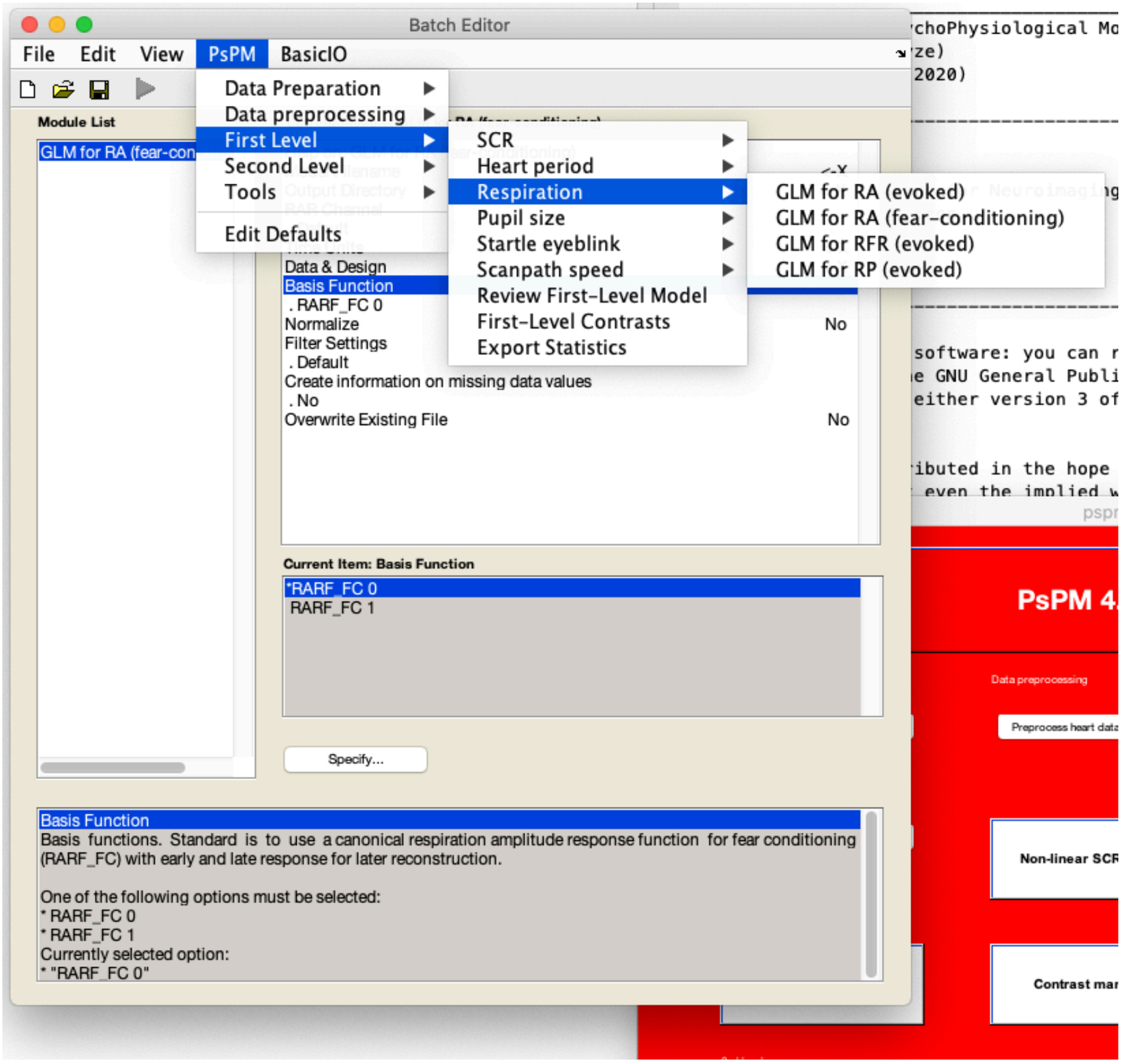
GUI: GLM



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Startle eye-blink responses (SEBR)

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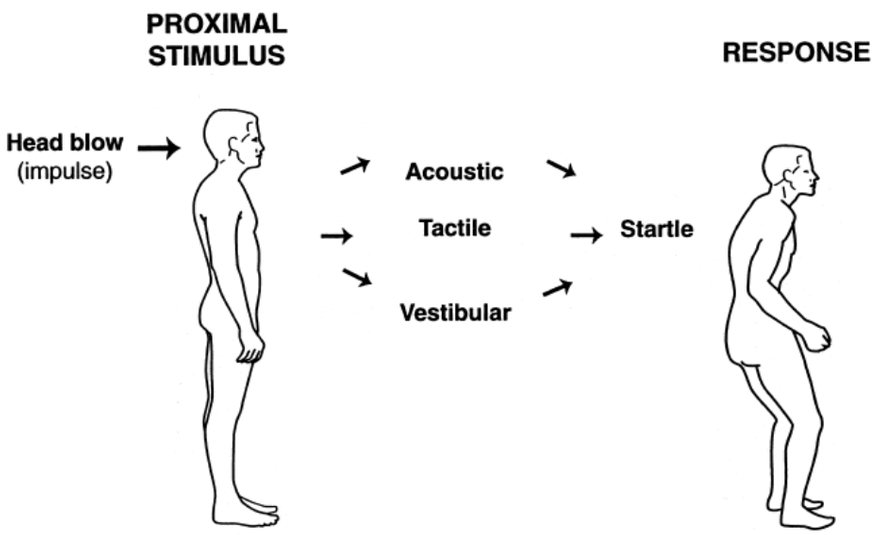
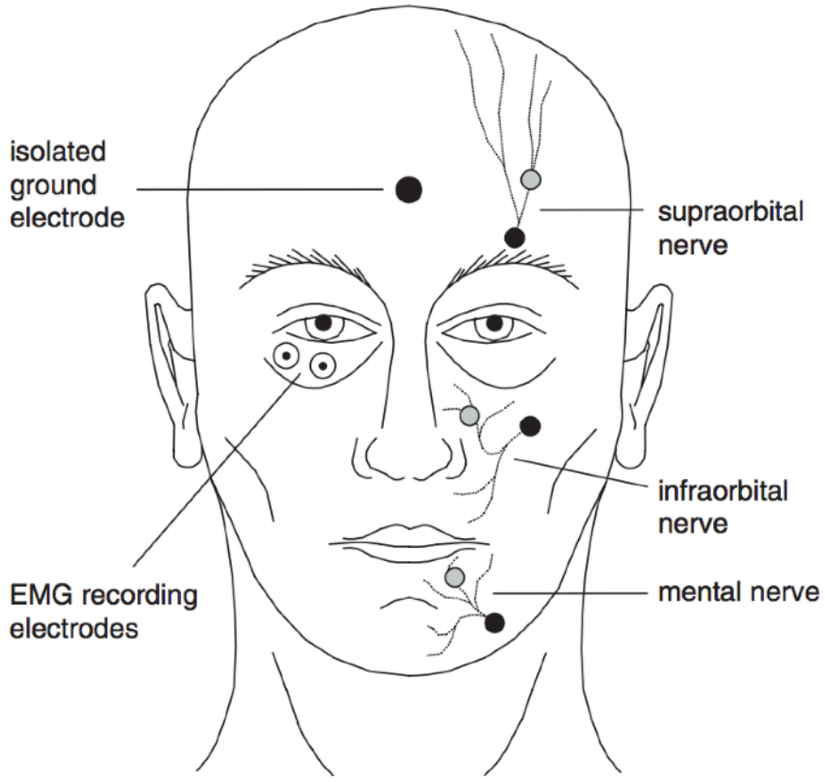
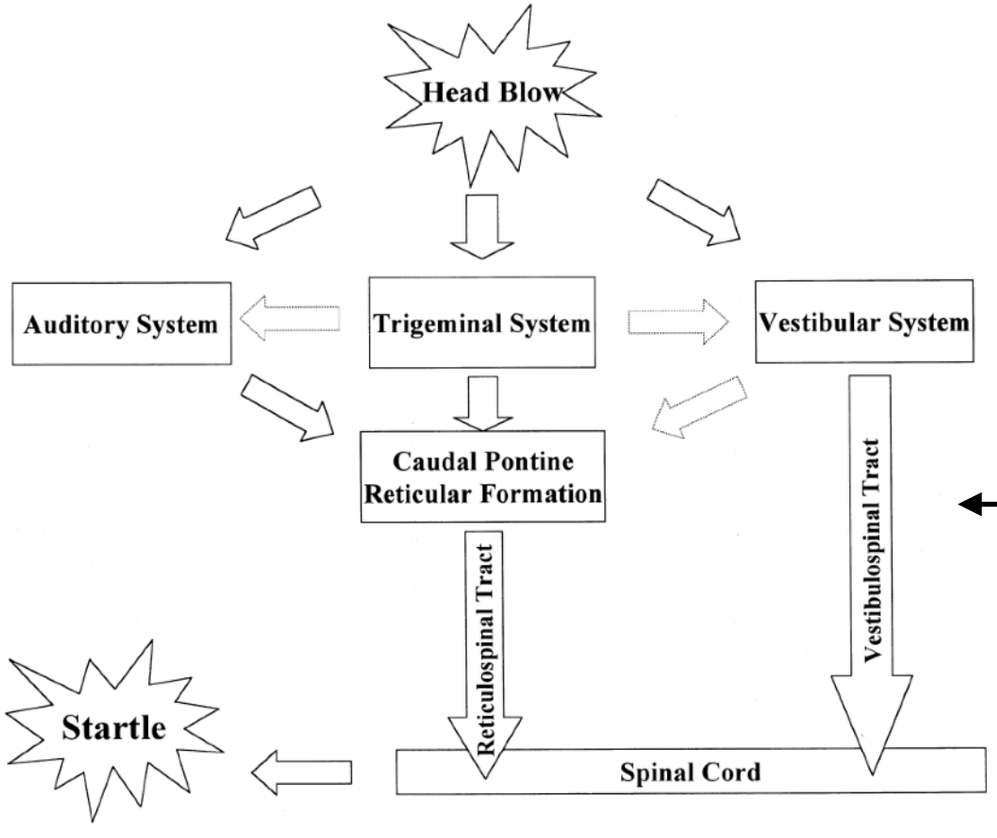
SEBR: physiology







Amygdala efferents
CRF
...

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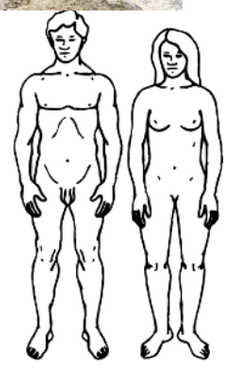
Yeomans et al. (2002), Bach (2015)

SEBR: psychology

Fear-potentiated startle (Brown et al. 1951)

- During CS+ presentation
- In fear-conditioned context
- After prior exposure to foot shocks
- Darkness (rodents: brightness)



Increased startle:
Imagination of negative events
Anticipation of negative events
Instruction to expect electric shock
Presentation of aversive images

Anticipation of financial reward and positive images
Instructed attention

Reduced startle:
Presentation of pleasant images

Motivational Priming Model
Motivational states facilitate compatible reflexes (Lang et al. 1990)

Cost minimisation model
Startle magnitude minimises sum of metabolic and opportunity cost, and survival utility (Bach 2015)

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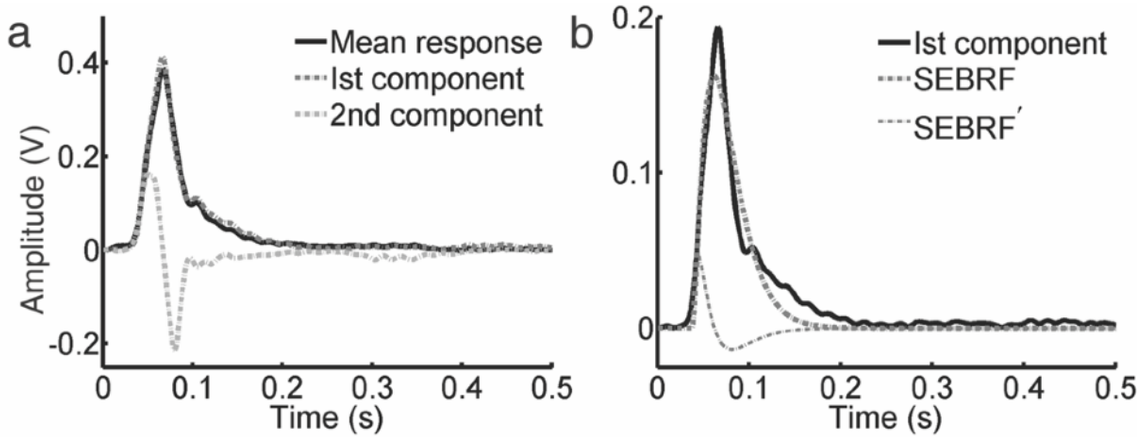
summarized in: Bach (2015) Journal of Theoretical Biology

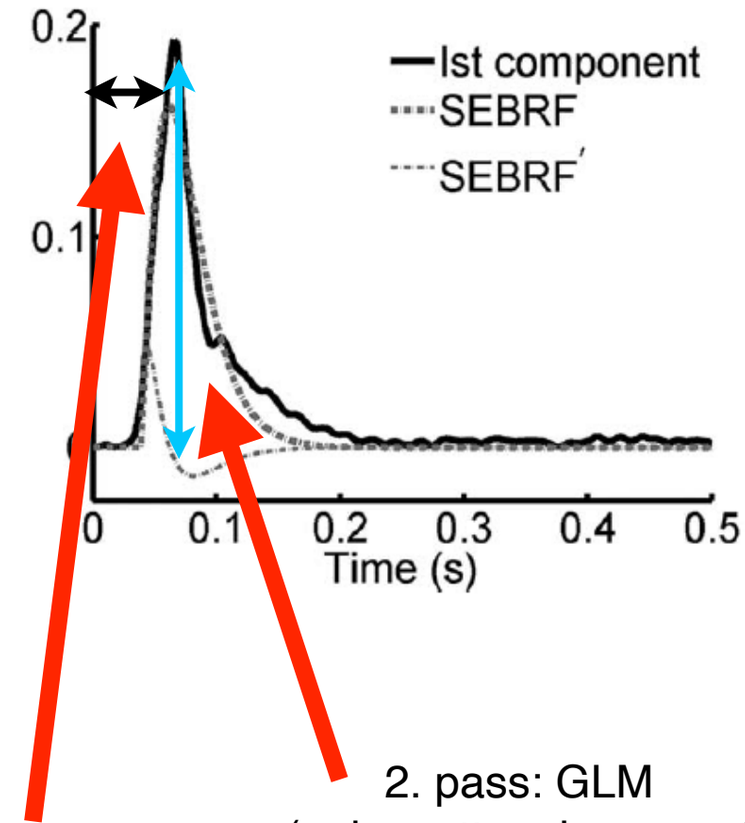
SEBR: forward model



Development data set (25 startle sounds in 20 participants)

- First PC explains ~60% variance

M1	SEBRF	
M2 (ST)	SEBRF + time derivative	ST: single trial
M3	SEBRF + late component	
M4 (ST)	SEBRF with flexible latency	ST: single trial



1. pass: Dictionary matching (i.e. grid search for latency)

2. pass: GLM (only matters in case of overlapping responses)

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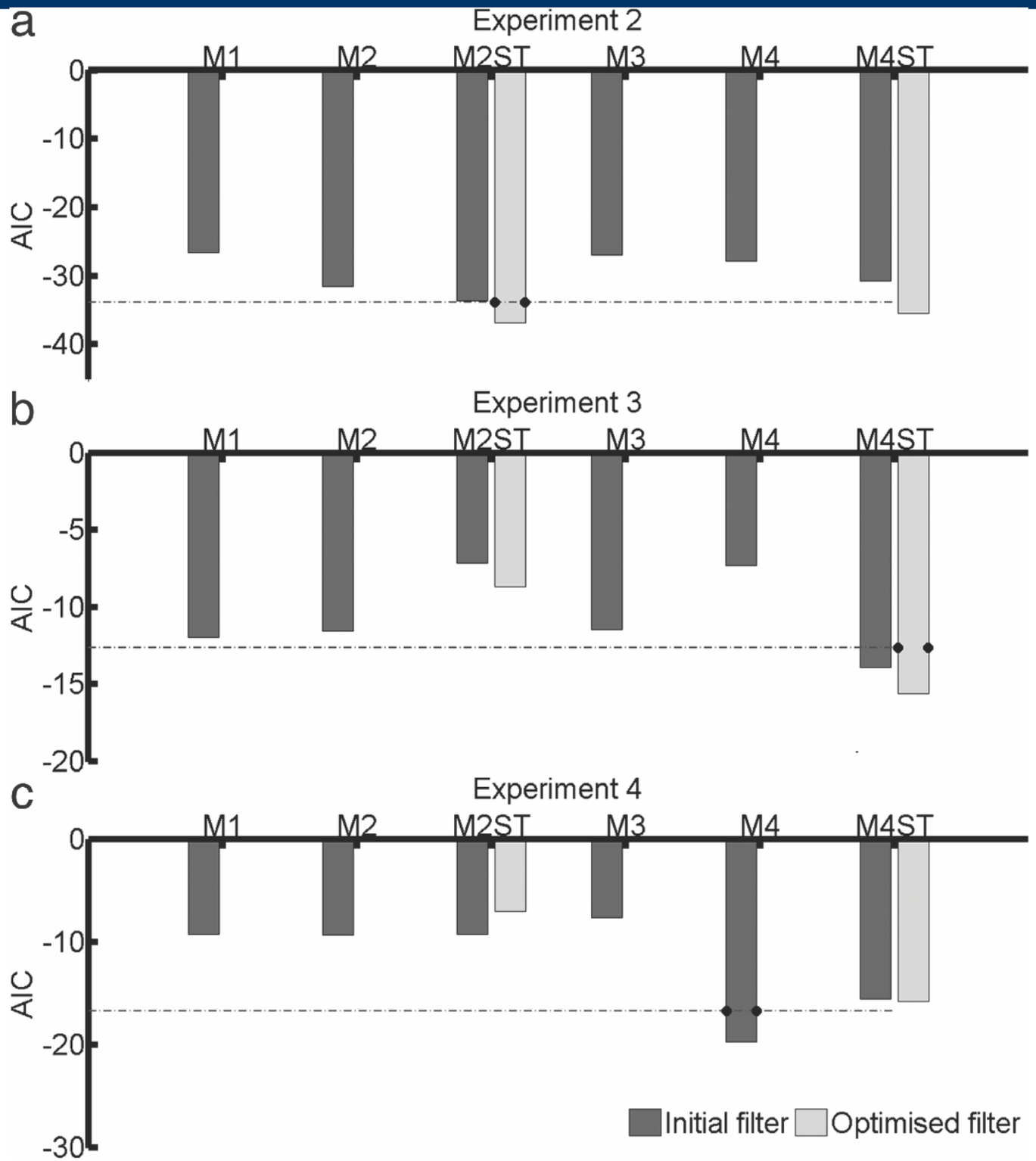
Khemka et al. (2017) Psychophysiology

Model variants



- Development data set: M2ST and M4ST win
- Filter optimisation for both models
- In validation data set (retention), M4ST wins
- In acquisition data set, M4ST wins (but M4 is better -> overfitting of blinks?)

M1	SEBRF	
M2 (ST)	SEBRF + time derivative	ST: single trial
M3	SEBRF + late component	
M4 (ST)	SEBRF with flexible latency	ST: single trial

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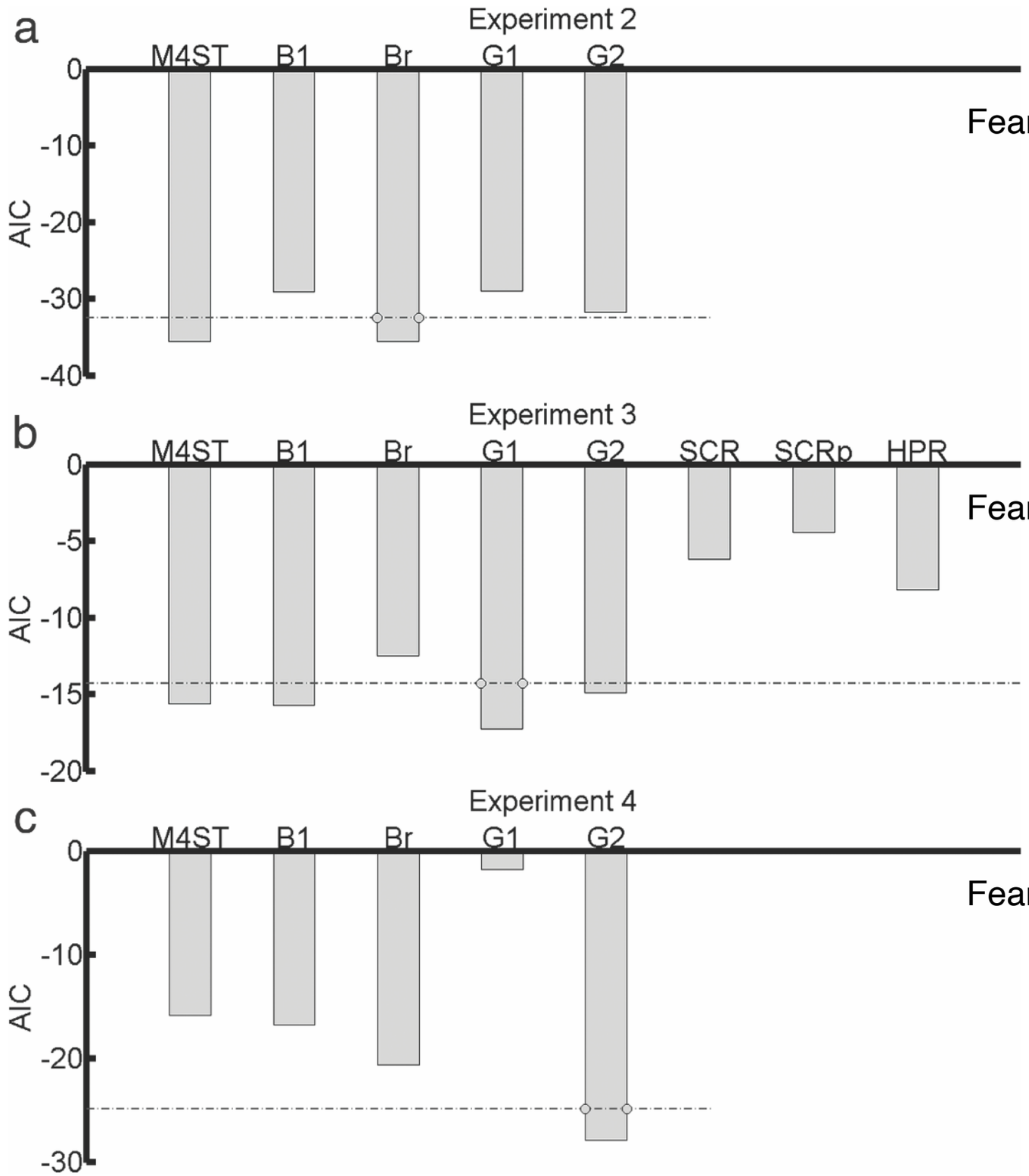
Khemka et al. (2017) Psychophysiology

Comparison with other measures



Fear retention

Fear retention w/o startle recordings

Fear acquisition

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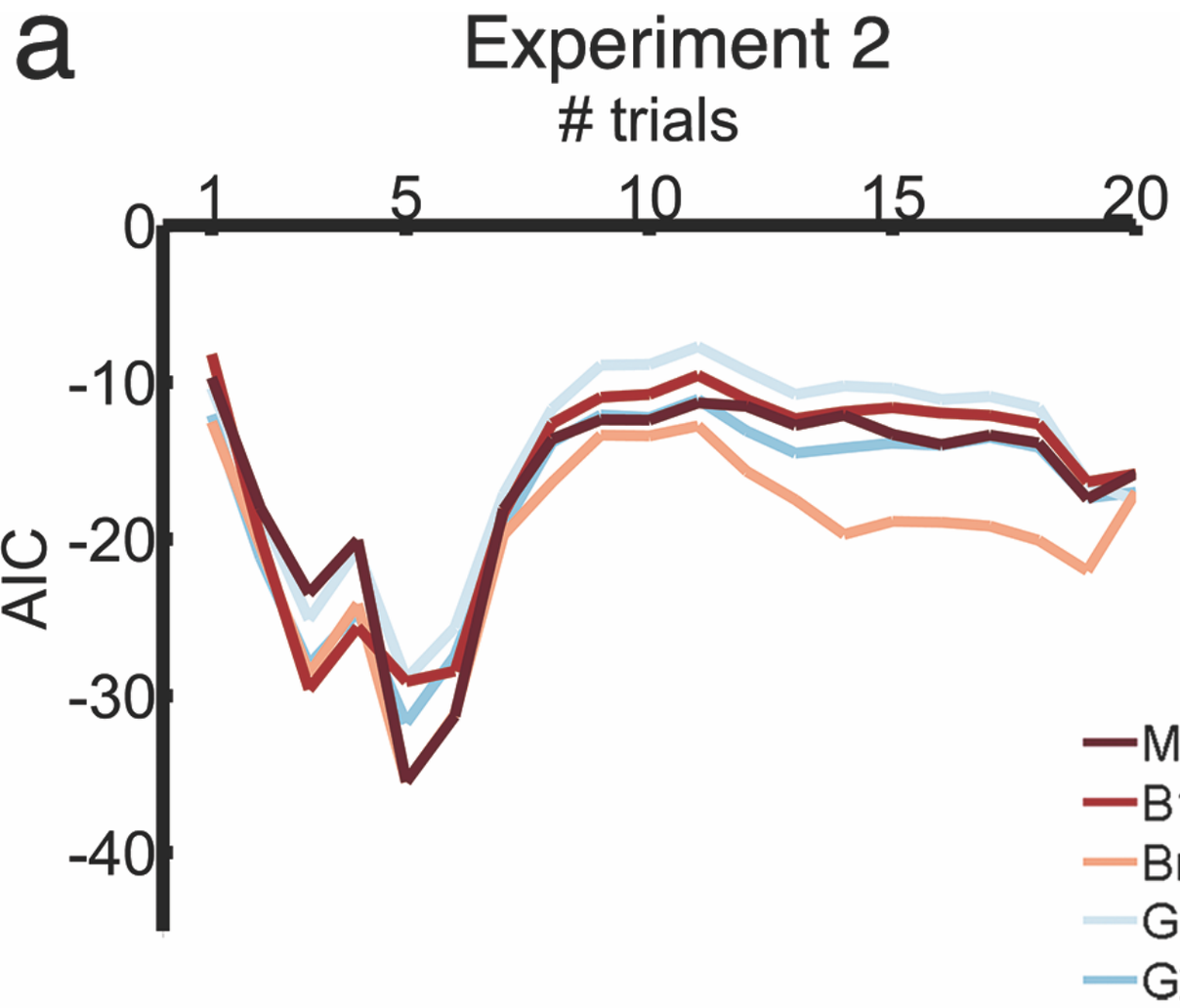
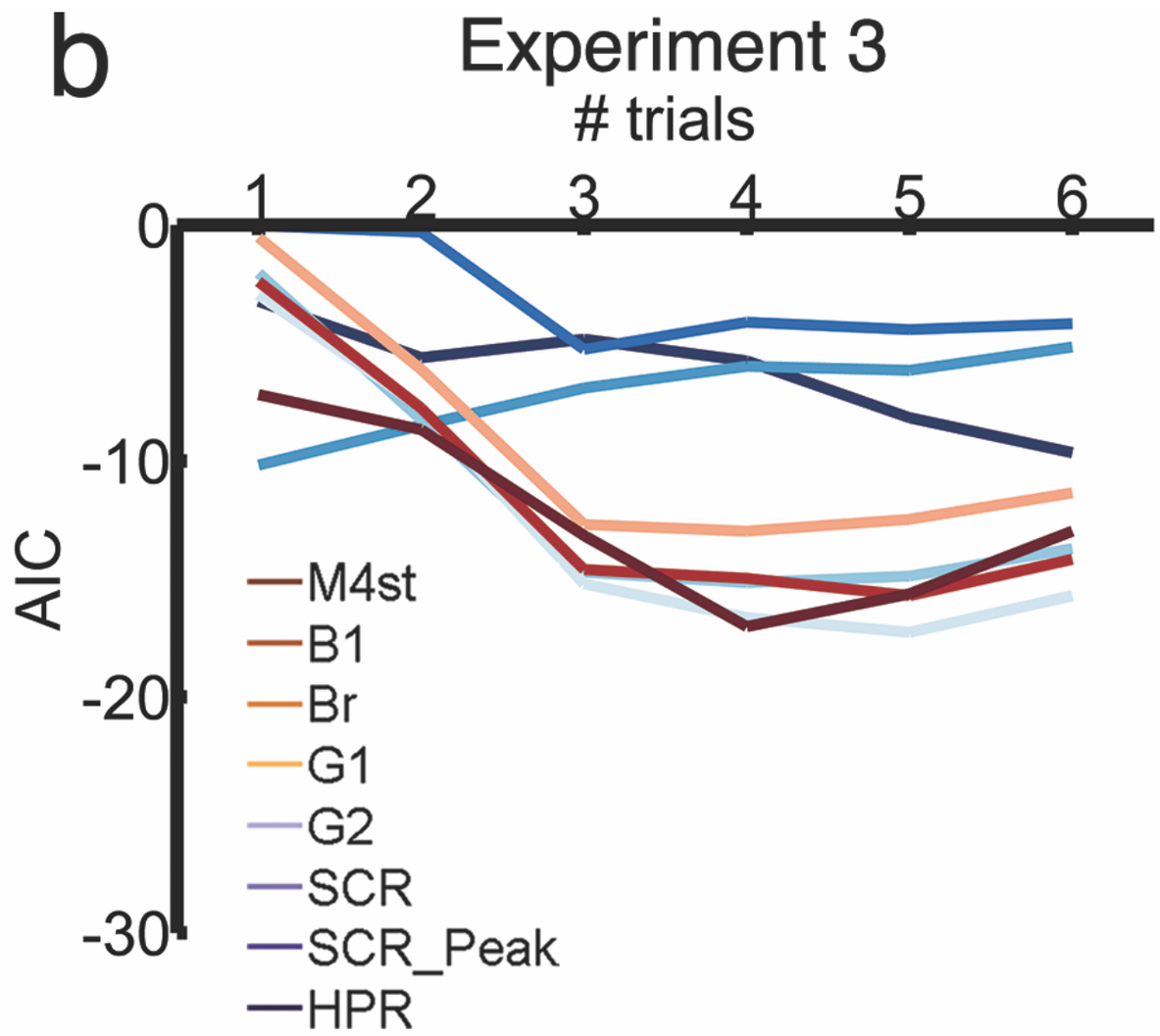
Khemka et al. (2017) Psychophysiology

Measuring fear memory retention





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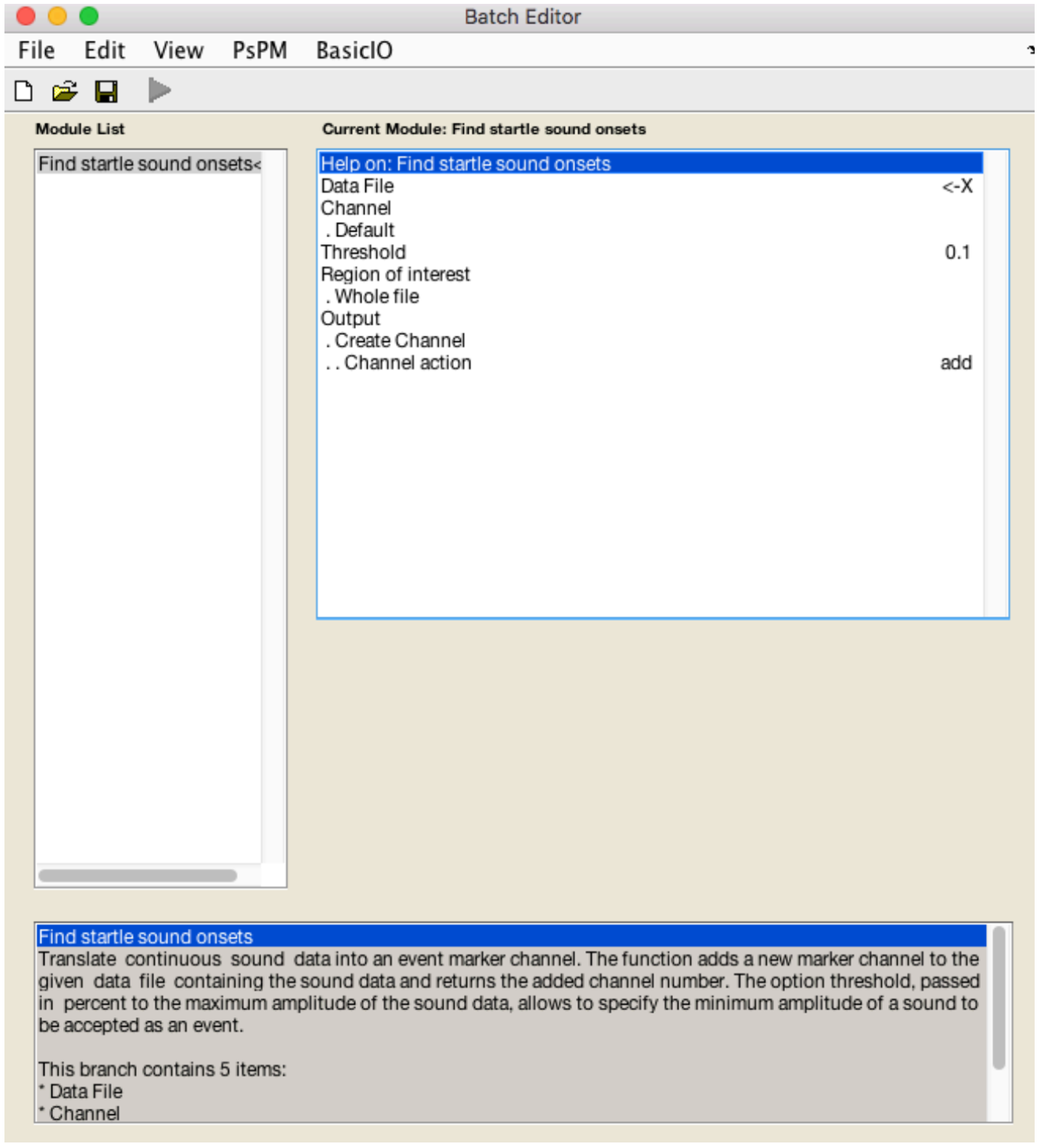
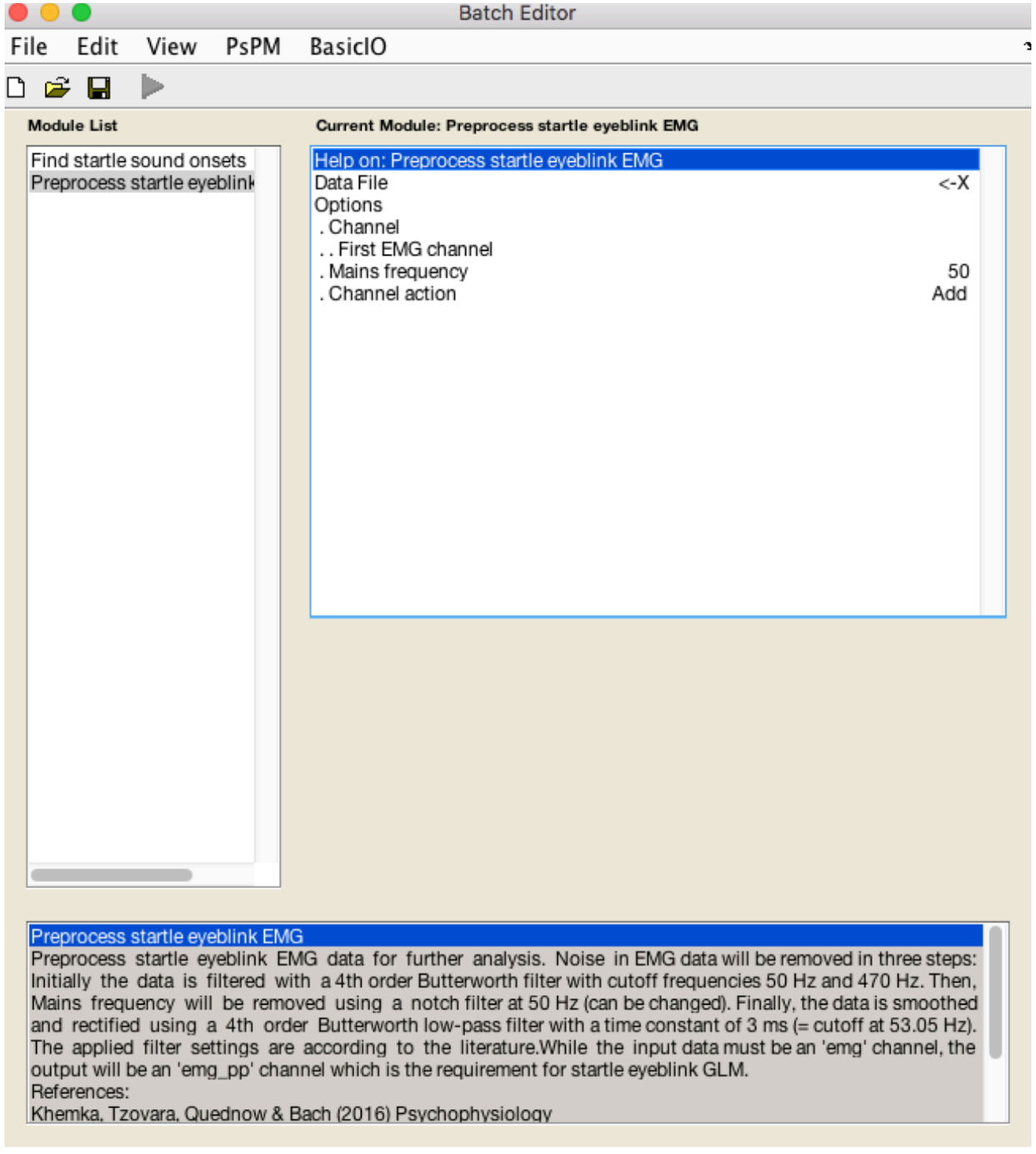
Khemka et al. (2017) Psychophysiology

SEBR: GUI implementation





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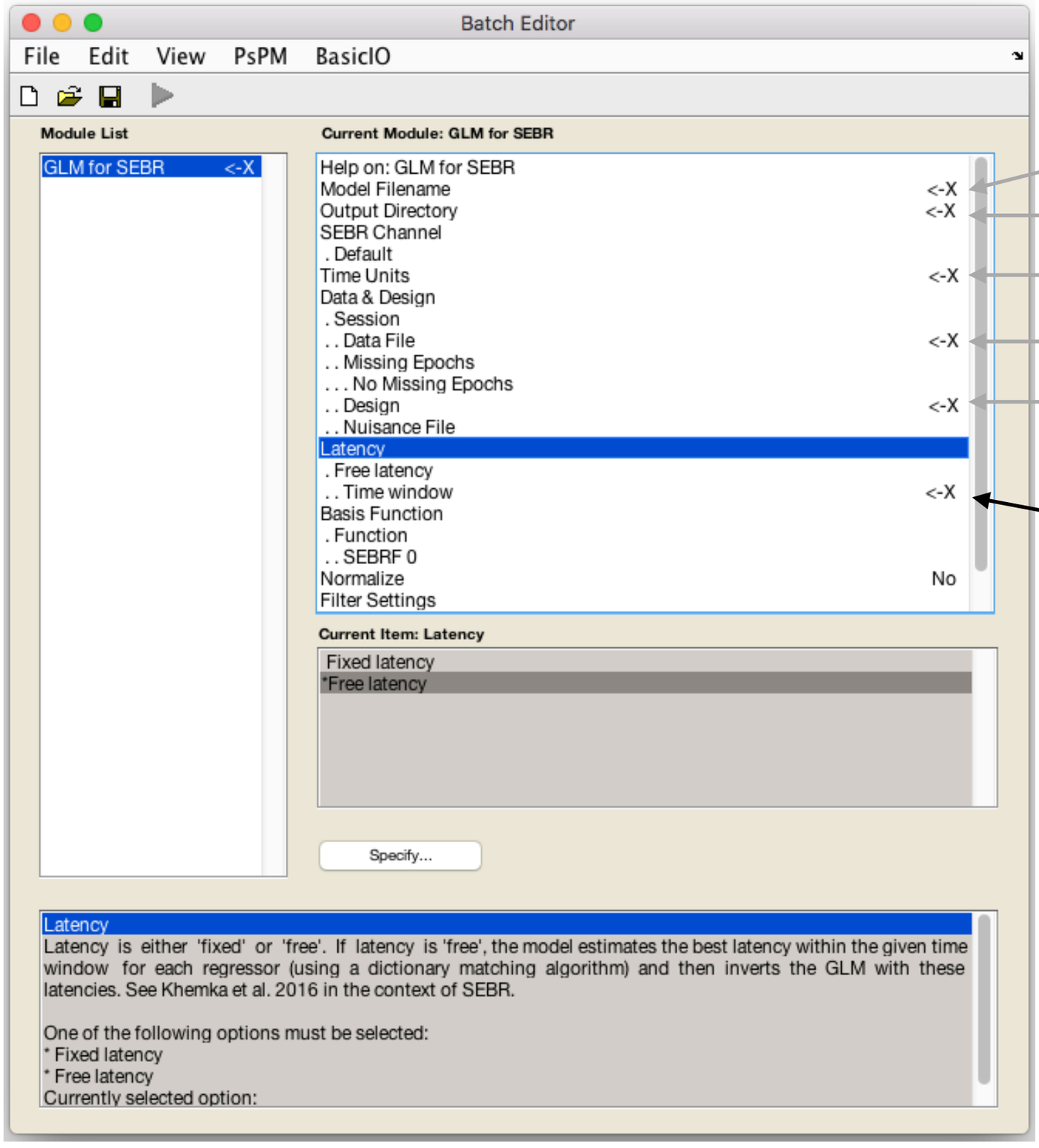
SEBR: GUI implementation



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)

Latency time window depends on experimental hardware, see Khemka et al. 2017

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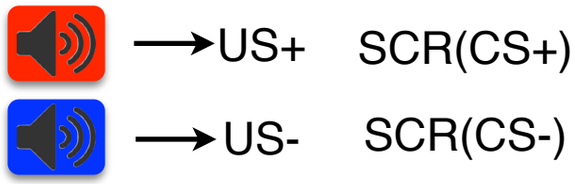
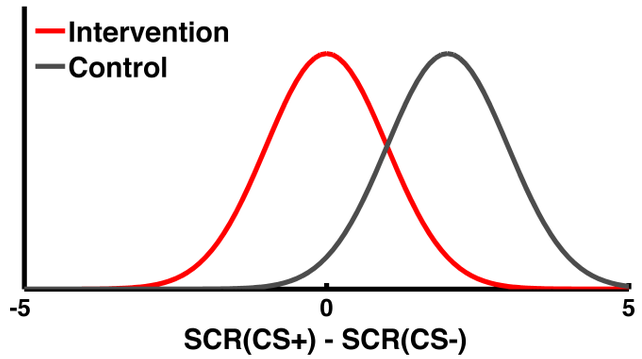
Comparison of measurement models





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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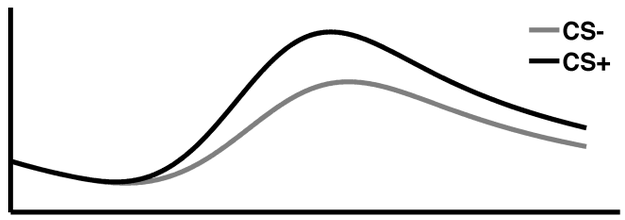
Bach & Melinscak (2020) Beh Res Ther

Outlook

CS+/CS- → US → Memory

Memory difference between CS+/CS-?

Lecture 7: 14.05.2020

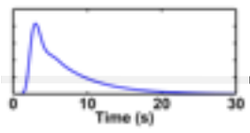


The "best possible" approximation to the true psychological variable.

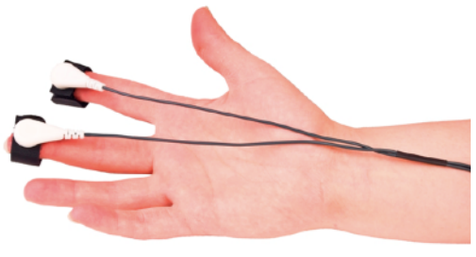
Lecture 2: 09.04.2020

Neural model

Peripheral LTI model

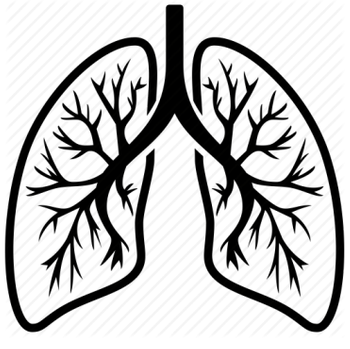
Psychological variable ← Neural activity ← 

— Physiological signal

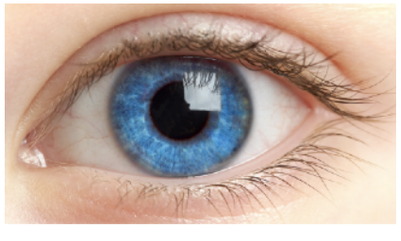


Lecture 3: 16.04.2020

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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erc

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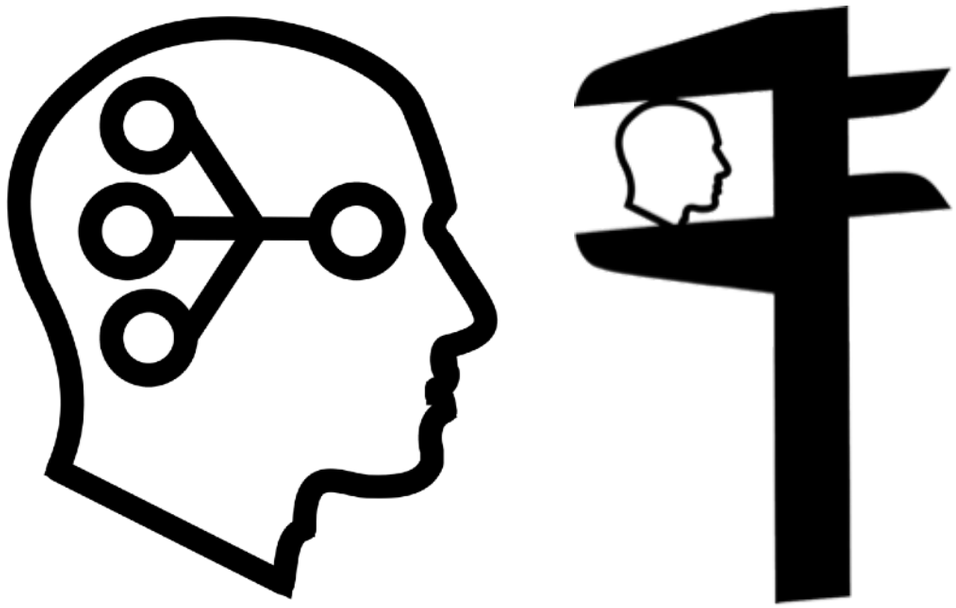

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