DCM for evoked responses

Ryszard Auksztulewicz

SPM for M/EEG course, 2018

Does network XYZ explain my data better than network XY?

Which XYZ connectivity structure best explains my data?

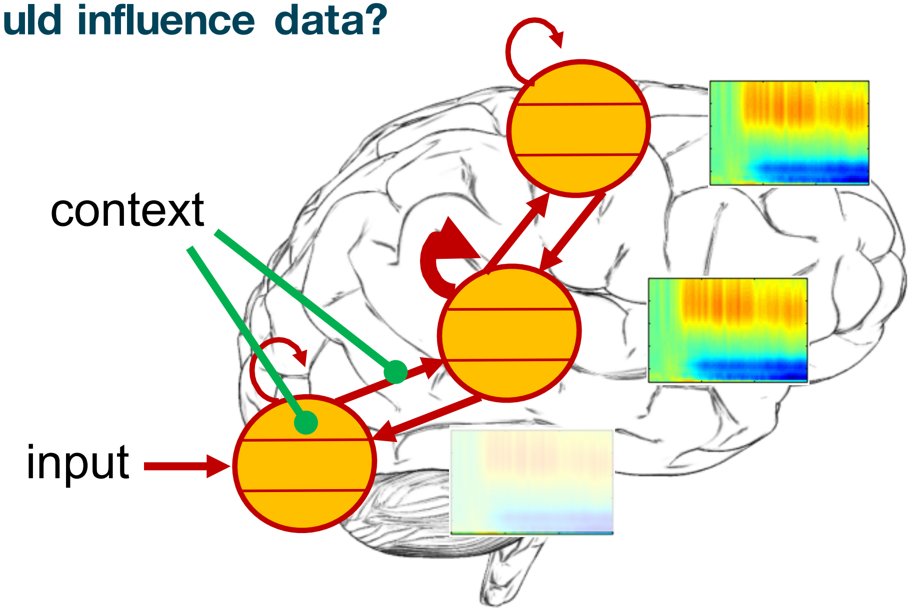
Are X & Y linked in a bottom-up, top-down or recurrent fashion?

Is my effect driven by extrinsic or intrinsic connections?

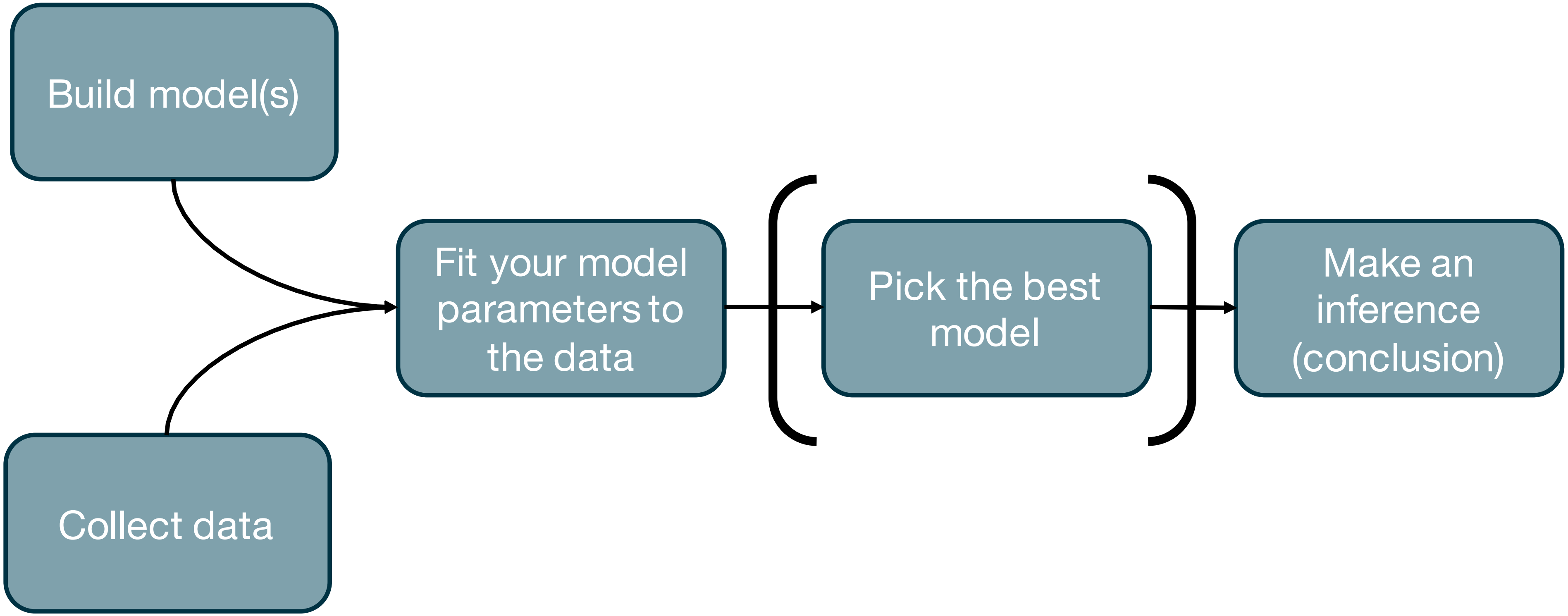
Which neural populations are affected by contextual factors?

Which connections determine observed frequency coupling?

How changing a connection/parameter would influence data?



The DCM analysis pathway



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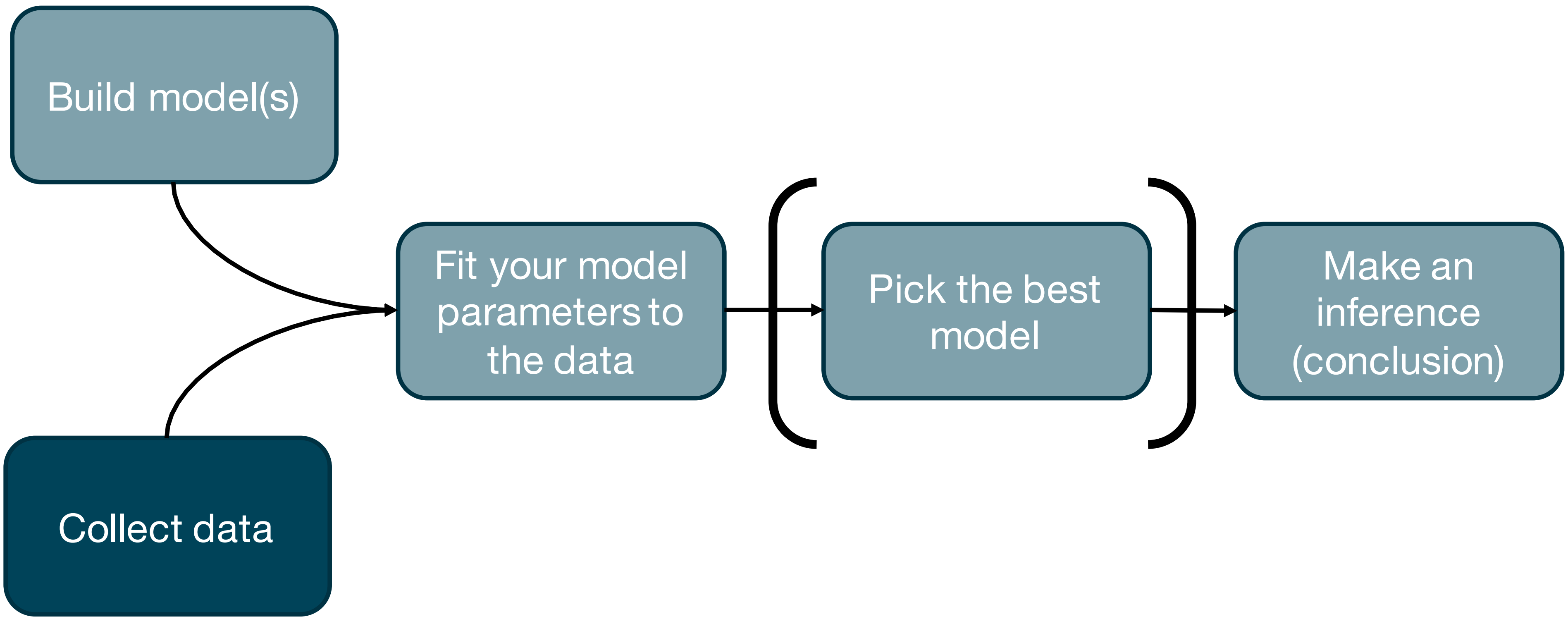
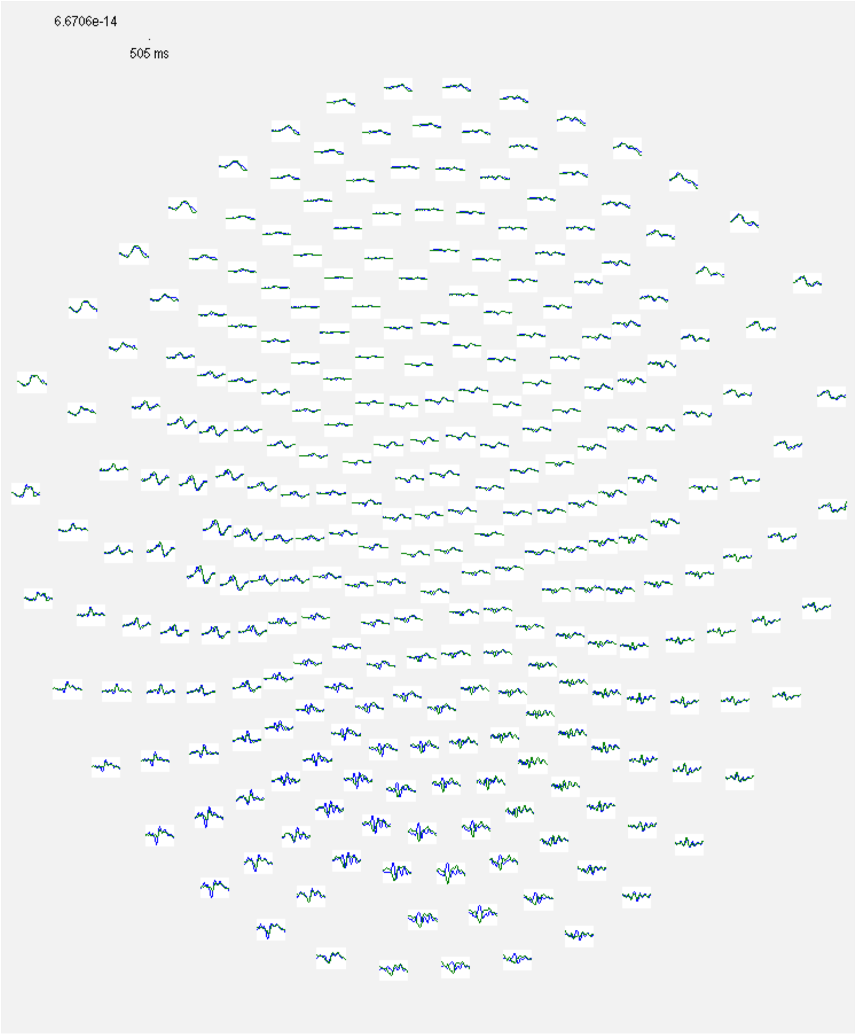


Data for DCM for ERPs / ERFs

1. Downsample
2. Filter (e.g. 1-40Hz)
3. Epoch
4. Remove artefacts
5. Average
   - Per subject
   - Grand average
6. Plausible sources
   - Literature / a priori
   - Dipole fitting / 3D source reconstruction



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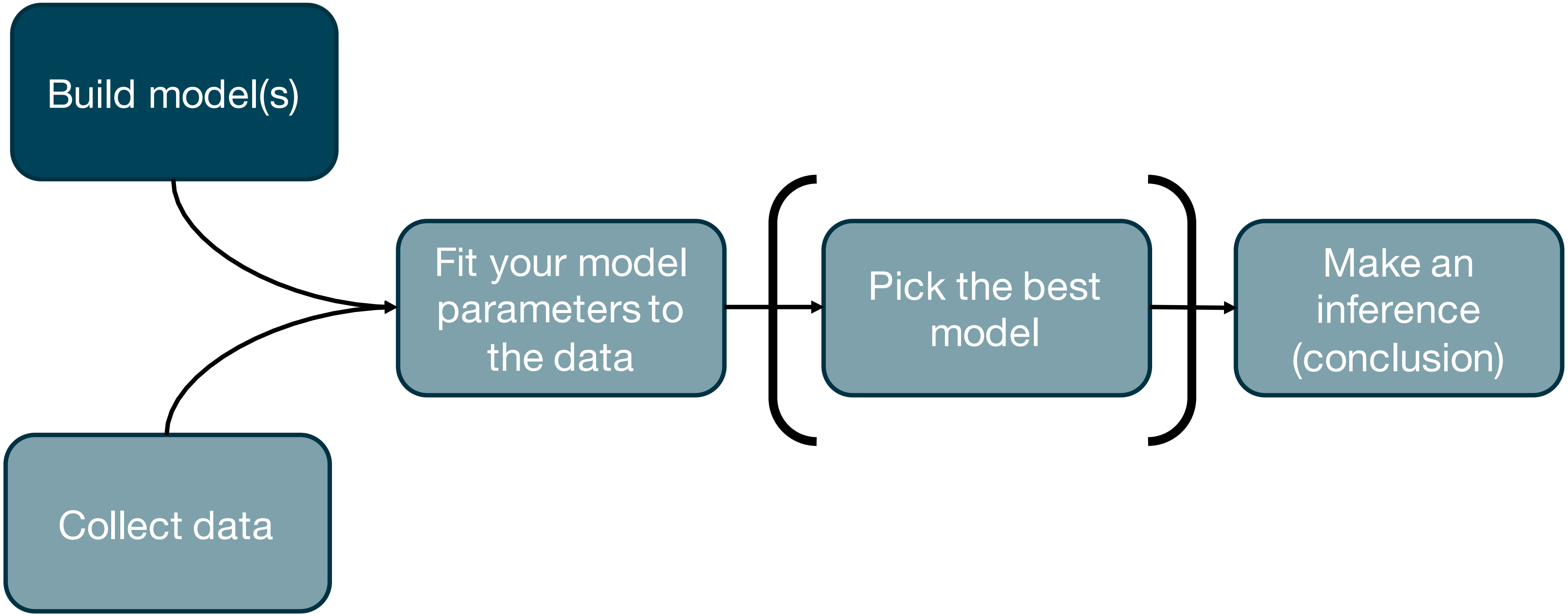

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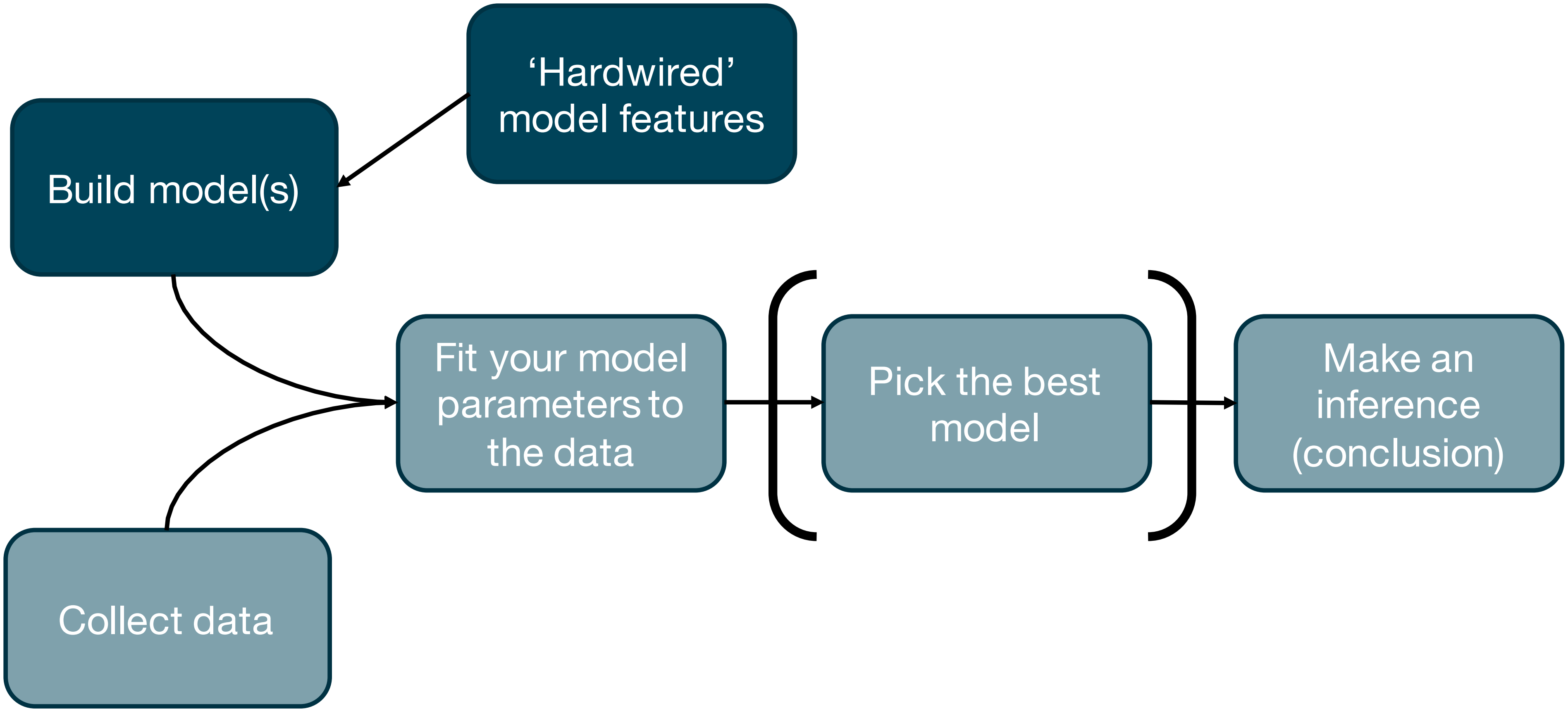
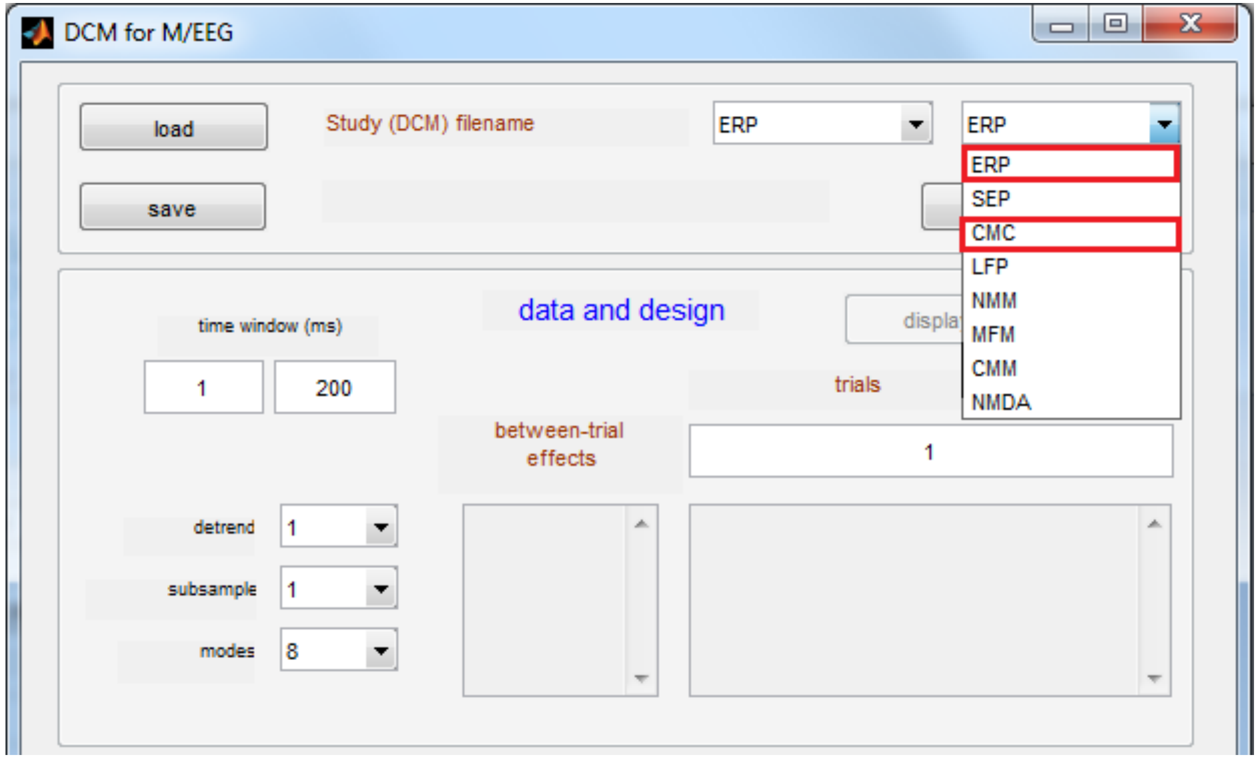


Models



frontiers in COMPUTATIONAL NEUROSCIENCE

REVIEW ARTICLE
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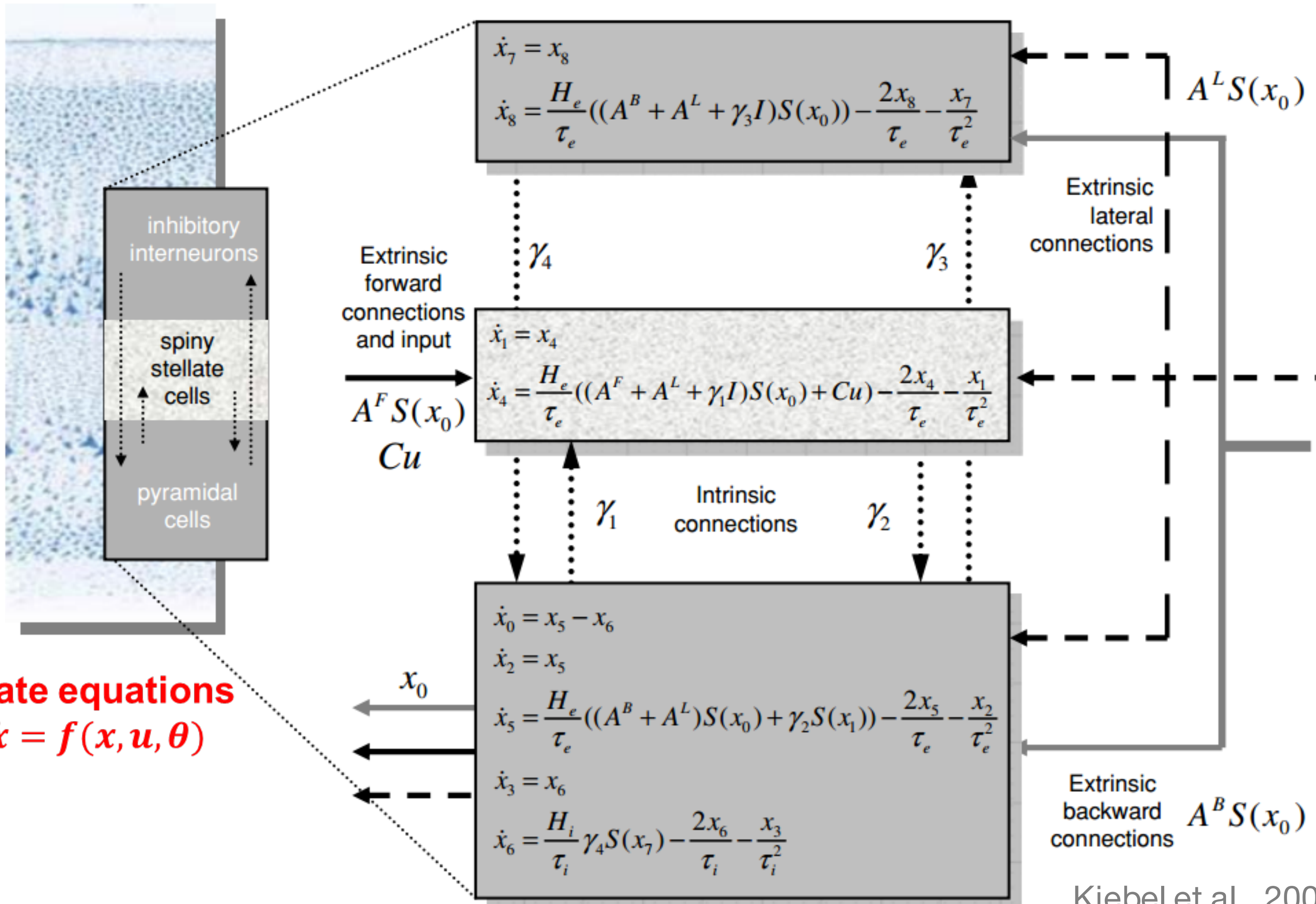
Neural masses and fields in dynamic causal modeling

***Rosalyn Moran*[1,2,3*†], *Dimitris A. Pinotsis*[1†] and *Karl Friston*[1]**

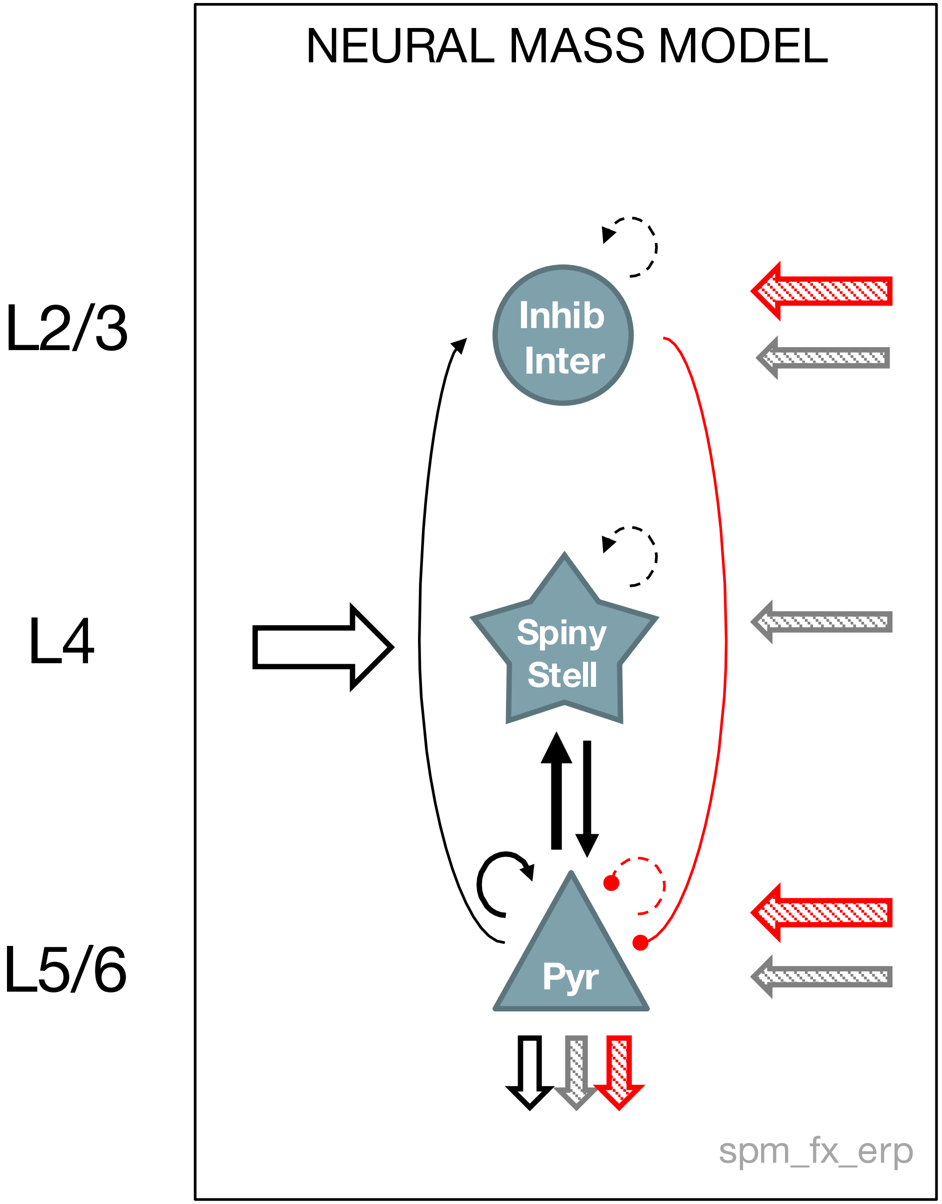
Neuronal (source) model



State equations

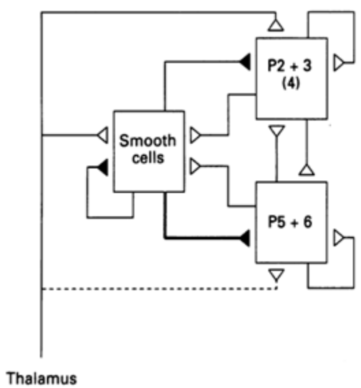
$$\dot{x} = f(x, u, \theta)$$

Kiebel et al., 2008


NEURAL MASS MODEL
L2/3
L4
L5/6
Inhib
Inter
Spiny
Stell
Pyr
spm_fx_erp

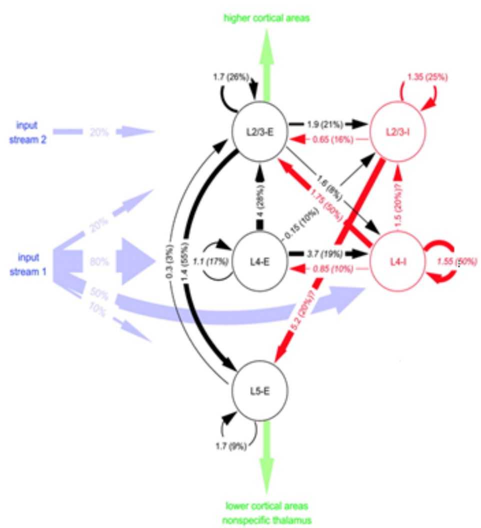
Canonical Microcircuit Model ('CMC')

Original proposal for canonical microcircuit



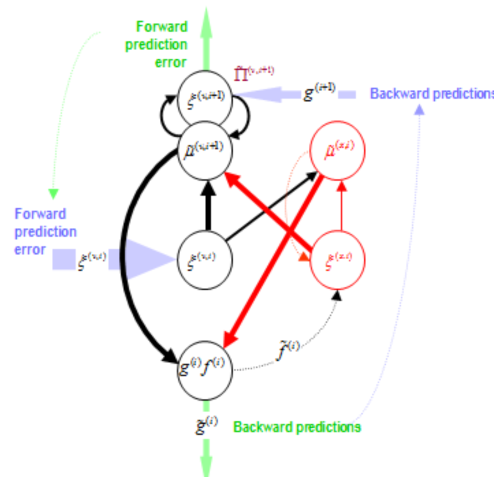
Douglas & Martin (1991)

Updated microcircuit



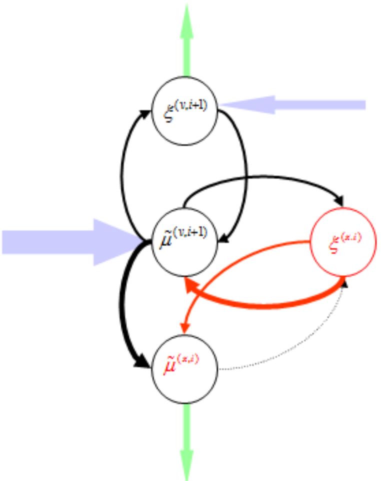
Adapted from Haeusler & Maass (2006)

Canonical microcircuit for predictive coding (full model)

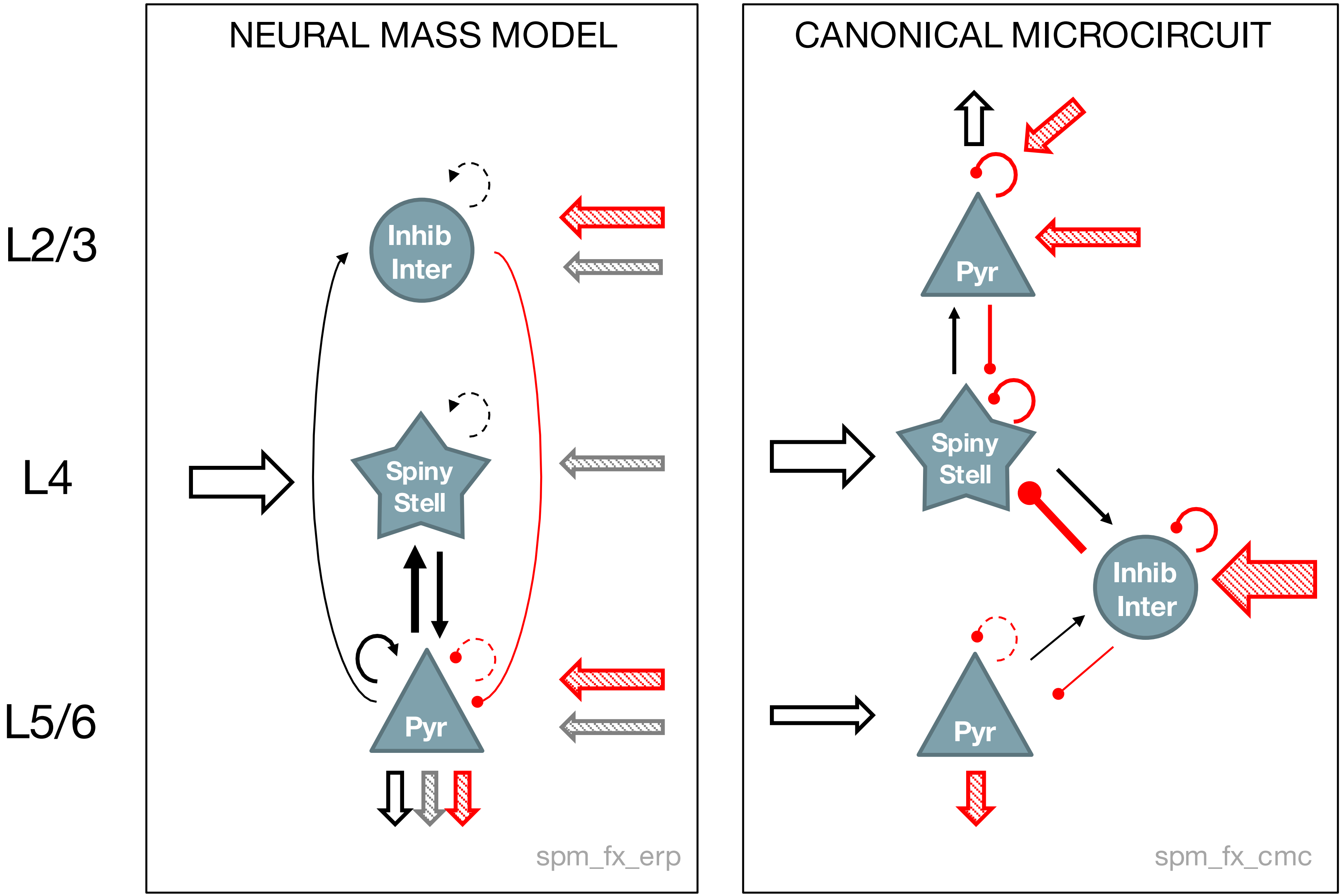


Bastos et al. (2012)

Reduced model (used in DCM)



Pinotsis et al. (2012)



L2/3
L4
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NEURAL MASS MODEL
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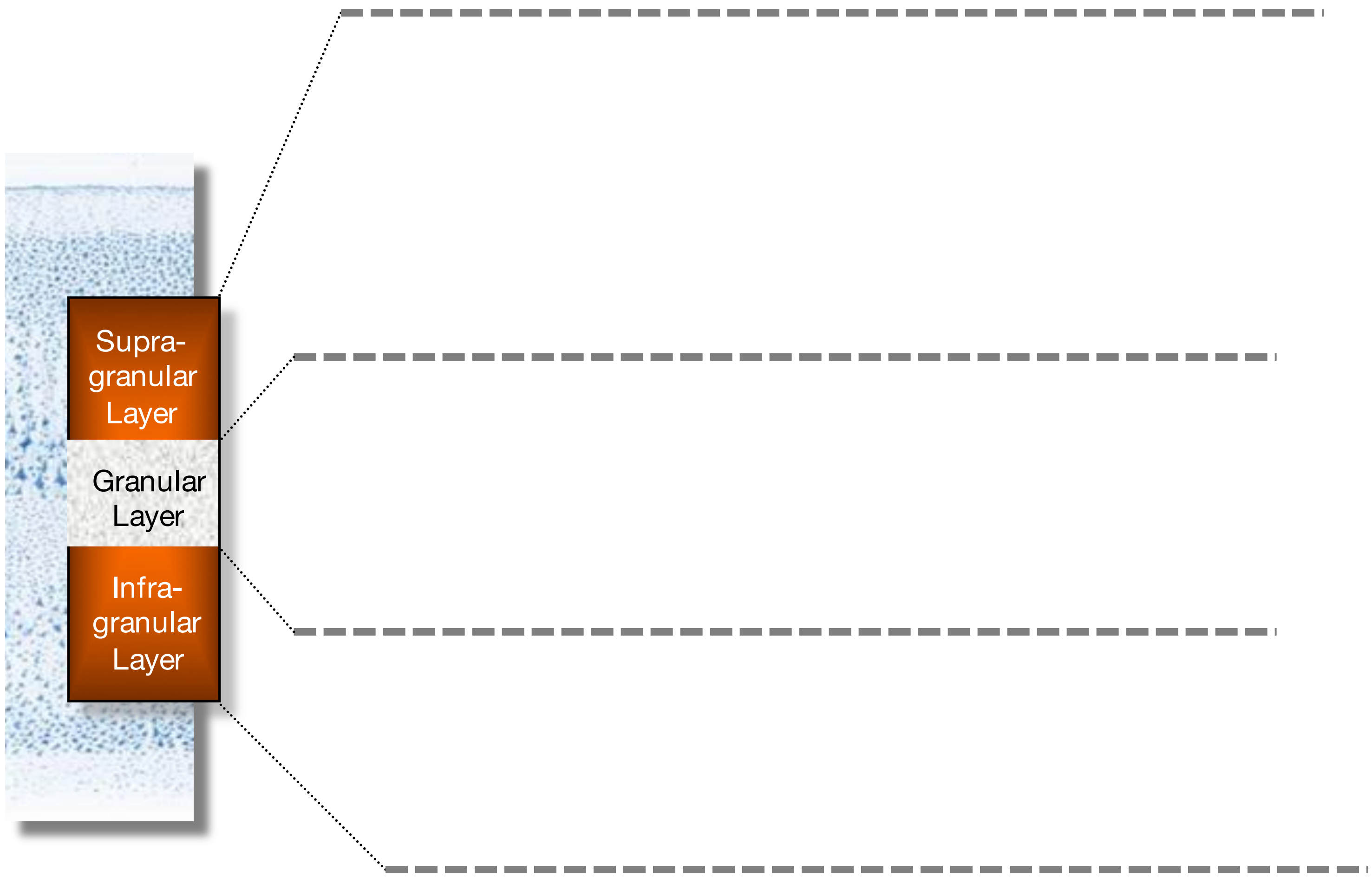
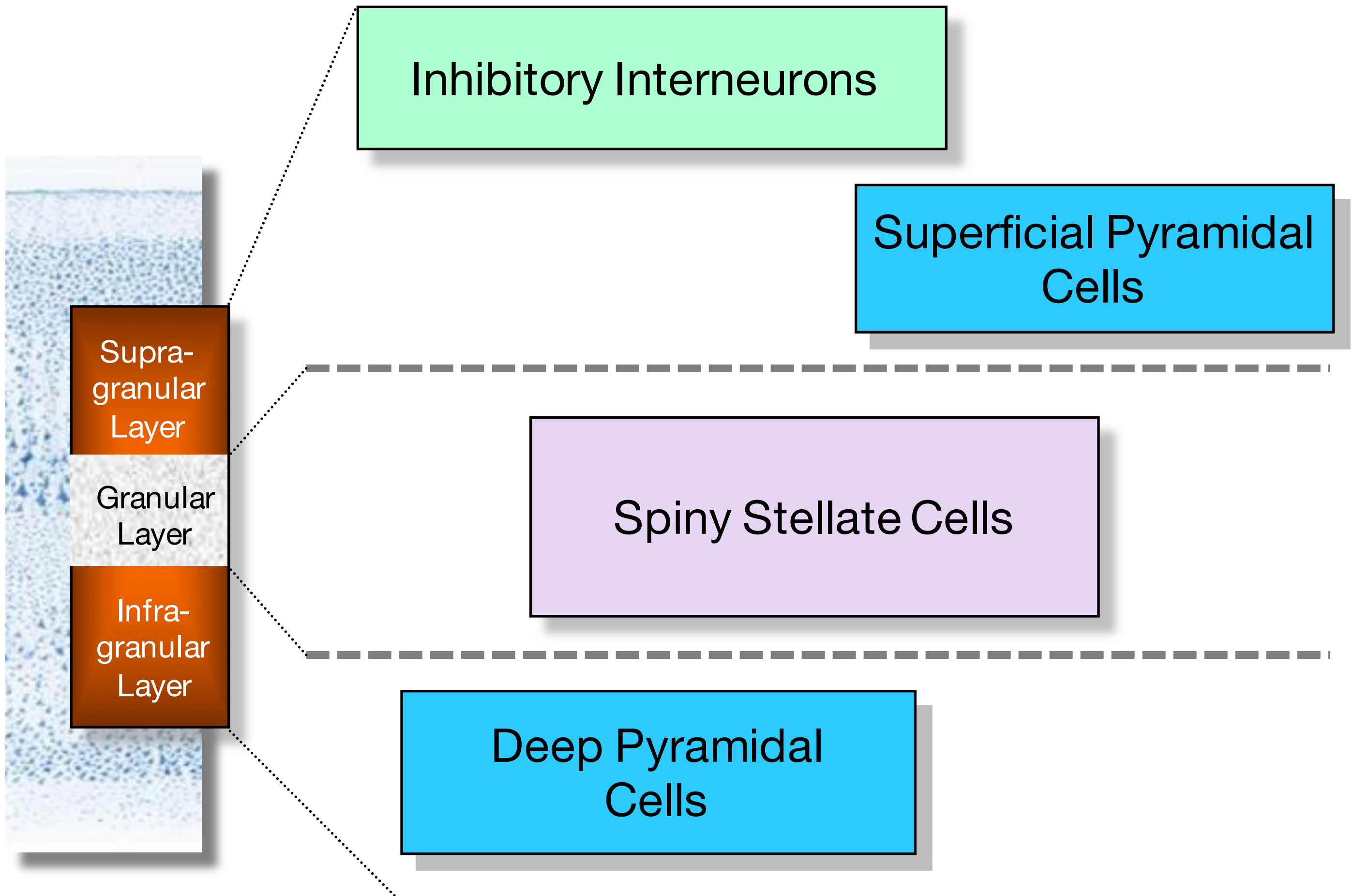
spm_fx_erp
CANONICAL MICROCIRCUIT
Pyr
Spiny Stell
Inhib Inter
Pyr
spm_fx_cmc

Canonical Microcircuit Model (‘CMC’)



Canonical Microcircuit Model ('CMC')



Pinotsis et al., 2012

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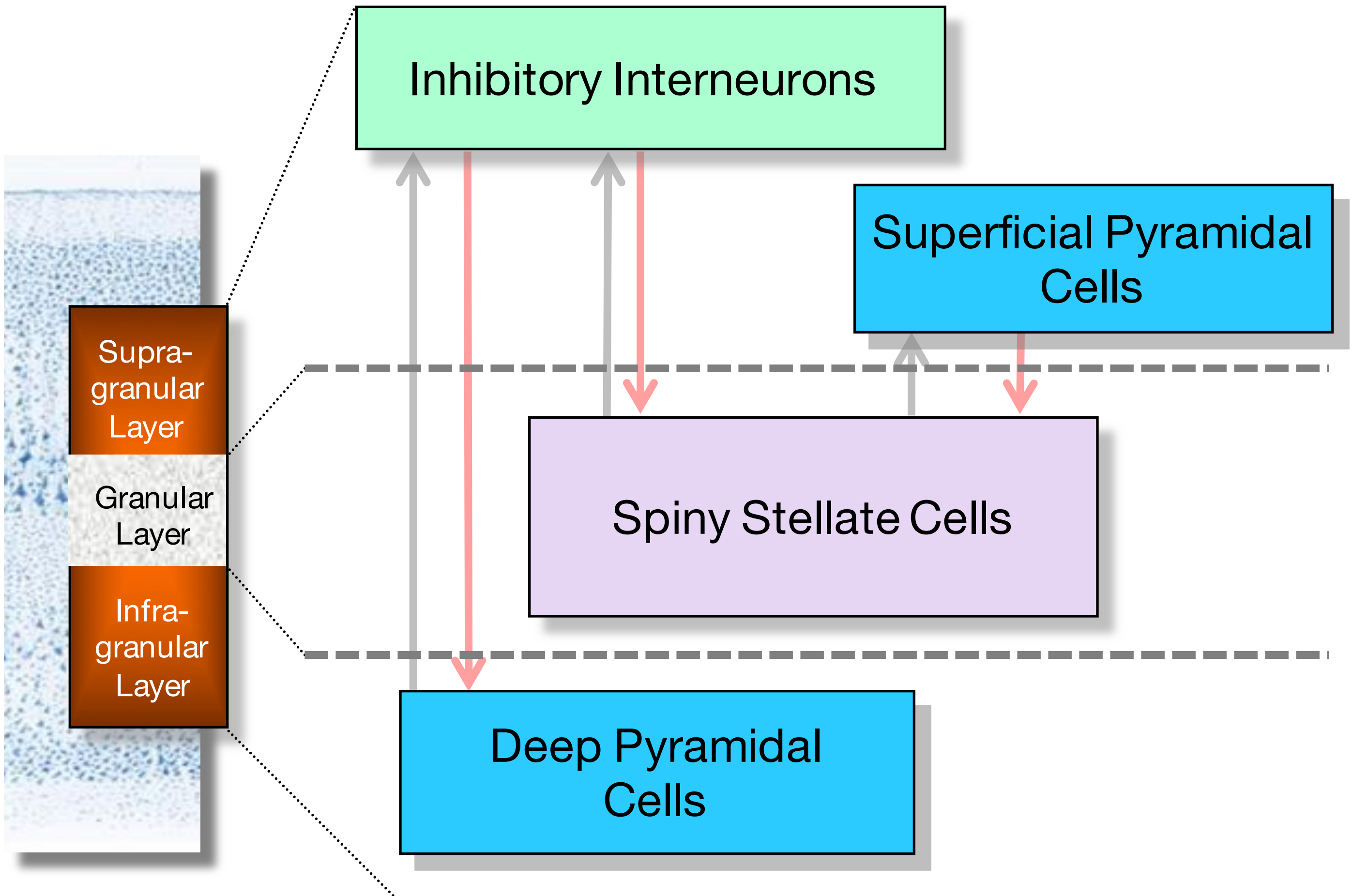

Pinotsis et al., 2012

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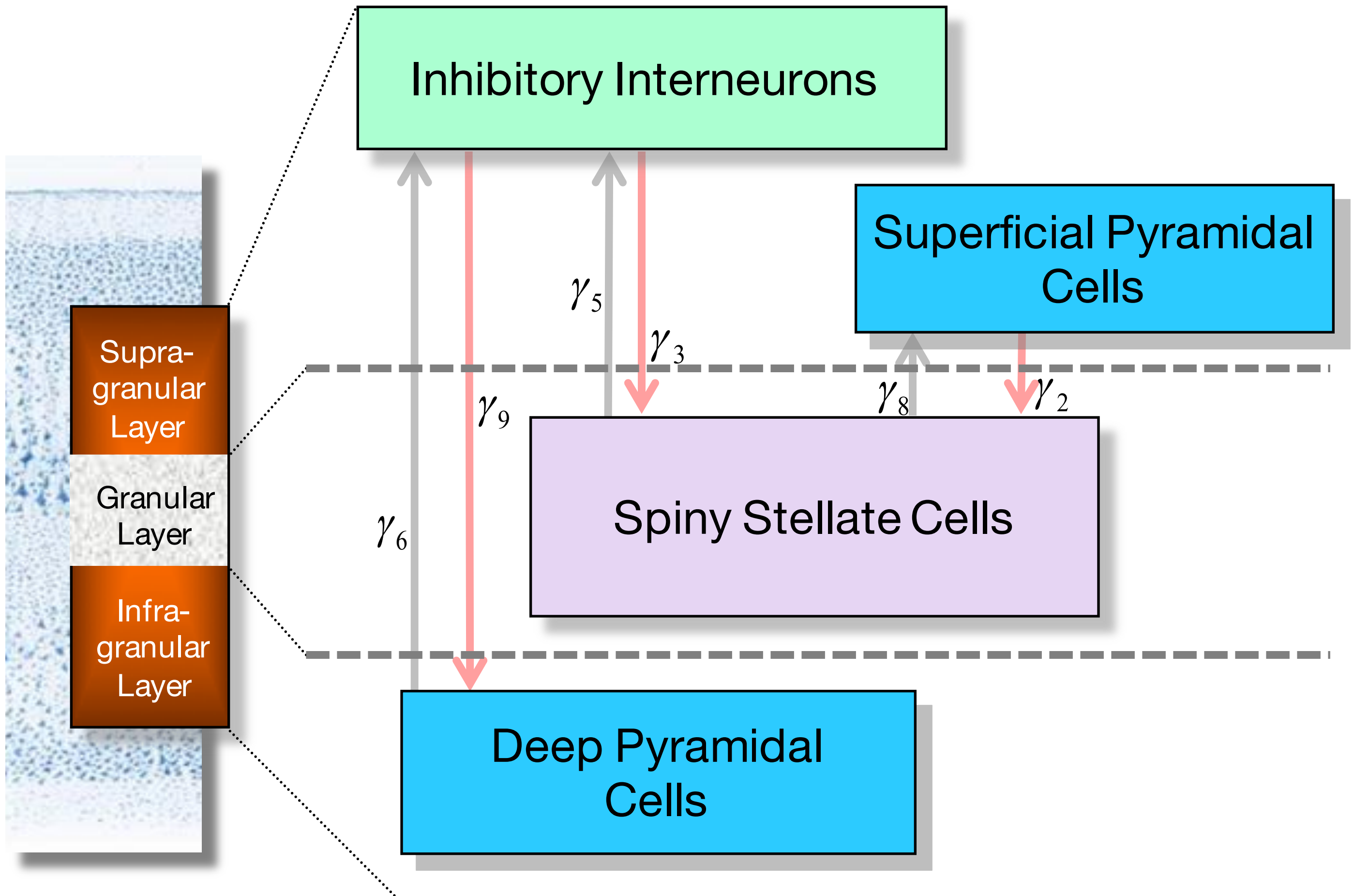

Pinotsis et al., 2012

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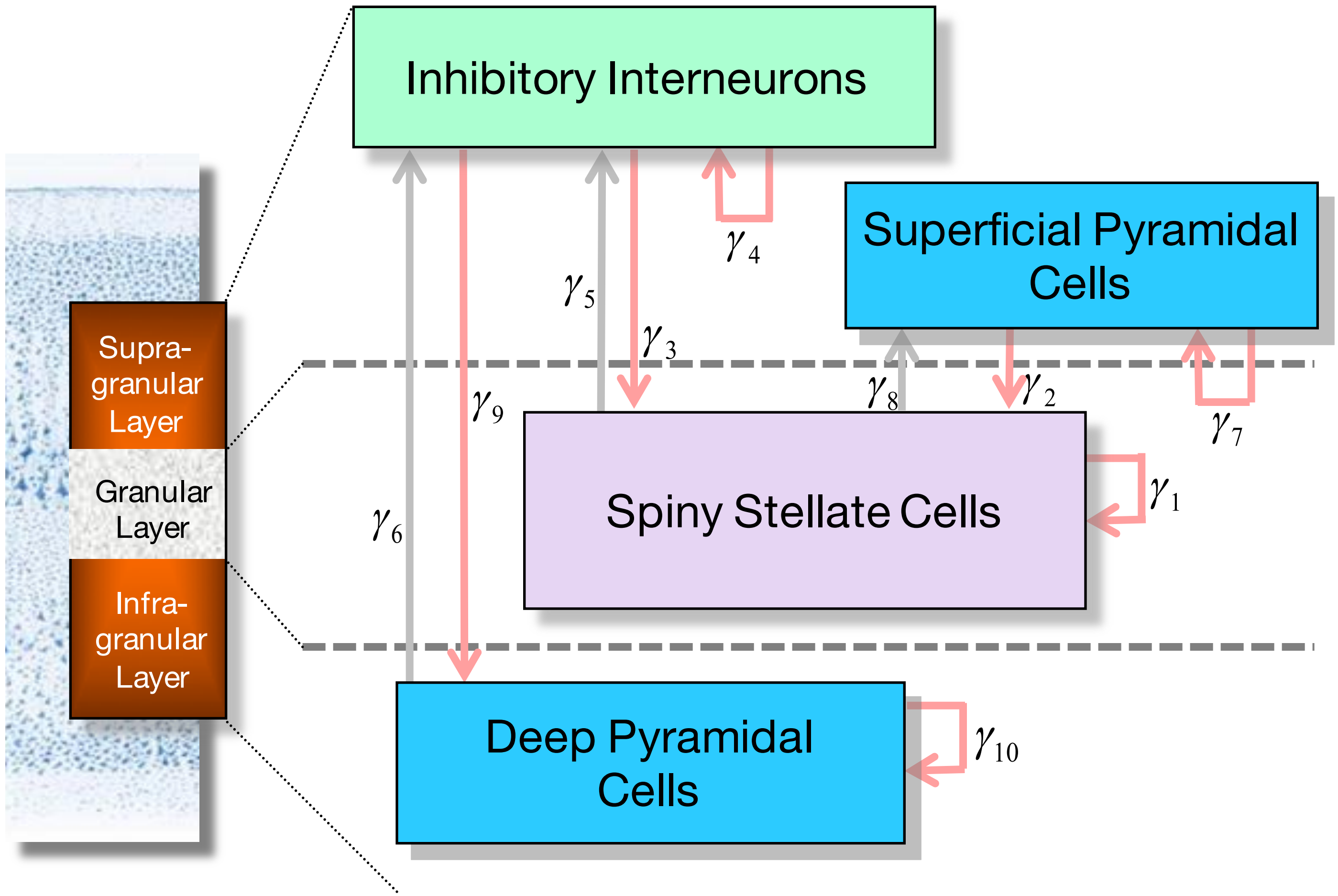

Pinotsis et al., 2012

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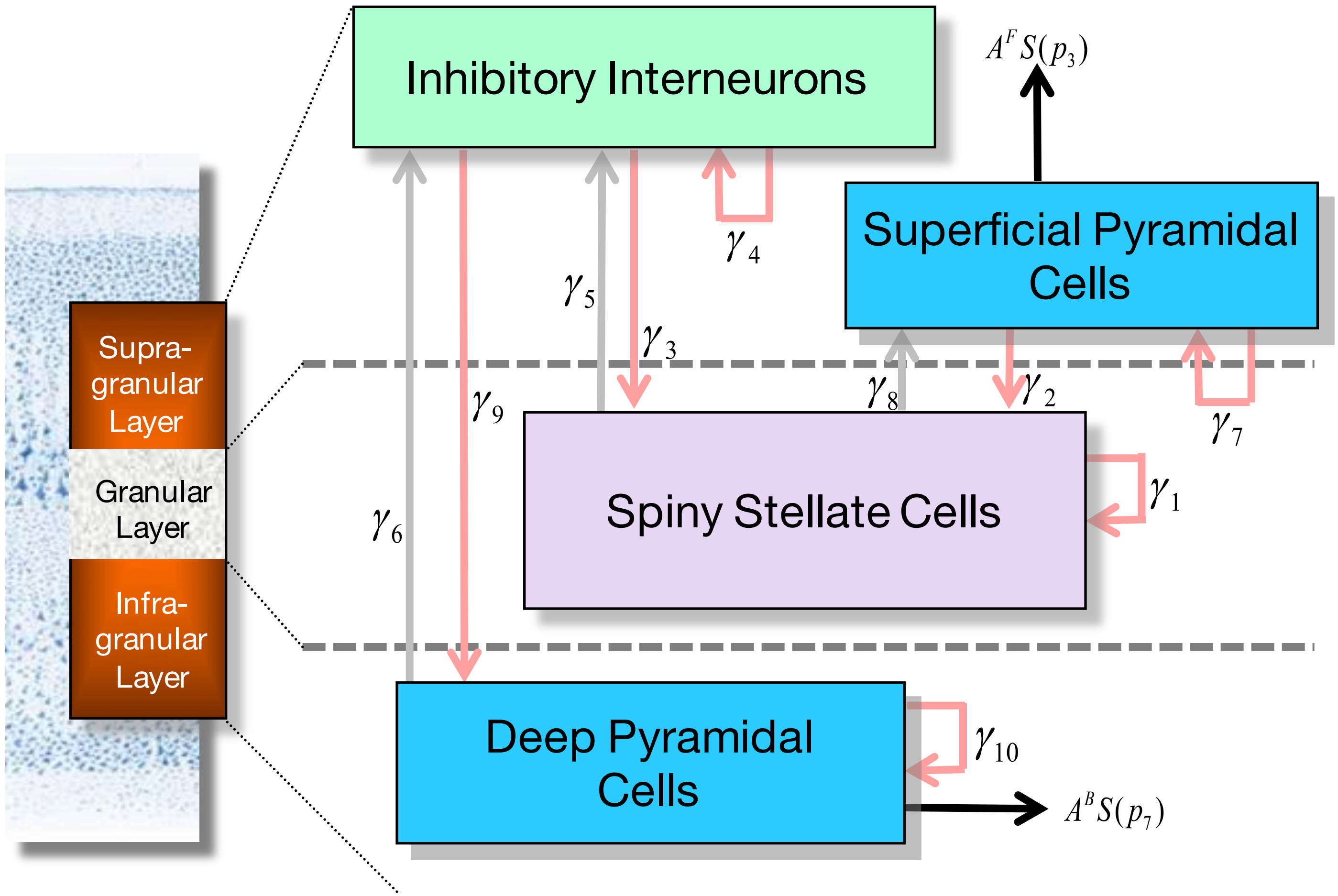

Pinotsis et al., 2012

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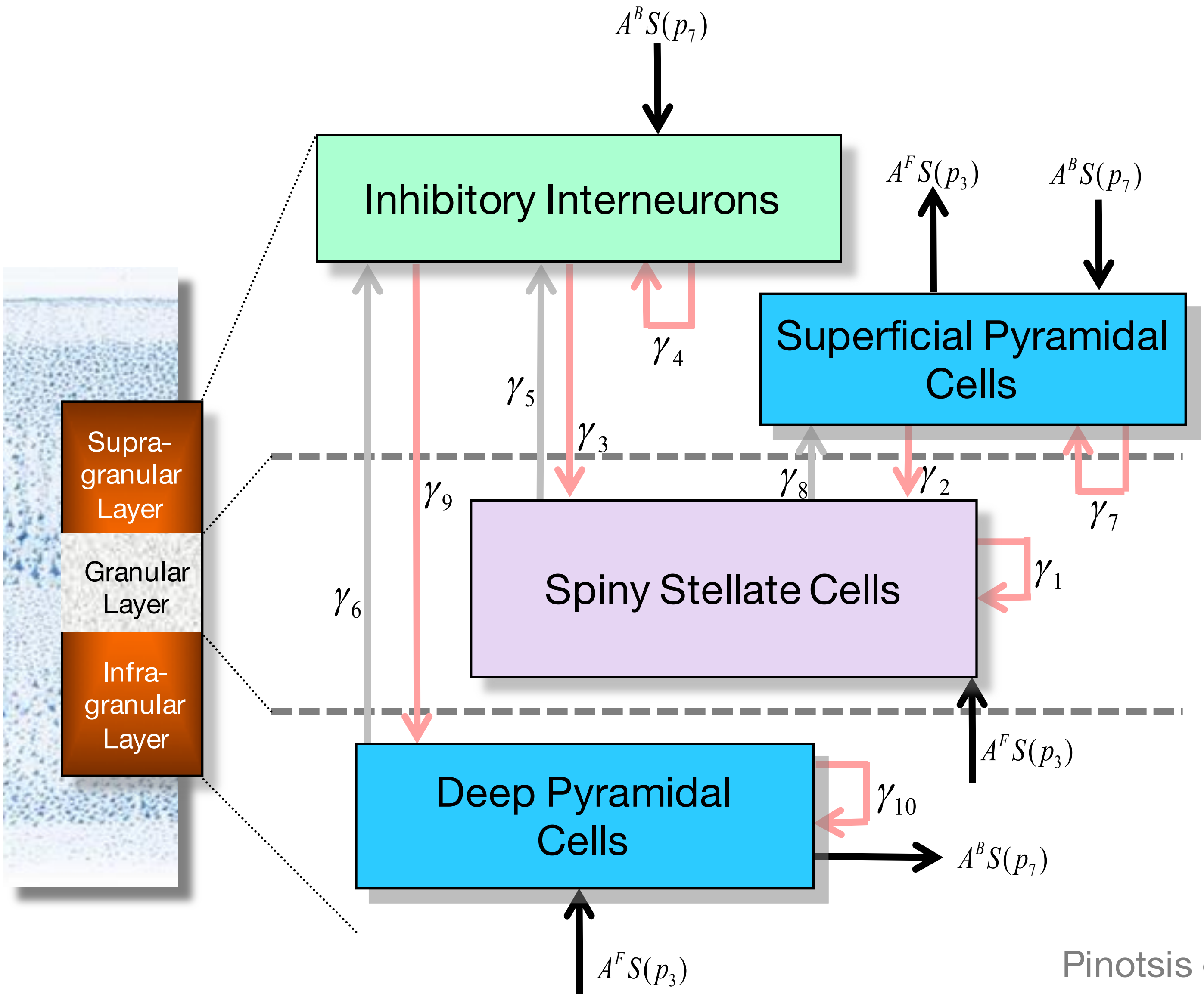
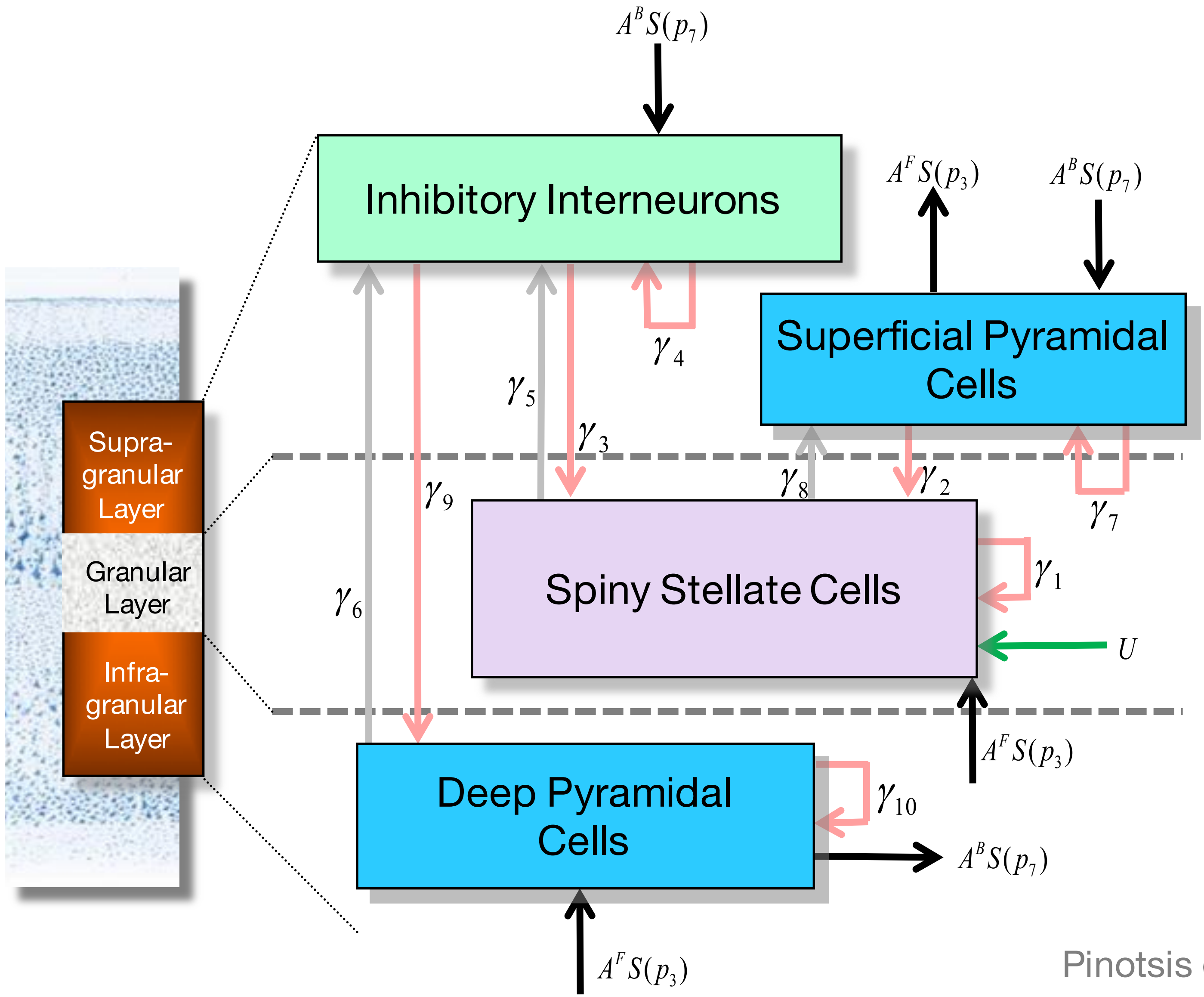


Pinotsis et al., 2012

Canonical Microcircuit Model ('CMC')



Pinotsis et al., 2012

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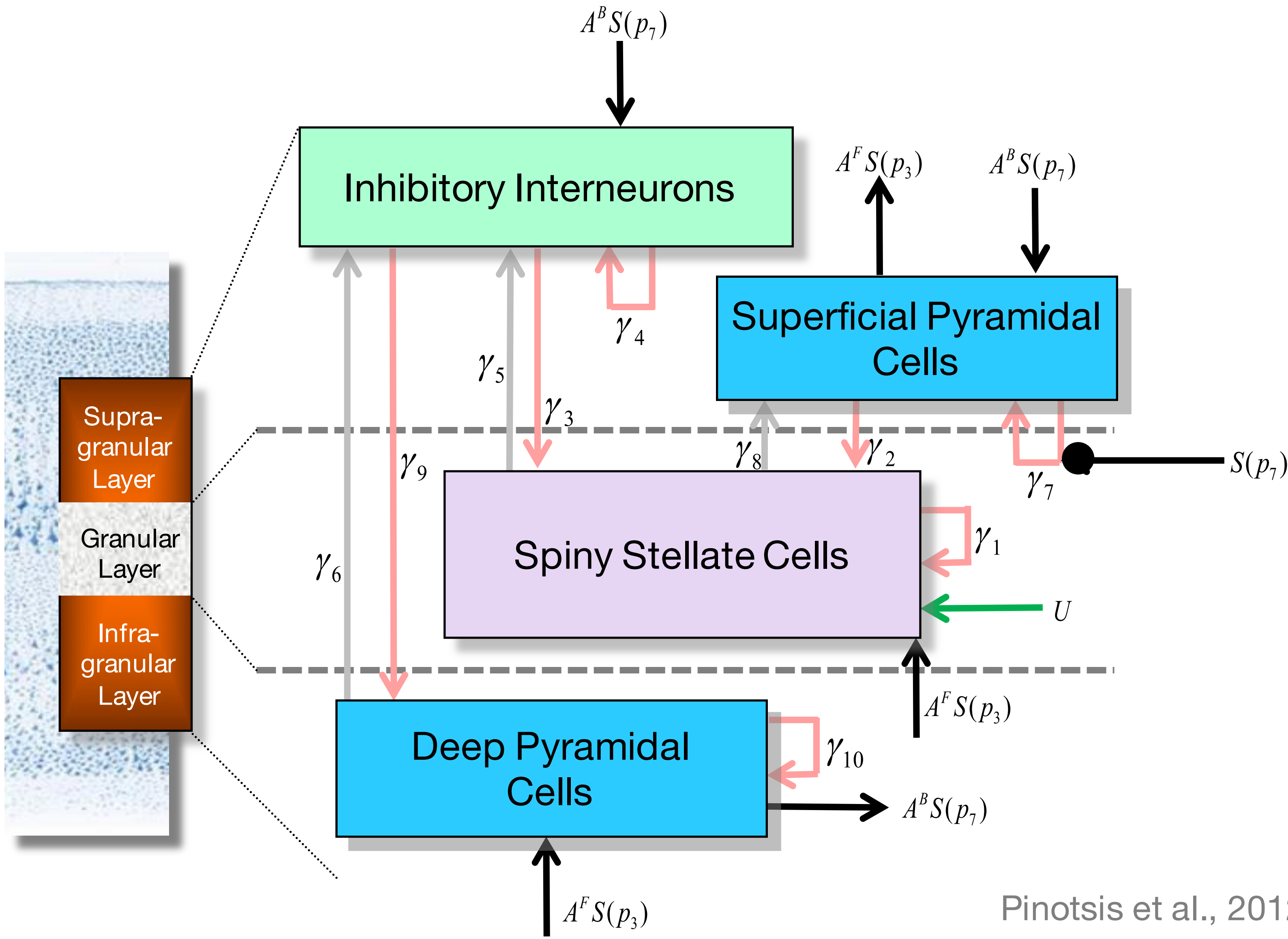

Pinotsis et al., 2012

Canonical Microcircuit Model ('CMC')

$$\dot{p}_7 = p_8$$

Voltage change rate: f(current)
Current change rate: f(voltage,current)

$$\dot{p}_8 = \frac{H_4}{\tau_4}(A^F S(p_2) - \gamma_{10} S(p_7) - \gamma_9 S(p_5)) - \frac{2p_8}{\tau_4} - \frac{p_7}{\tau_4^2}$$

Pinotsis et al., 2012

Canonical Microcircuit Model ('CMC')

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Voltage change rate: f(current)
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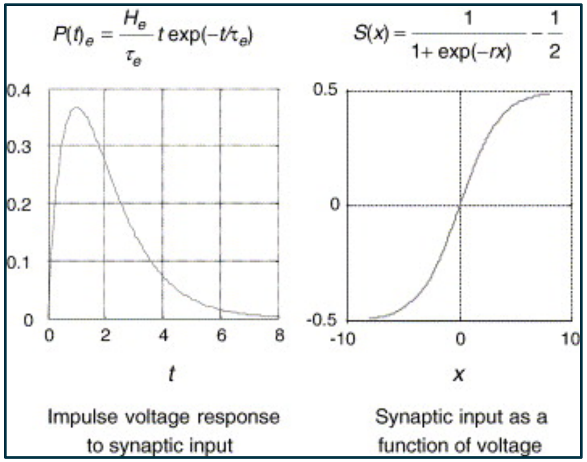
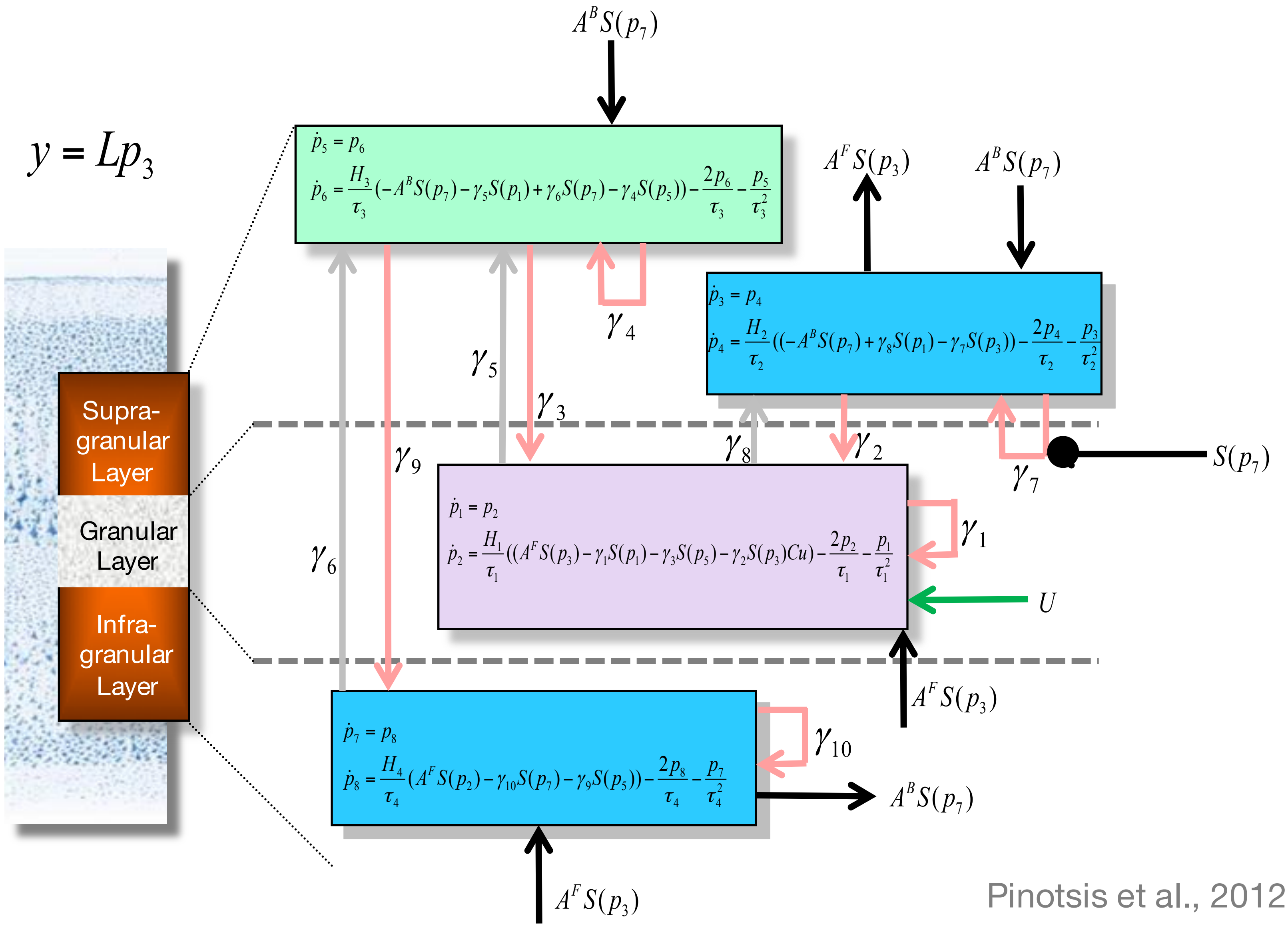
H*, *τ Kernels: pre-synaptic inputs -> post-synaptic membrane potentials
[***H:*** max PSP; ***τ:*** rate constant]

S Sigmoid operator: PSP -> firing rate



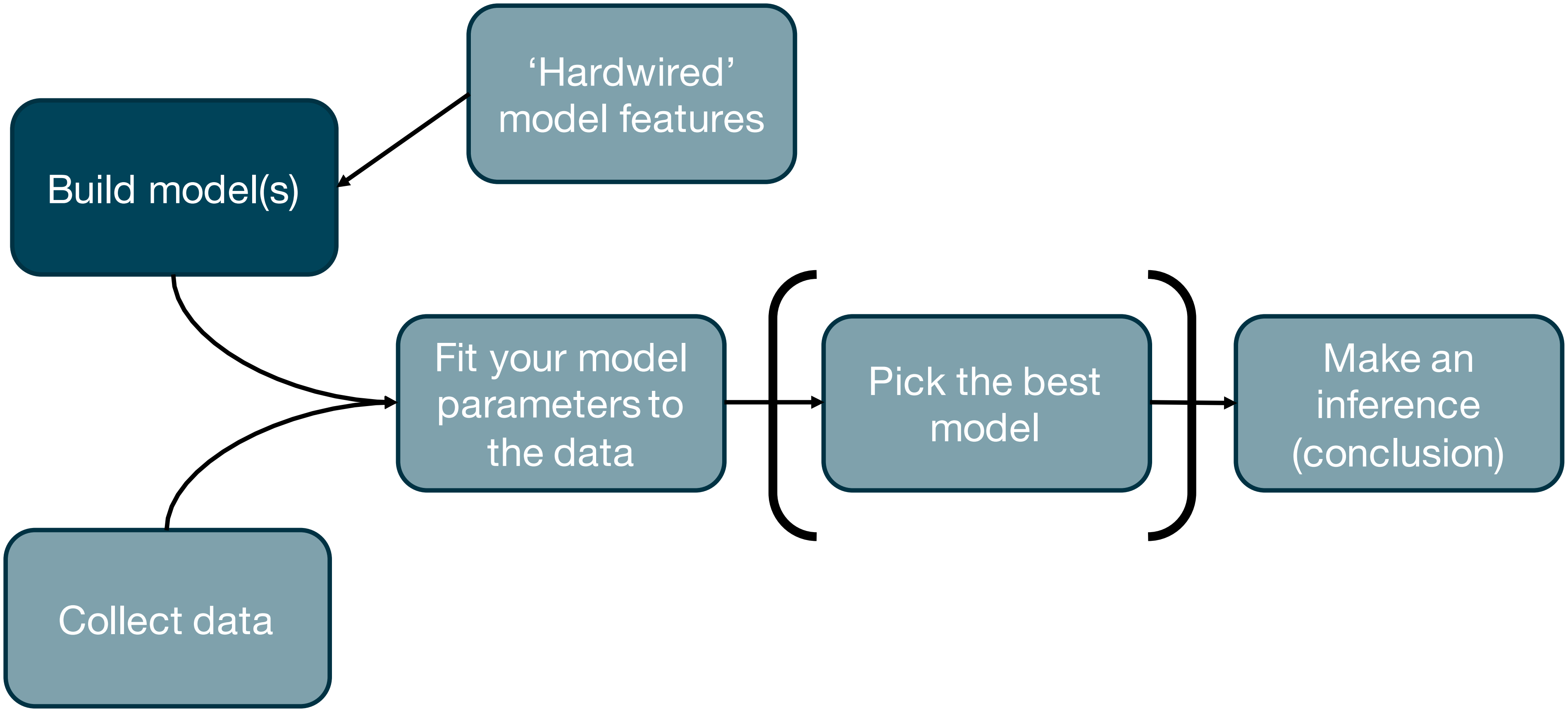
David et al., 2006; Pinotsis et al., 2012

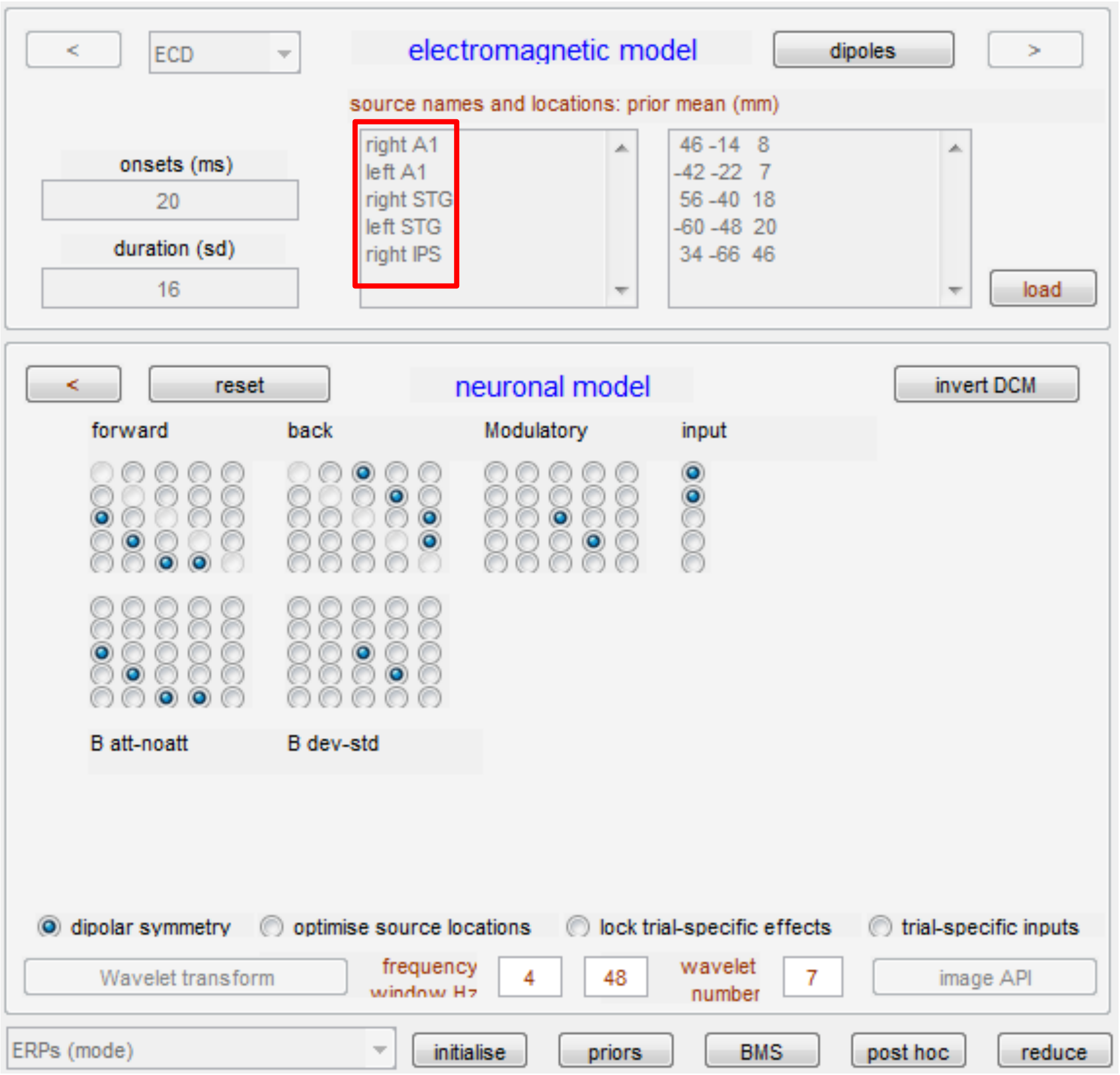
Canonical Microcircuit Model ('CMC')



Pinotsis et al., 2012

The DCM analysis pathway





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electromagnetic model
dipoles
>
source names and locations: prior mean (mm)
onsets (ms)
20
duration (sd)
16
right A1
left A1
right STG
left STG
right IPS
46 -14 8
-42 -22 7
56 -40 18
-60 -48 20
34 -66 46
load
<
reset
neuronal model
invert DCM
forward
back
Modulatory
input
B att-noatt
B dev-std
dipolar symmetry
optimise source locations
lock trial-specific effects
trial-specific inputs
Wavelet transform
frequency window Hz
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wavelet number
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image API
ERPs (mode)
initialise
priors
BMS
post hoc
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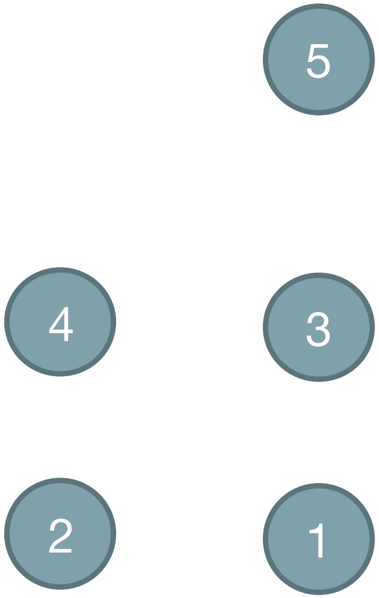

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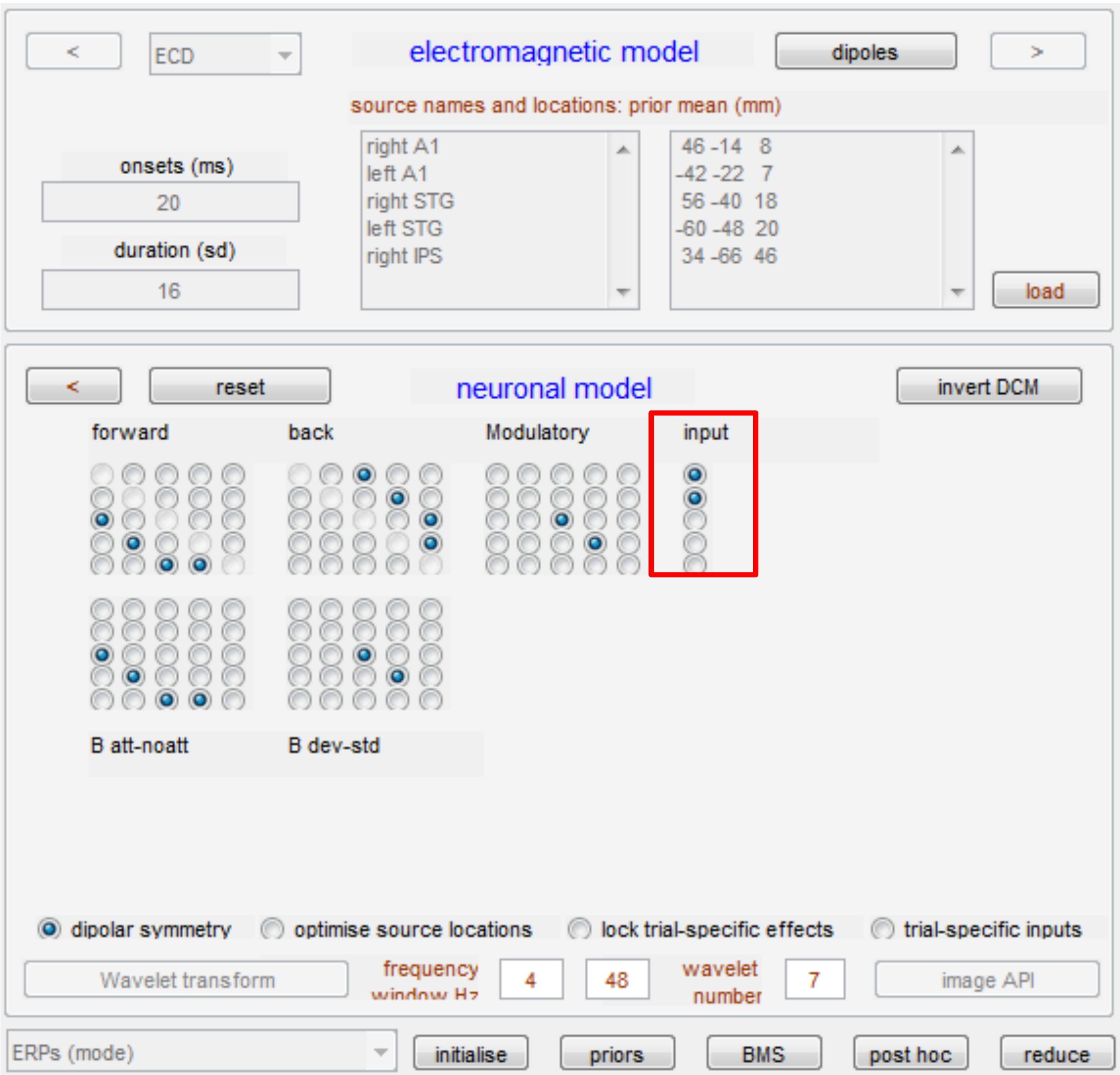
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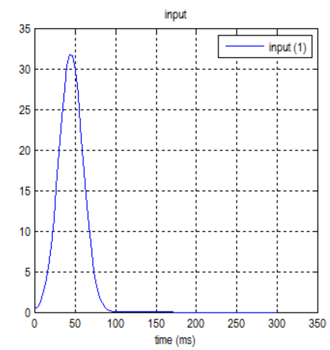
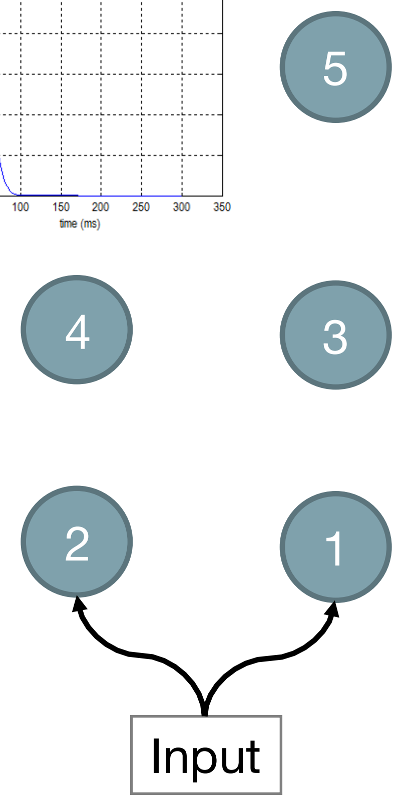

input
input (1)
time (ms)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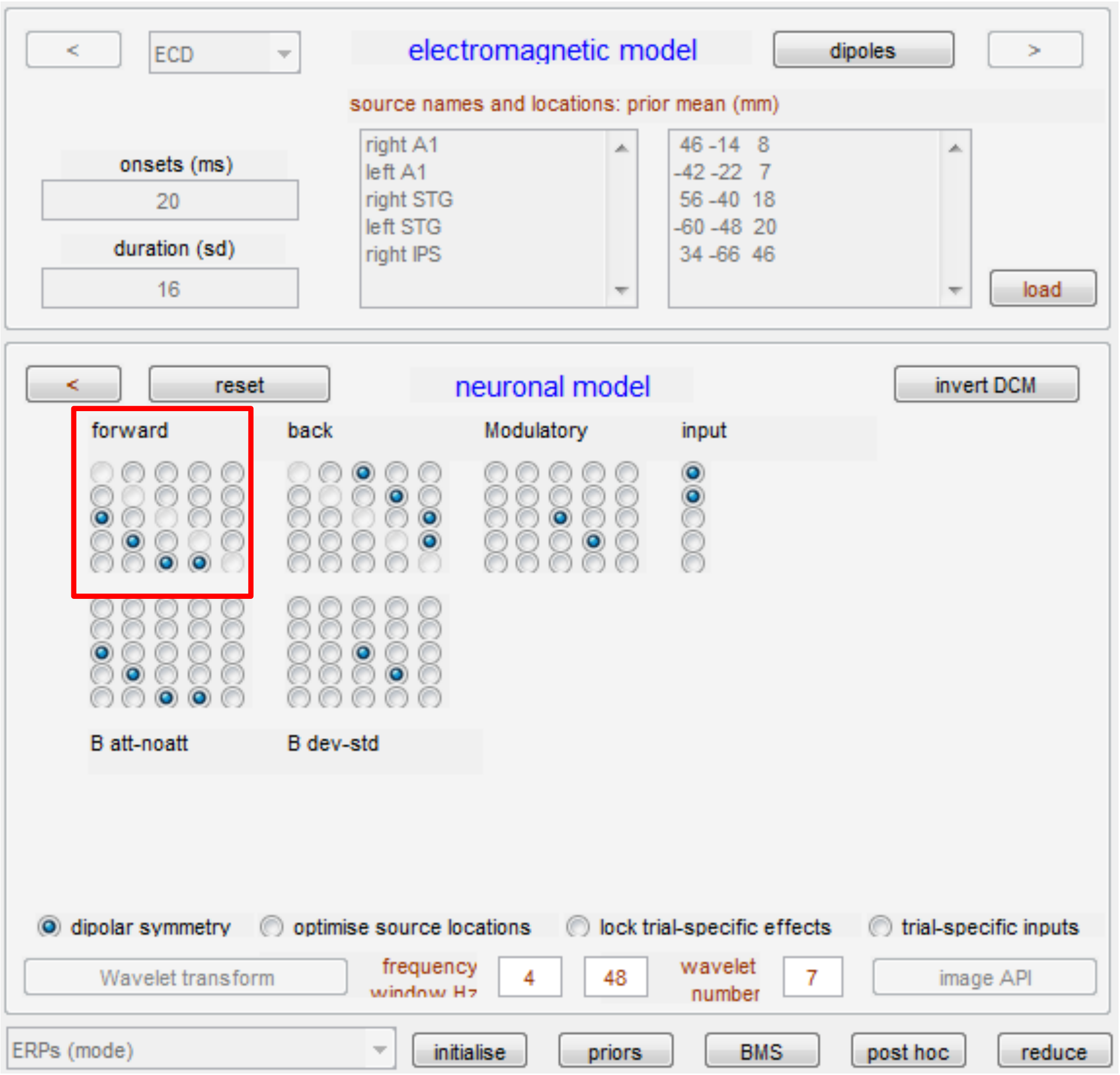

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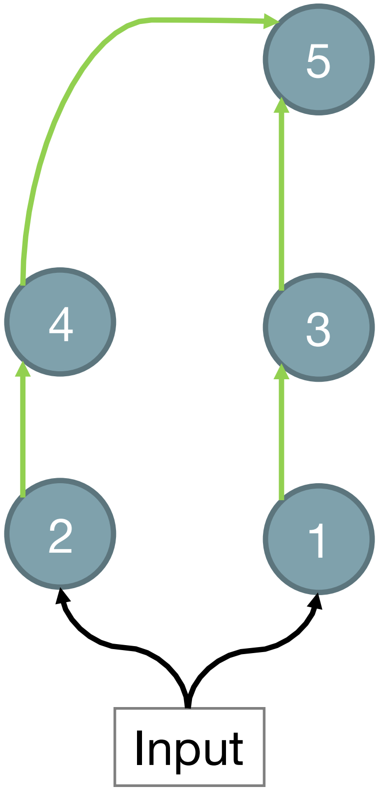

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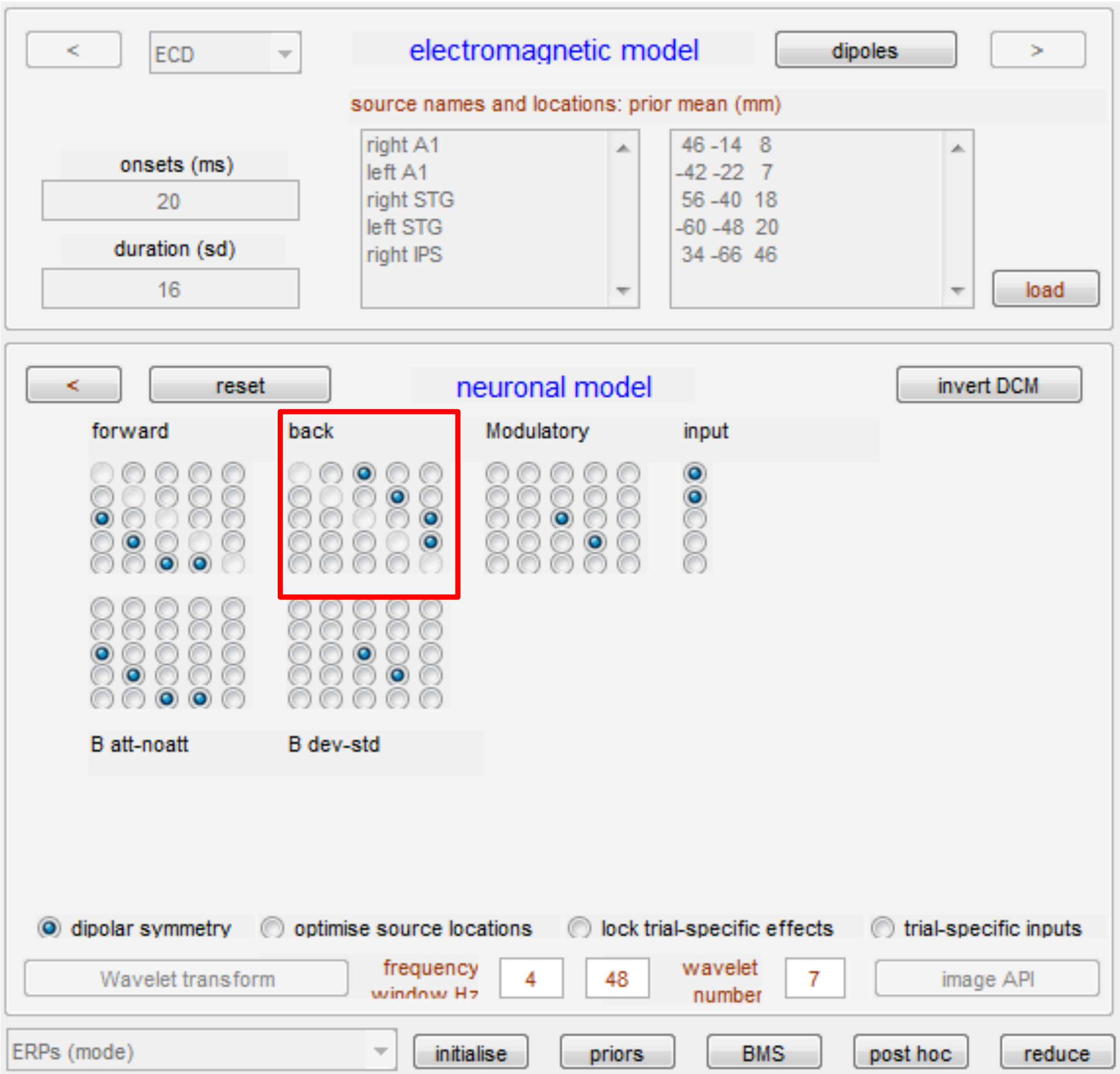

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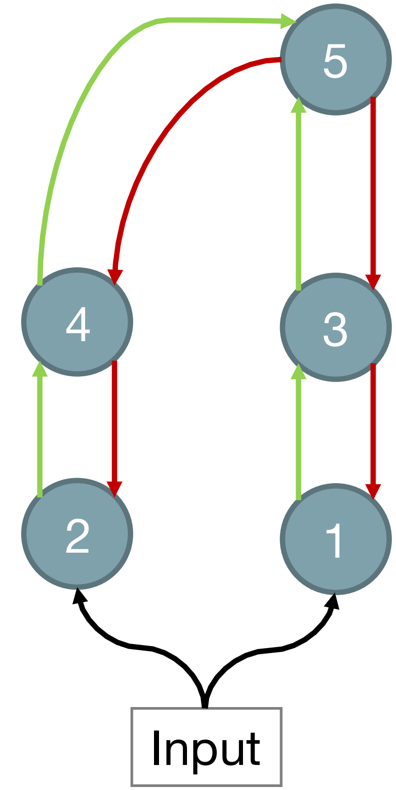

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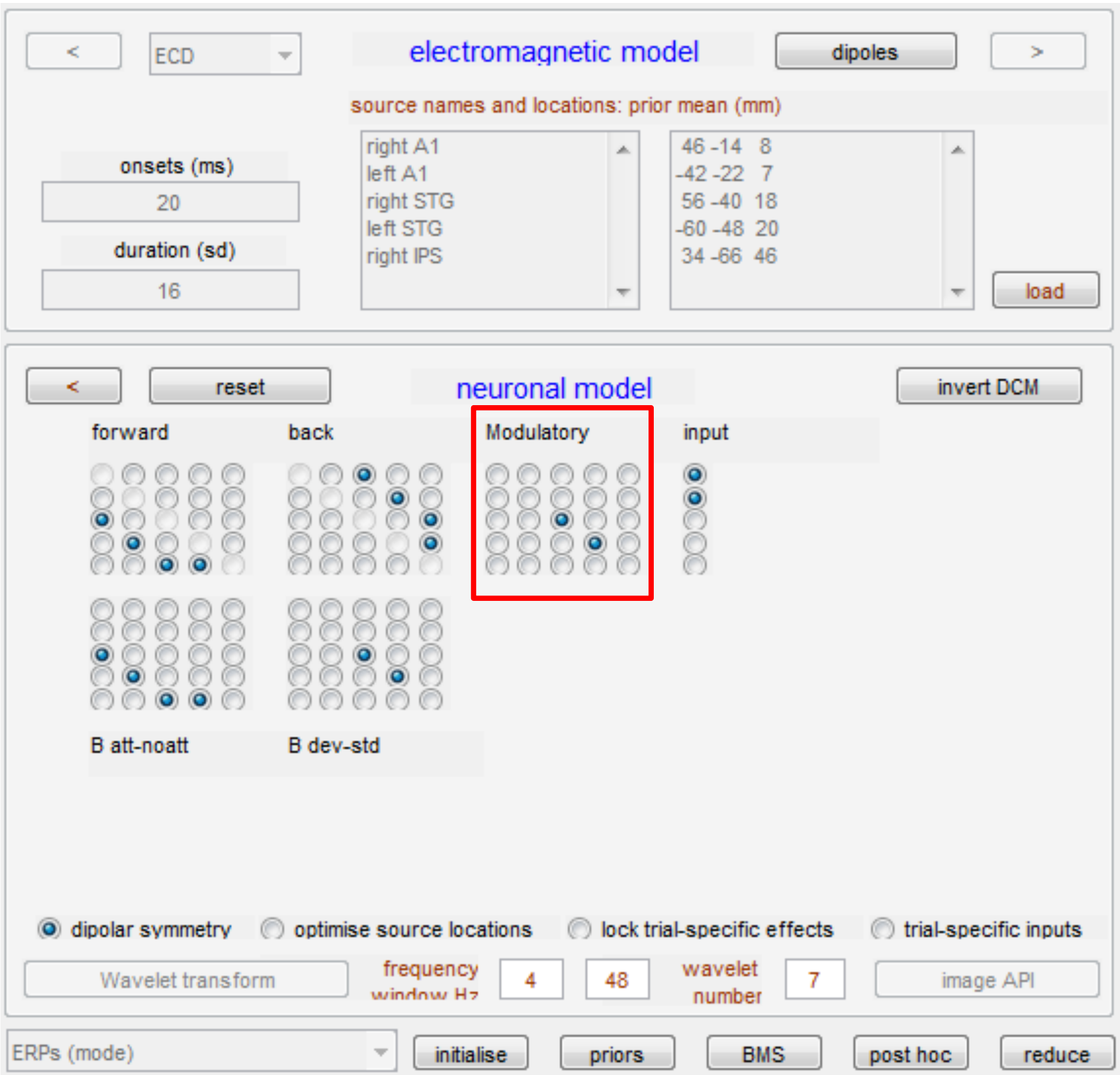
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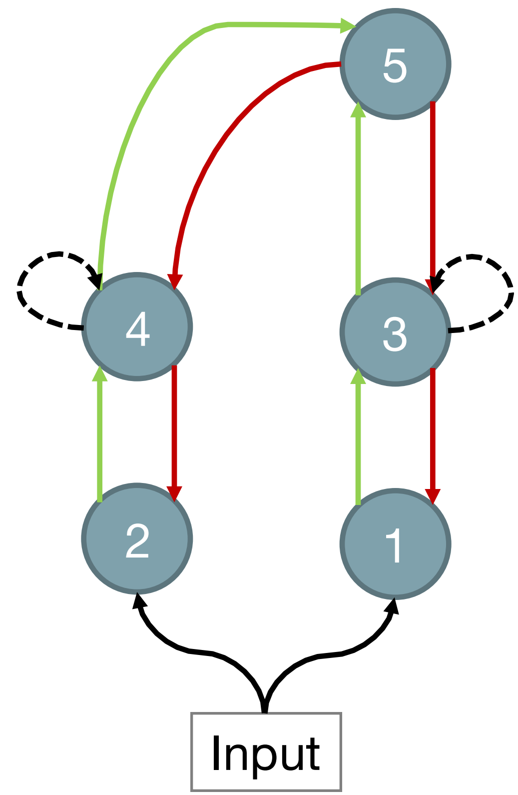
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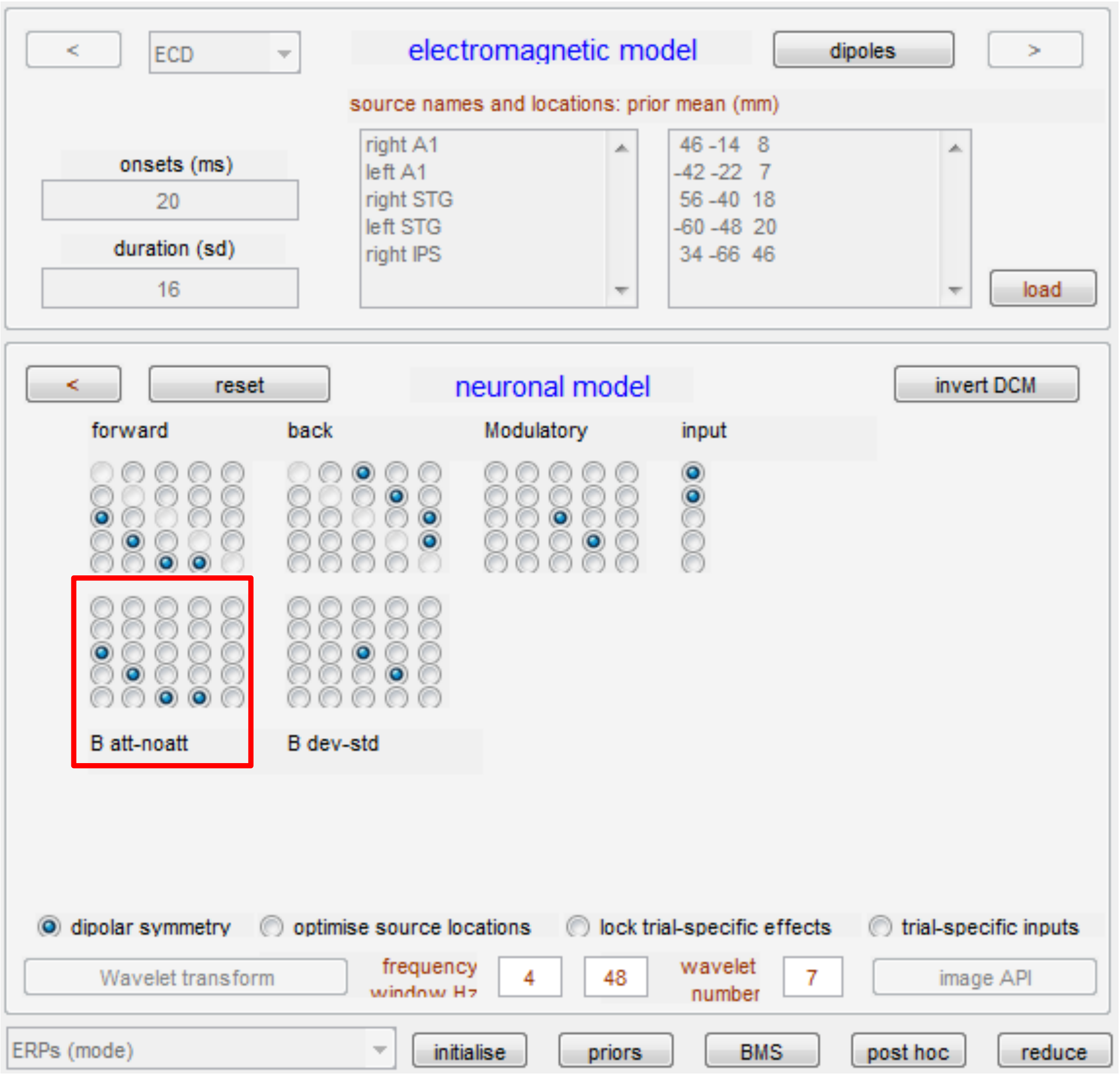

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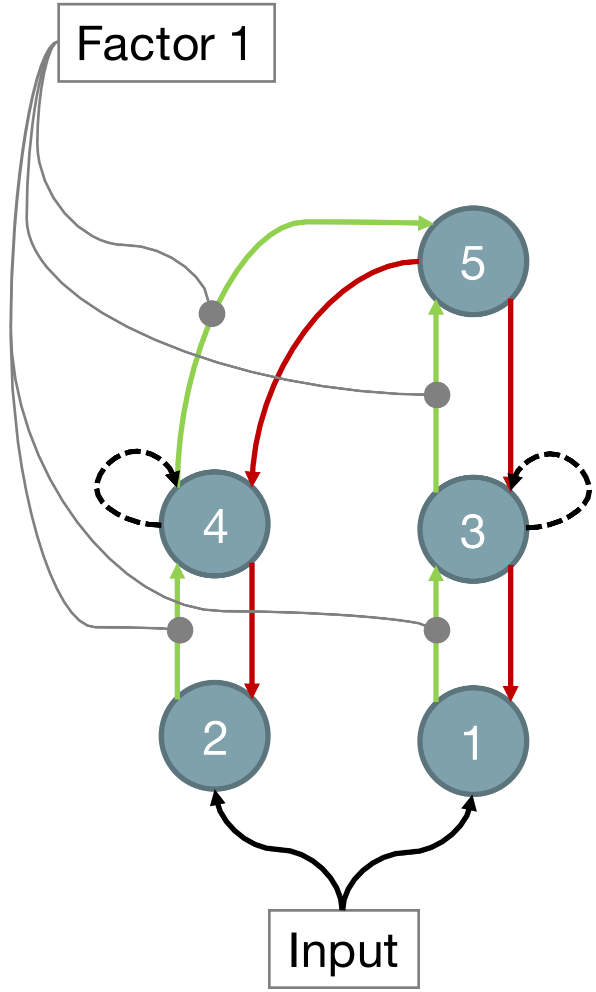

Factor 1
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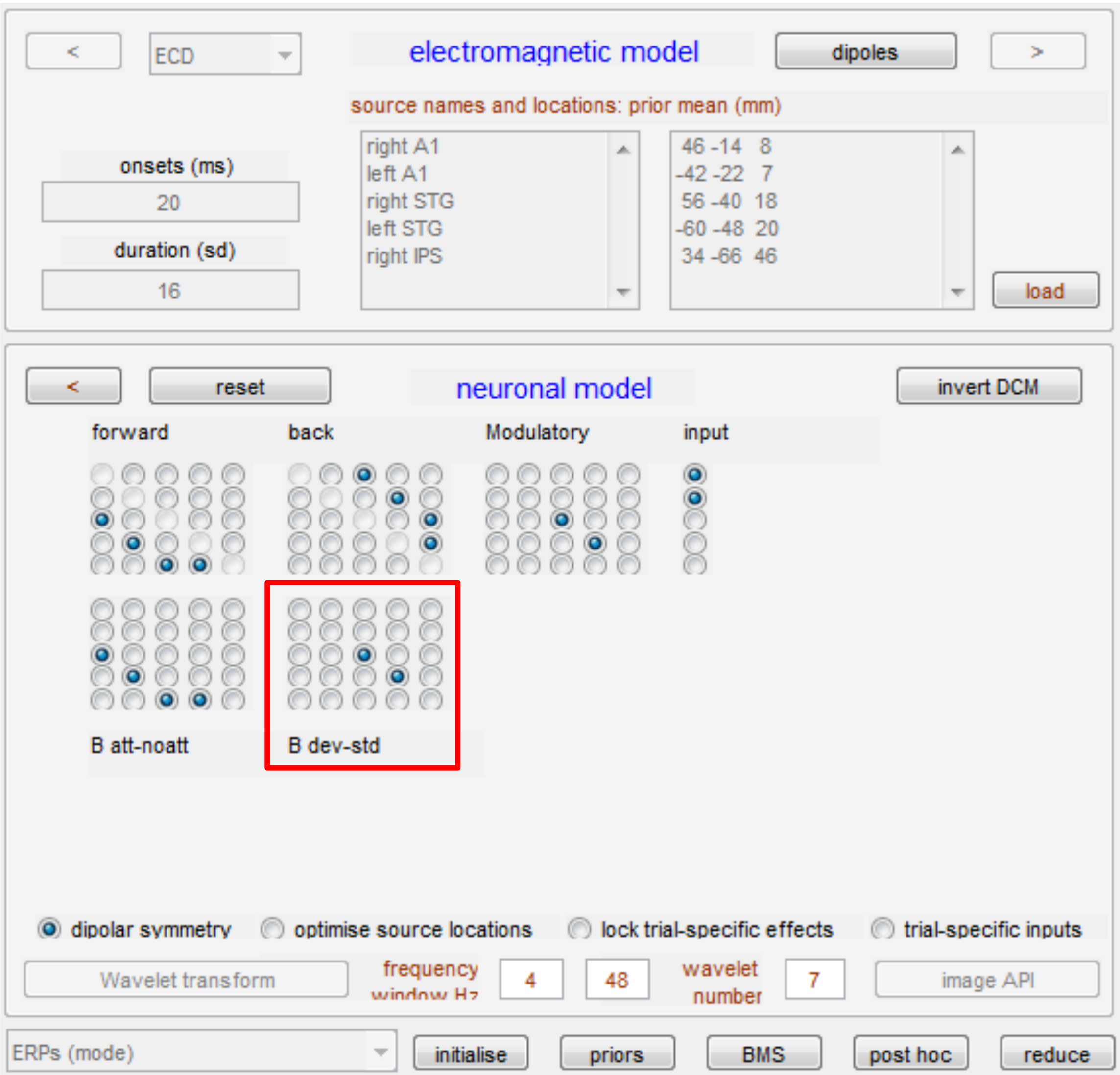
Input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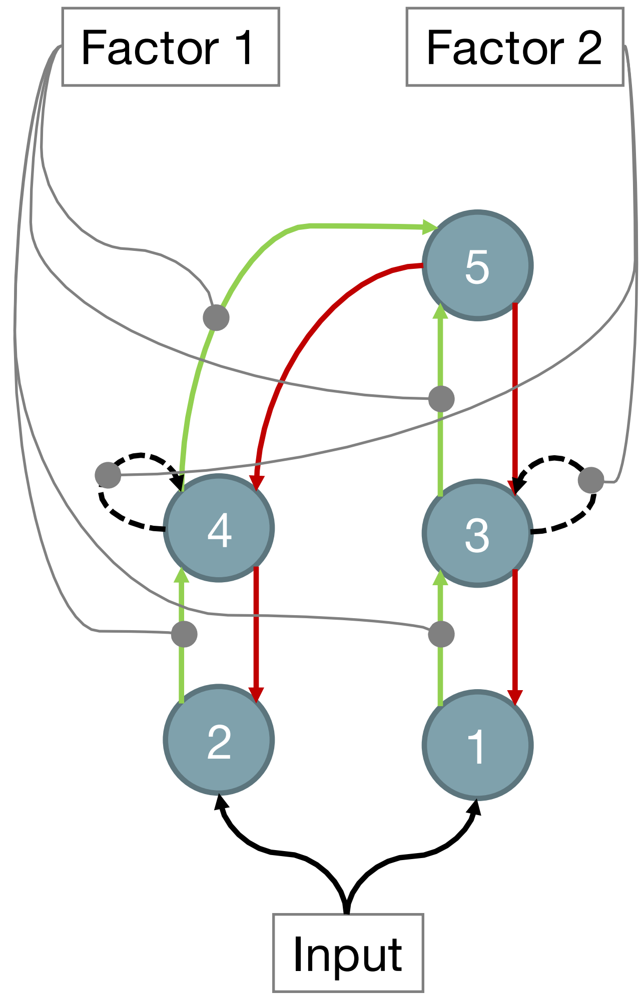
Factor 1
Factor 2
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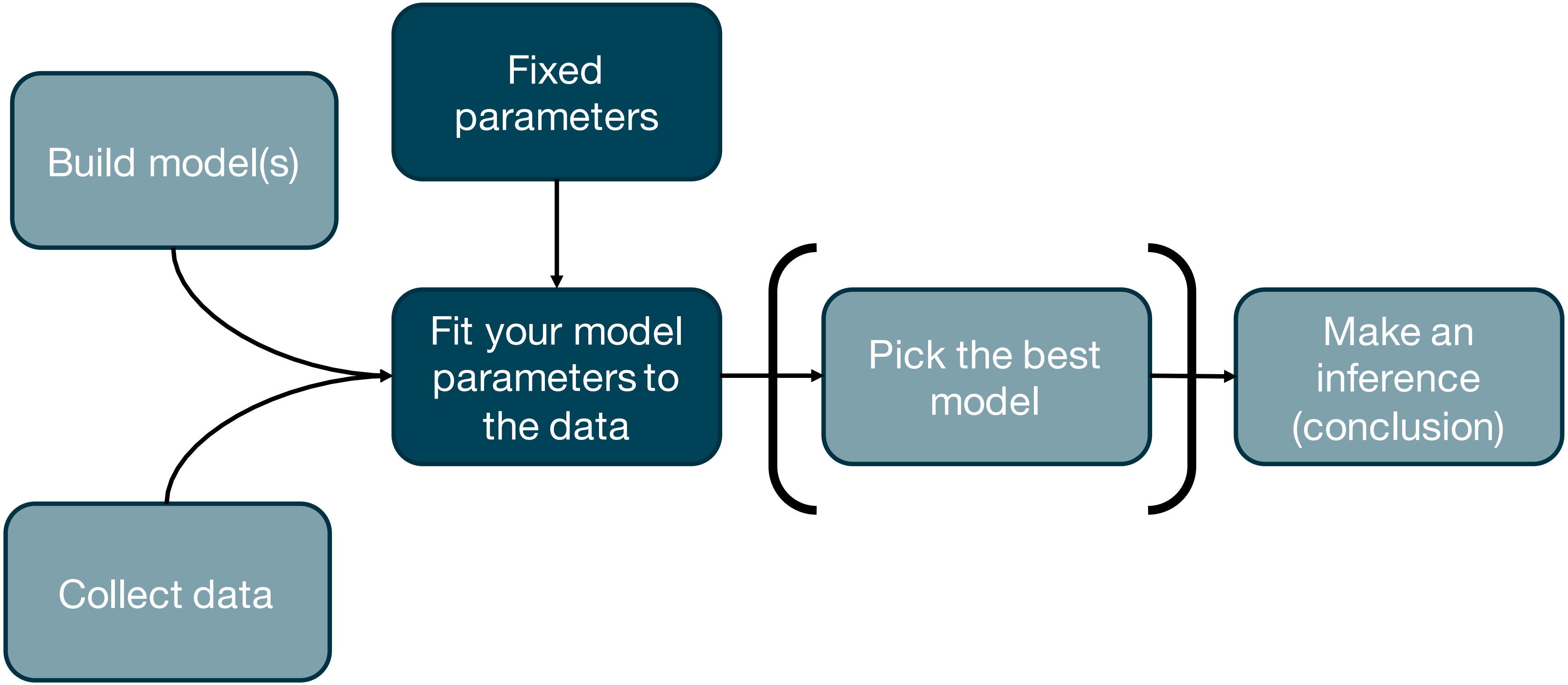
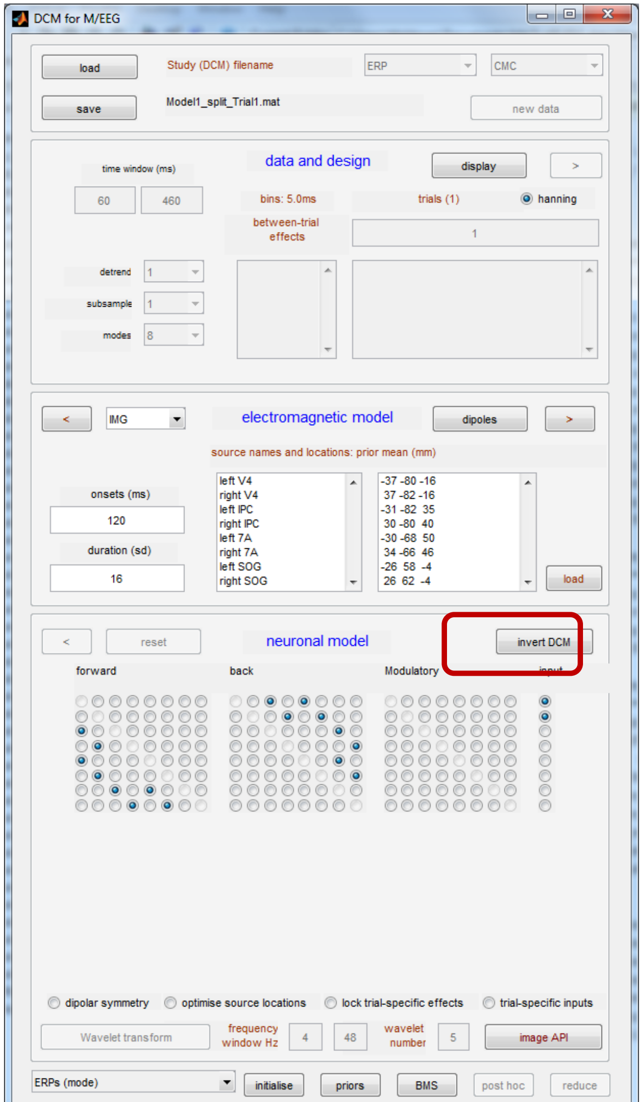
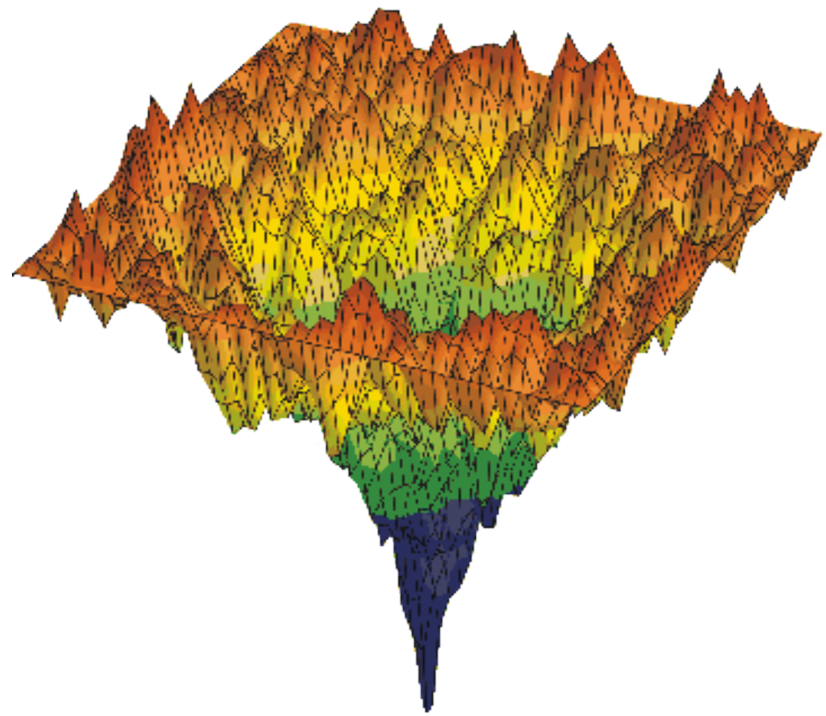
Input

The DCM analysis pathway



Fitting DCMs to data





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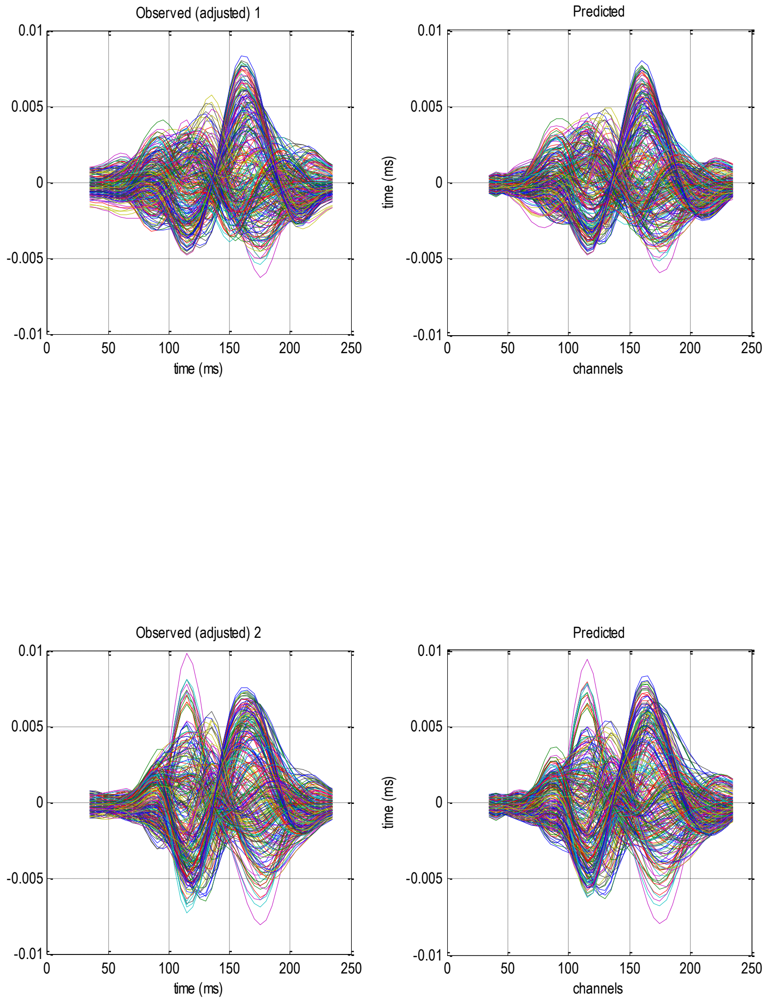
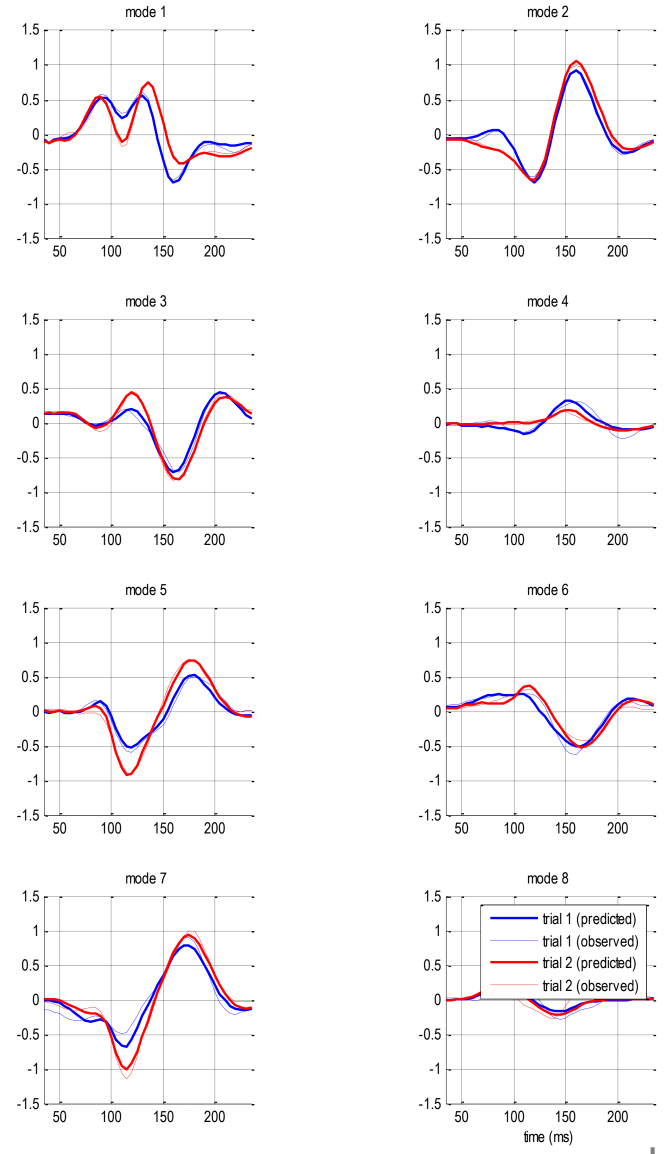
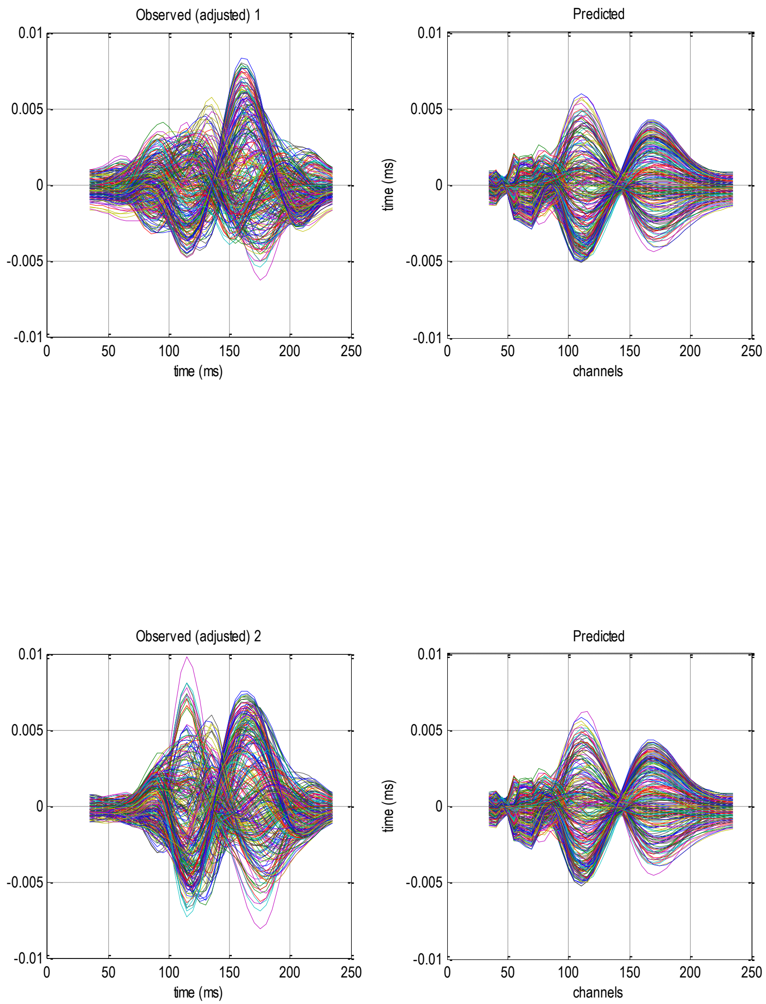
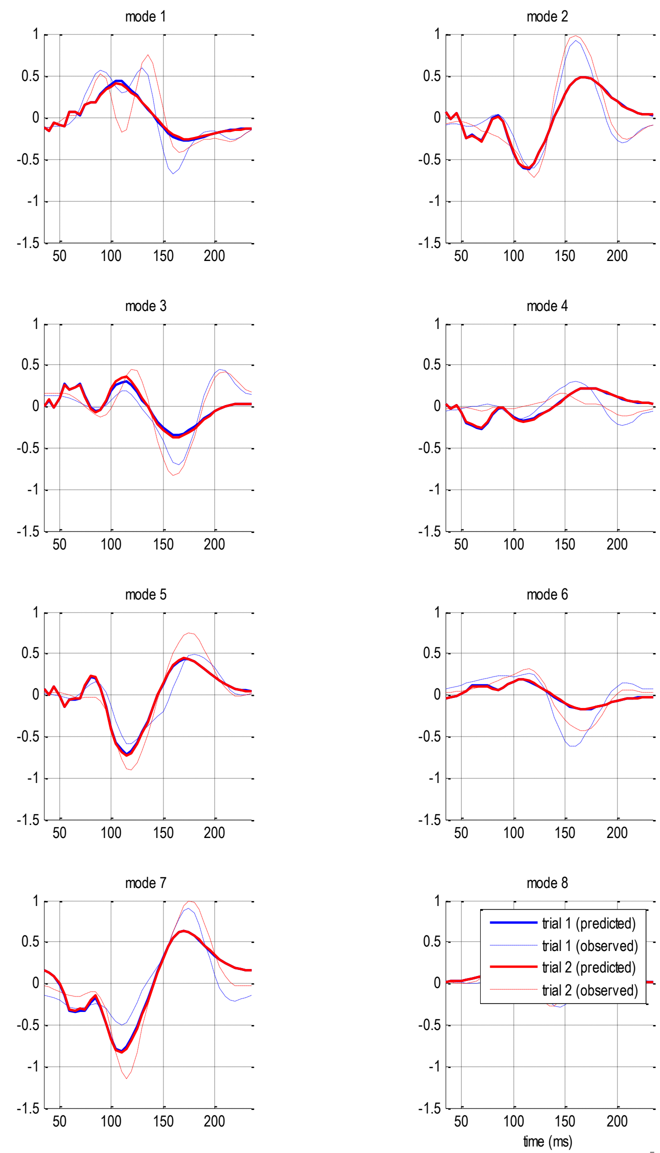




H. Brown

Fitting DCMs to data





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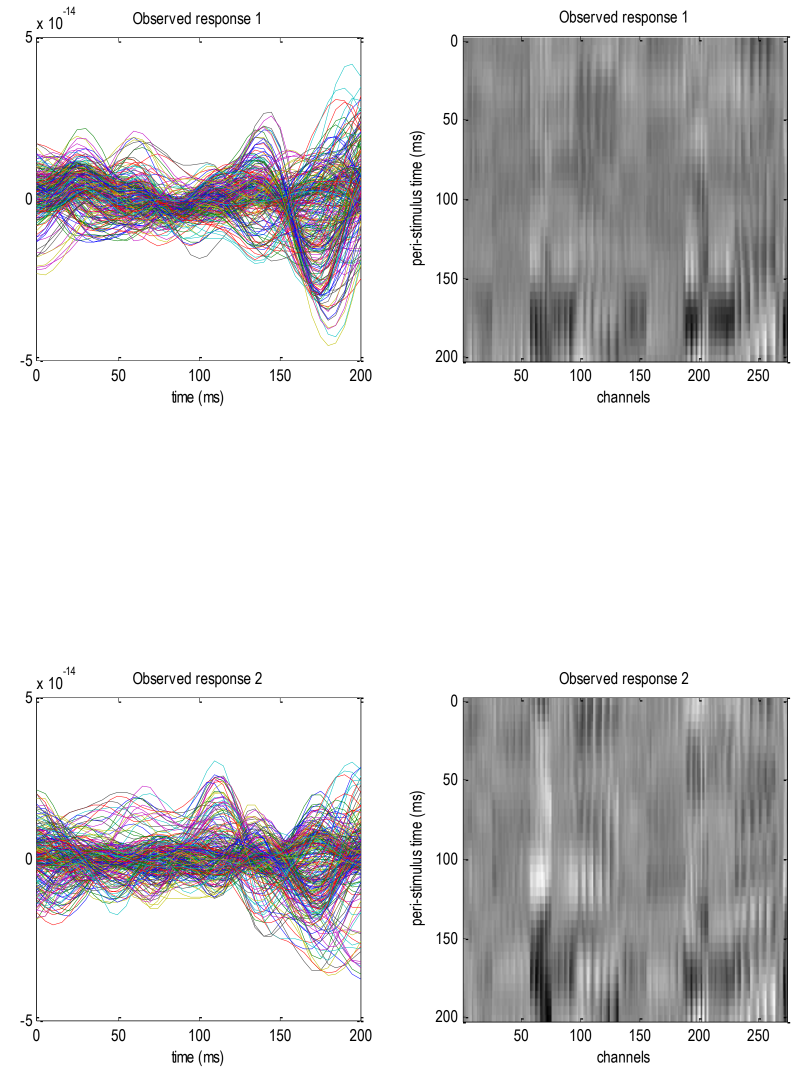
Fitting DCMs to data

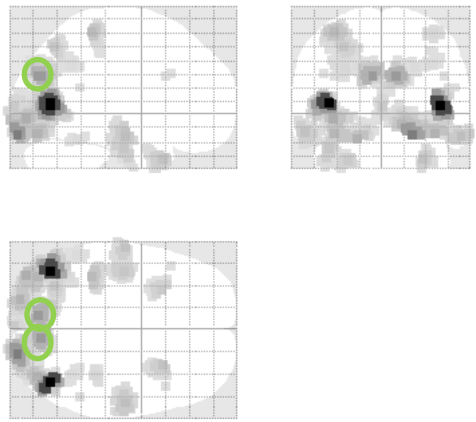
1. Check your data



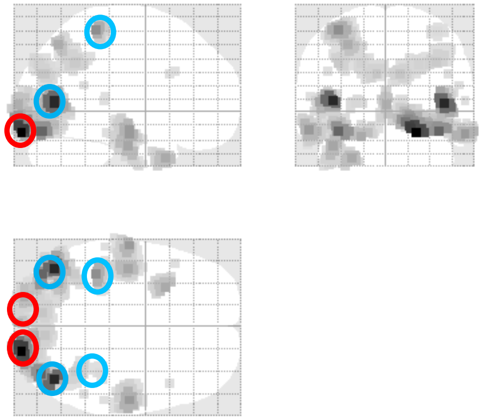
H. Brown

Fitting DCMs to data

1. Check your data



2. Check your sources



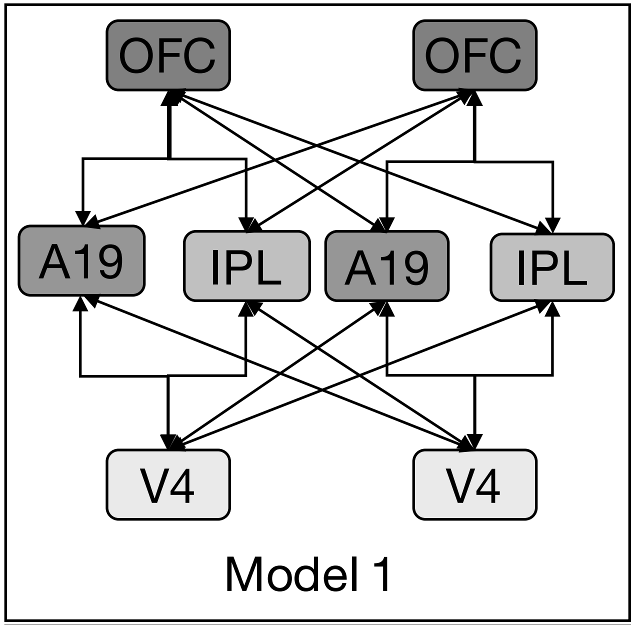
H. Brown

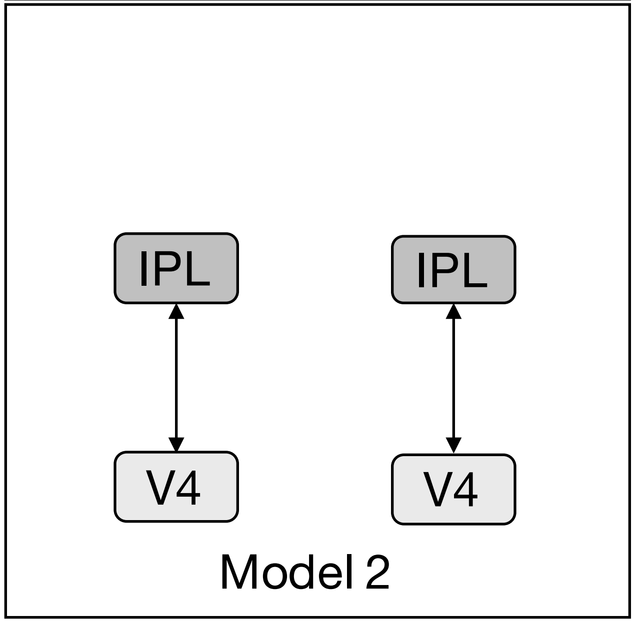
Fitting DCMs to data

1. Check your data

2. Check your sources

3. Check your model





H. Brown

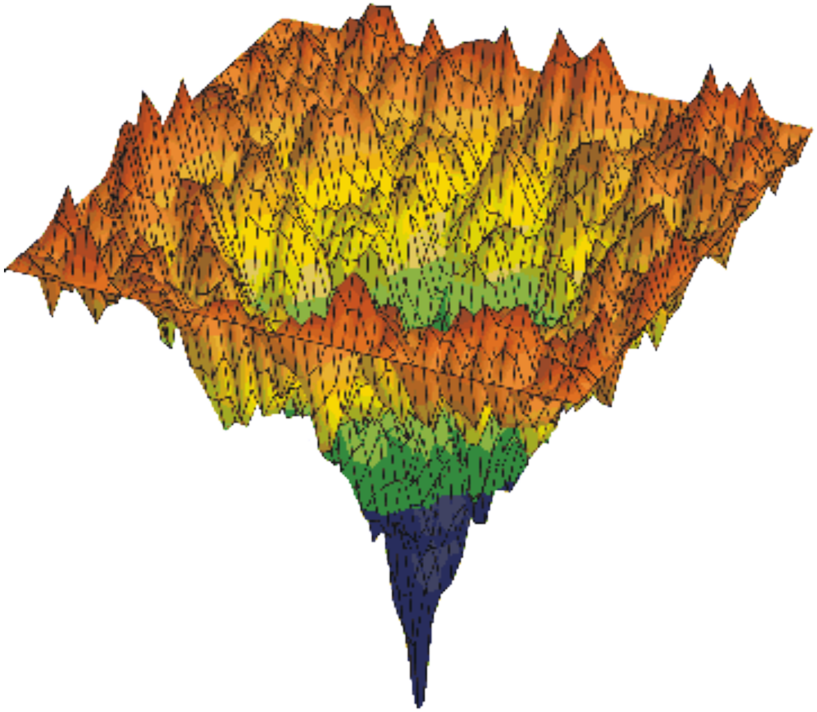
Fitting DCMs to data

1. Check your data

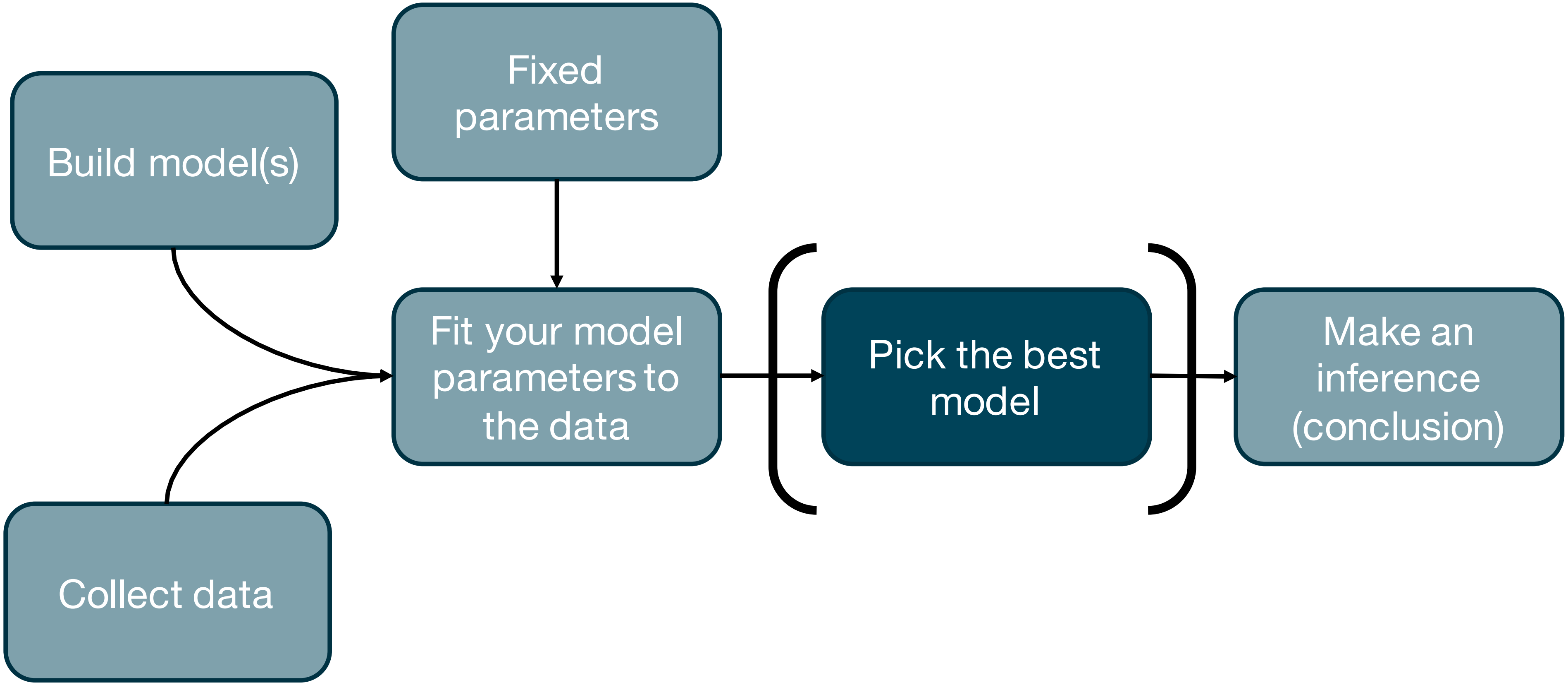
2. Check your sources

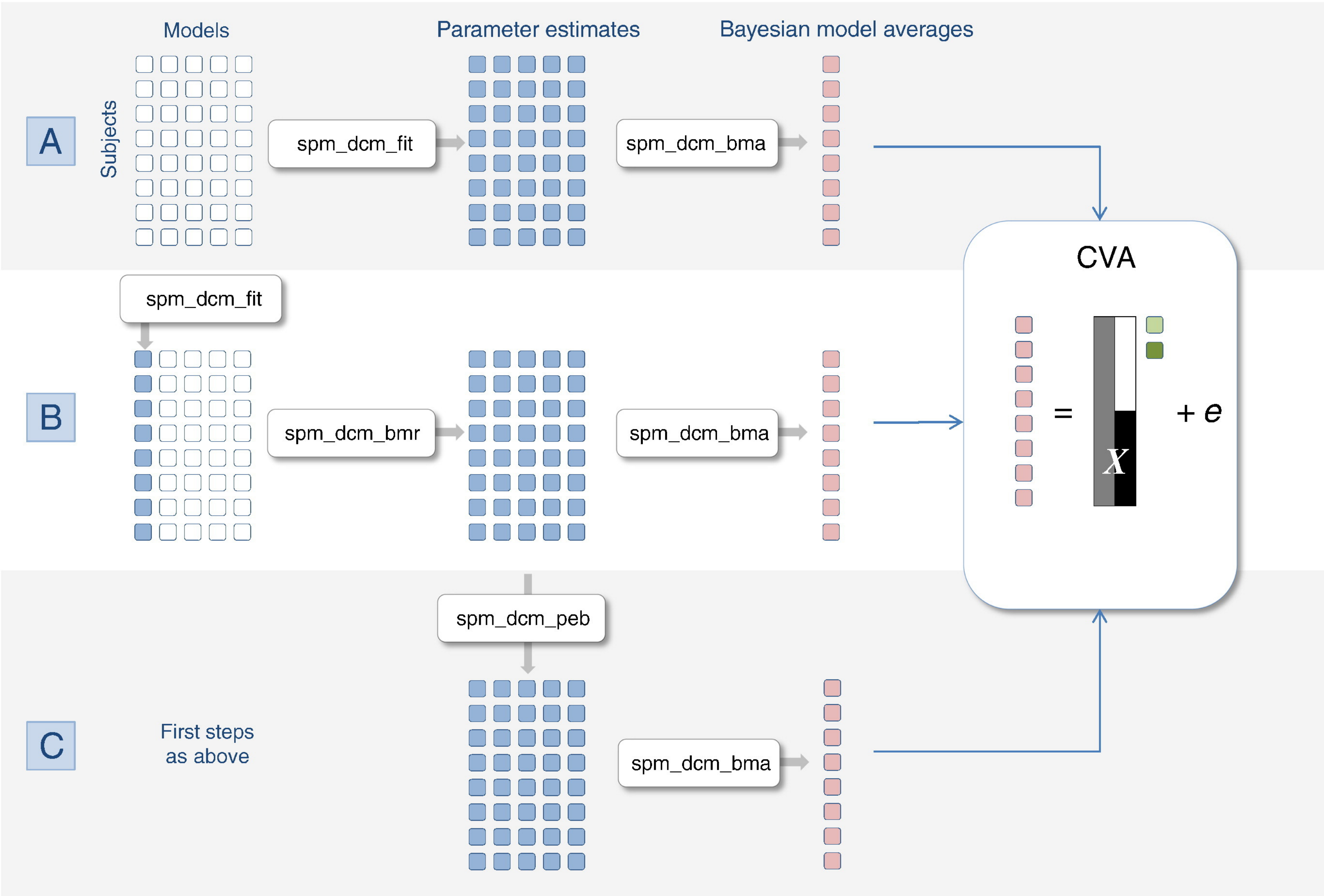
3. Check your model

4. Re-run model fitting



The DCM analysis pathway





Friston et al., 2016

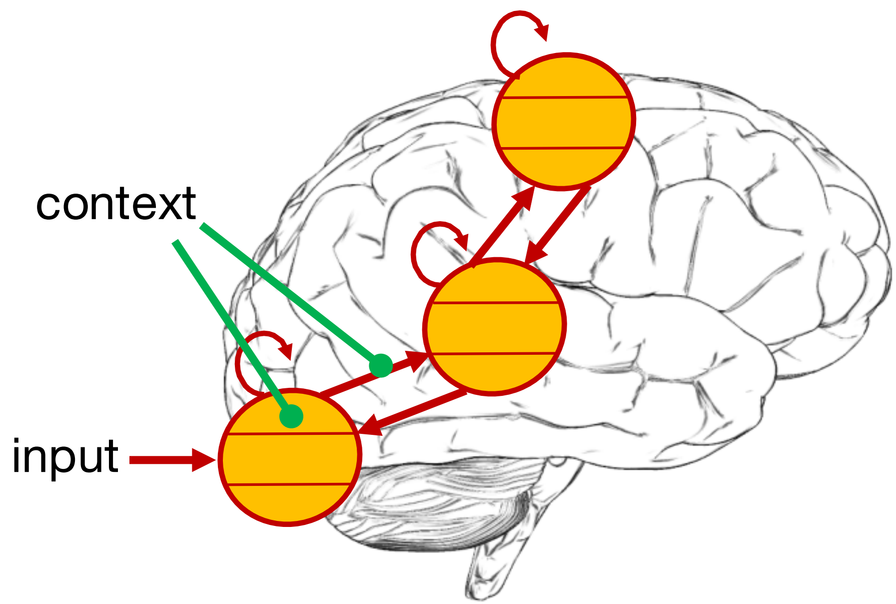
Does network XYZ explain my data better than network XY?

Which XYZ connectivity structure best explains my data?

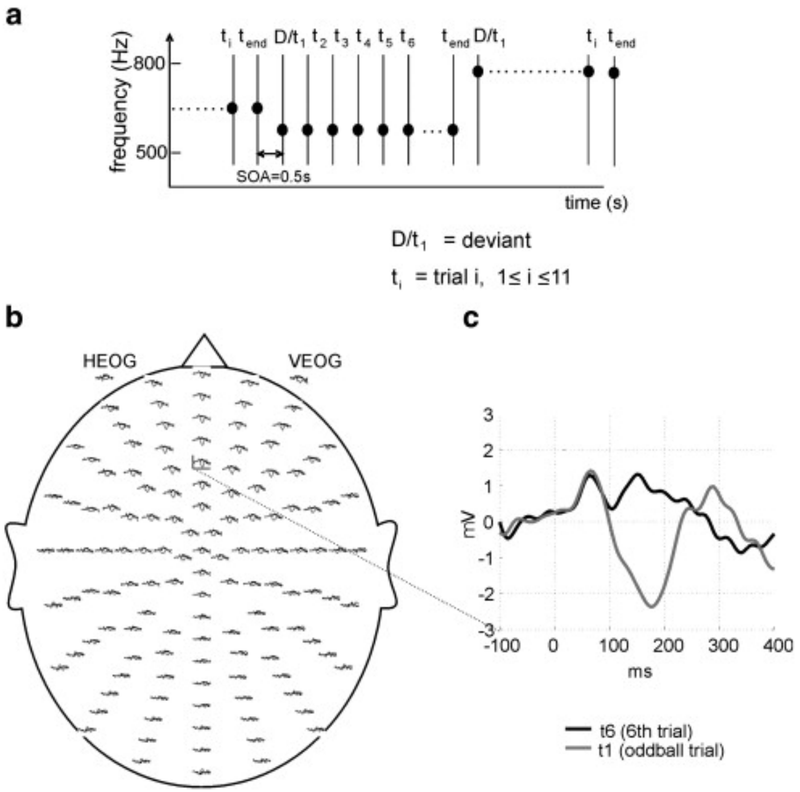
Are X & Y linked in a bottom-up, top-down or recurrent fashion?

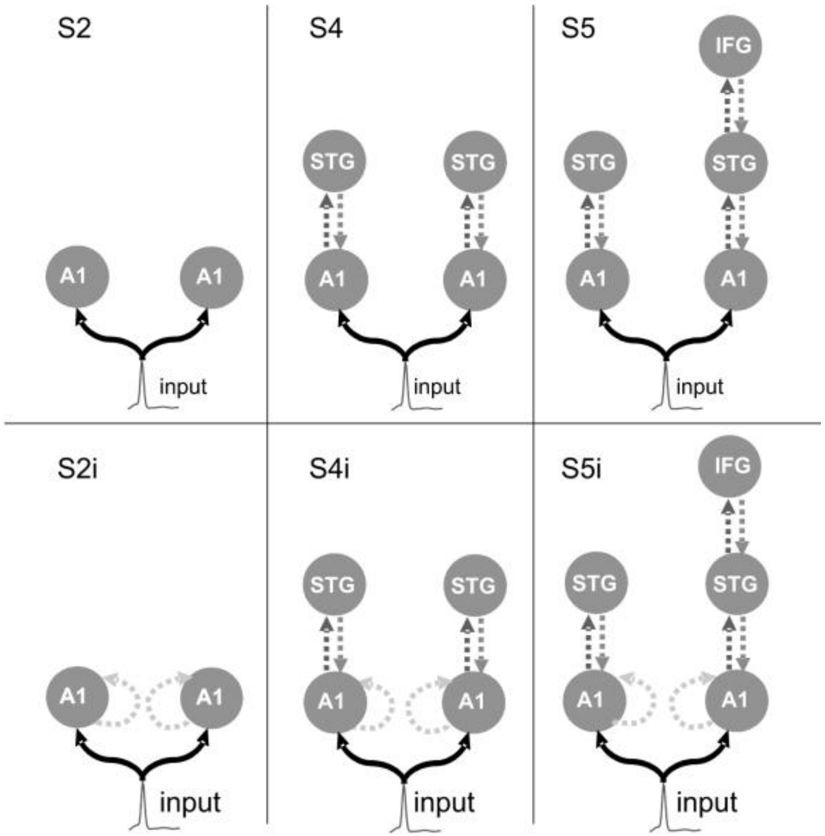
Is my effect driven by extrinsic or intrinsic connections?

Which connections/populations are affected by contextual factors?



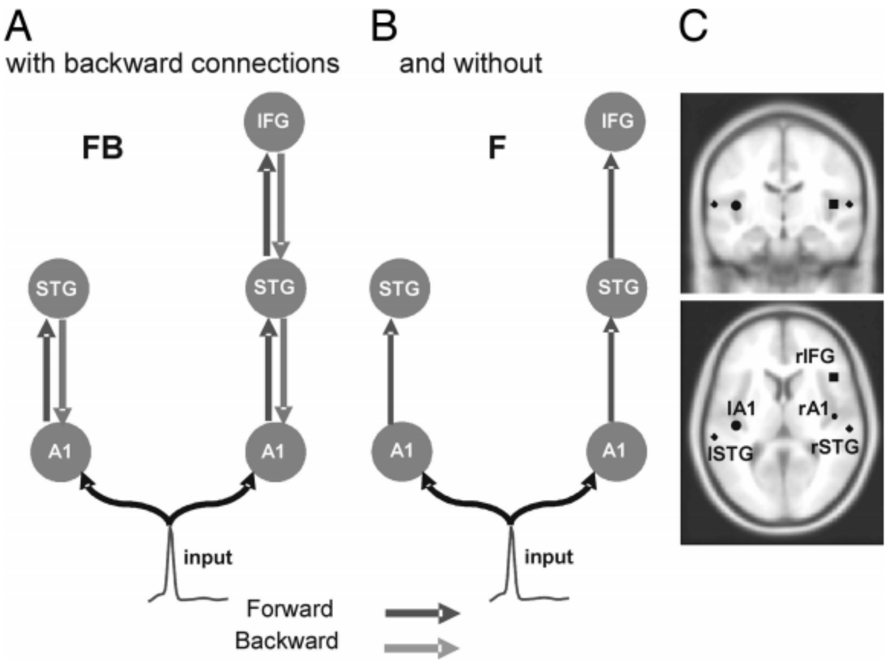
Example #1: Architecture of MMN

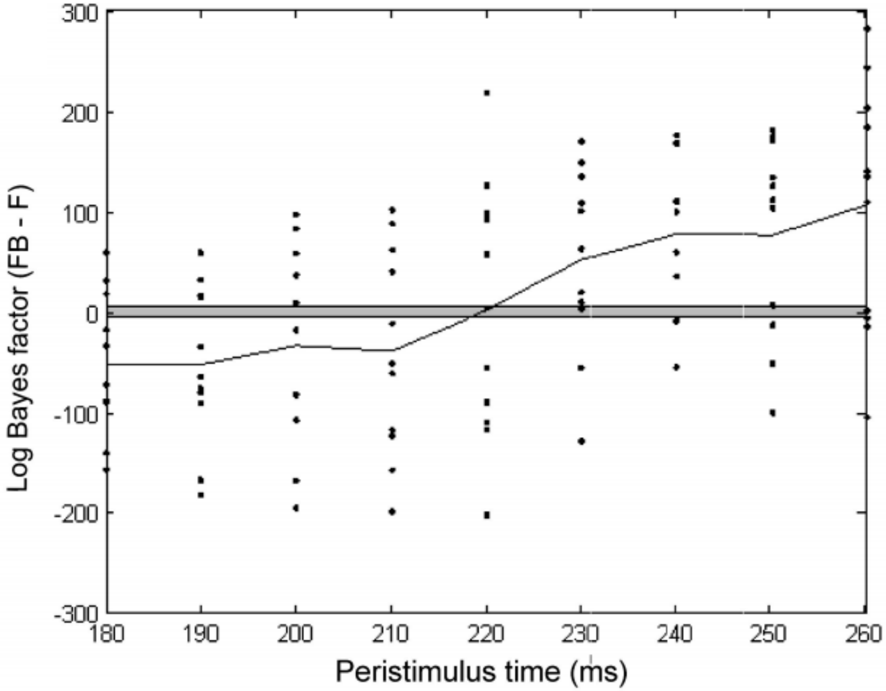




Garrido et al., 2008

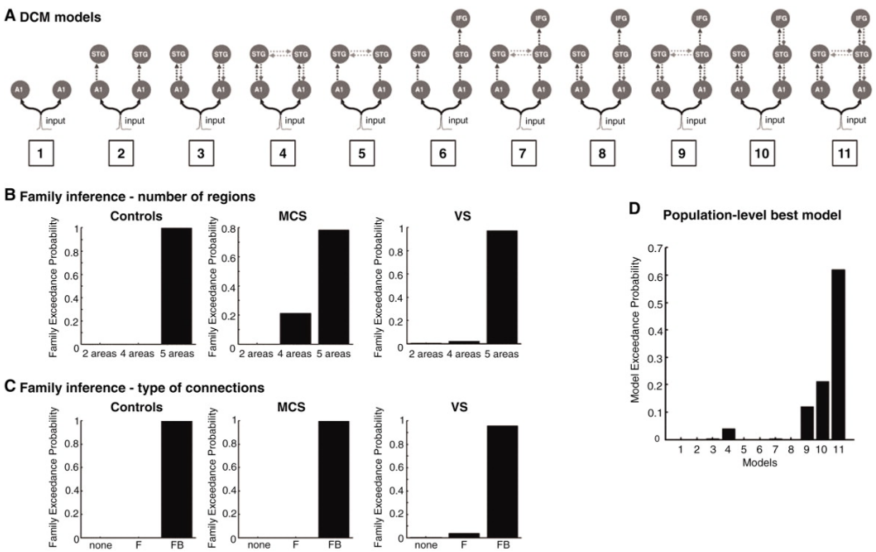
Example #2: Role of feedback connections

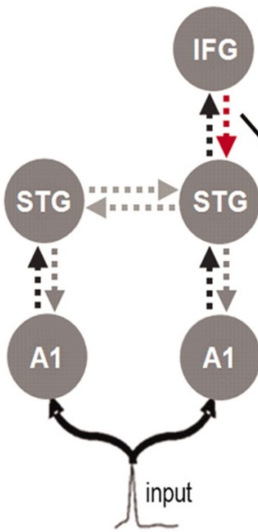


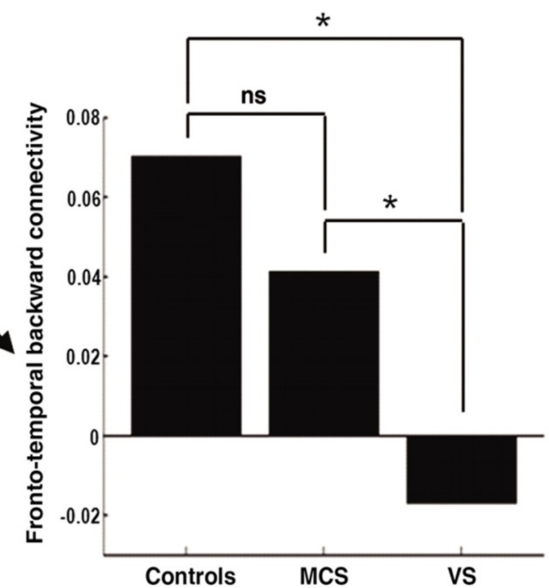


Garrido et al., 2007

Example #3: Group differences

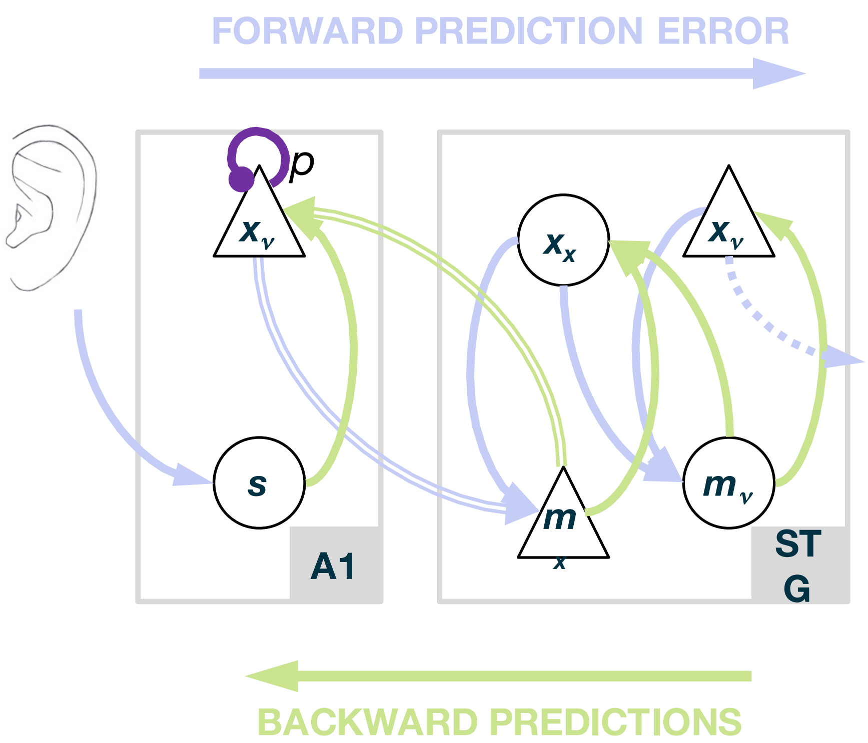


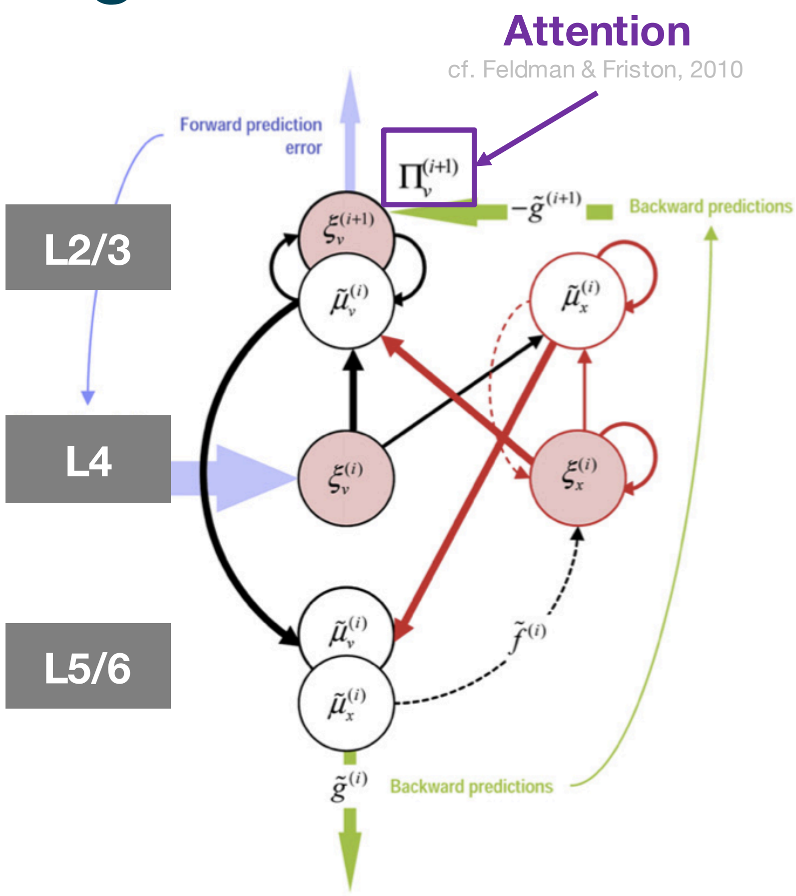




Boly et al., 2011

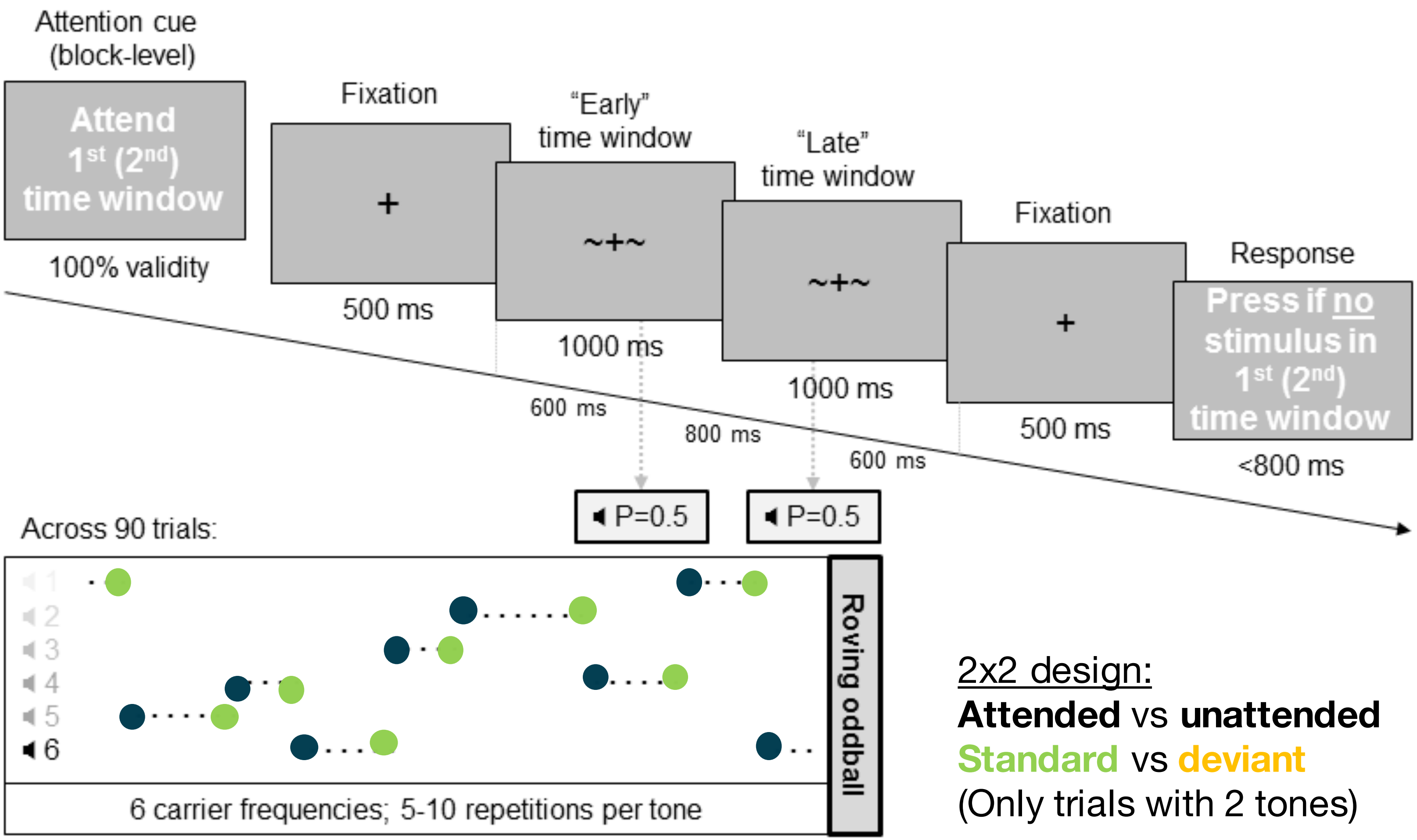
Example #4: Factorial design & CMC





Bastos et al., *Neuron* 2012

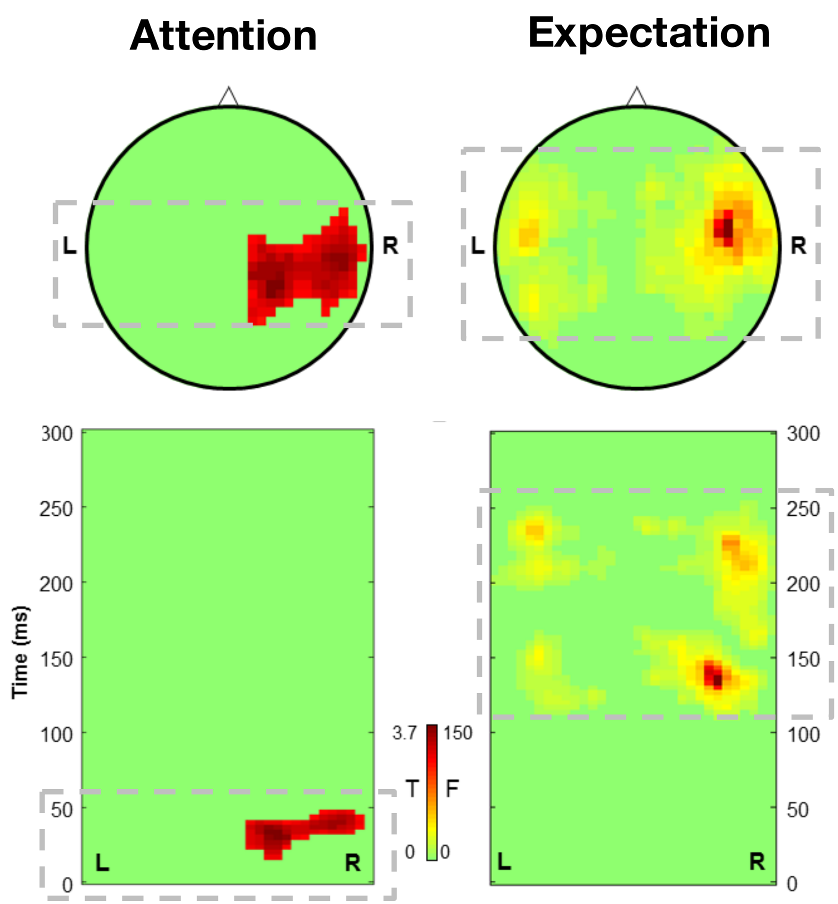
Auksztulewicz & Friston, 2015



2x2 design:
Attended vs **unattended**
Standard vs **deviant**
(Only trials with 2 tones)

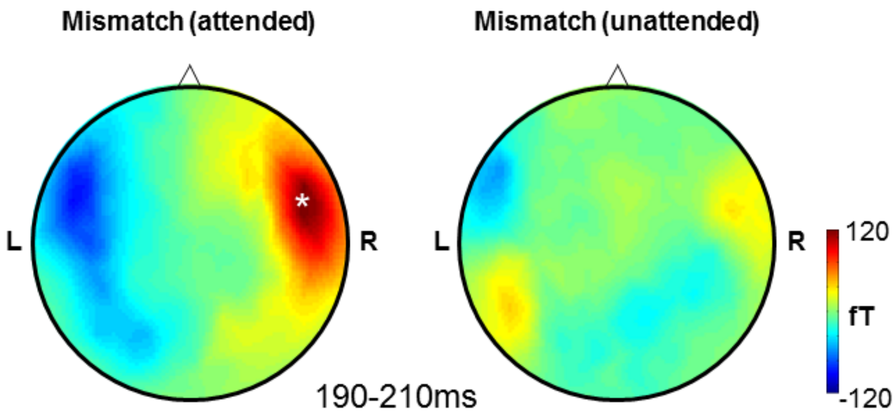
N=20

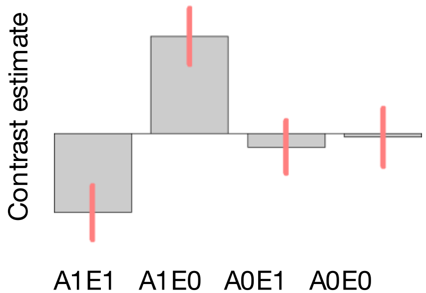
Auksztulewicz & Friston, 2015



Flexible factorial design
Thresholded at p<.005 peak-level
Corrected at a cluster-level pFWE<.05

Auksztulewicz & Friston, 2015



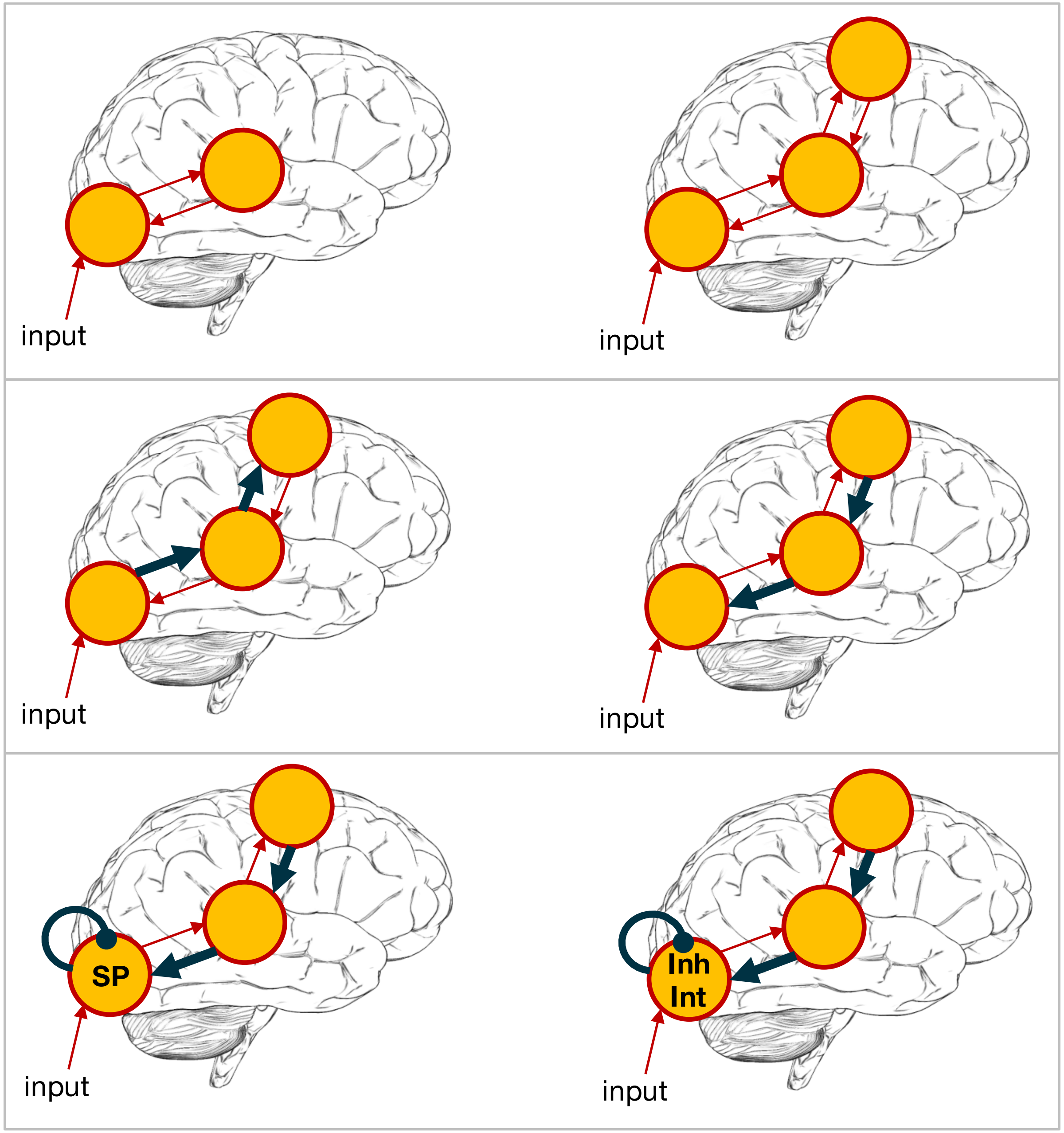


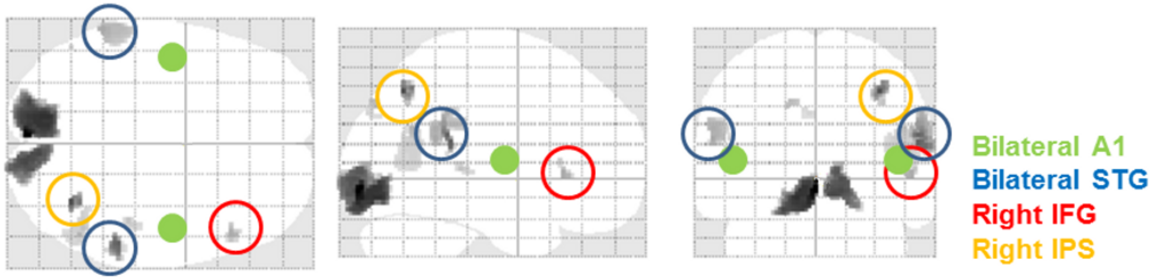
Auksztulewicz & Friston, 2015

Connectivity structure

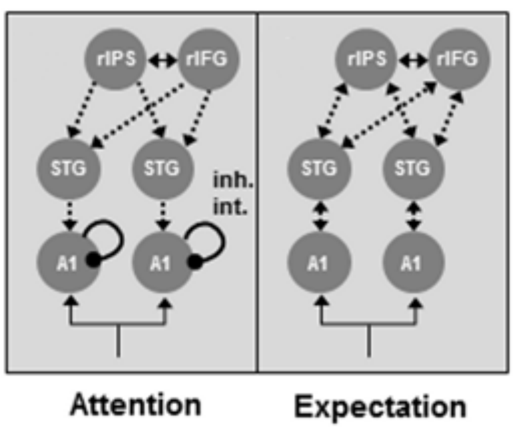
Extrinsic modulation

Intrinsic modulation

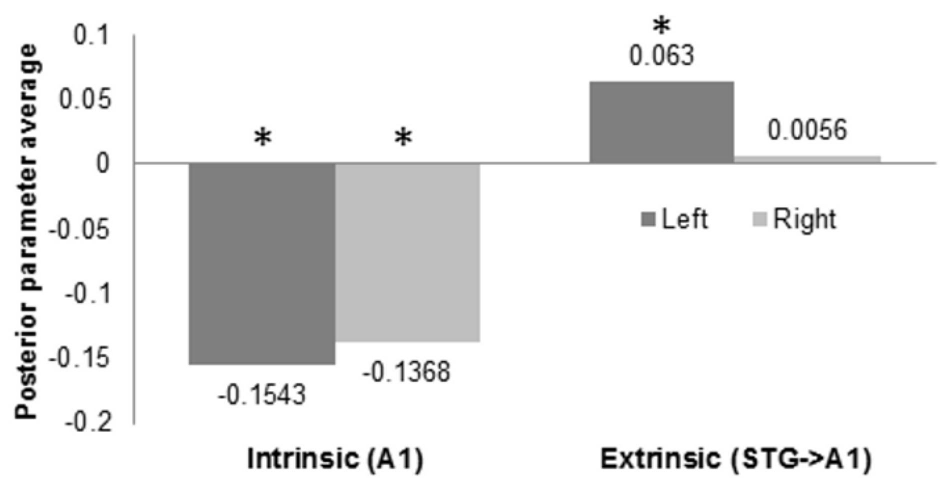


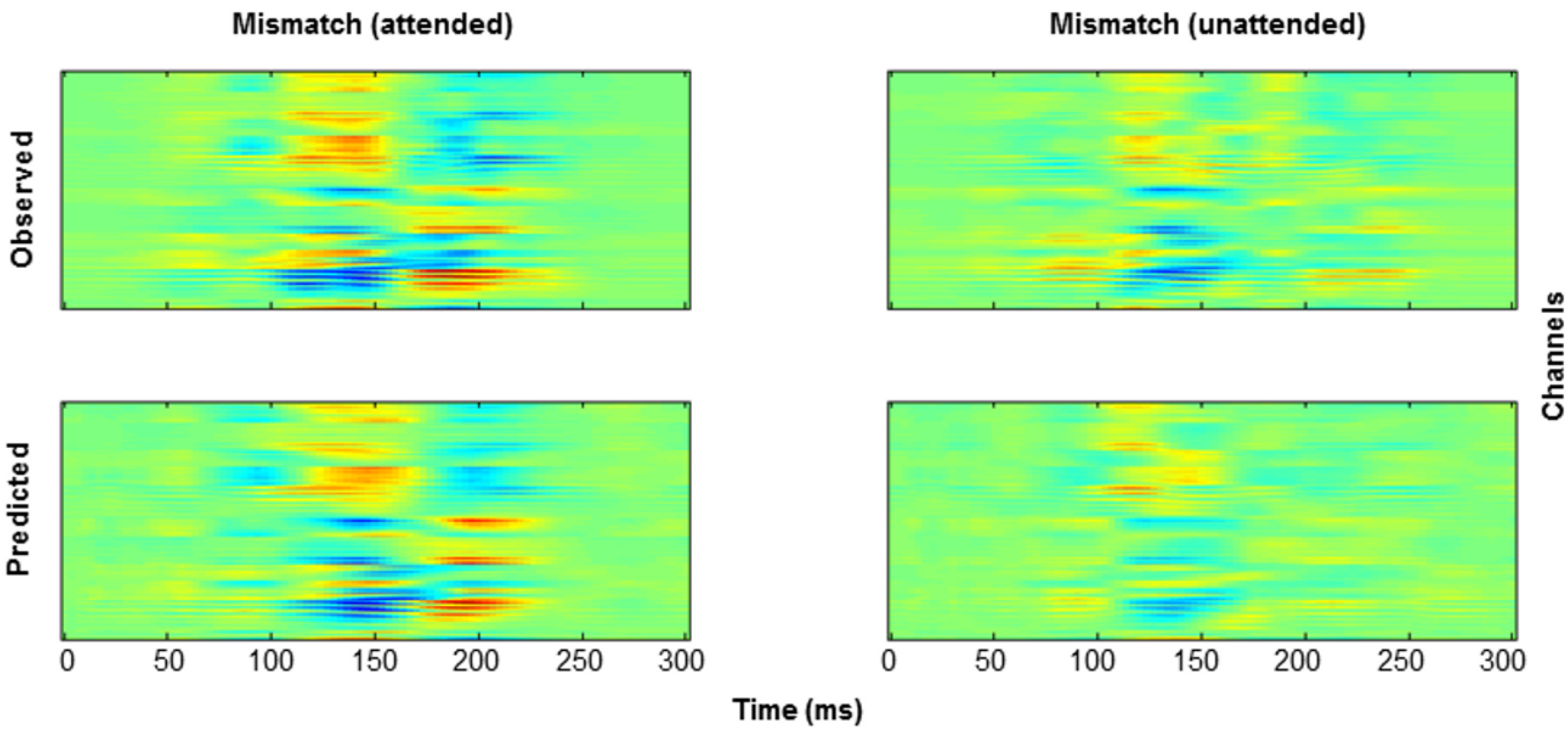


Winning model



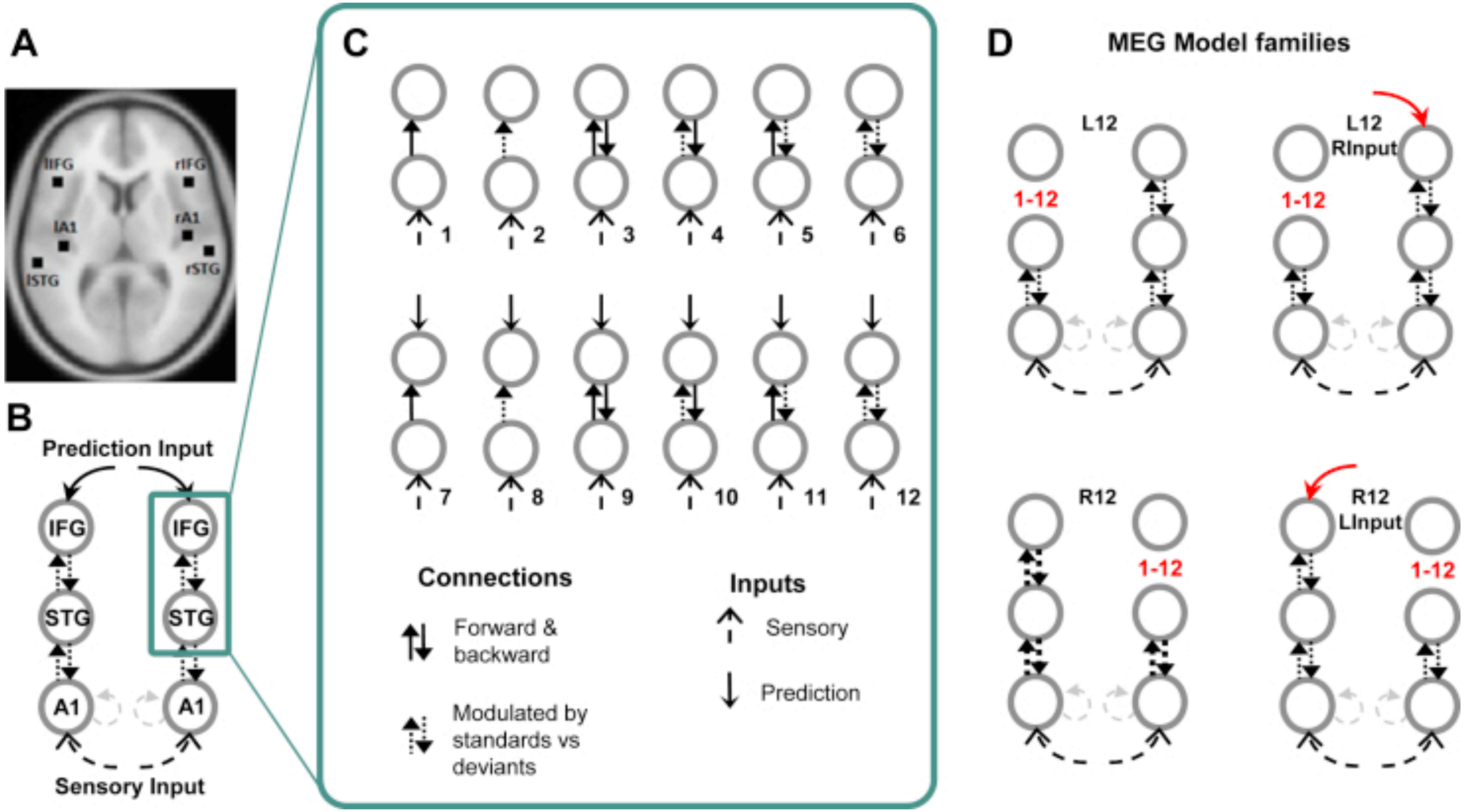
Parameter inference





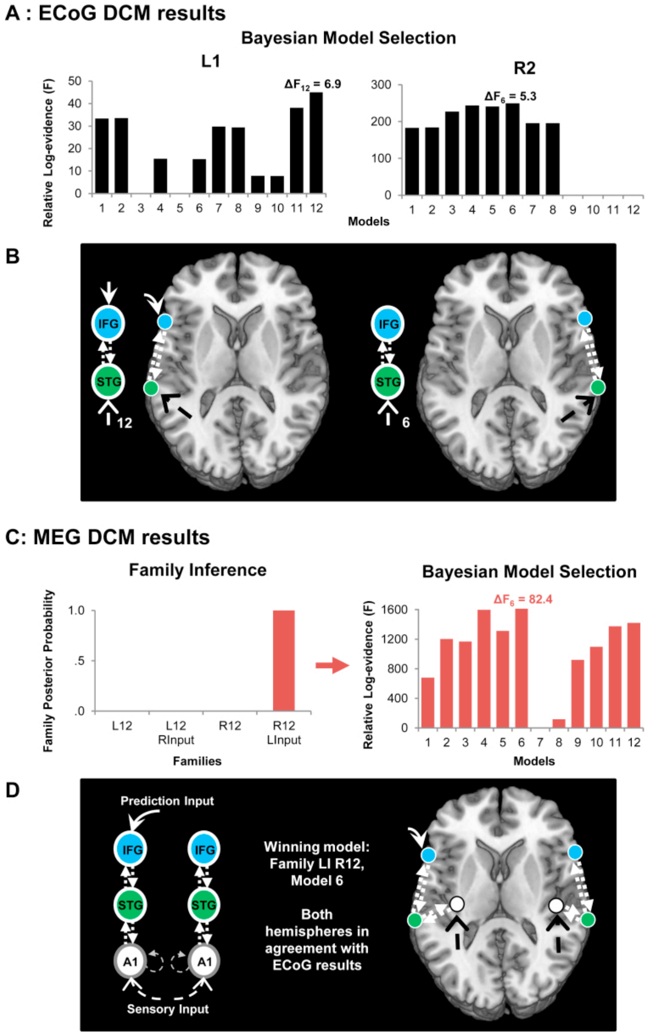
Auksztulewicz & Friston, 2015

Example #5: Same paradigm, different data



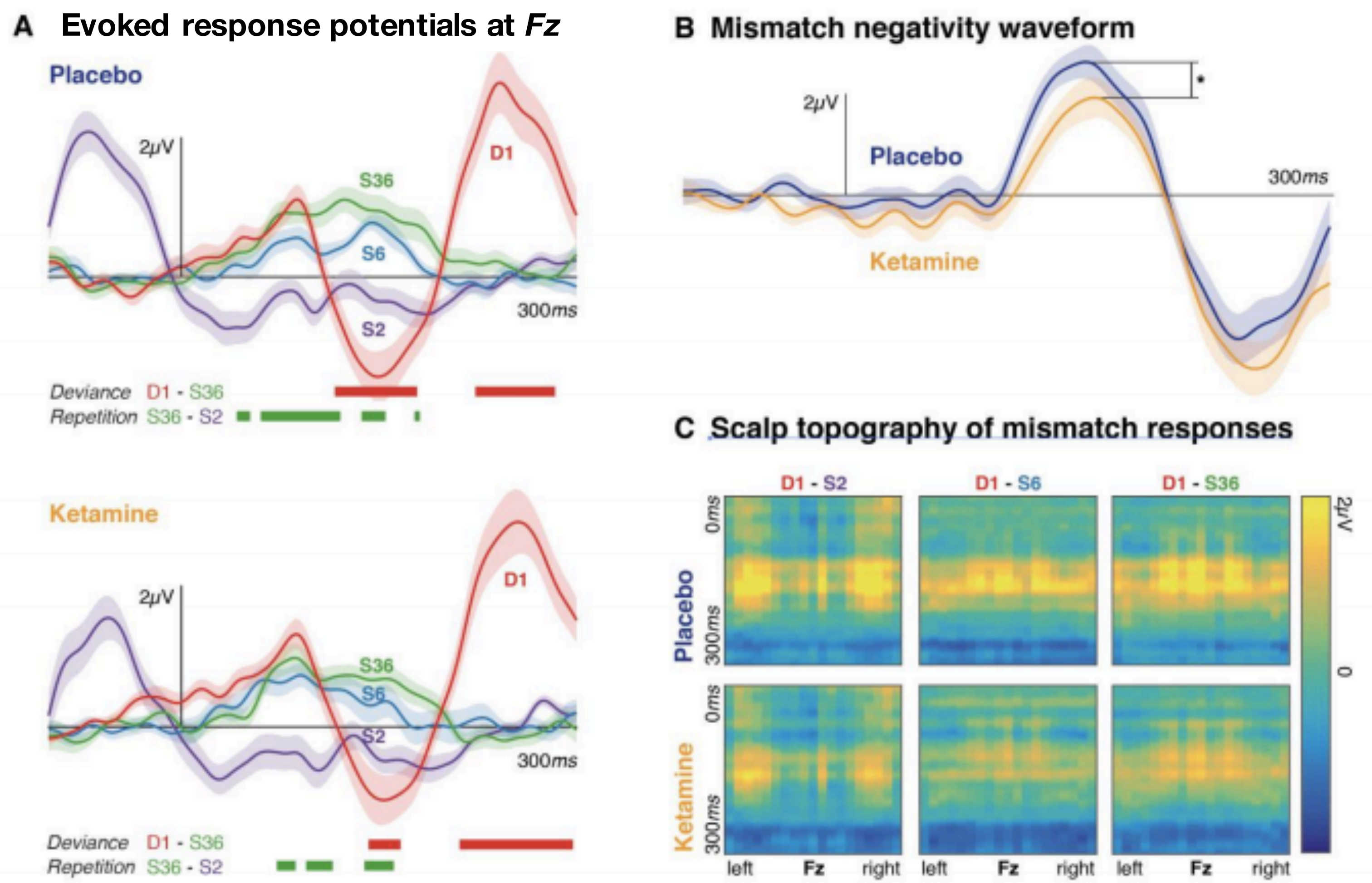
Phillips et al., 2016

Example #5: Same paradigm, different data

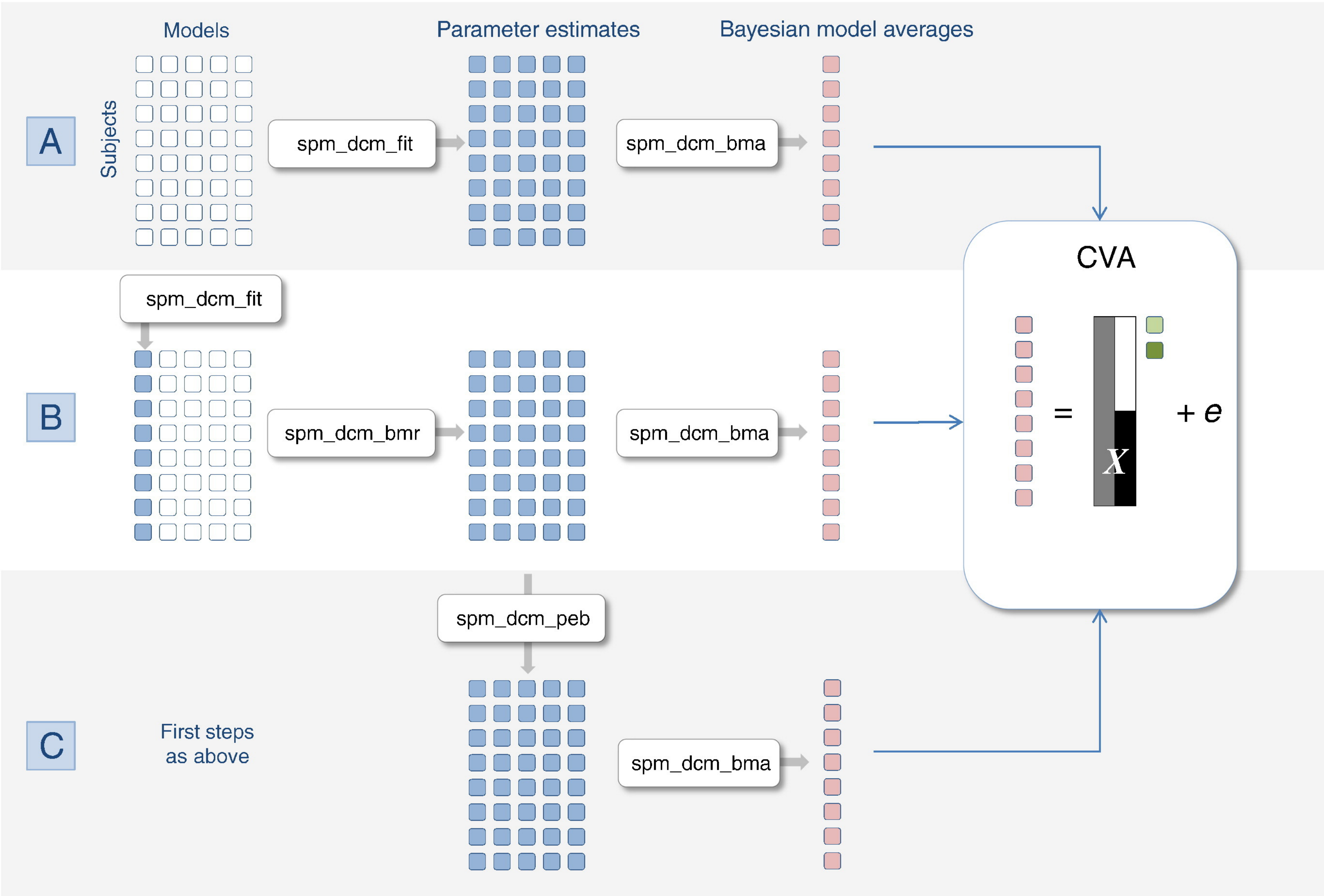


Phillips et al., 2016

Example #6: Hierarchical modelling

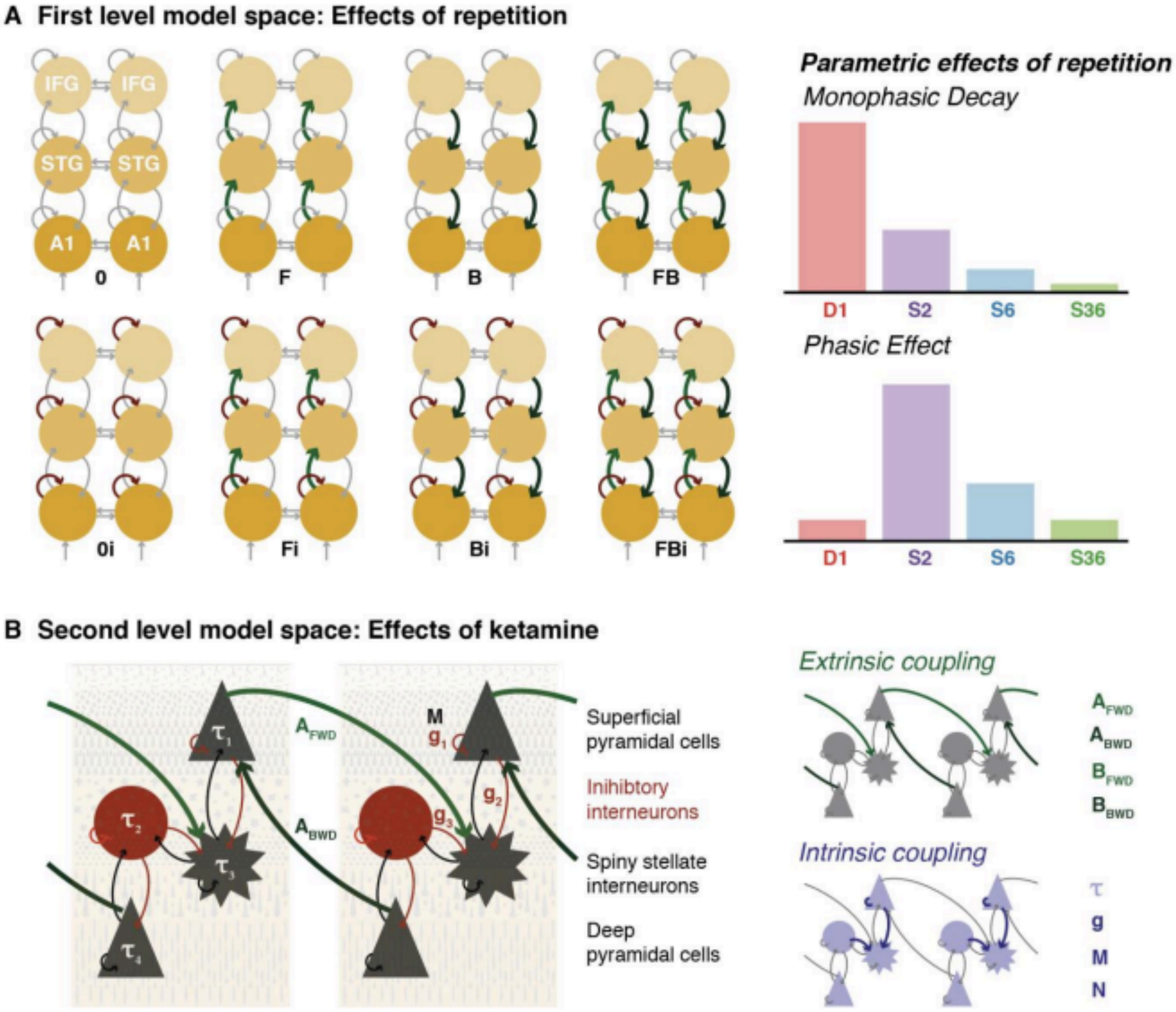


Rosch et al., 2017



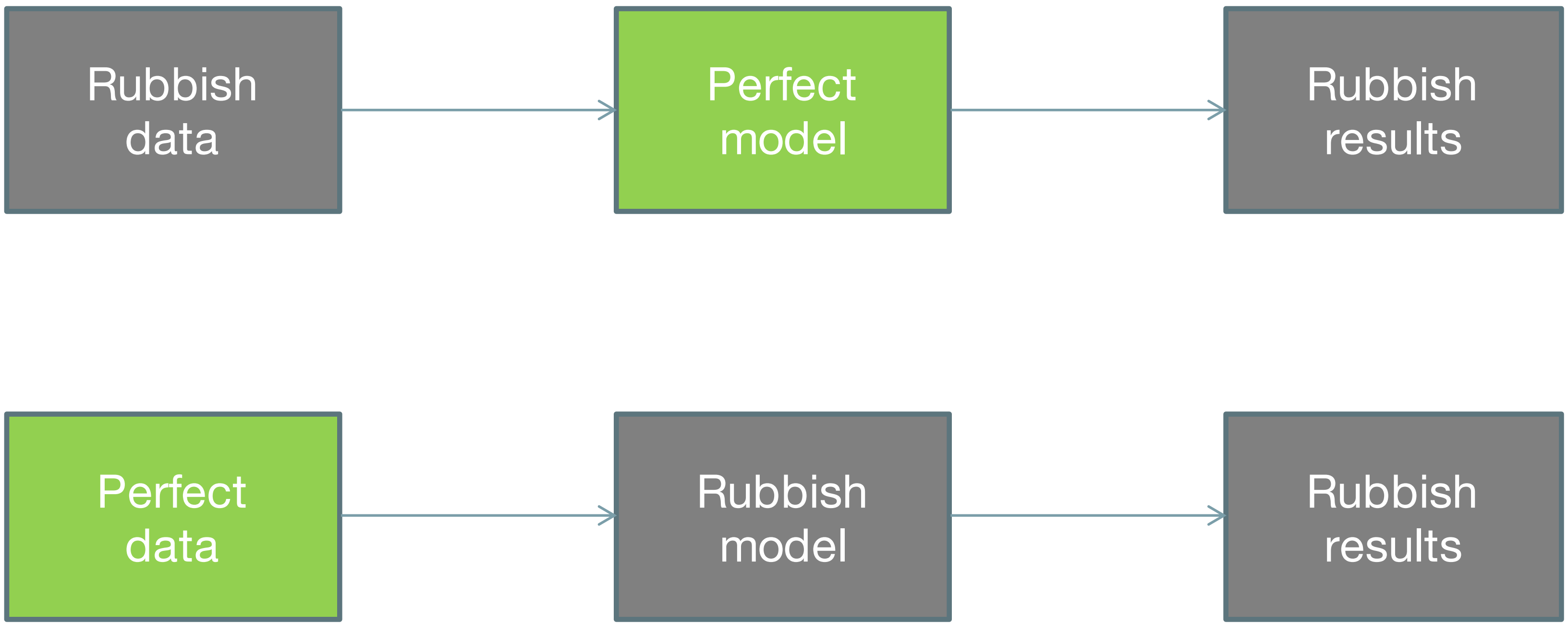
Friston et al., 2016

Example #6: Hierarchical modelling



Rosch et al., 2017

Motivate your assumptions!



Thank you!

Karl Friston
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Marta Garrido
Stefan Kiebel
Vladimir Litvak
Rosalyn Moran
Will Penny
Dimitris Pinotsis
Richard Rosch
Bernadette van Wijk