

M/EEG Connectivity using Dynamic Causal Modelling (DCM) Part II – Group DCM

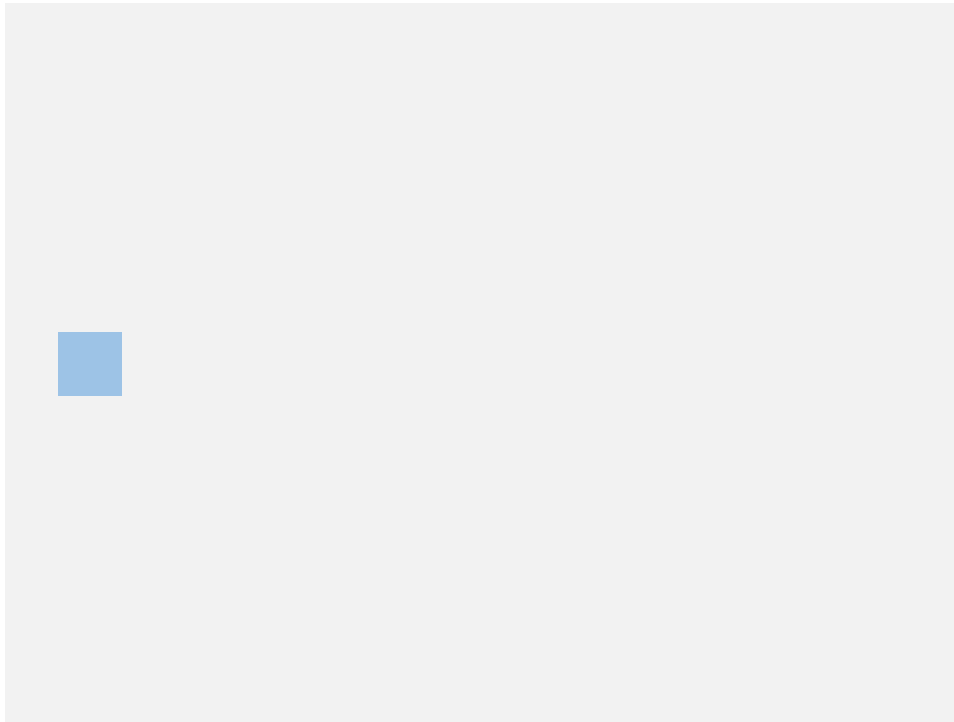
Rik Henson, Pranay Yadav

COGNESTIC Summer School, Sep 2022

<https://www.mrc-cbu.cam.ac.uk/conferences/cognestic2022/>

Batch Processing Steps for Estimation

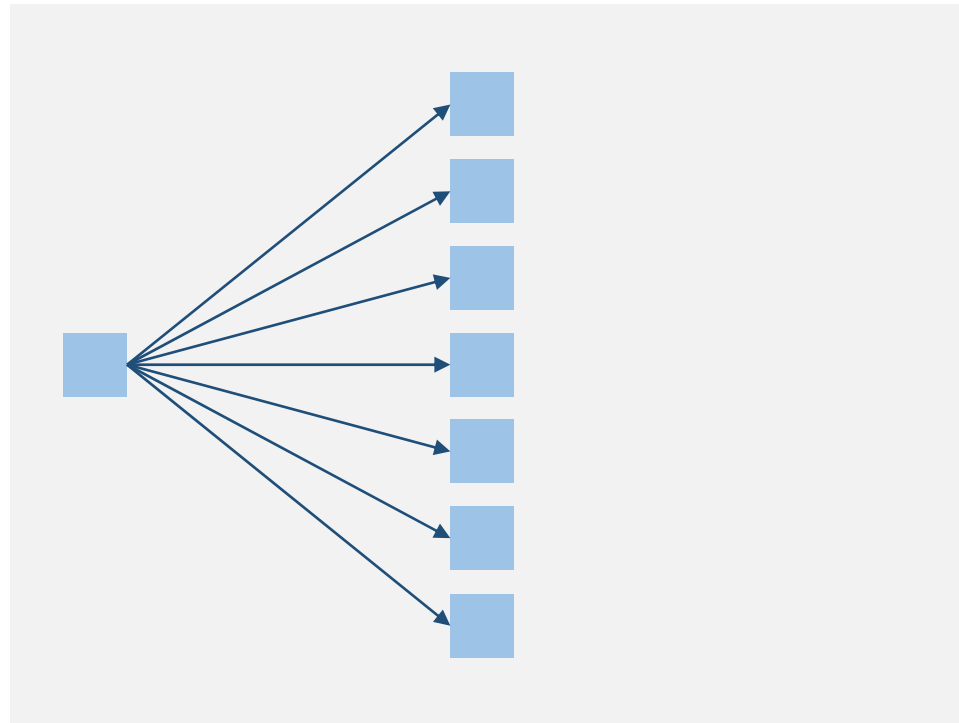
GCM Specification



Single
'Full' DCM

Batch Processing Steps for Estimation

GCM Specification

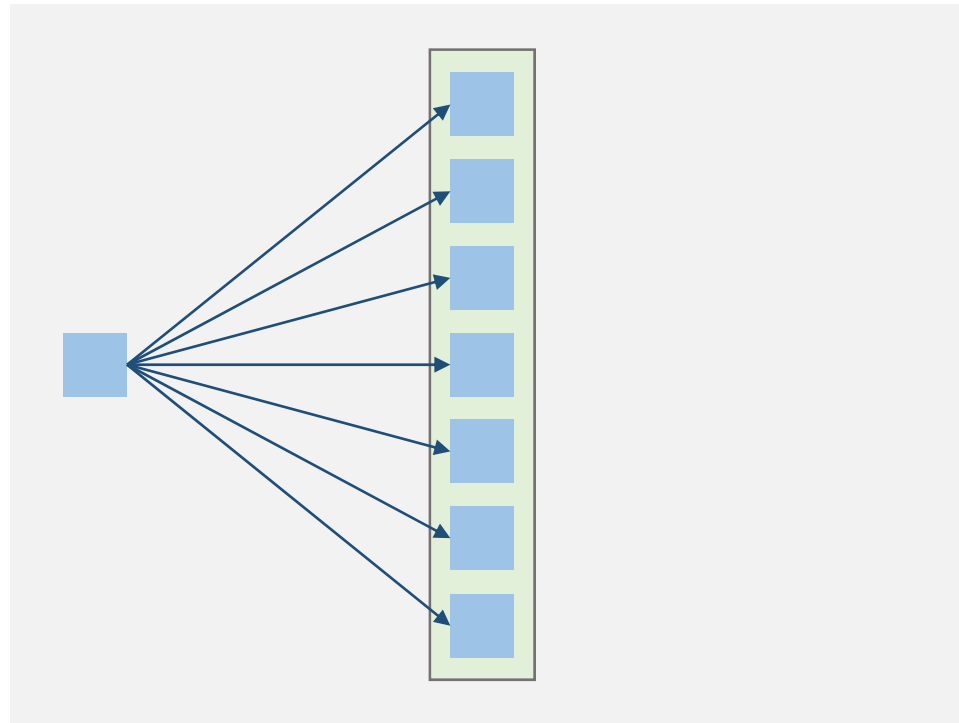


Single
'Full' DCM

Multiple
'Full' DCMs

Batch Processing Steps for Estimation

GCM Specification

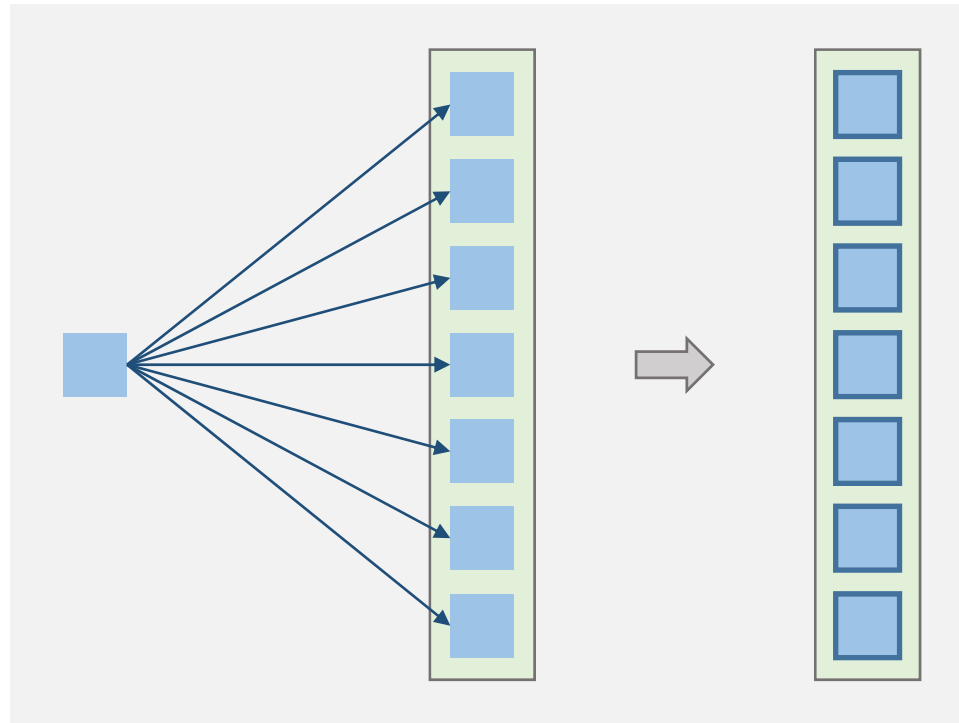


Single
'Full' DCM

Multiple
'Full' DCMs
(=Full GCM)

Batch Processing Steps for Estimation

GCM Specification

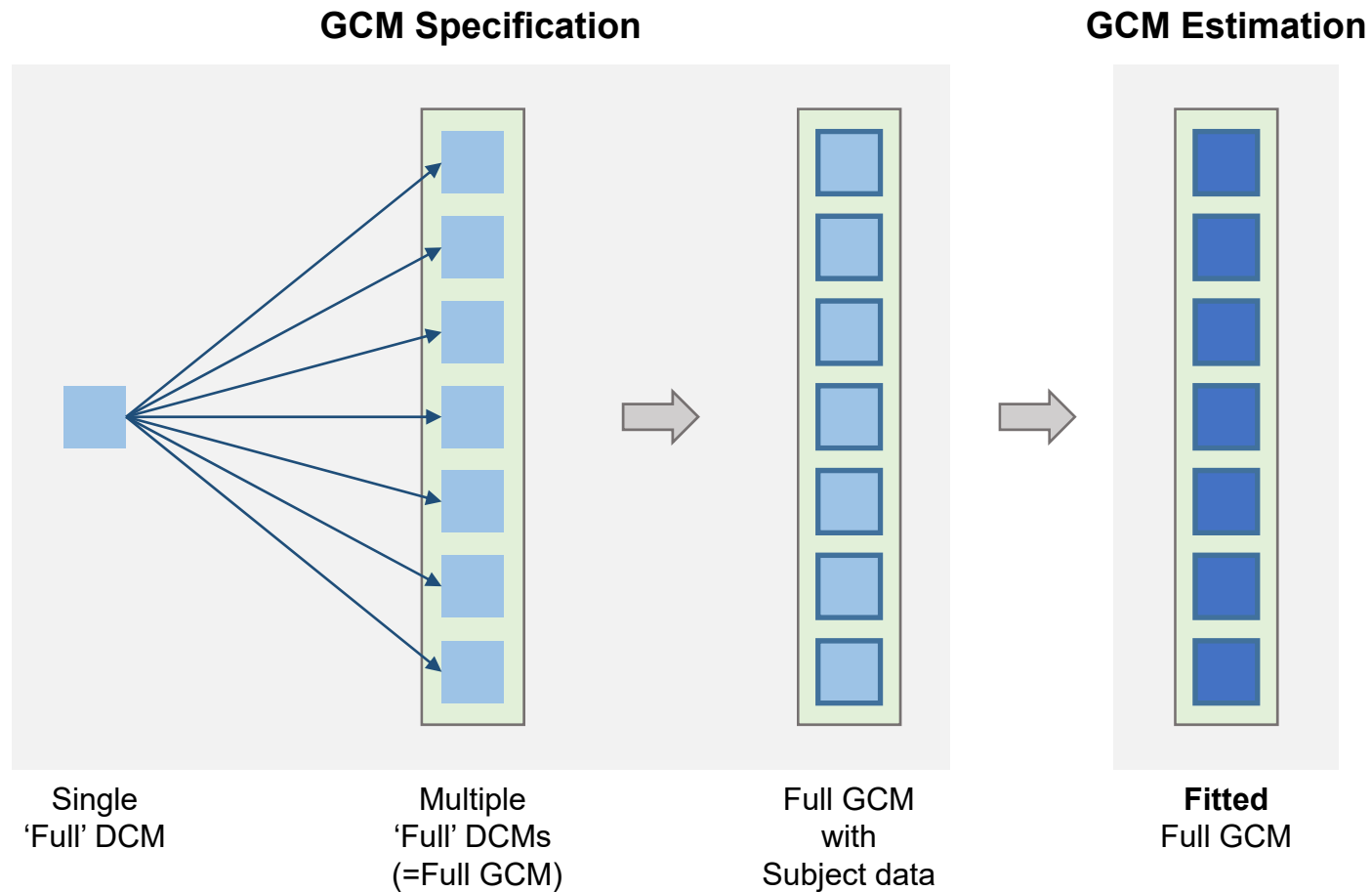


Single
'Full' DCM

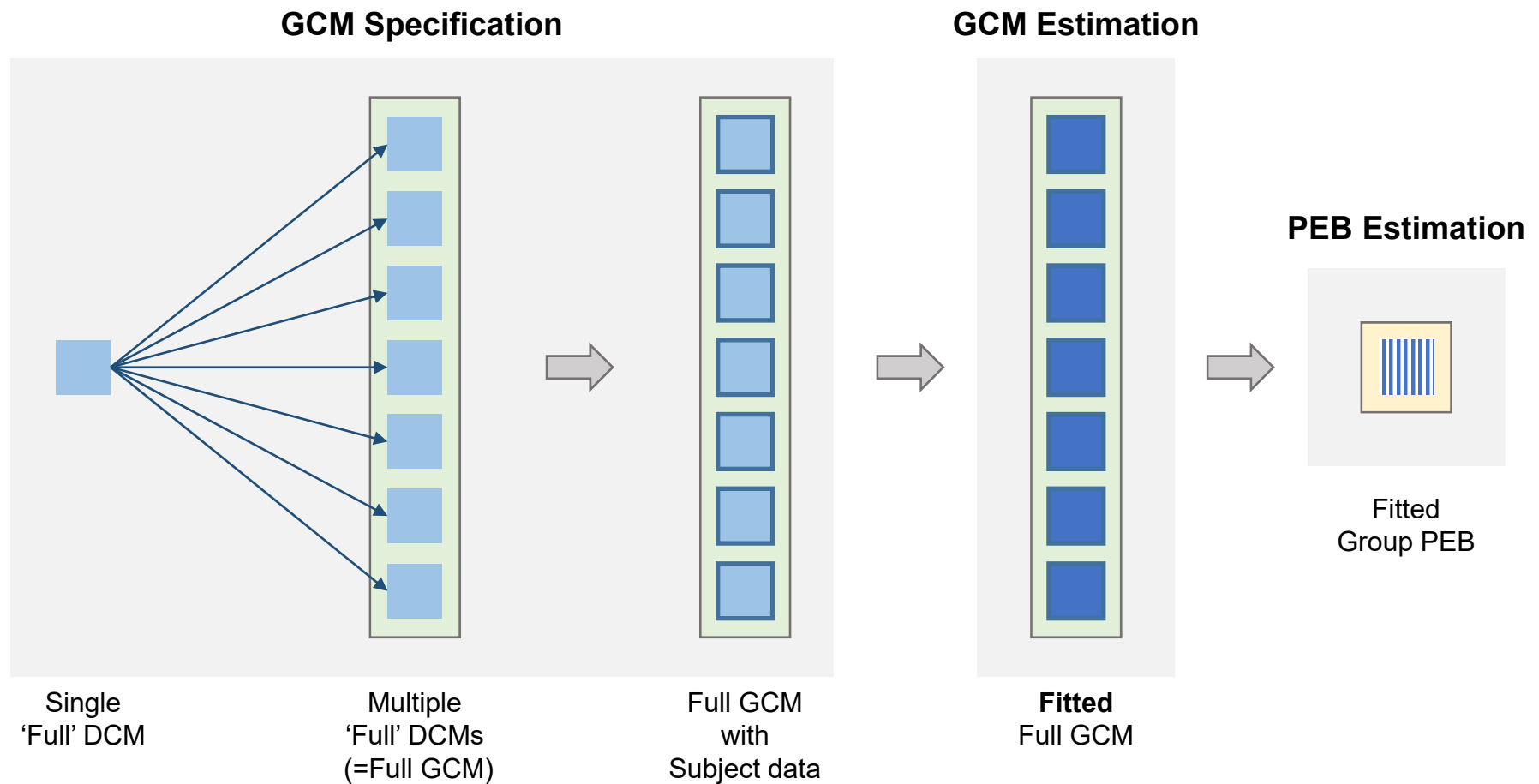
Multiple
'Full' DCMs
(=Full GCM)

Full GCM
with
Subject data

Batch Processing Steps for Estimation

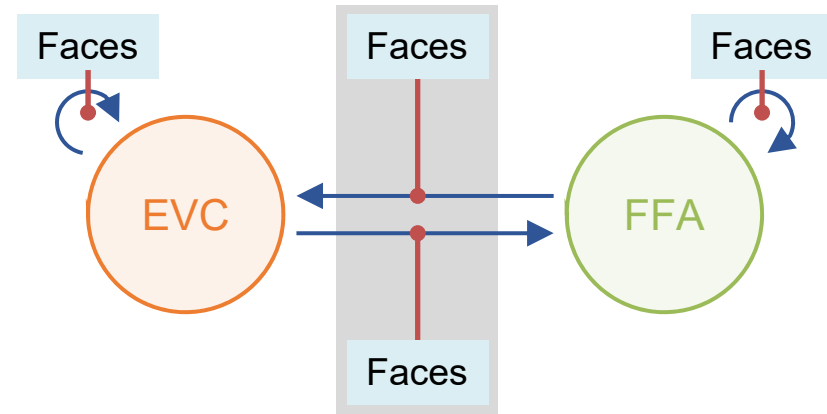


Batch Processing Steps for Estimation

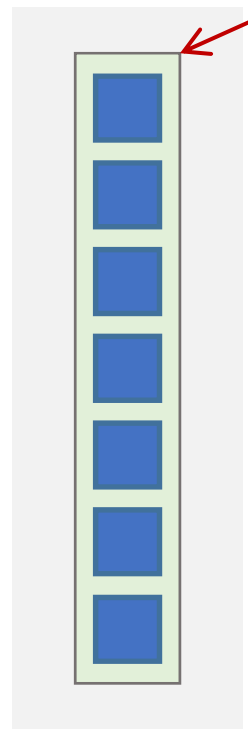
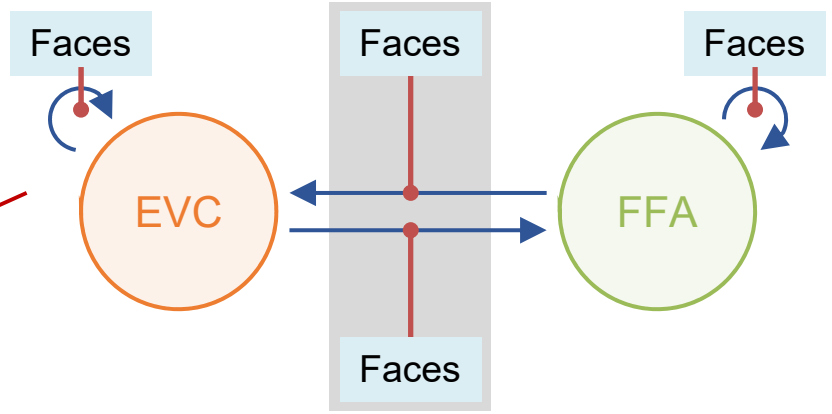


Search all nested models with Greedy-BMR

'Full' Model

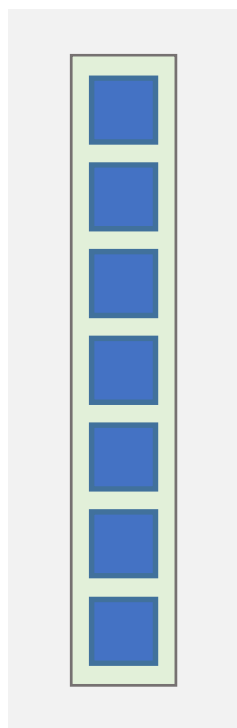
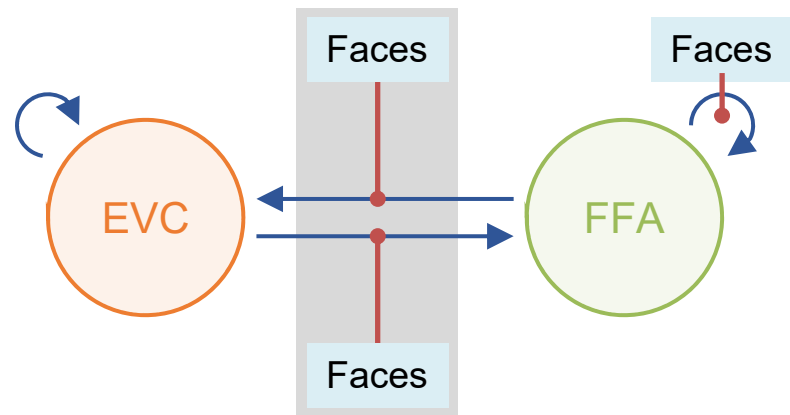


'Full' Model



Fitted
Full GCM

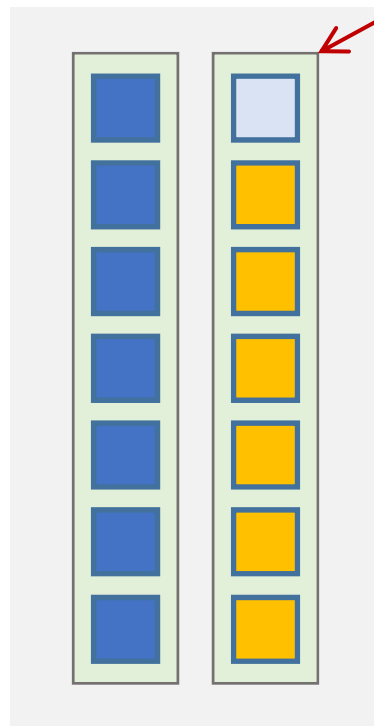
Switch 'off' a connection



Fitted
Full GCM

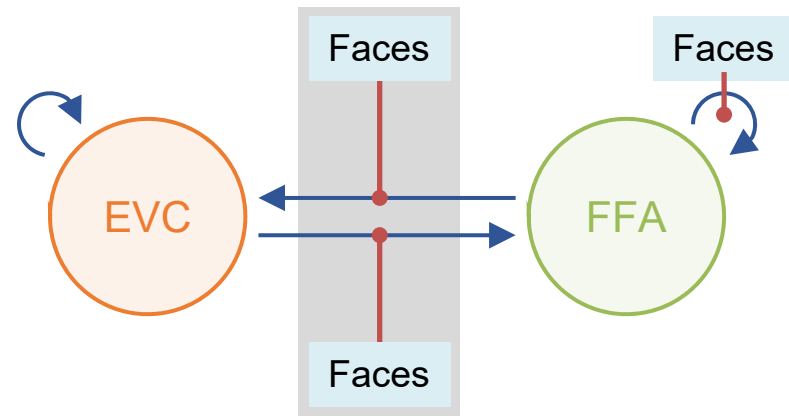
Switch 'off' a connection

'Nested' version of 'Full' model

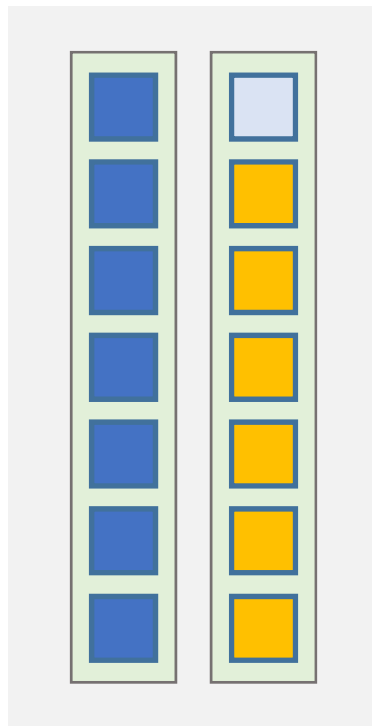


Full

Nested₁

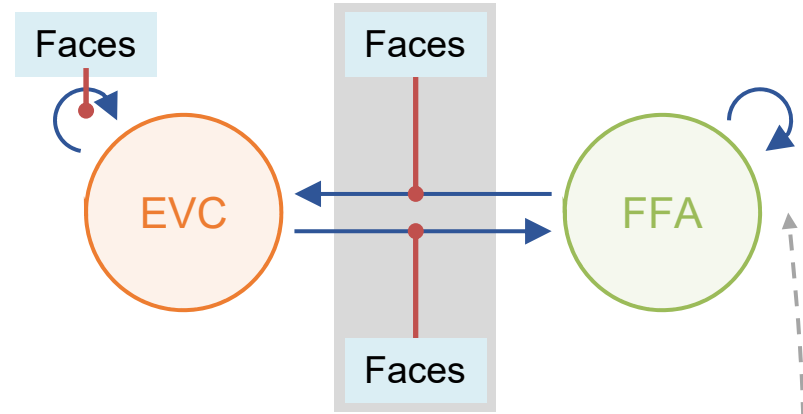


Switch 'off' another connection



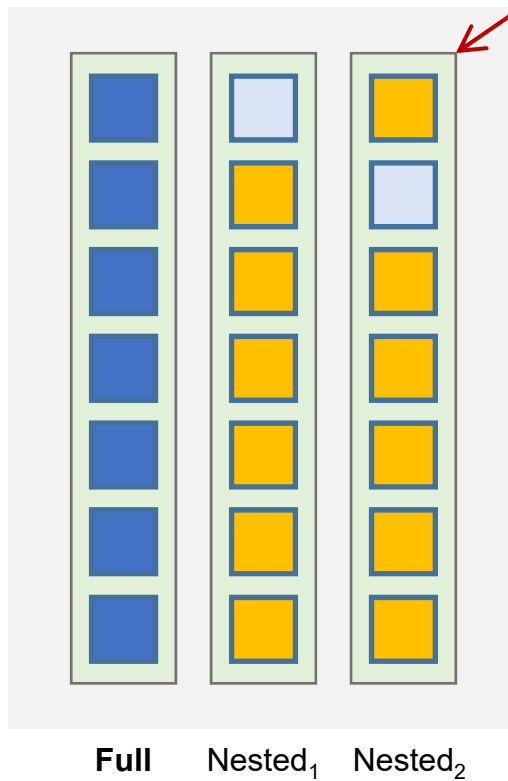
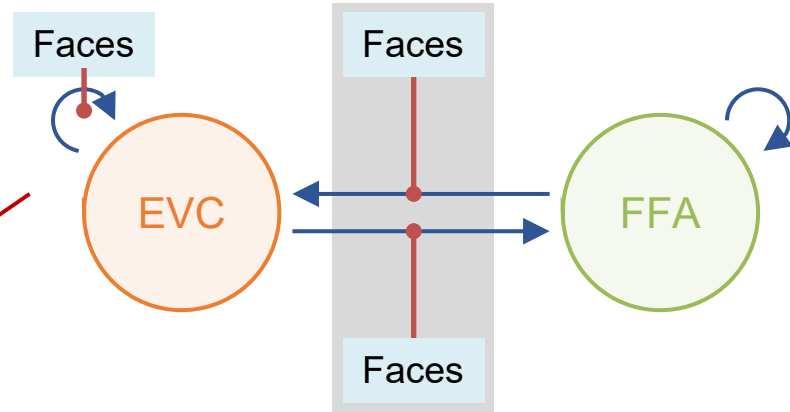
Full

Nested₁

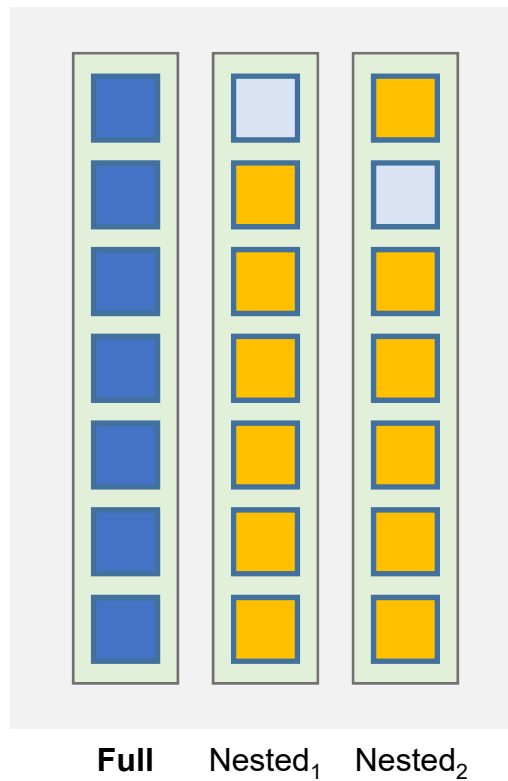


Switch 'off' another connection

Another 'Nested' version of 'Full' model

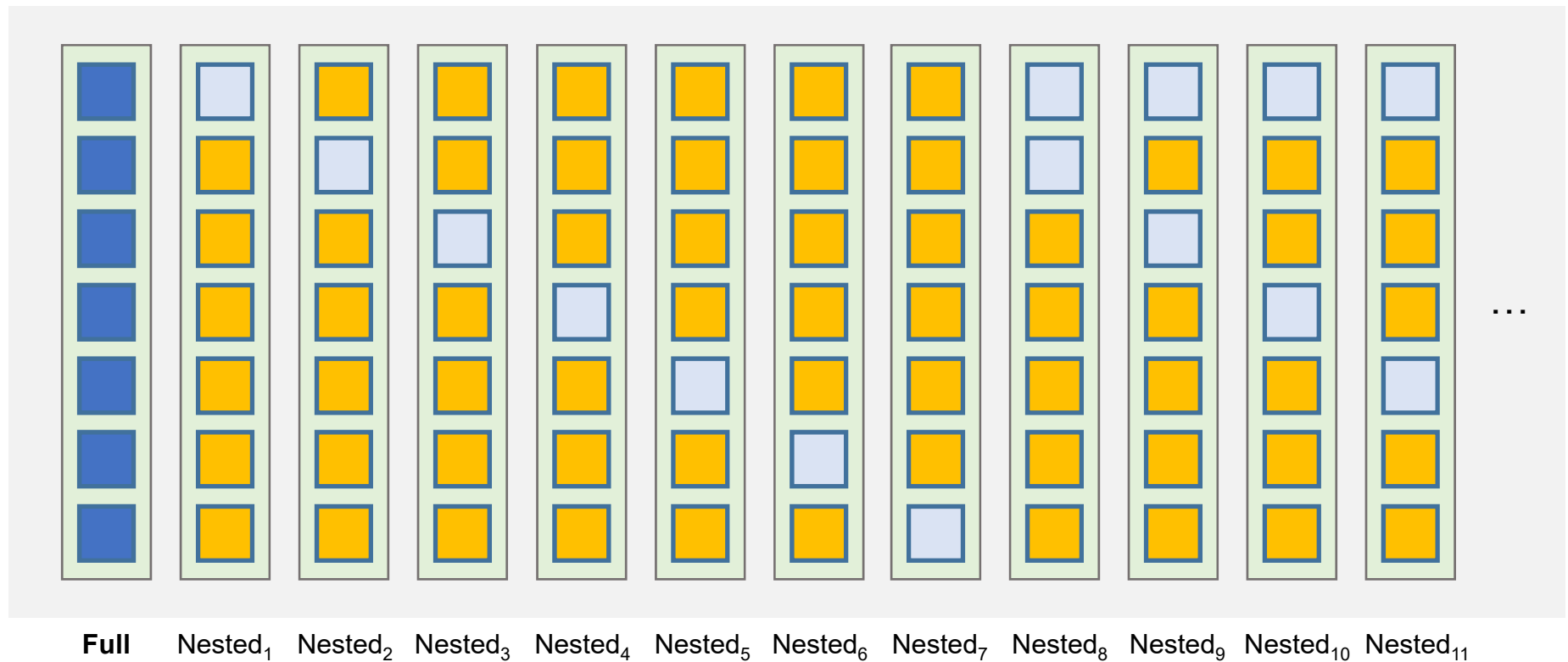


Continue this process for each connection (=parameter)

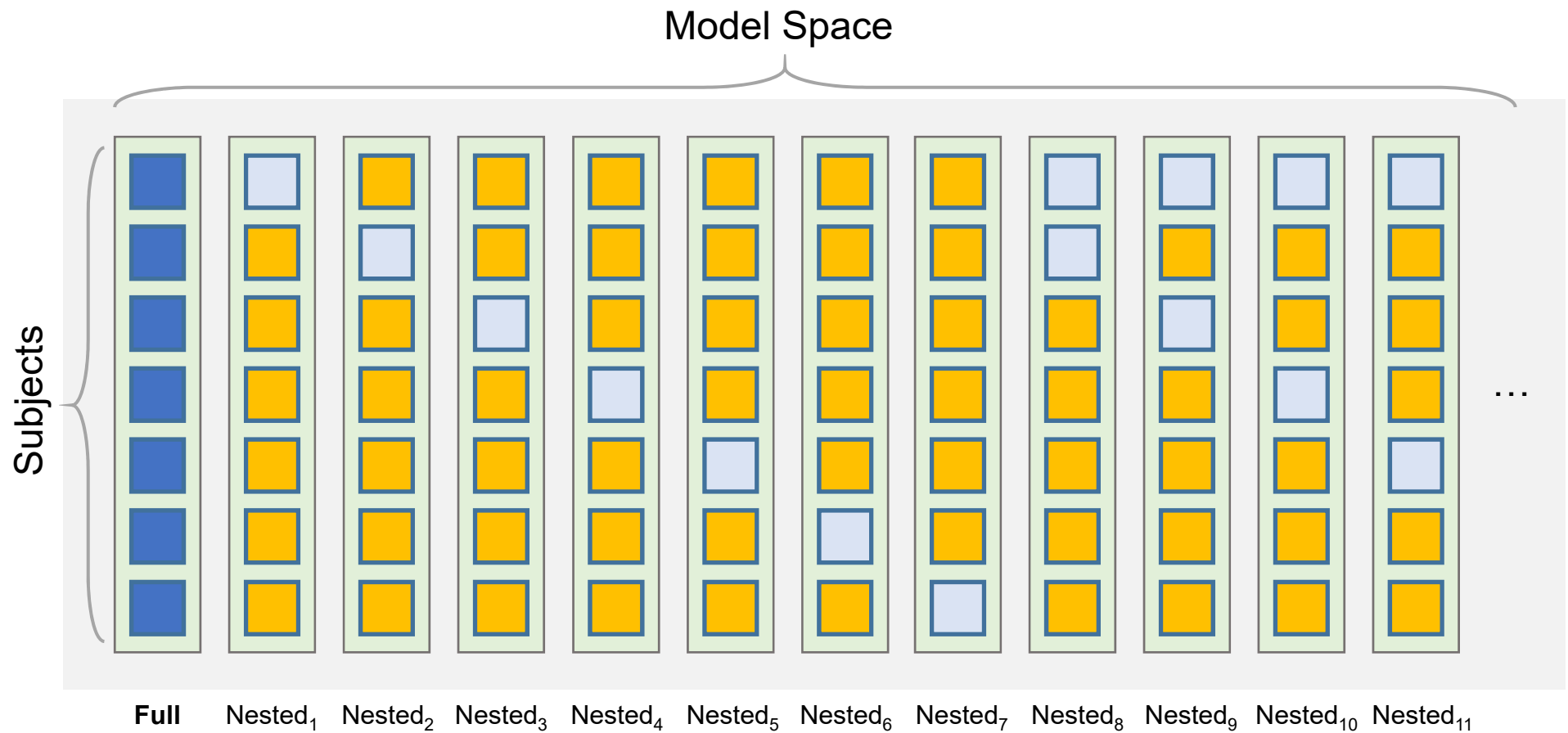


Continue this process for each connection (=parameter)

Generate all possible 'Nested' versions of 'Full' model

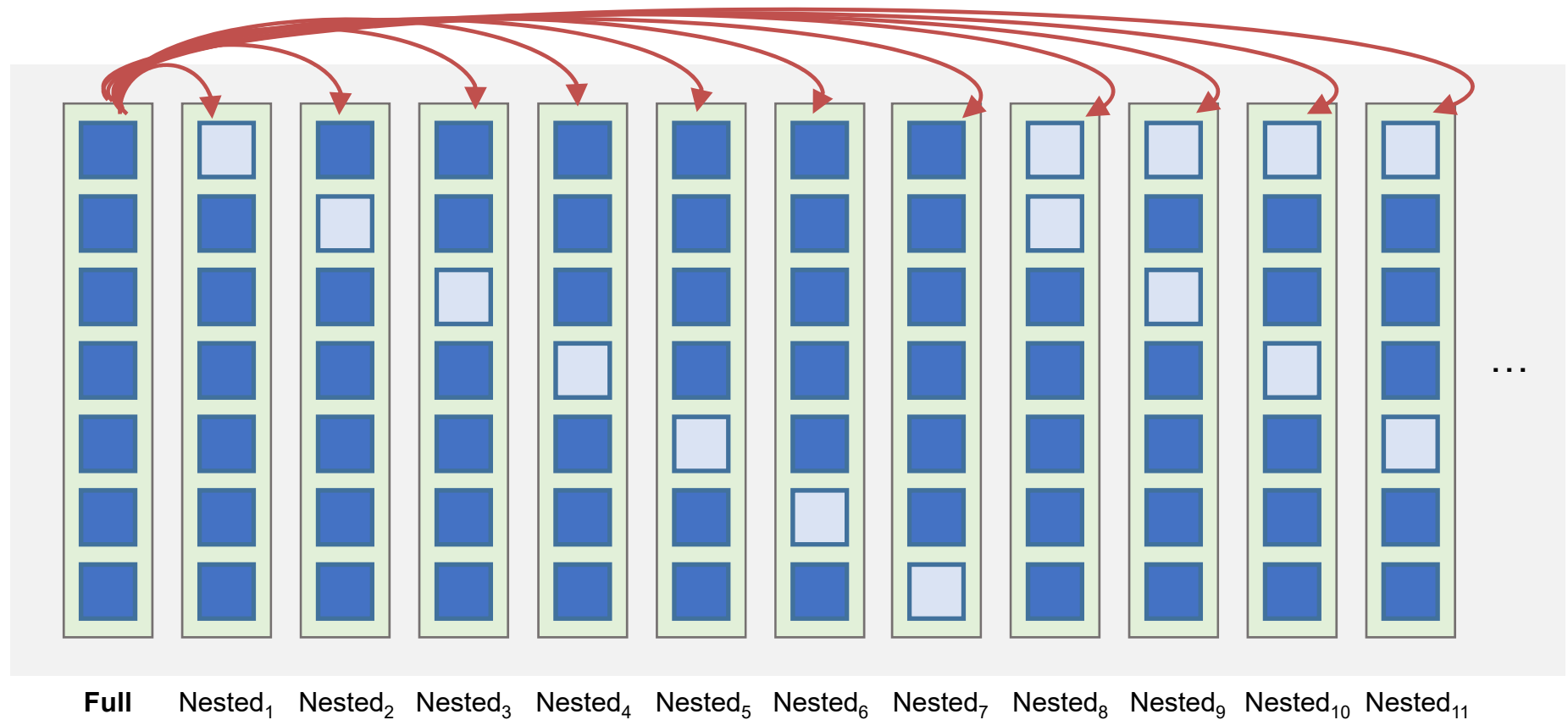


Generate all possible 'Nested' versions of 'Full' model (=model space)



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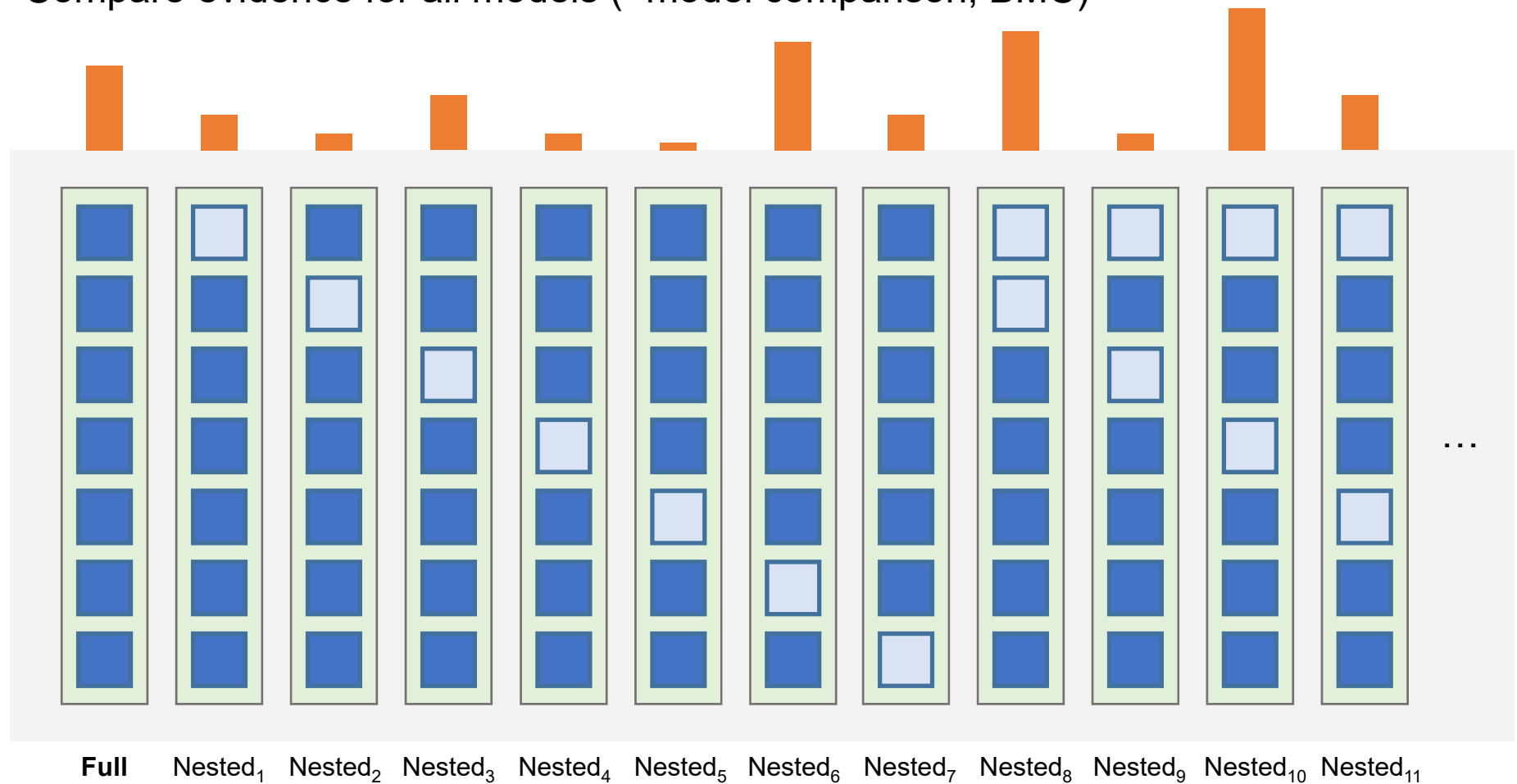
Infer parameters of 'Nested' models (=model reduction, BMR)



Generate all possible 'Nested' versions of 'Full' model (=model space)

Infer parameters of 'Nested' models (=model reduction, BMR)

Compare evidence for all models (=model comparison, BMC)



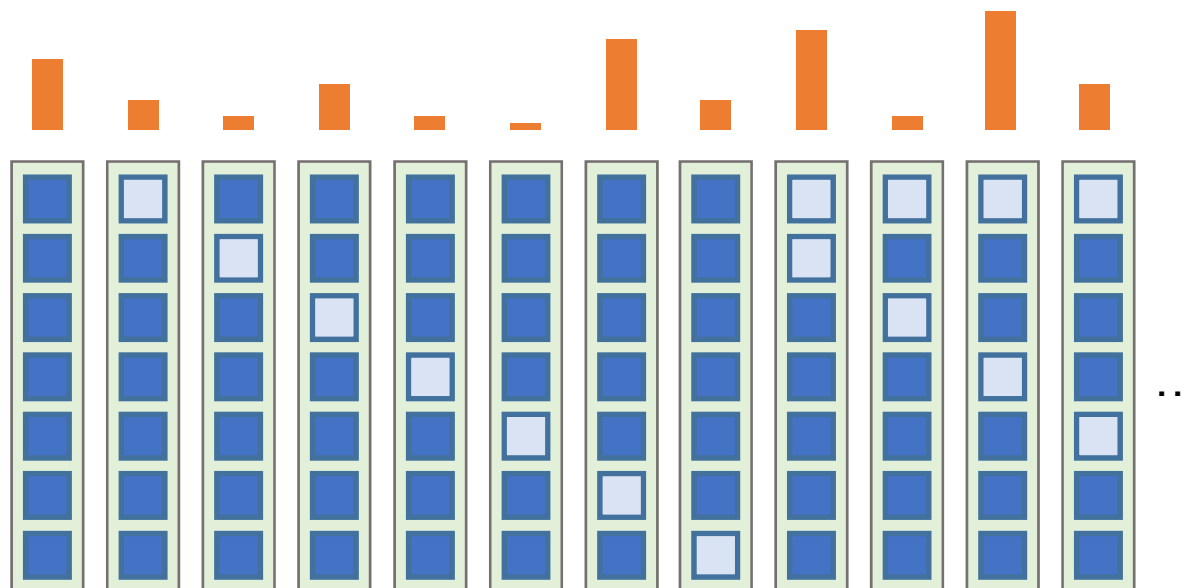
Generate all possible 'Nested' versions of 'Full' model (=model space)

Infer parameters of 'Nested' models (=model reduction, BMR)

Compare evidence for all models (=model comparison, BMC)

Take a weighted average of model parameters (=model averaging, BMA)

*weighted by model evidence of each model



Generate all possible 'Nested' versions of 'Full' model (=model space)

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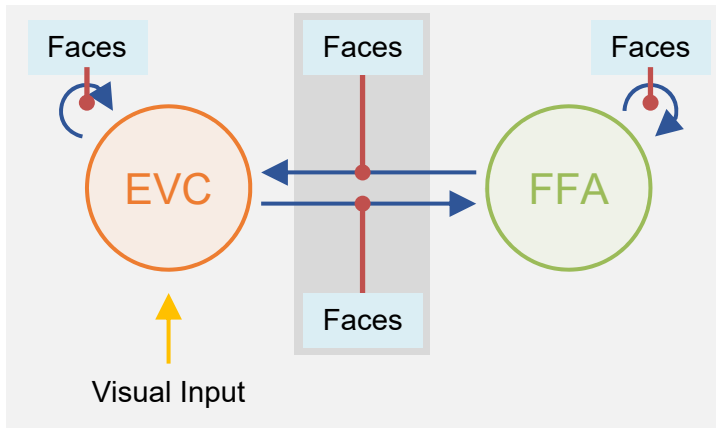
*weighted by model evidence of each model



Testing groups of between-region connections

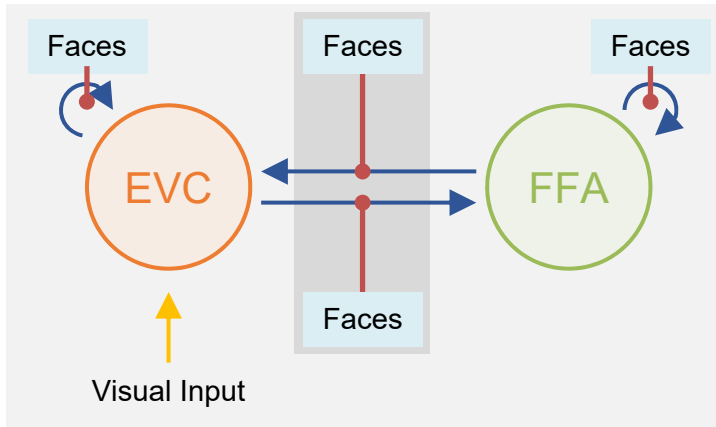
'Full' model

Faces modulate Forward & Backward connections



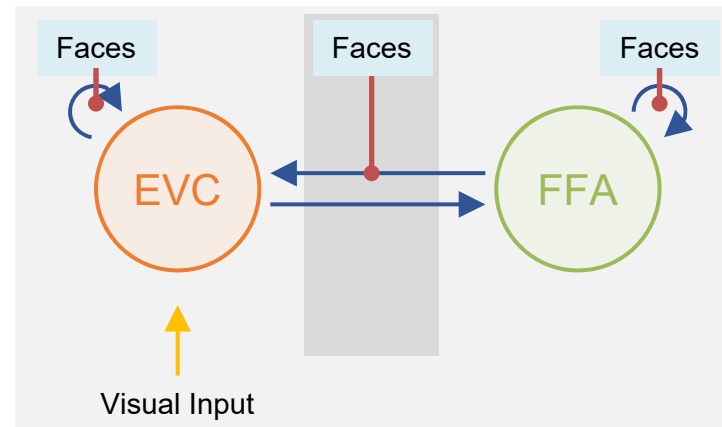
'Full' model

Faces modulate Forward & Backward connections



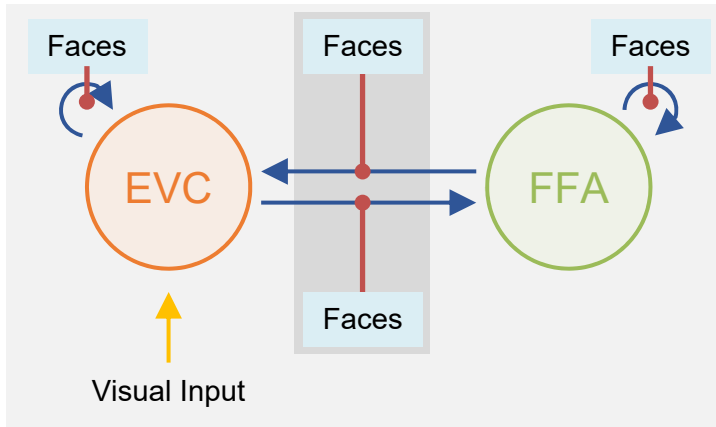
'No-Forward' model

Faces modulate only Backward connections



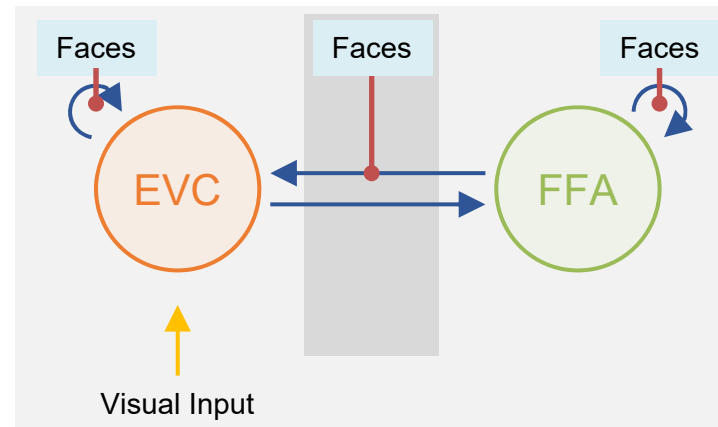
'Full' model

Faces modulate Forward & Backward connections



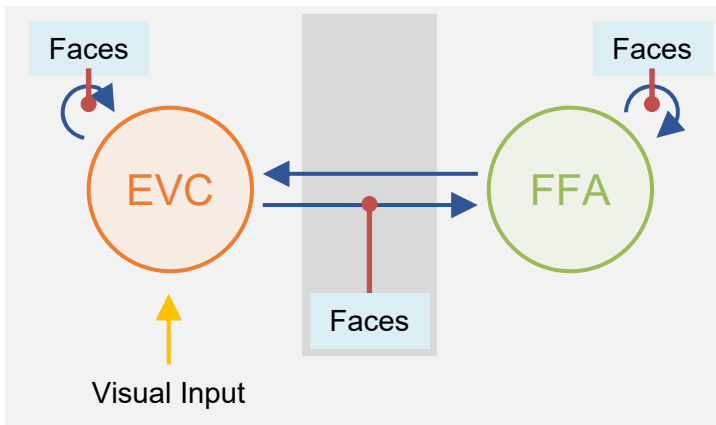
'No-Forward' model

Faces modulate only Backward connections



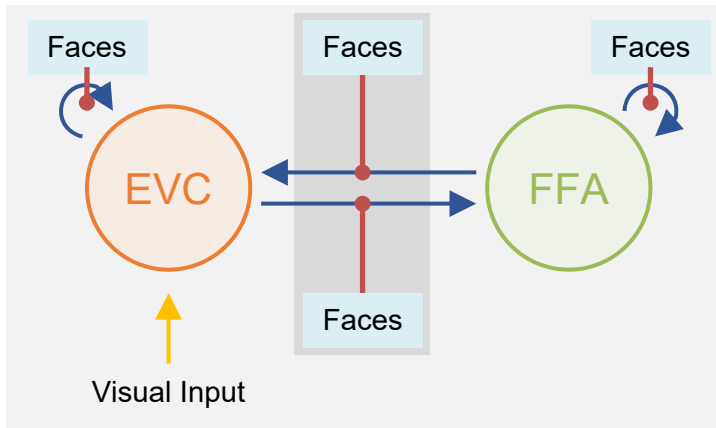
'No-Backward' model

Faces modulate only Forward connections



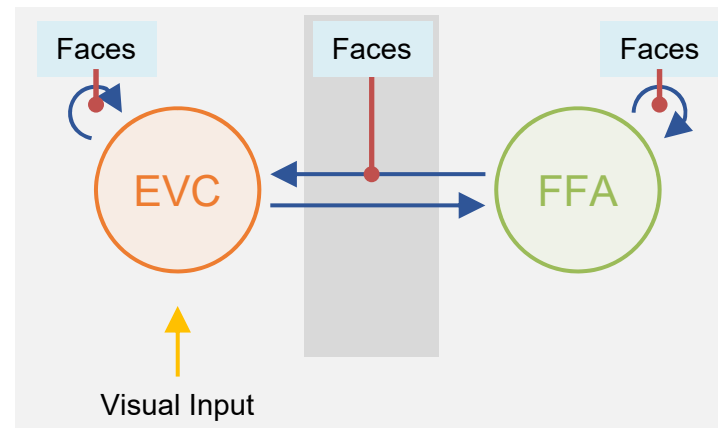
'Full' model

Faces modulate Forward & Backward connections



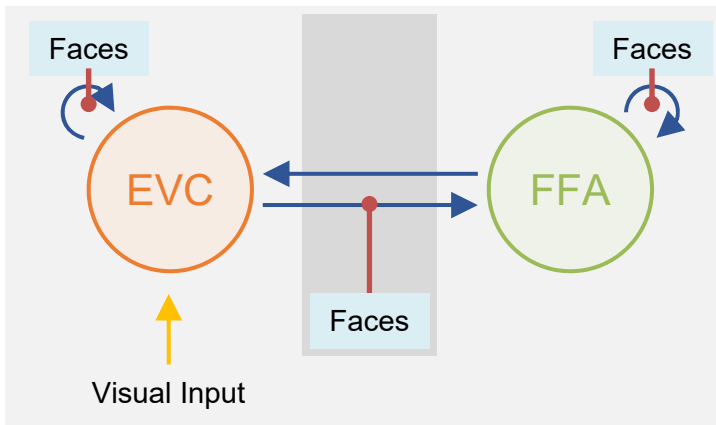
'No-Forward' model

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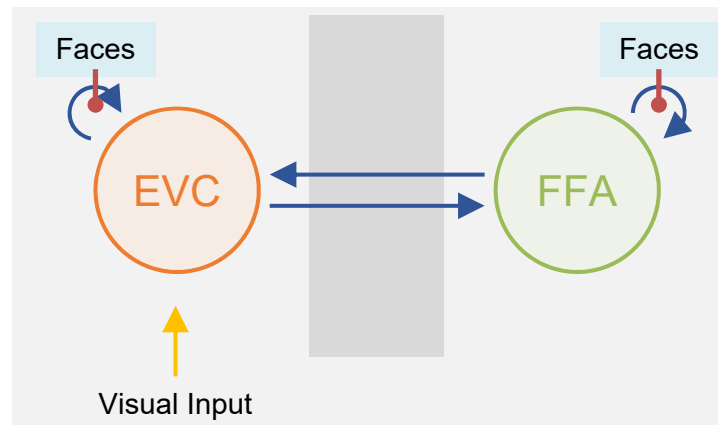
'No-Backward' model

Faces modulate only Forward connections



'Null' model

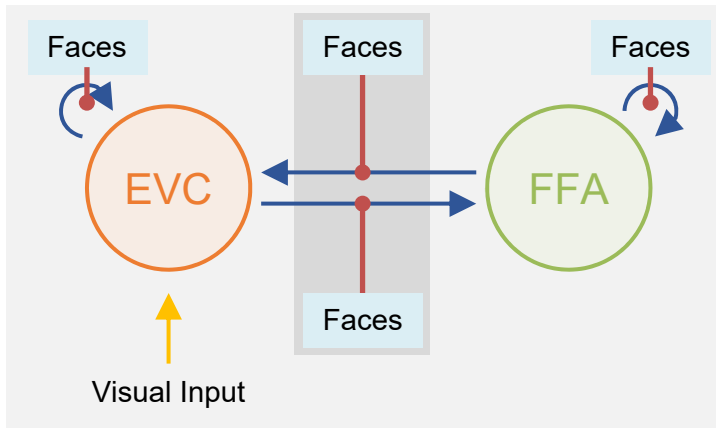
Faces modulate neither F/B connection



Compare all four models and pick 'winning' model?

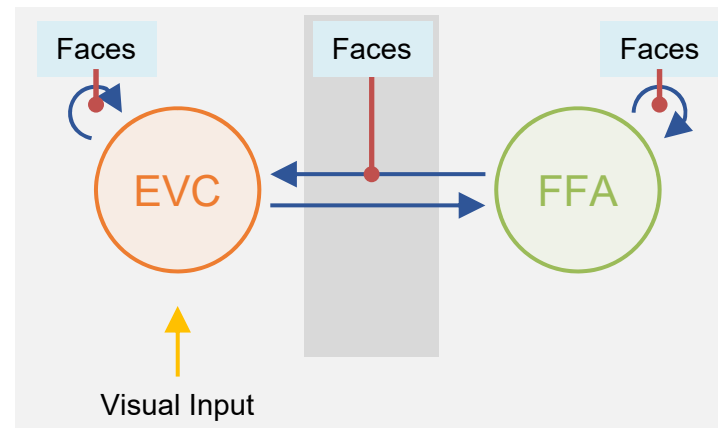
'Full' model

Faces modulate Forward & Backward connections



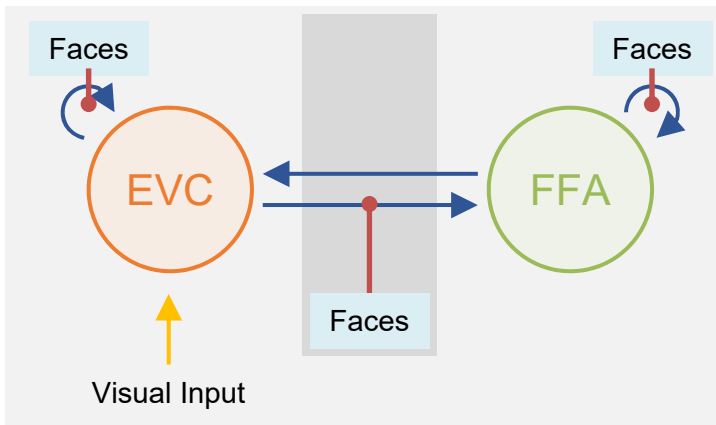
'No-Forward' model

Faces modulate only Backward connections



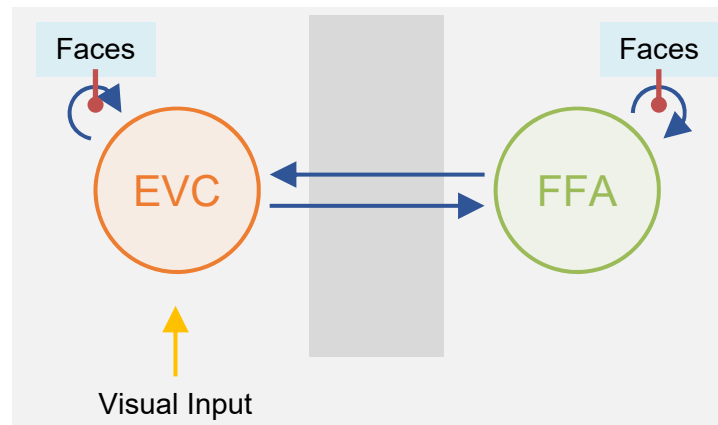
'No-Backward' model

Faces modulate only Forward connections



'Null' model

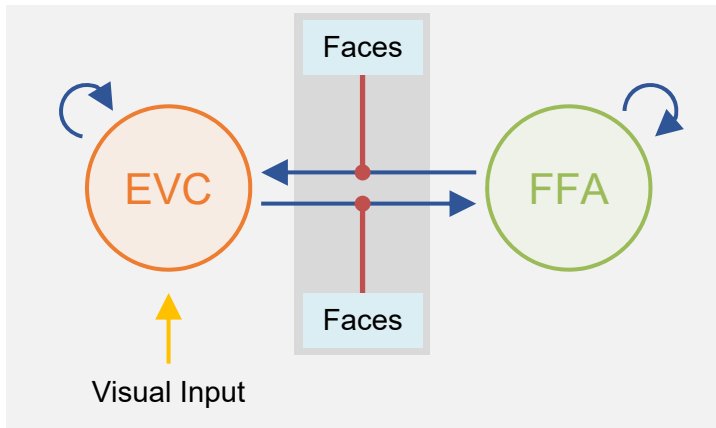
Faces modulate neither F/B connection



Self-connections are modulated in addition to between-region connections

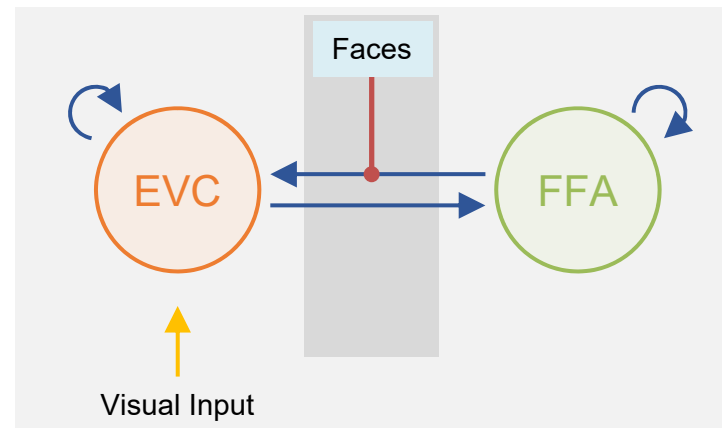
'Full' model

Faces modulate Forward & Backward connections



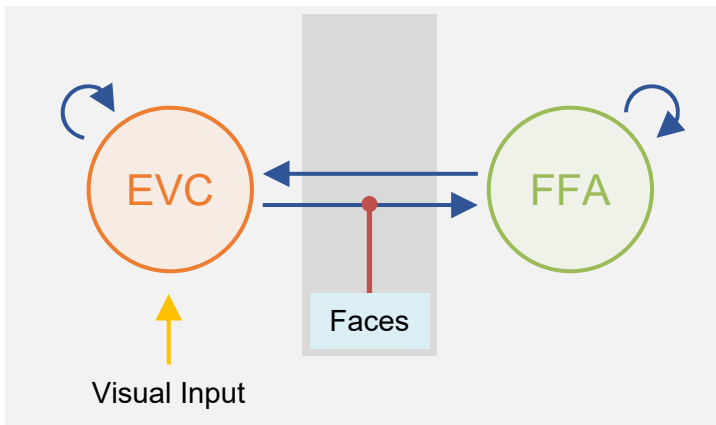
'No-Forward' model

Faces modulate only Backward connections



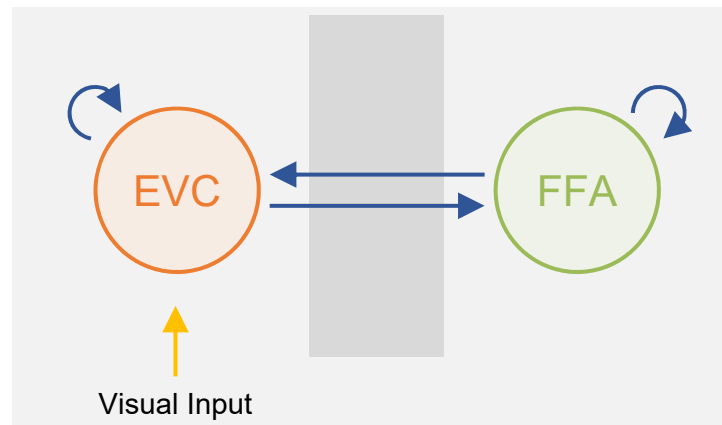
'No-Backward' model

Faces modulate only Forward connections



'Null' model

Faces modulate neither F/B connection



Self-connections may not be modulated...

Model space defined by:

1. Whether forward connections are modulated
2. Whether backward connections are modulated
3. Whether lateral connections are modulated
4. Whether self-connections are modulated

Model space defined by:

1. Whether forward connections are modulated: yes / no
2. Whether backward connections are modulated: yes / no
3. Whether lateral connections are modulated: yes / no
4. Whether self-connections are modulated: yes / no

Model space defined by:

1. Whether forward connections are modulated: yes / no
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Total number of models: $2^4 = 16$

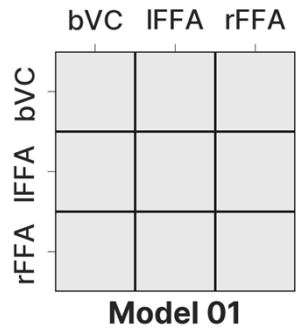
Model space defined by:

1. Whether forward connections are modulated: yes / no
2. Whether backward connections are modulated: yes / no
3. Whether lateral connections are modulated: yes / no
4. Whether self-connections are modulated: yes / no

Total number of models: $2^4 = 16$

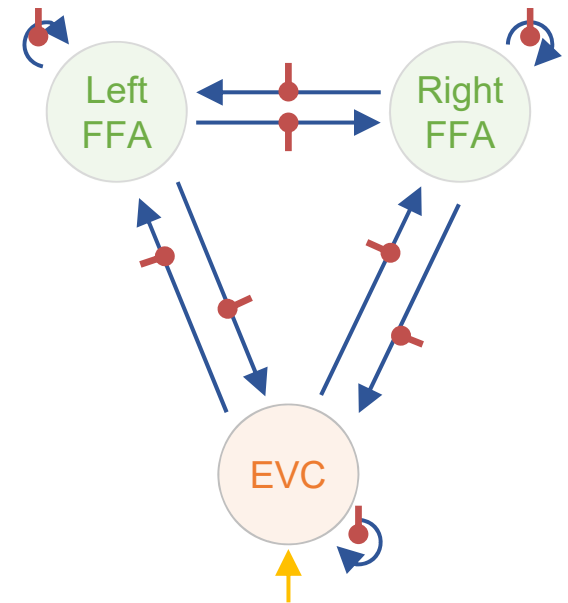
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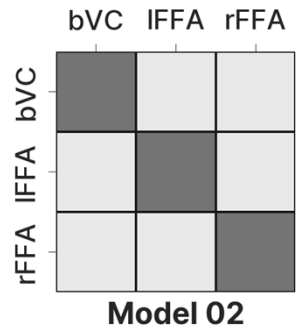
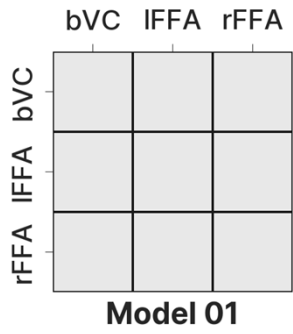
- Both (bilateral) forward connections are grouped together
- Both (bilateral) backward connections are grouped together
- Both lateral connections are grouped together
- All three self-connections are grouped together



Model Space

F+B+L+S

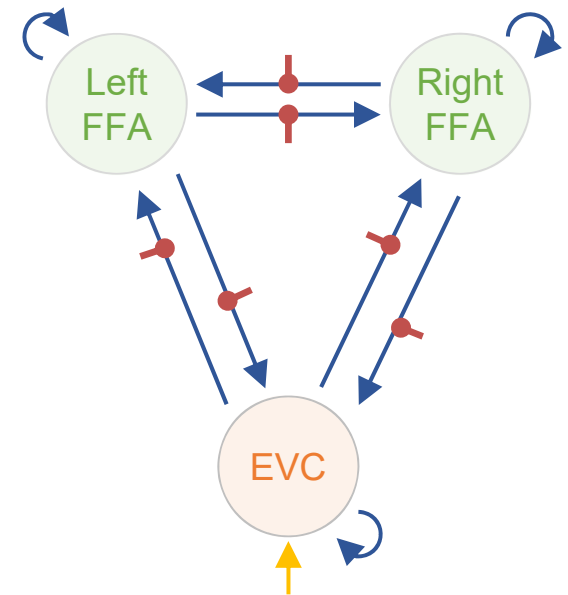


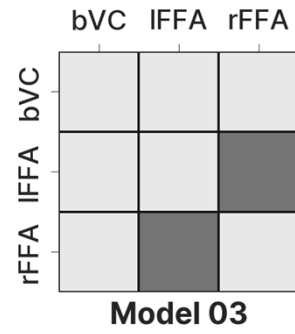
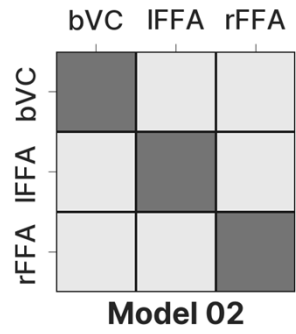
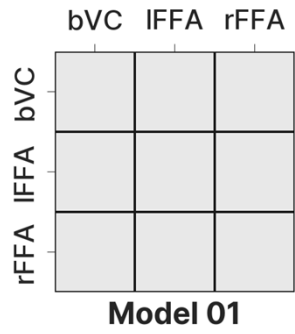


Model Space

F+B+L

No S

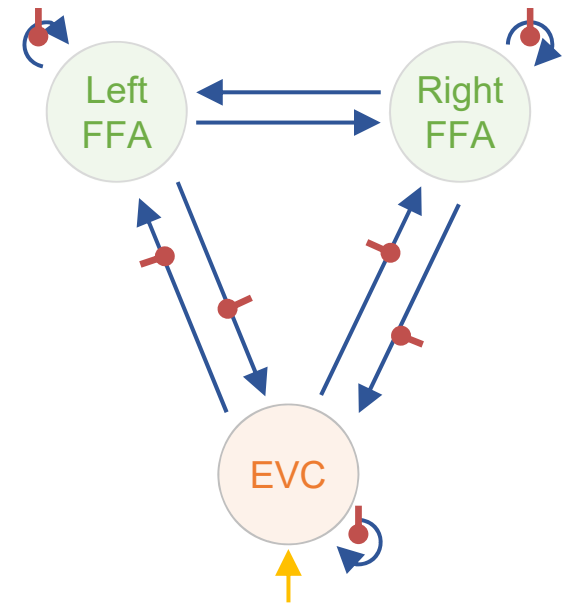


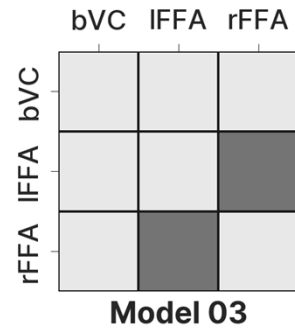
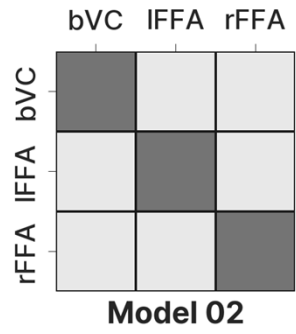
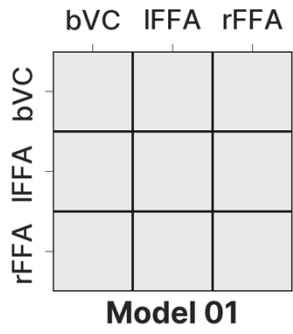


Model Space

F+B+S

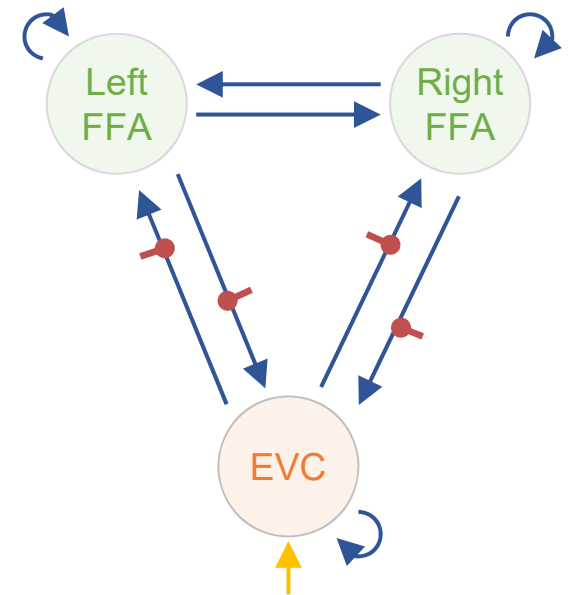
No L

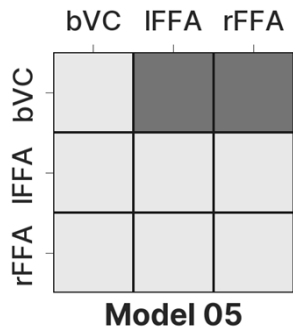
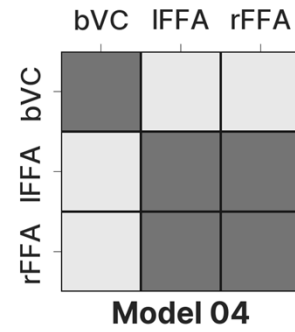
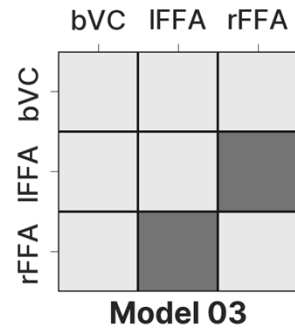
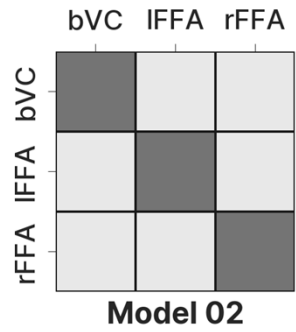
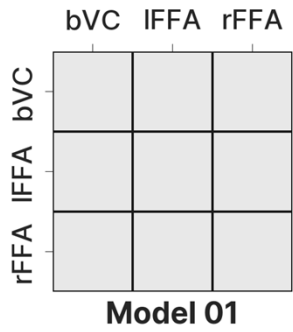




Model Space

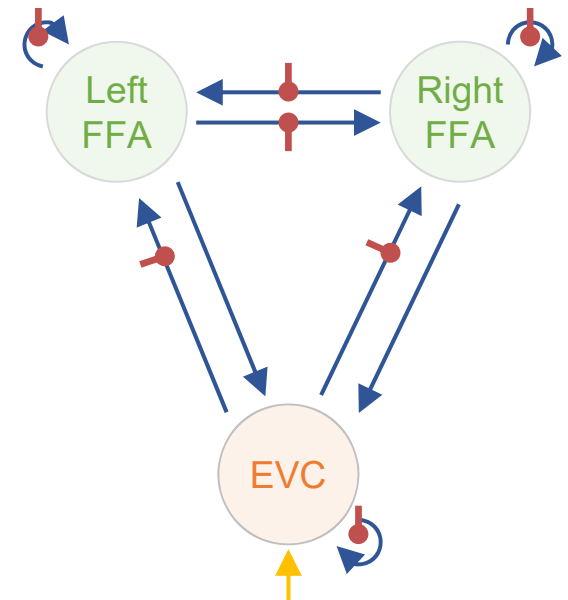
F+B
No S
No L

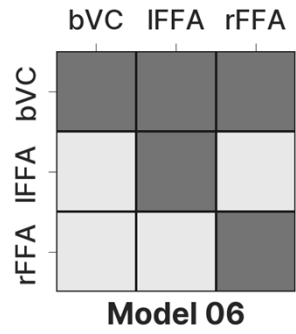
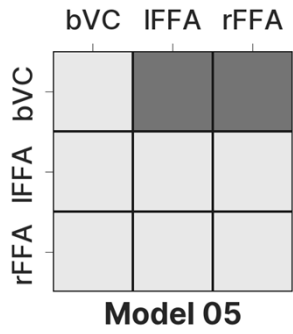
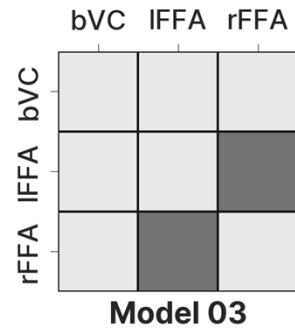
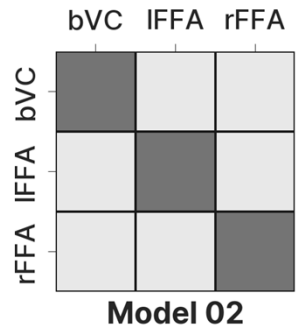
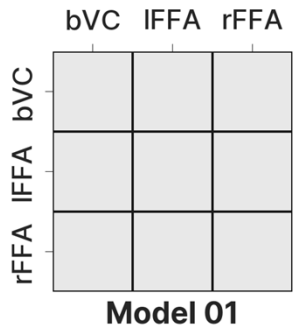




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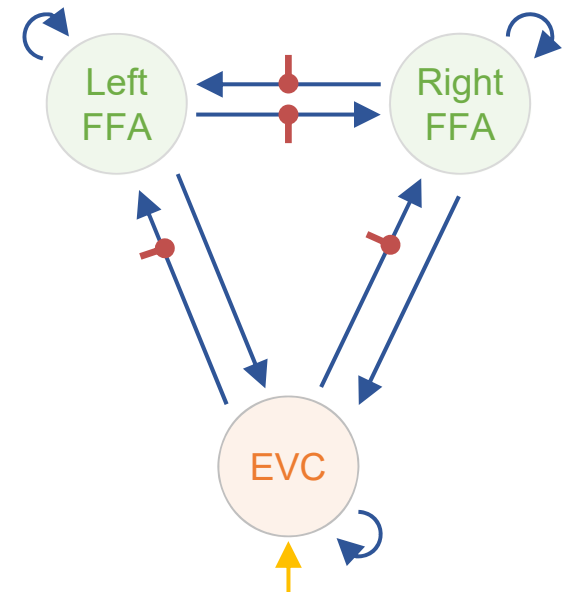
F+S+L
No B

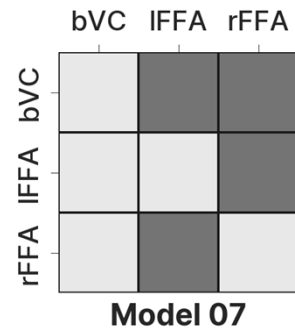
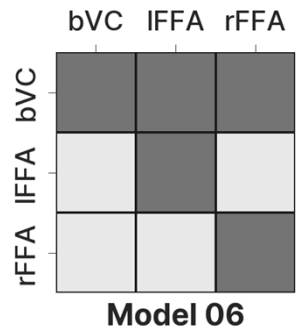
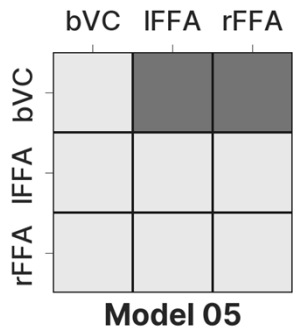
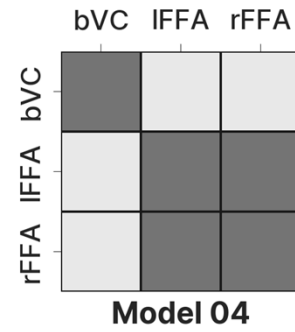
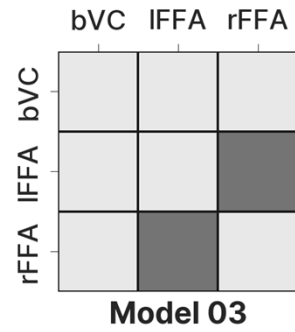
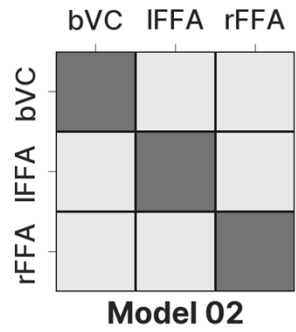
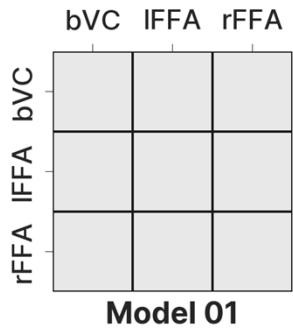




Model Space

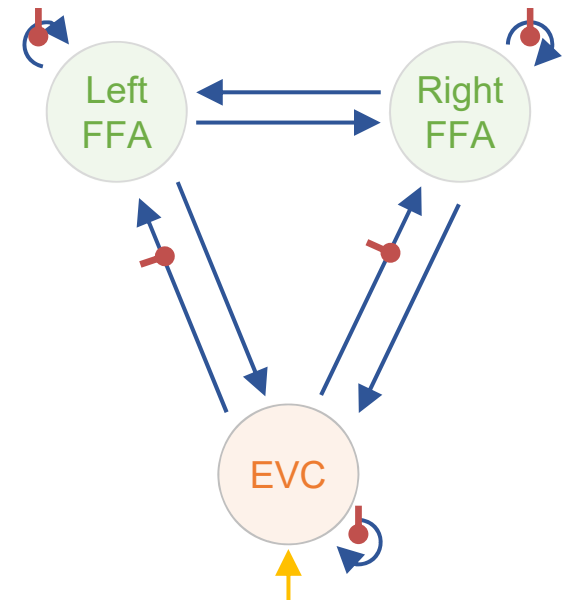
F+L
No B
No S





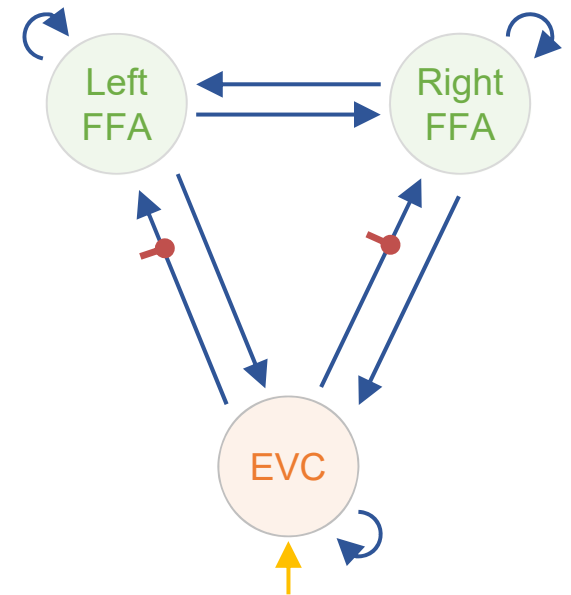
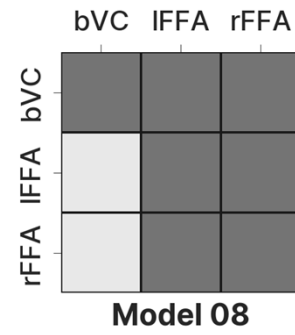
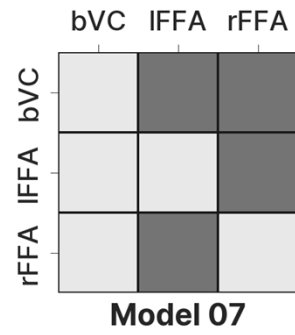
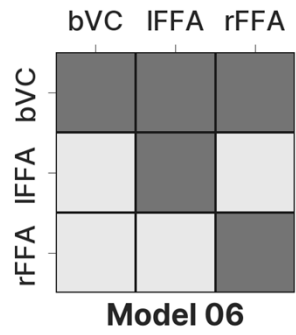
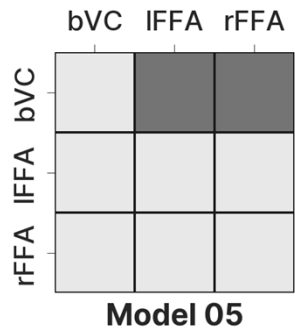
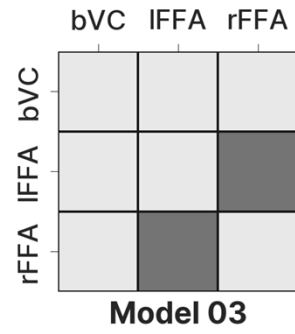
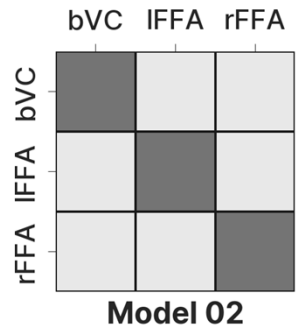
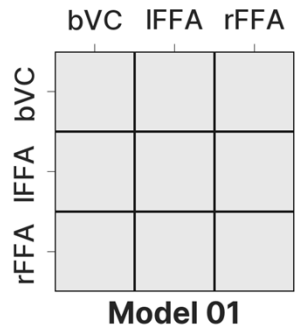
Model Space

F+S
No B
No L

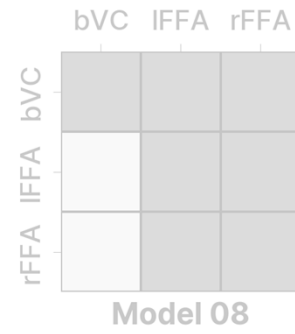
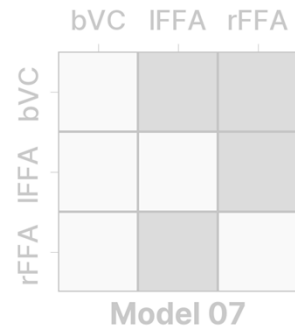
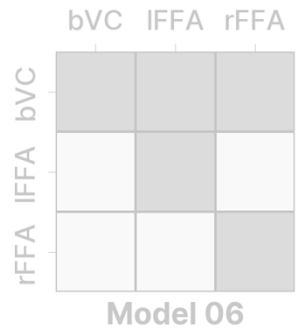
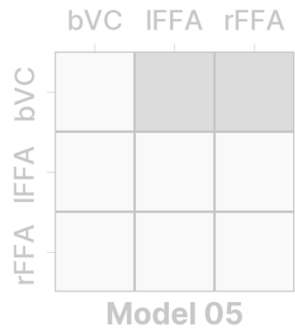
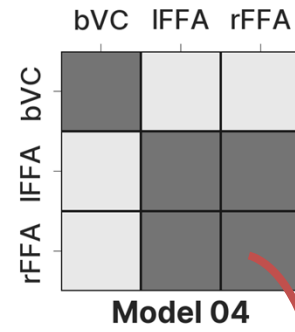
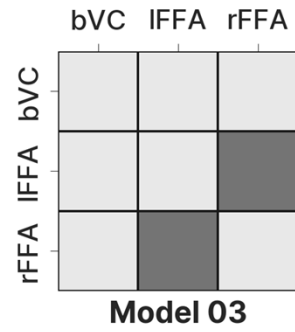
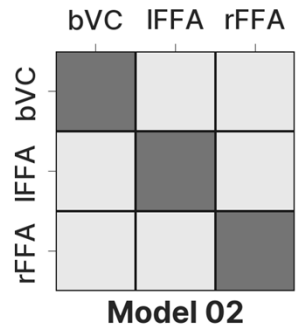
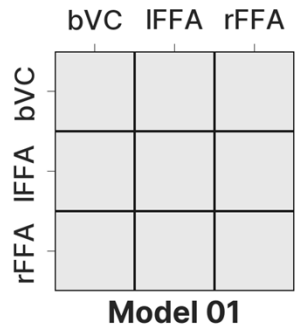


Model Space

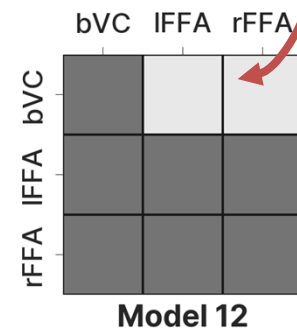
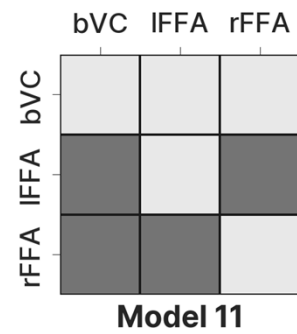
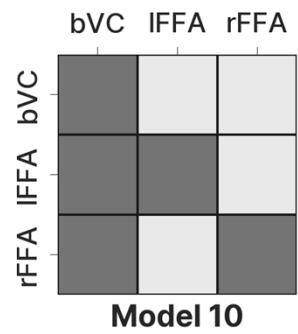
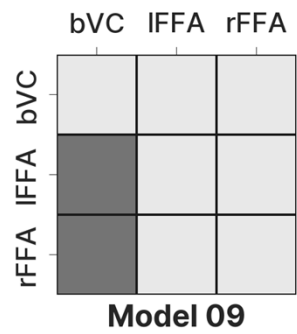
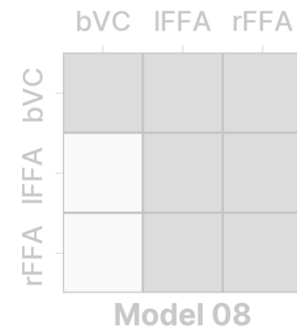
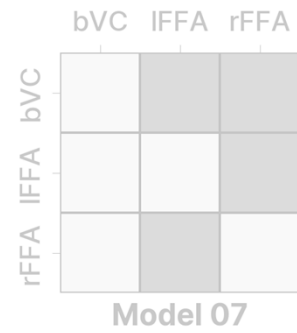
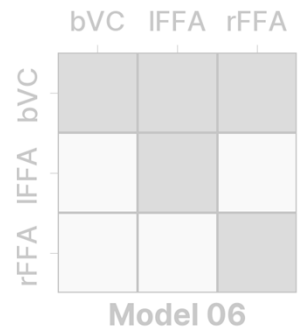
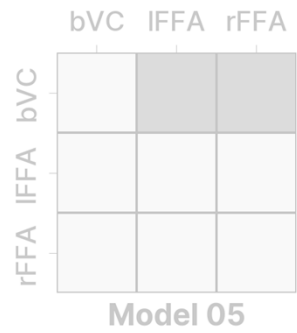
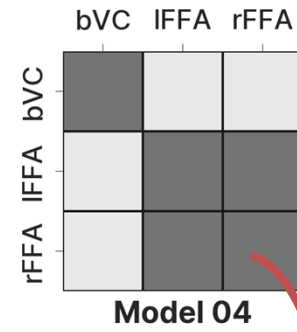
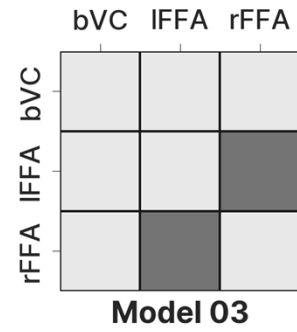
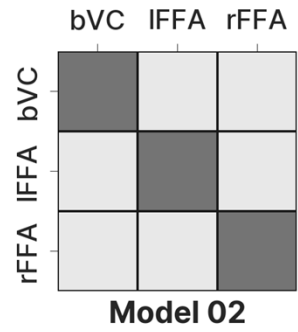
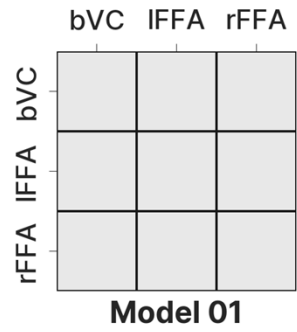
F
No B
No S
No L



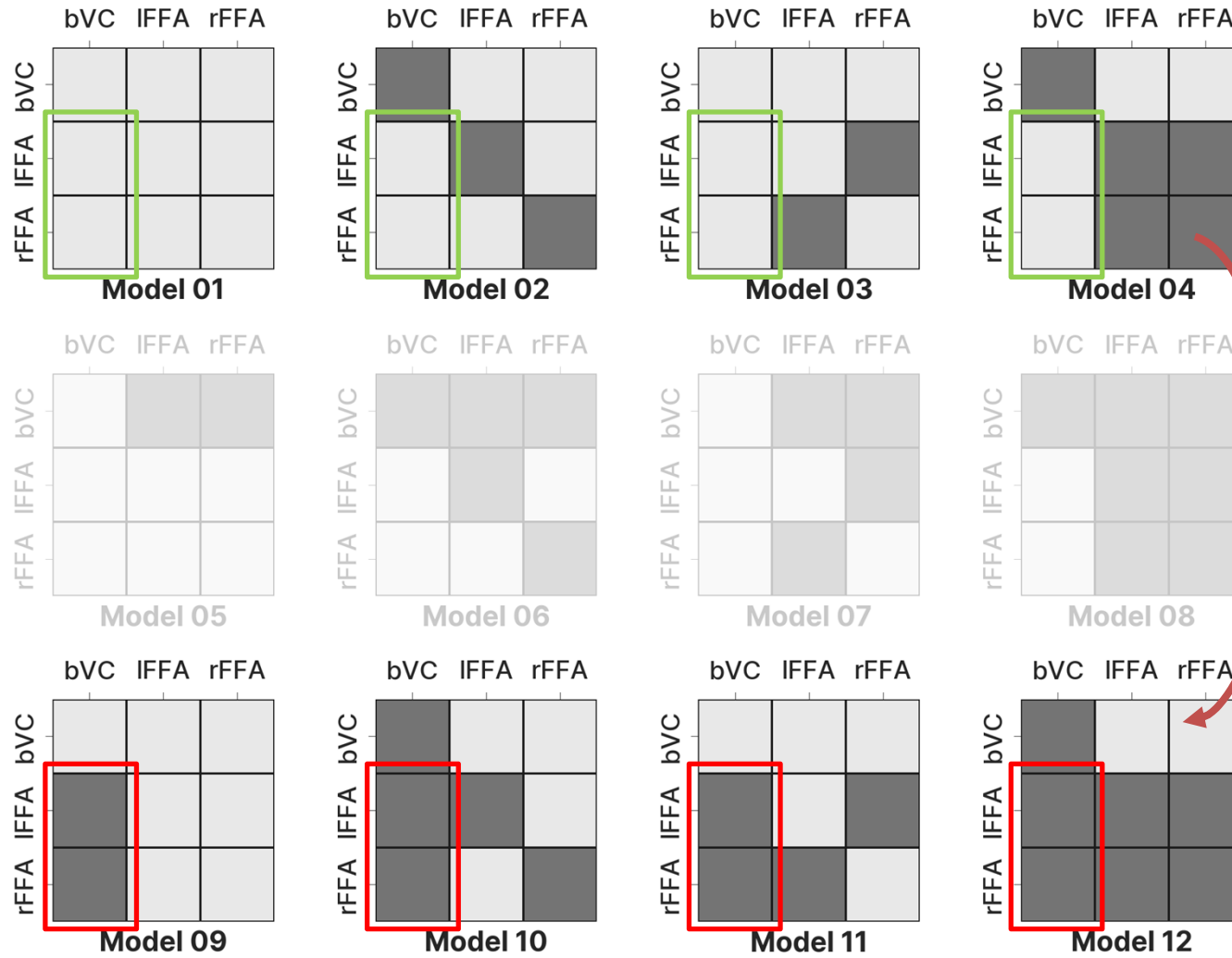
Model Space



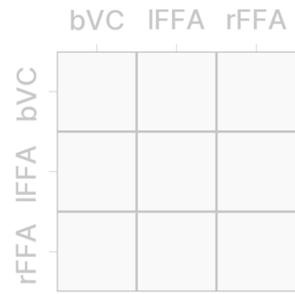
Model Space



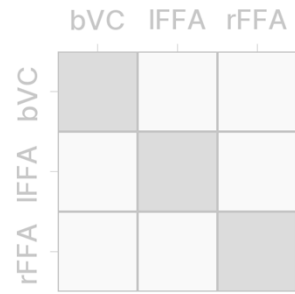
Model Space



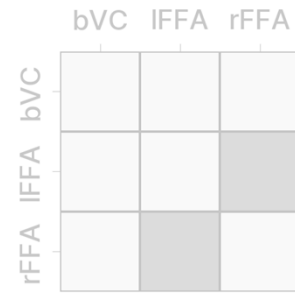
Model Space



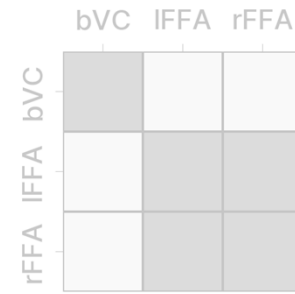
Model 01



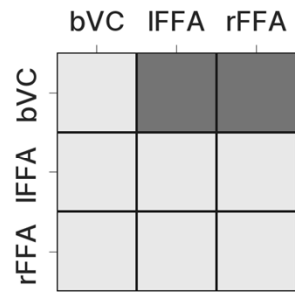
Model 02



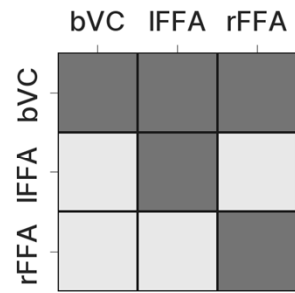
Model 03



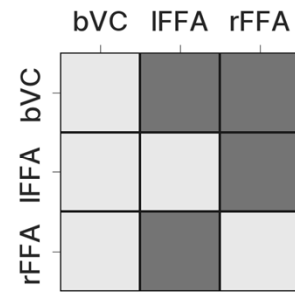
Model 04



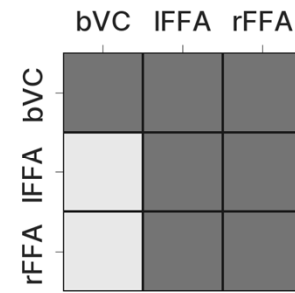
Model 05



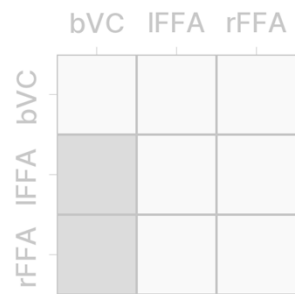
Model 06



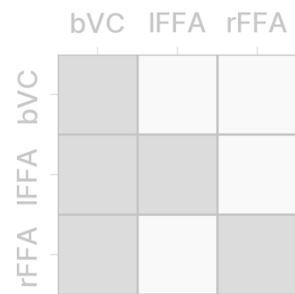
Model 07



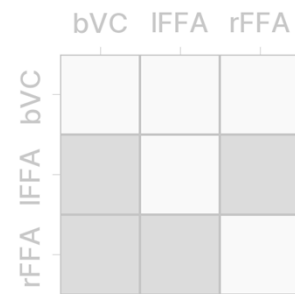
Model 08



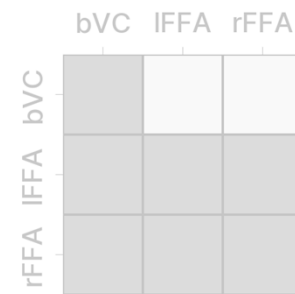
Model 09



Model 10

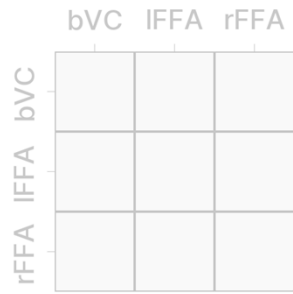


Model 11

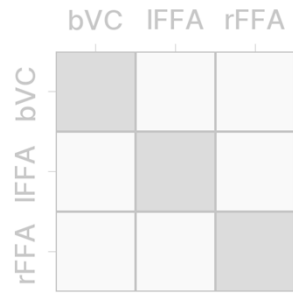


Model 12

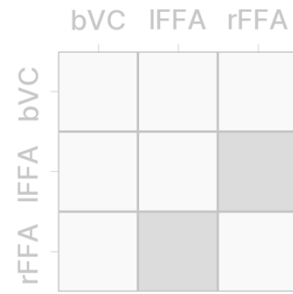
Model Space



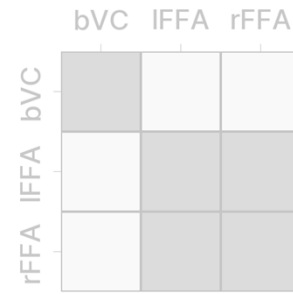
Model 01



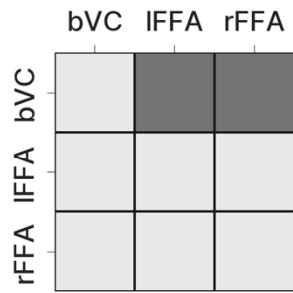
Model 02



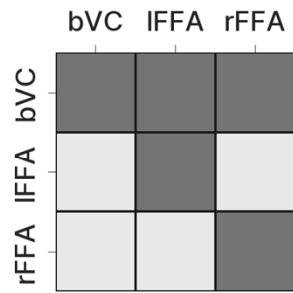
Model 03



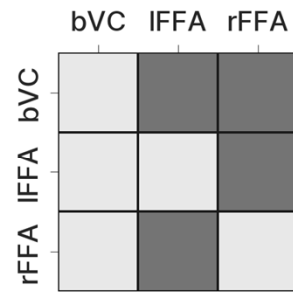
Model 04



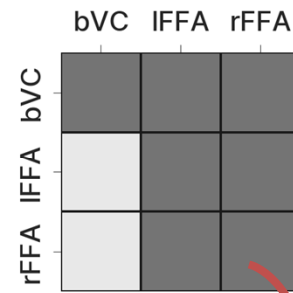
Model 05



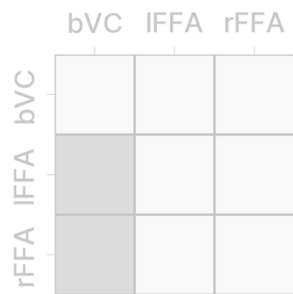
Model 06



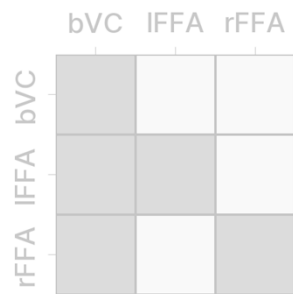
Model 07



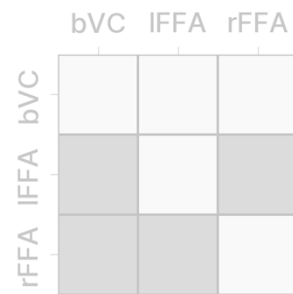
Model 08



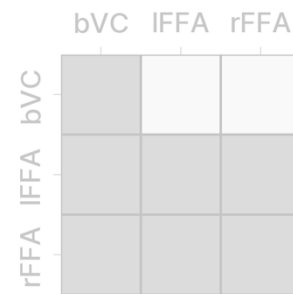
Model 09



Model 10



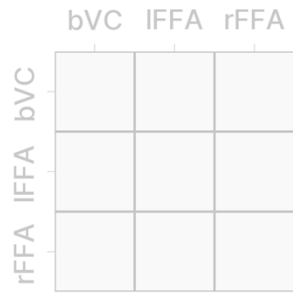
Model 11



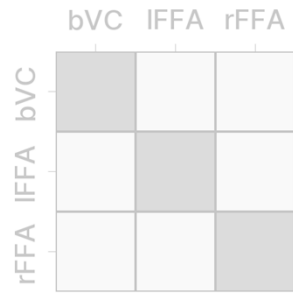
Model 12



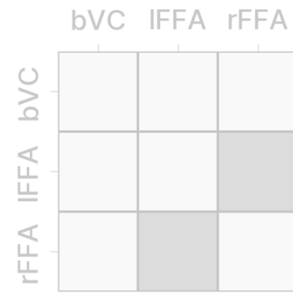
Model Space



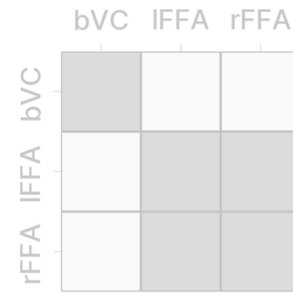
Model 01



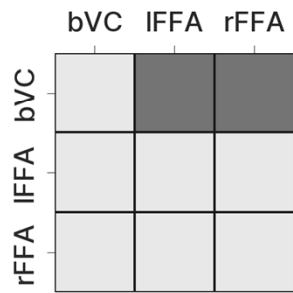
Model 02



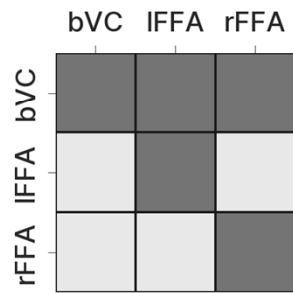
Model 03



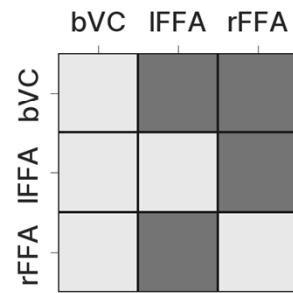
Model 04



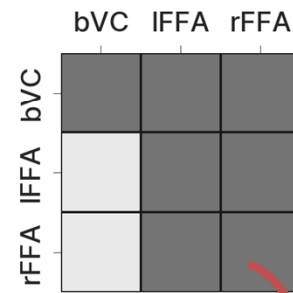
Model 05



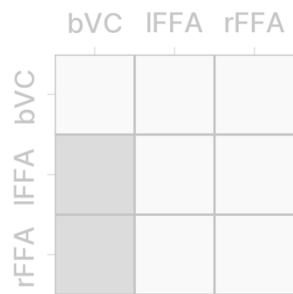
Model 06



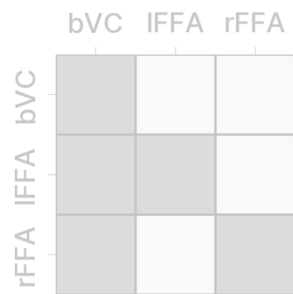
Model 07



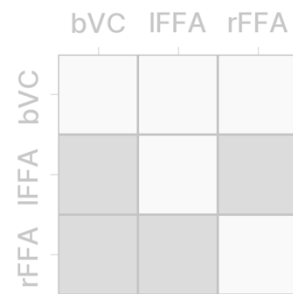
Model 08



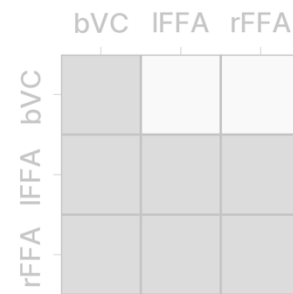
Model 09



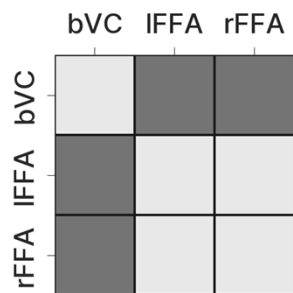
Model 10



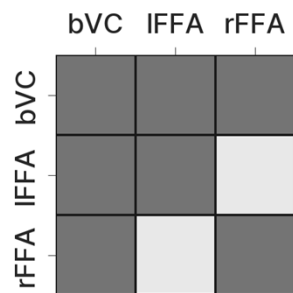
Model 11



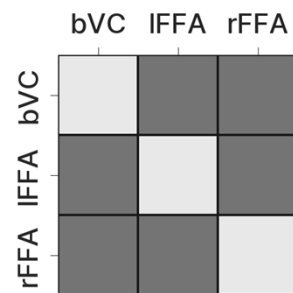
Model 12



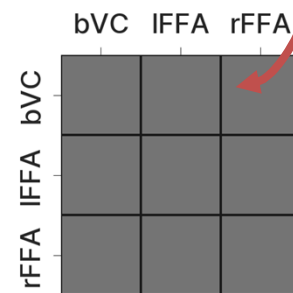
Model 13



Model 14



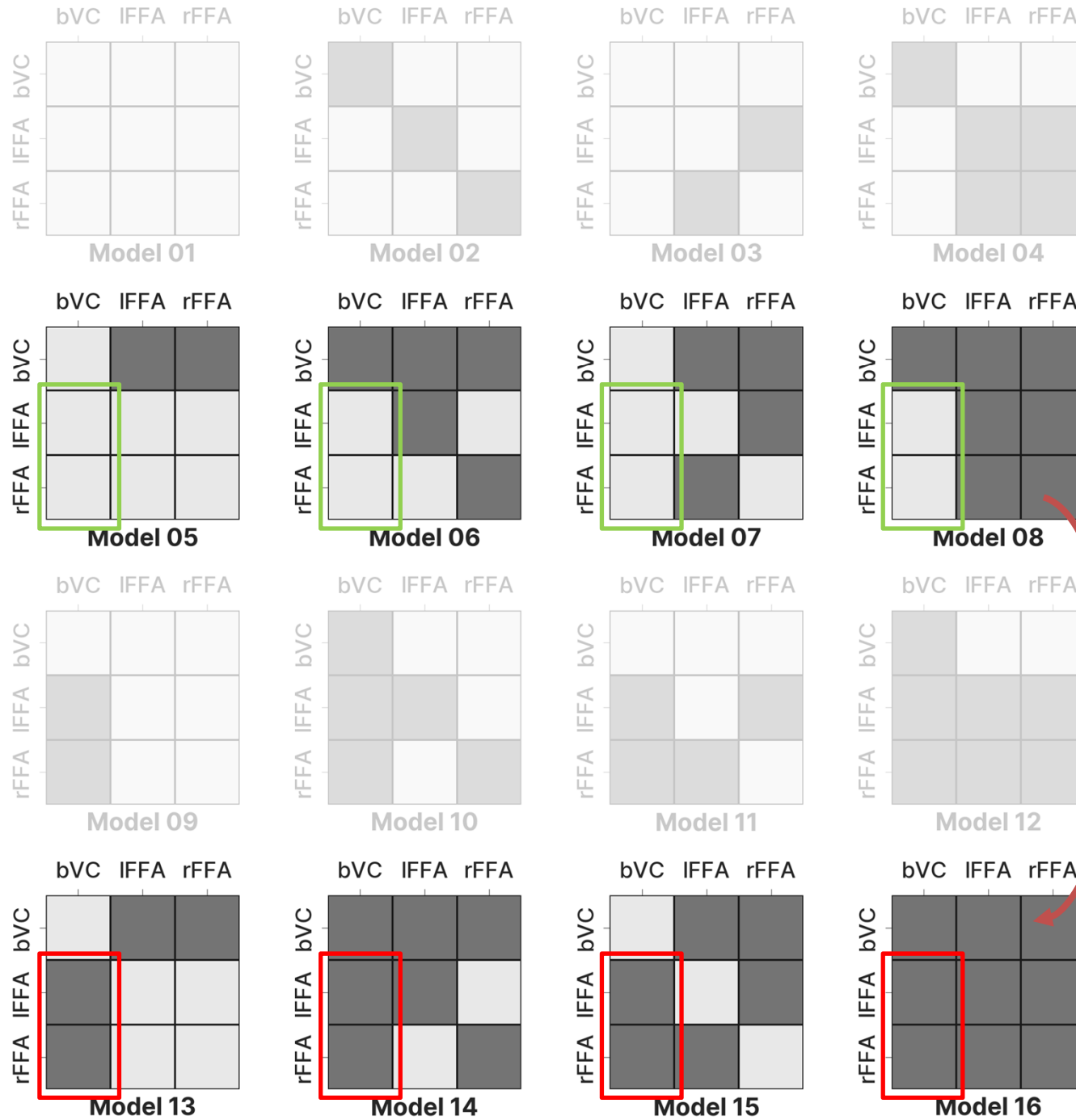
Model 15



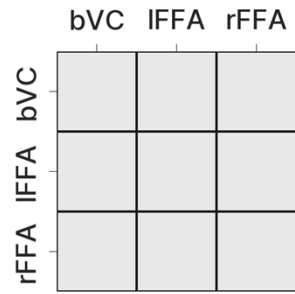
Model 16



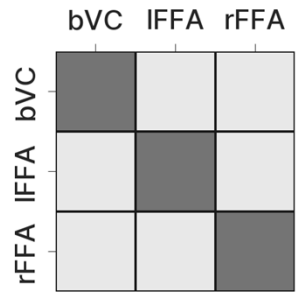
Model Space



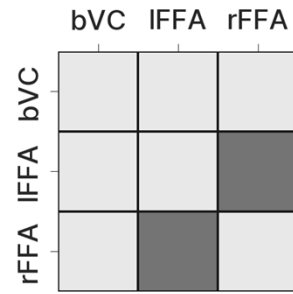
Model Space



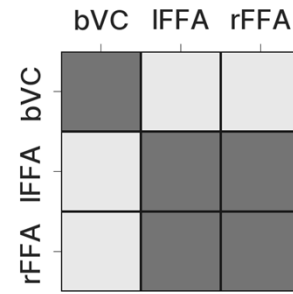
Model 01



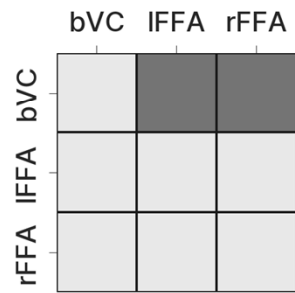
Model 02



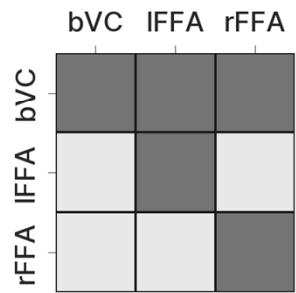
Model 03



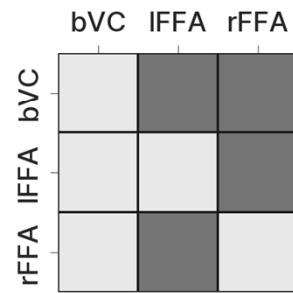
Model 04



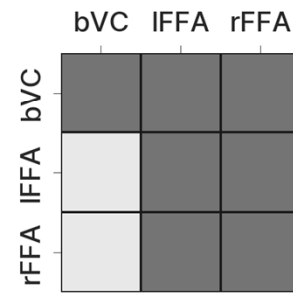
Model 05



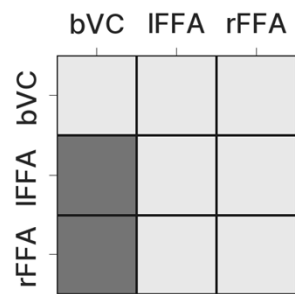
Model 06



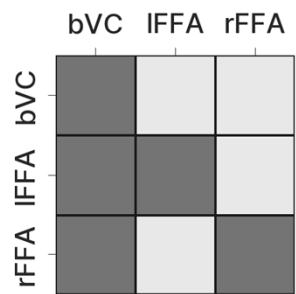
Model 07



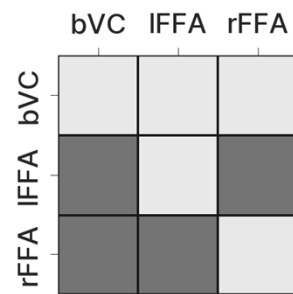
Model 08



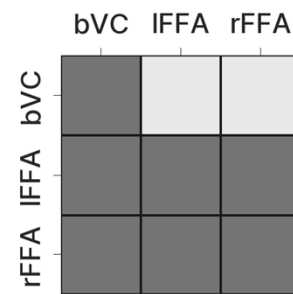
Model 09



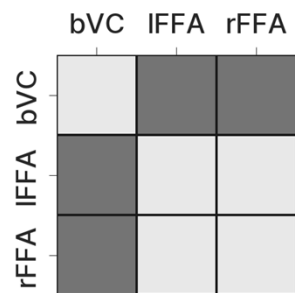
Model 10



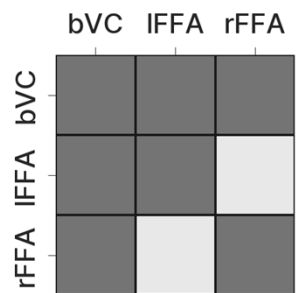
Model 11



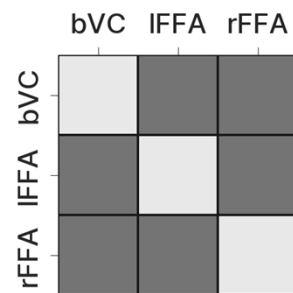
Model 12



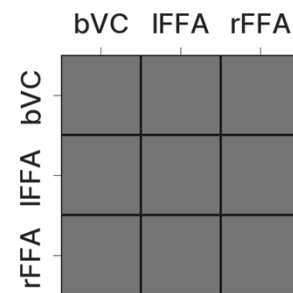
Model 13



Model 14



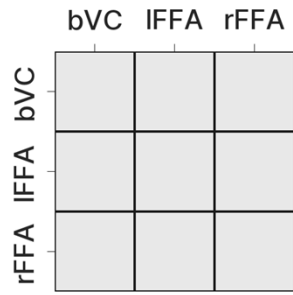
Model 15



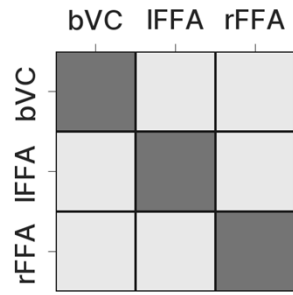
Model 16

Model Space

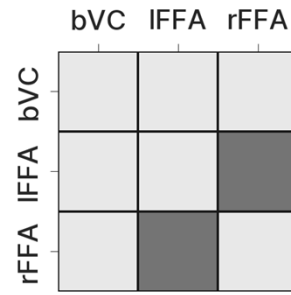
Partition
into
Families



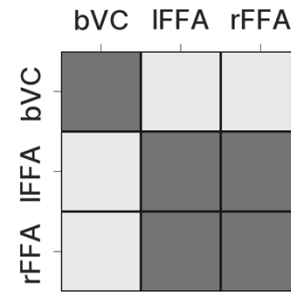
Model 01



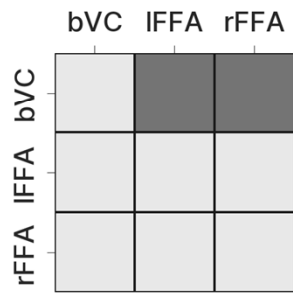
Model 02



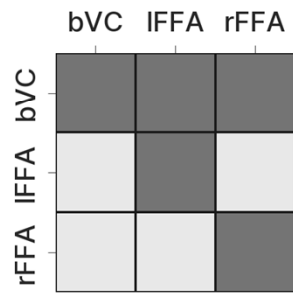
Model 03



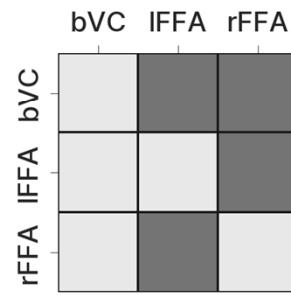
Model 04



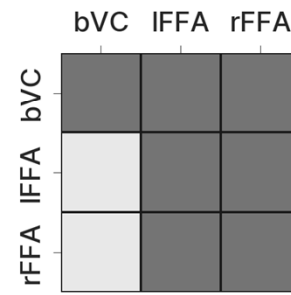
Model 05



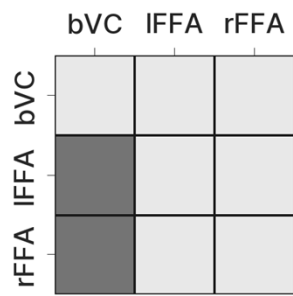
Model 06



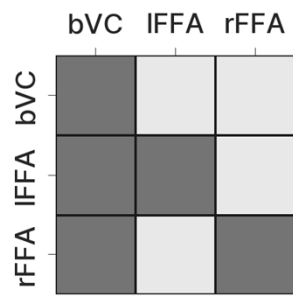
Model 07



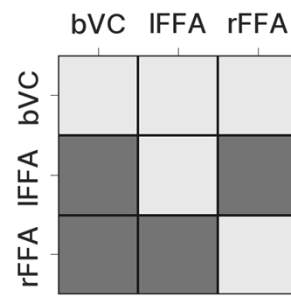
Model 08



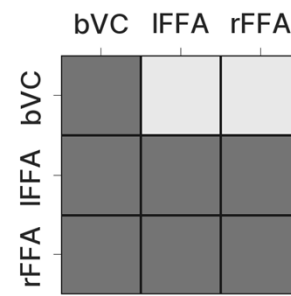
Model 09



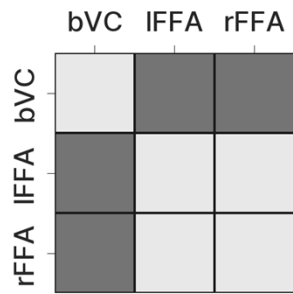
Model 10



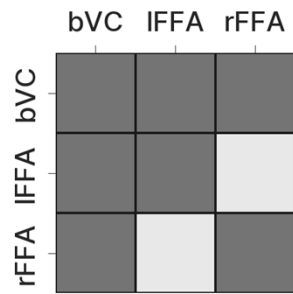
Model 11



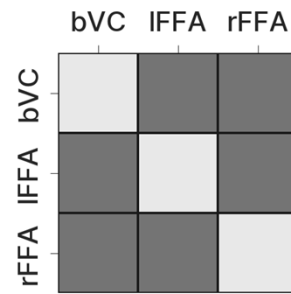
Model 12



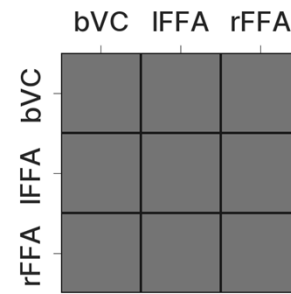
Model 13



Model 14



Model 15



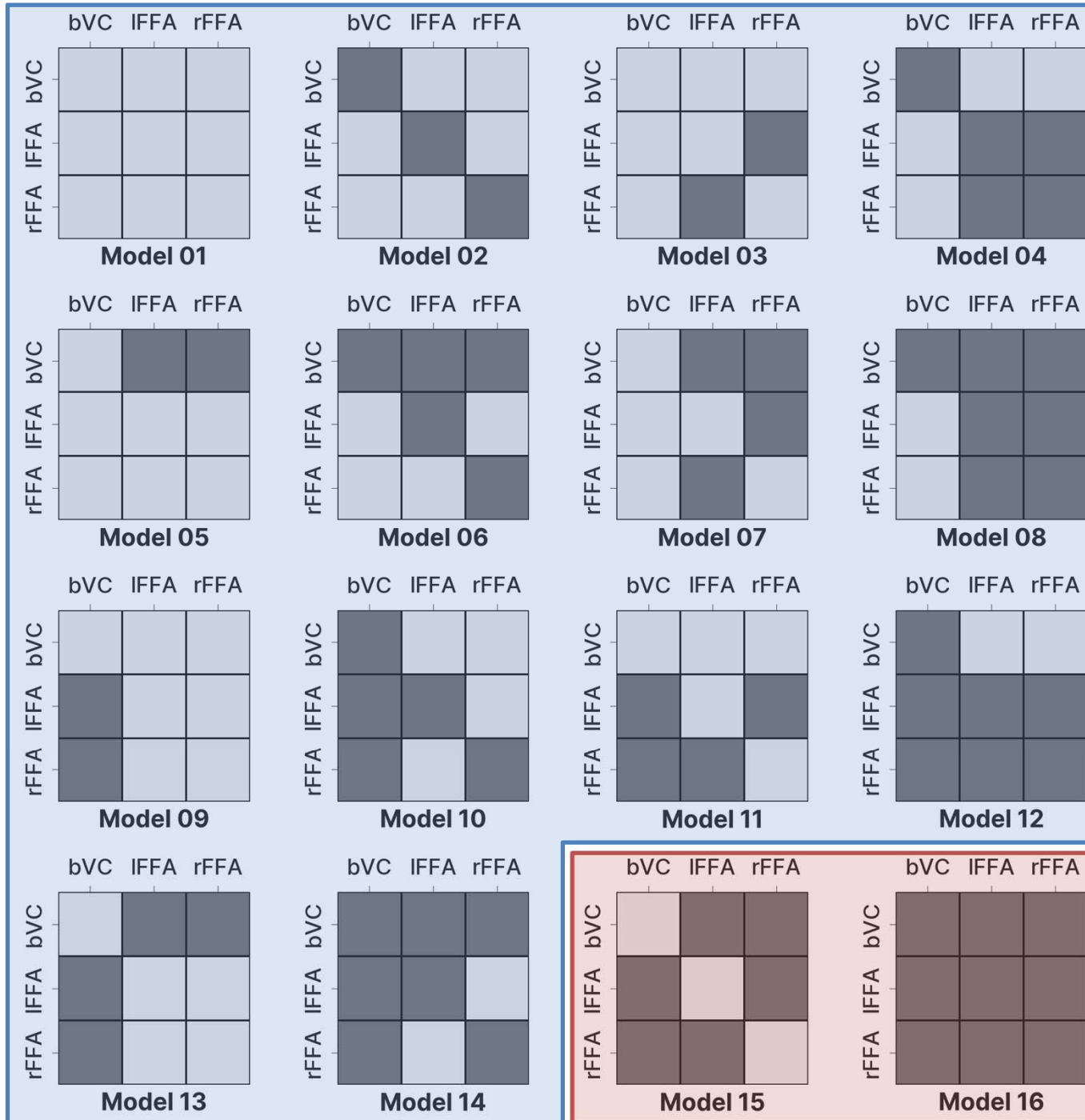
Model 16

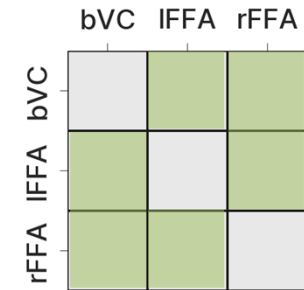
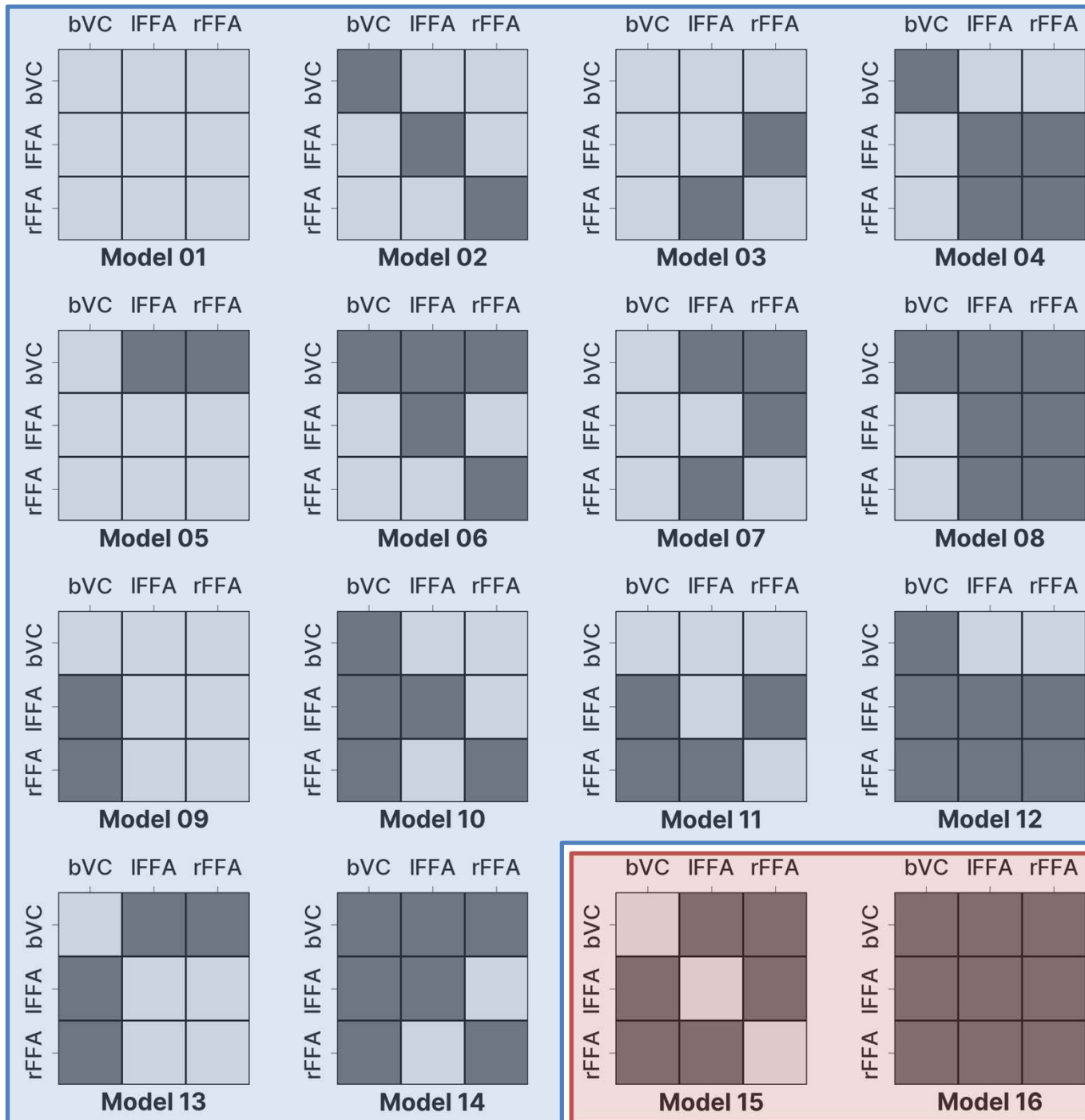
Model Space

Partition
into
Families

Family 1
At least one
forward or backward
or lateral connection

Family 2
No
forward or backward
or lateral connection
(Only self)

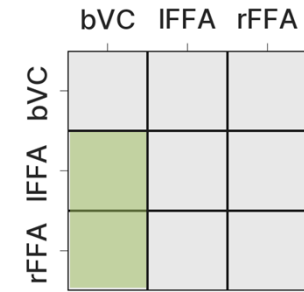
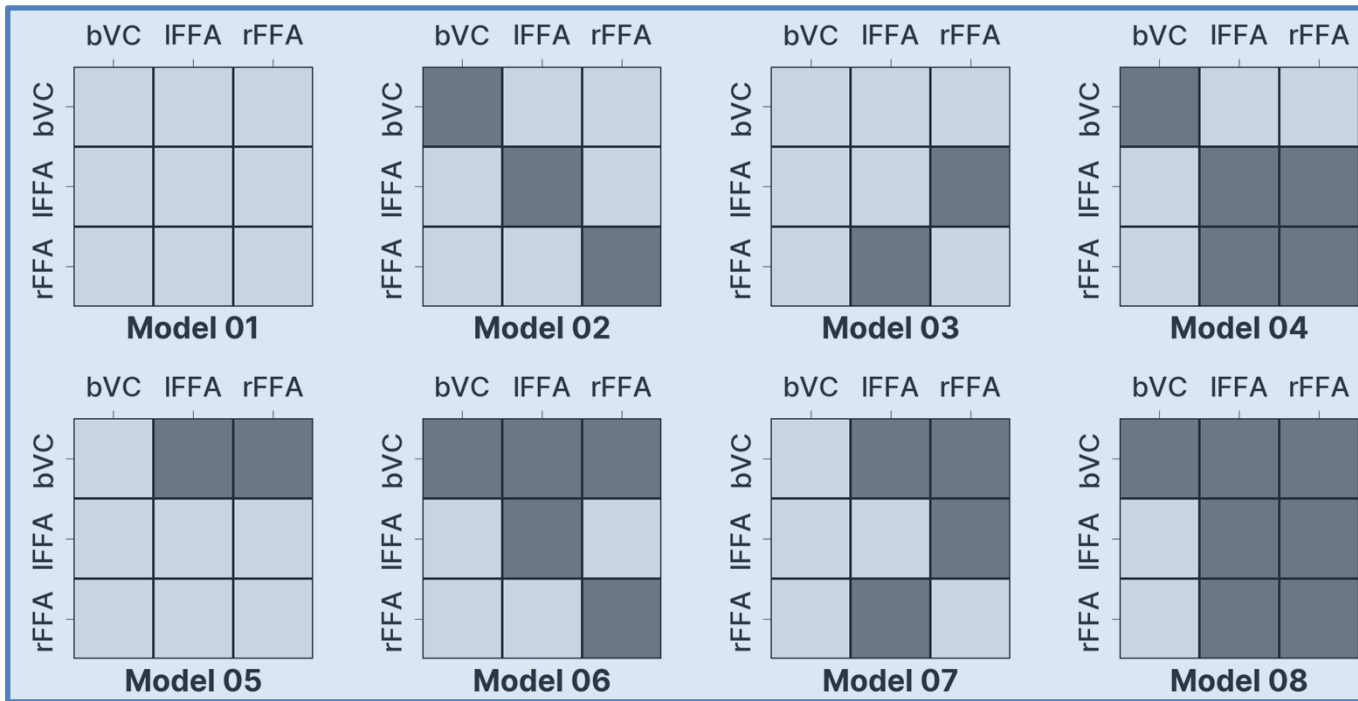




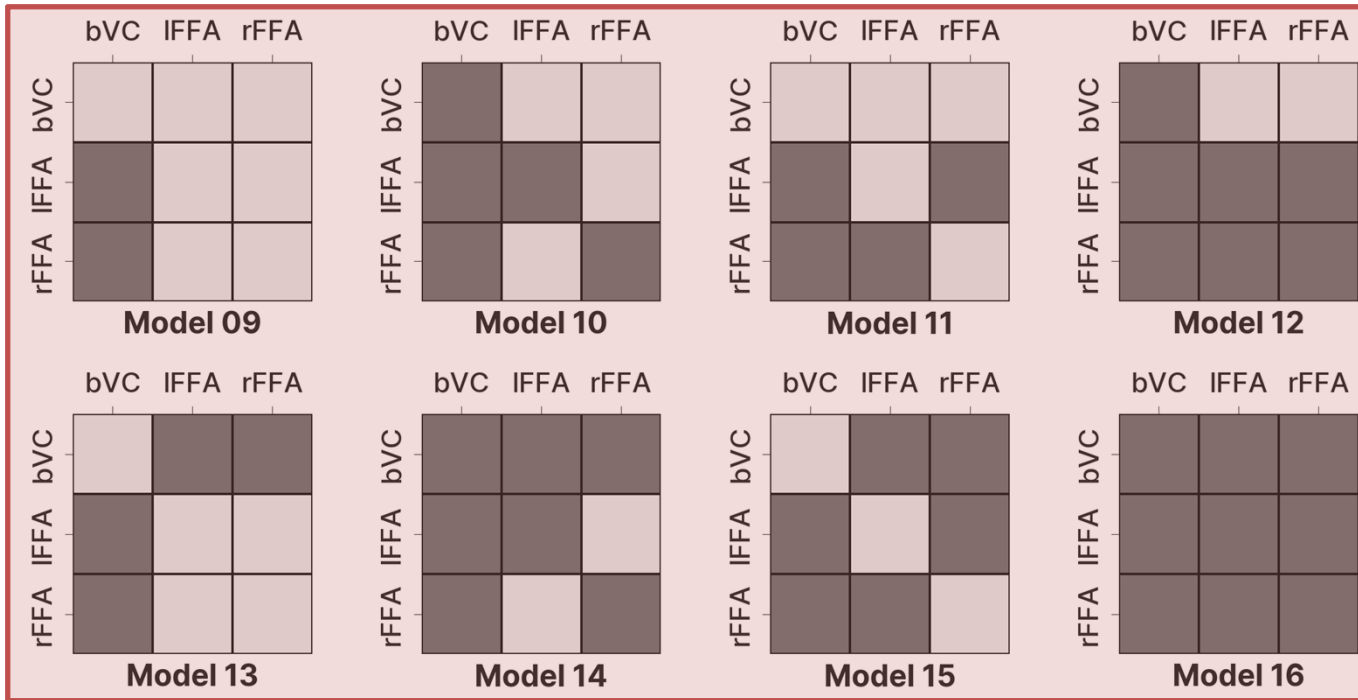
Family 1
At least one
 forward or backward
 or lateral connection

Are **between-region**
 connections modulated
 by Faces regardless
 of self-connections?

Family 2
No
 forward or backward
 or lateral connection
 (Only self)

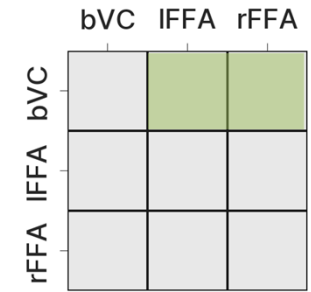
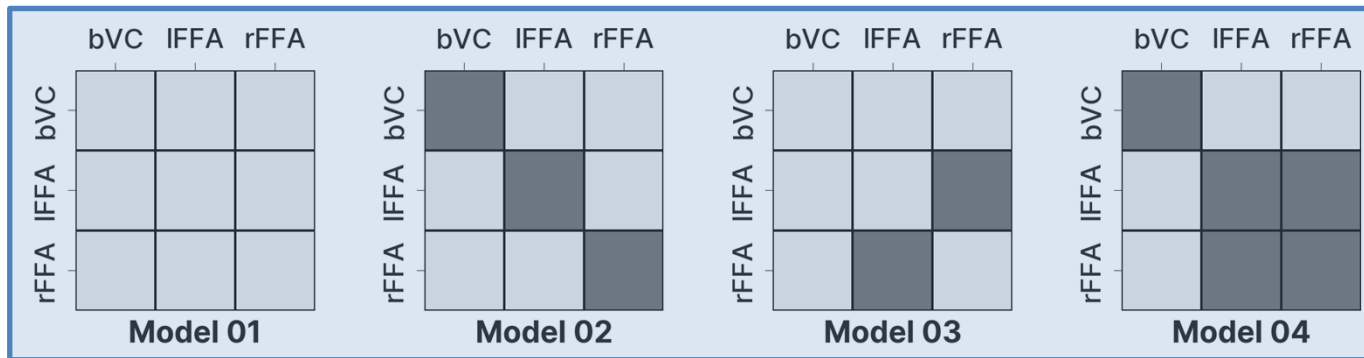


Family 1
With
forward connections

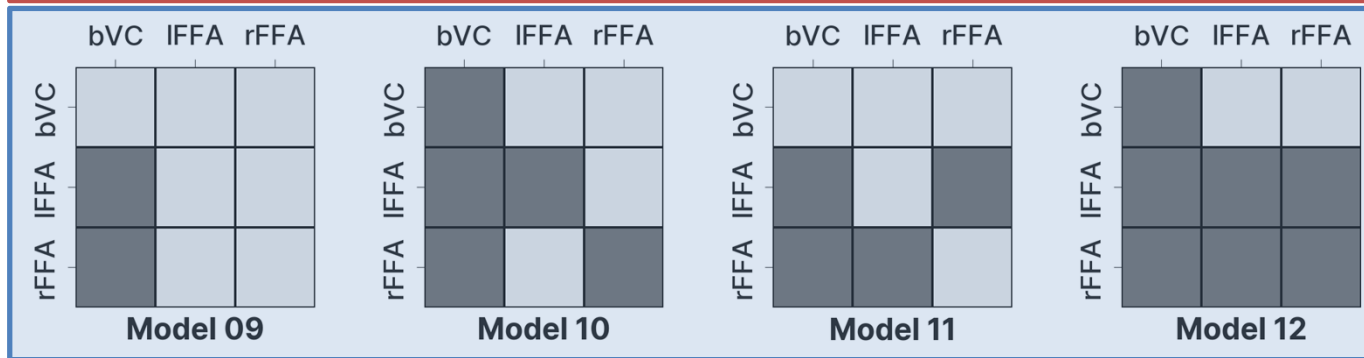
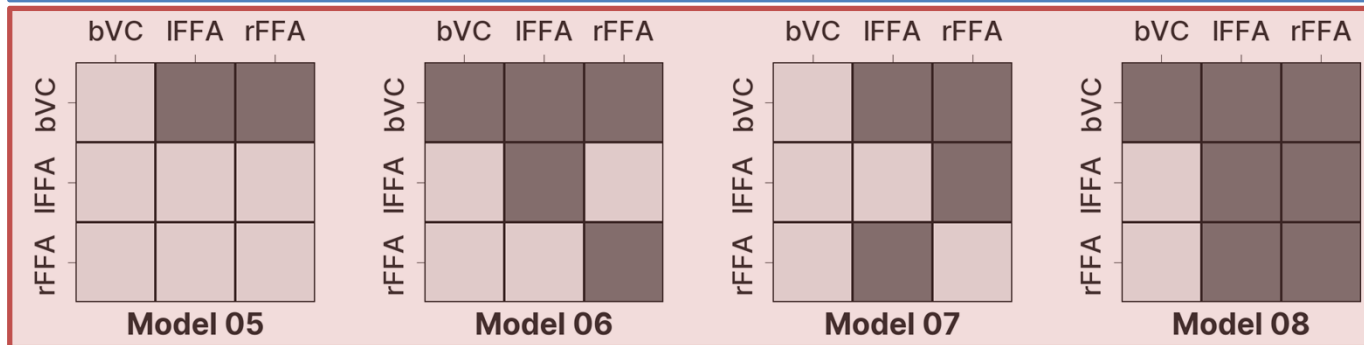


Are **forward**
connections modulated
by Faces regardless of
all other connections?

Family 2
Without
forward connections

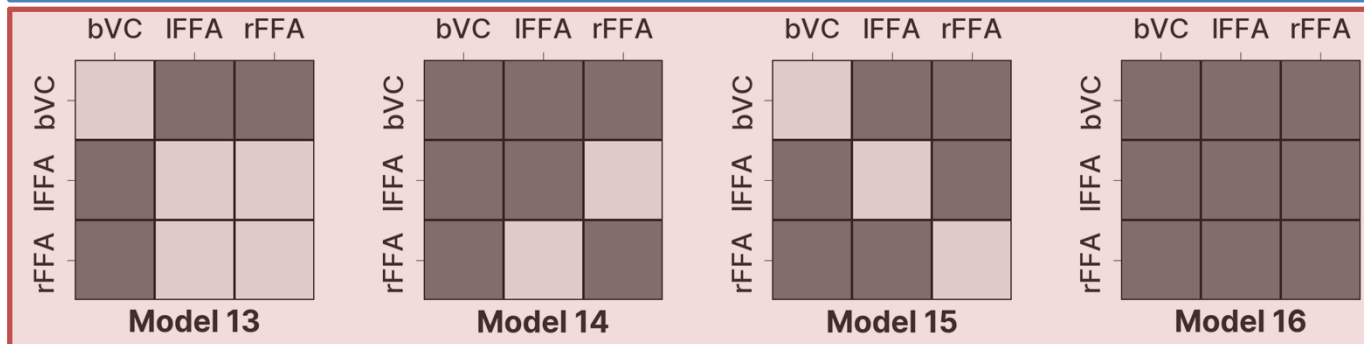


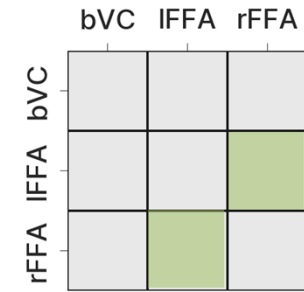
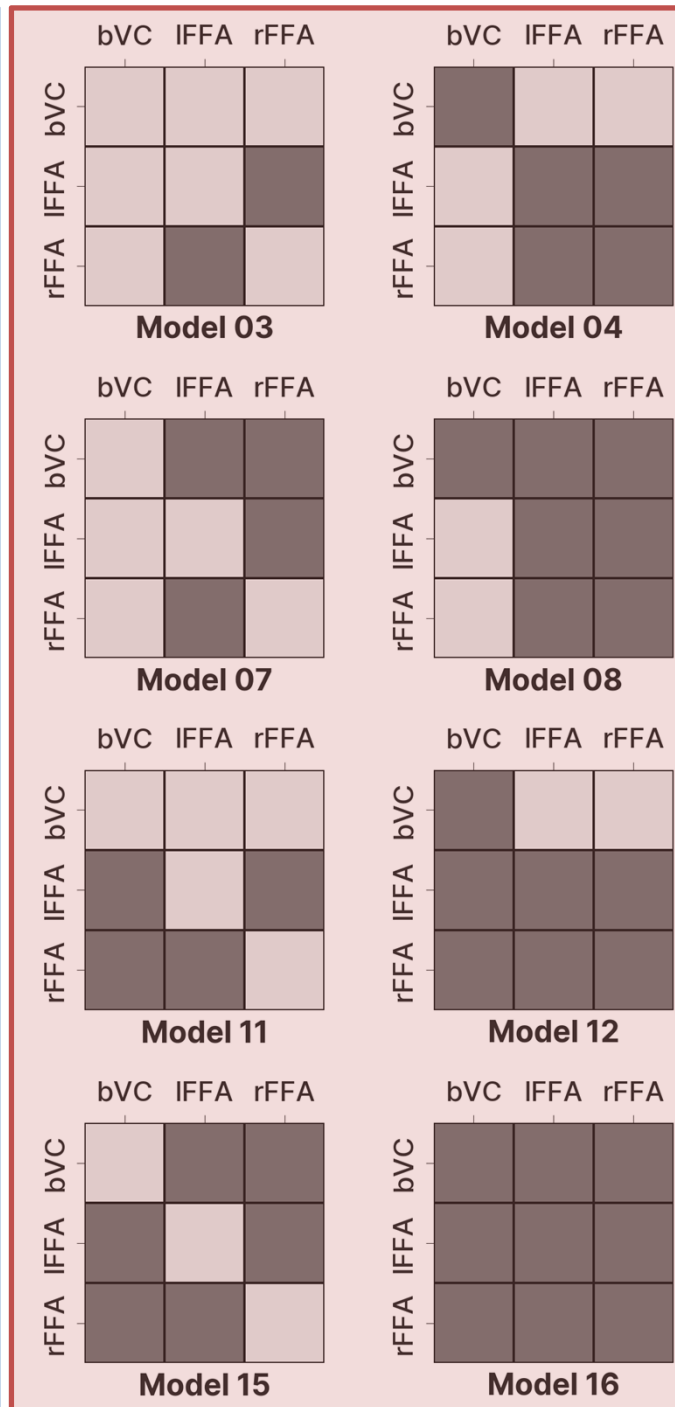
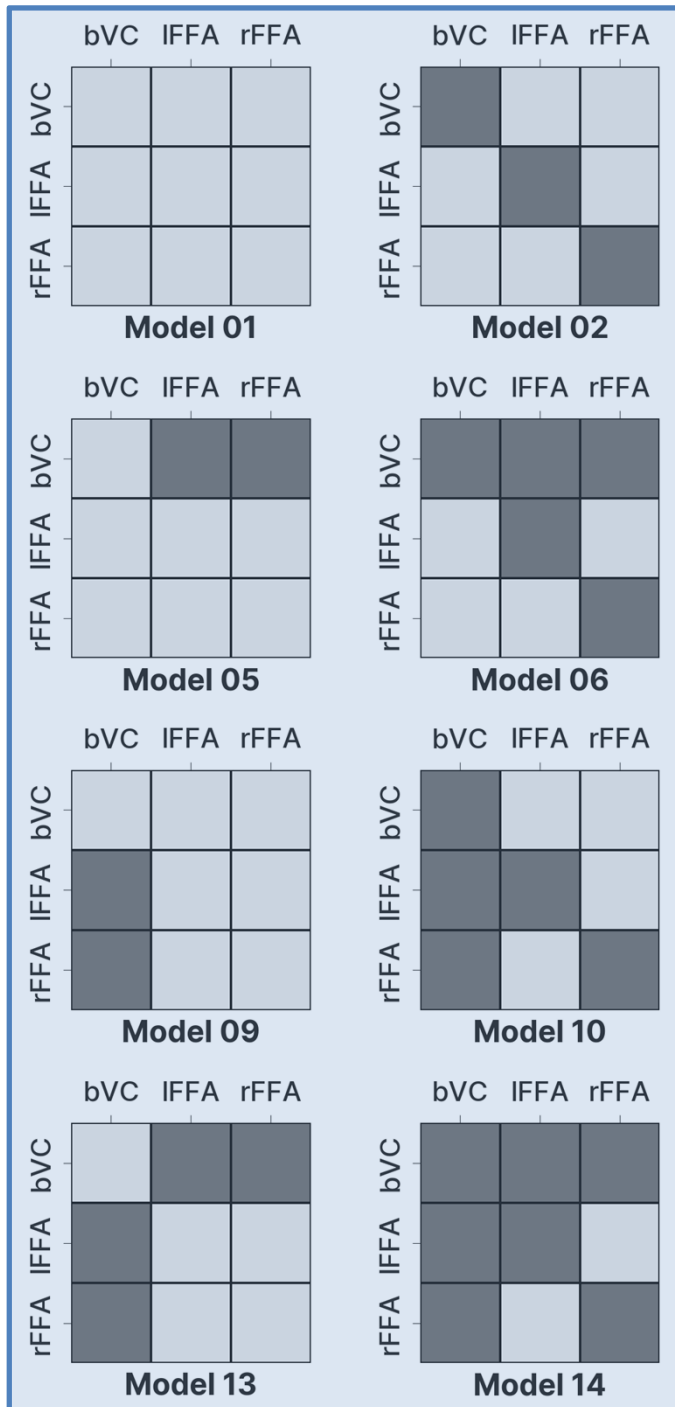
Family 1
With
backward connections



Are **backward**
connections modulated
by Faces regardless of
all other connections?

Family 2
Without
backward connections

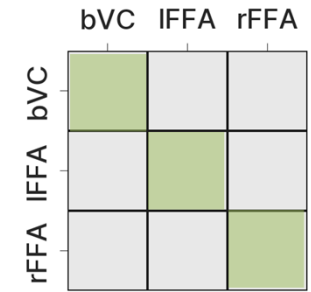
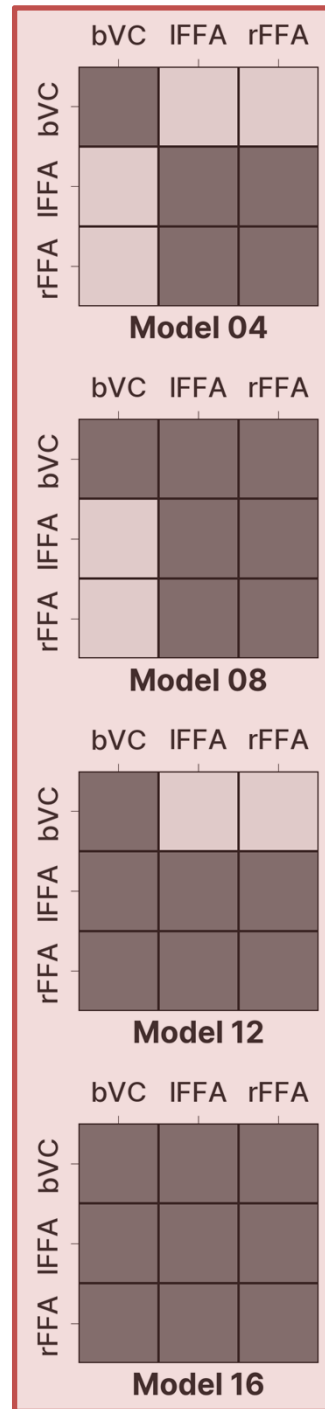
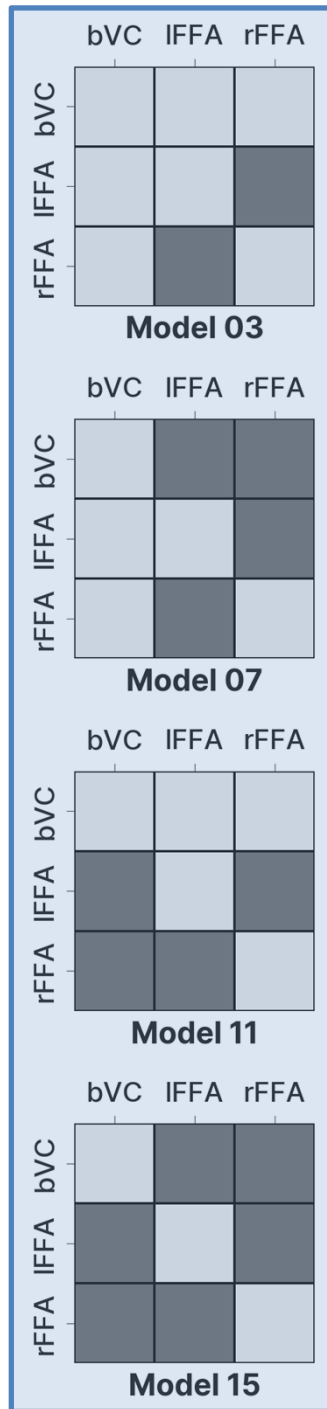
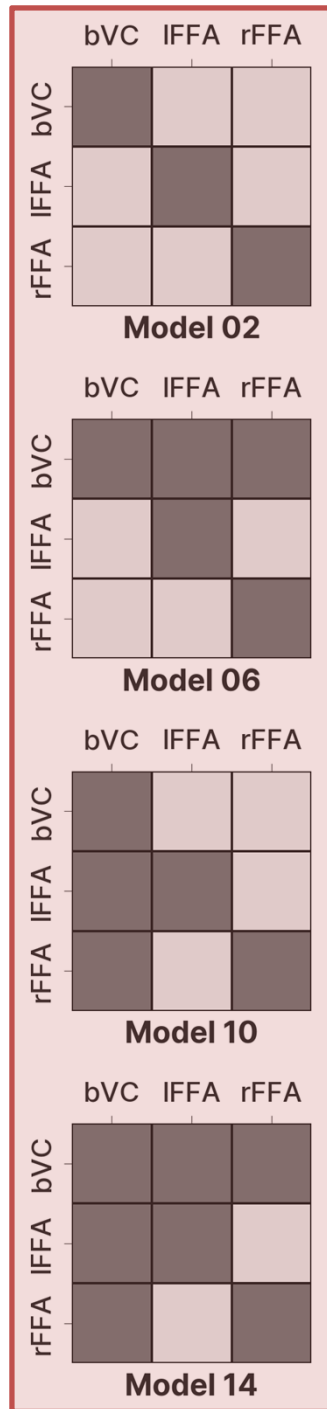
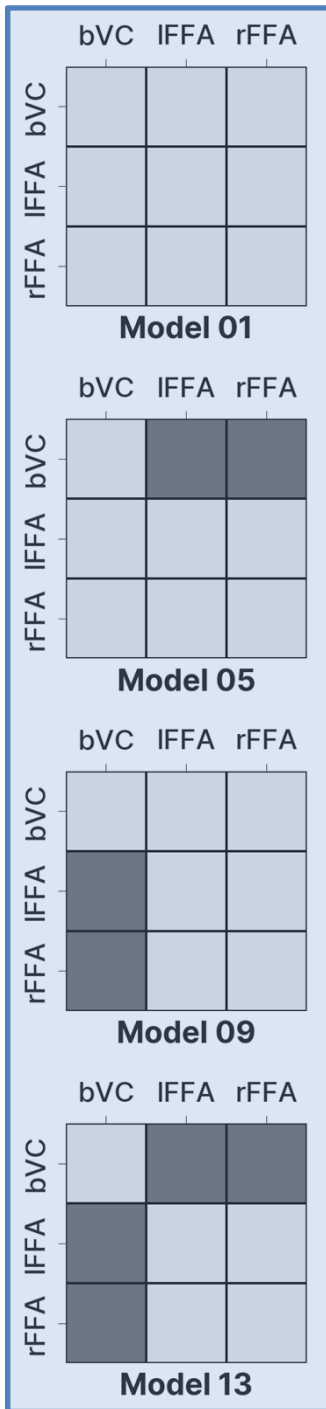




Family 1
With
lateral connections

Are **lateral**
connections modulated
by Faces regardless of
all other connections?

Family 2
Without
lateral connections



Family 1
With
self connections

Are **self**
connections modulated
by Faces regardless of
all other connections?

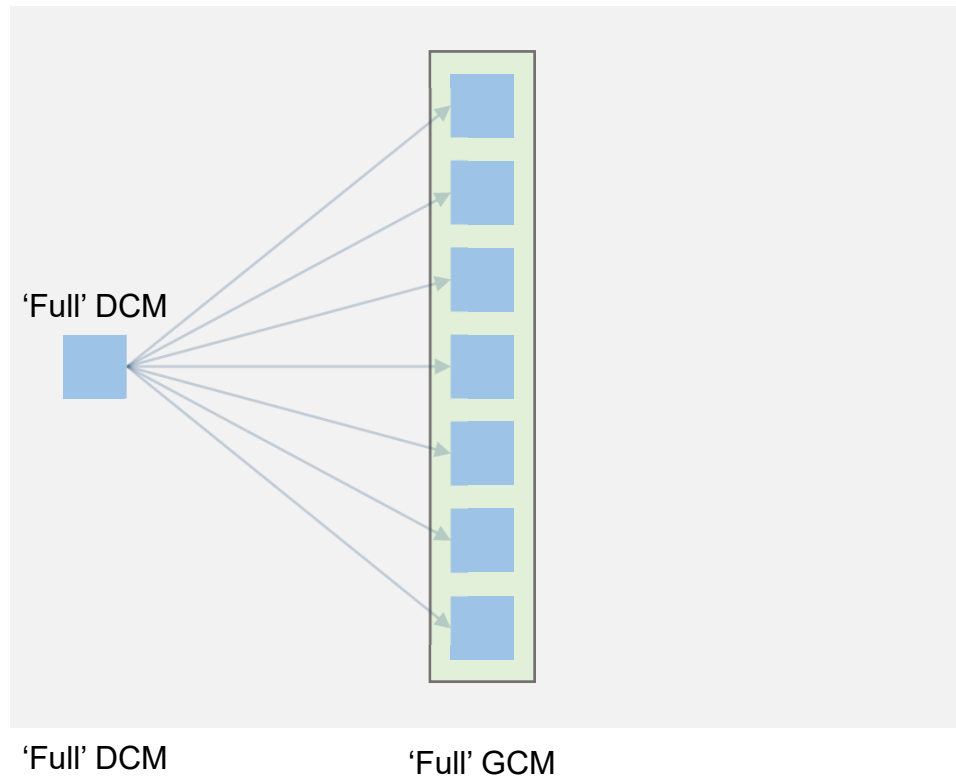
Family 2
Without
self connections

Thank you

Binary BMC

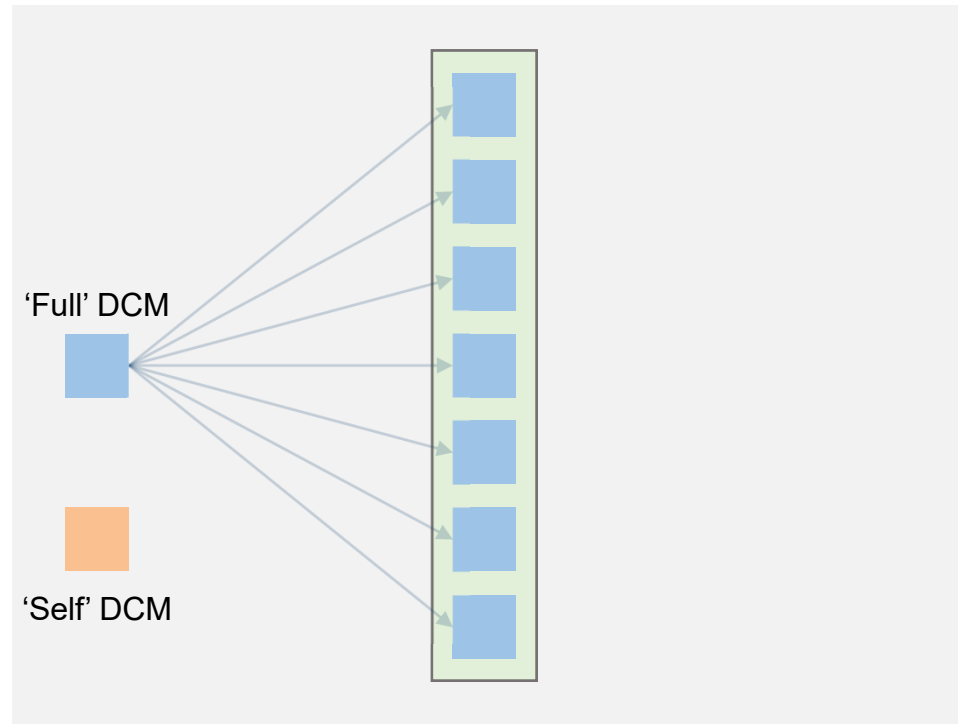
Batch Processing Steps for Comparison

Define Model Space through GCM Specification



Batch Processing Steps for Comparison

Define Model Space through GCM Specification

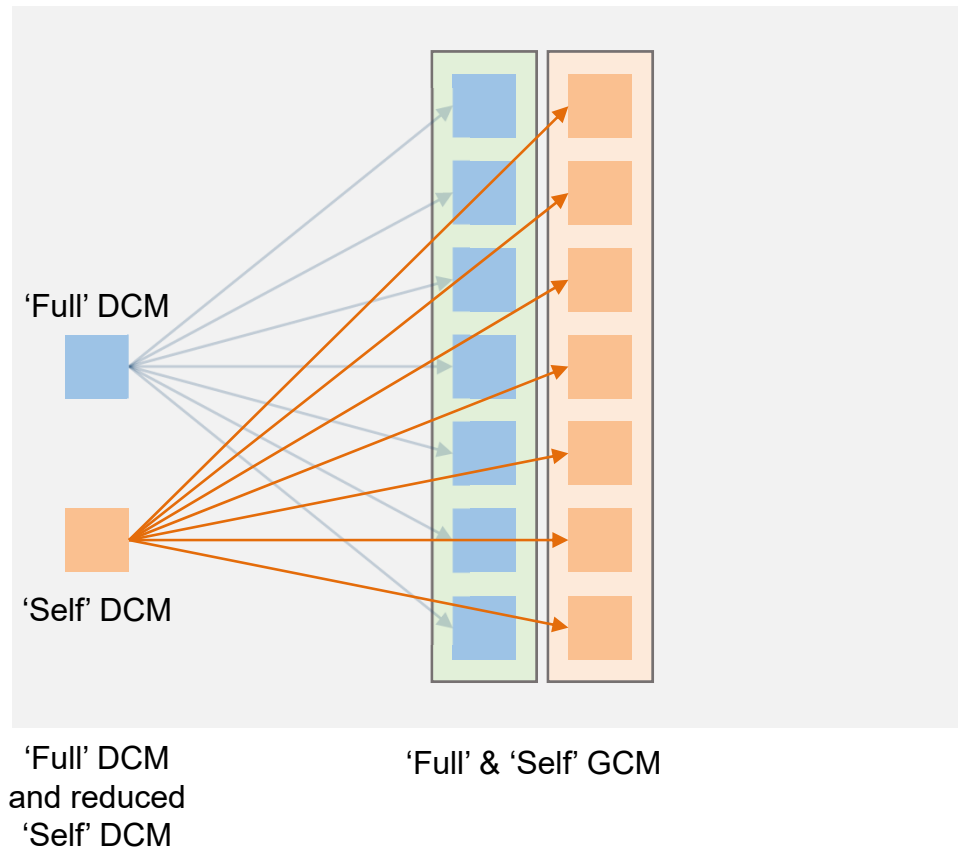


'Full' DCM
and reduced
'Self' DCM

'Full' GCM

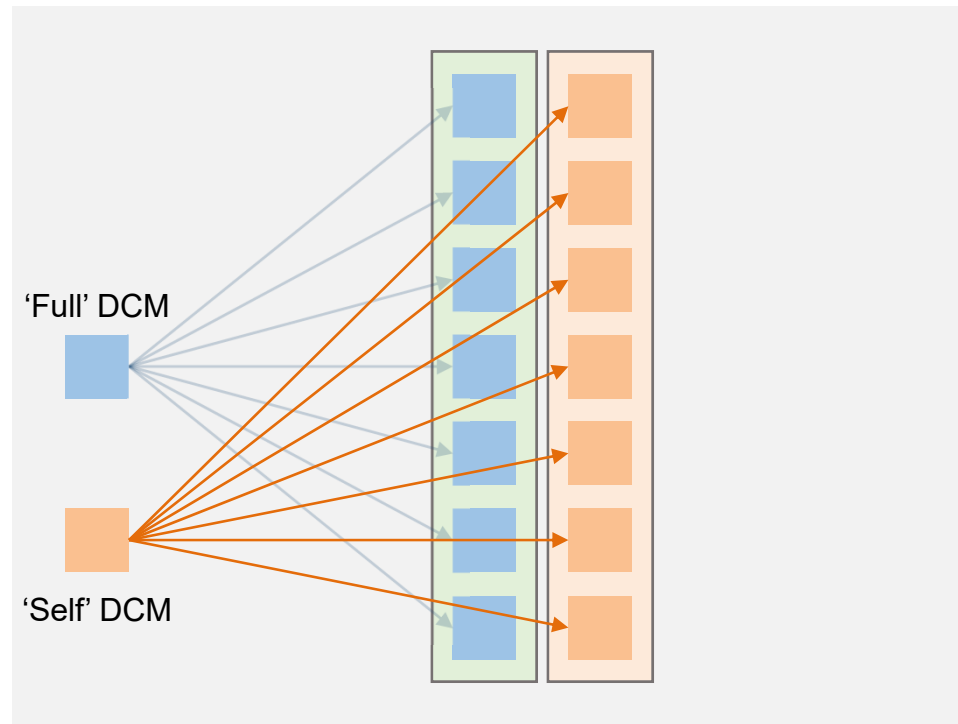
Batch Processing Steps for Comparison

Define Model Space through GCM Specification



Batch Processing Steps for Comparison

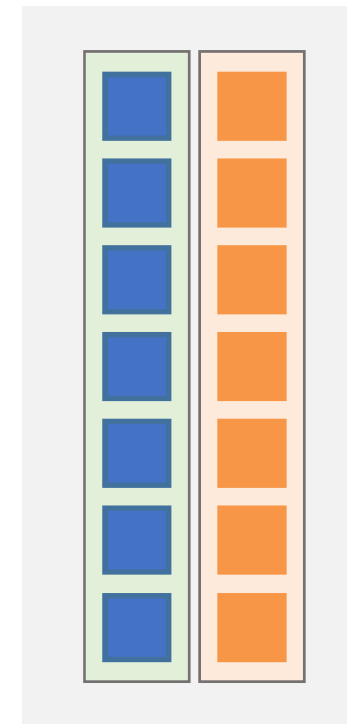
Define Model Space through GCM Specification



'Full' DCM
and reduced
'Self' DCM

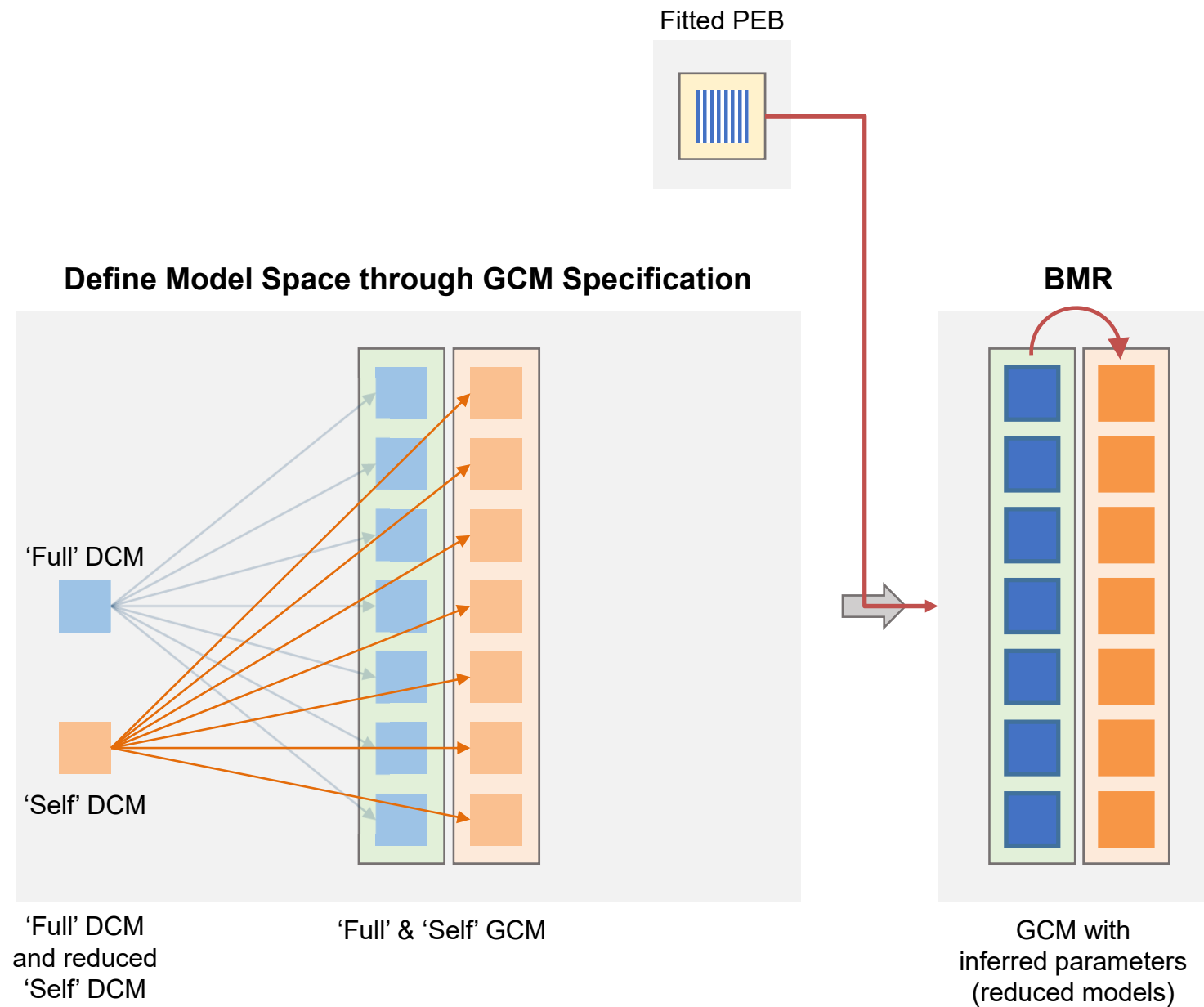
'Full' & 'Self' GCM

BMR

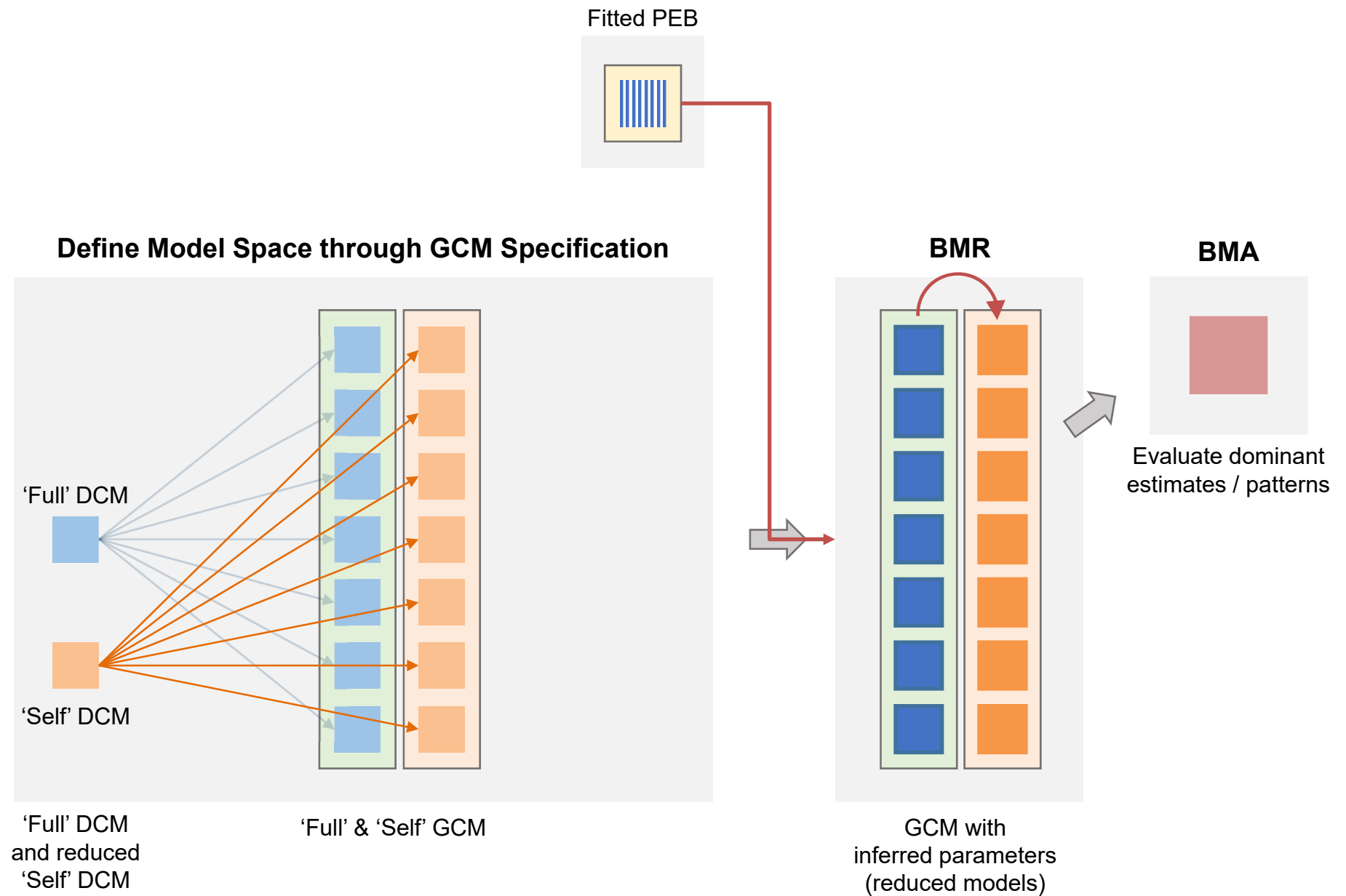


GCM with
inferred parameters
(reduced models)

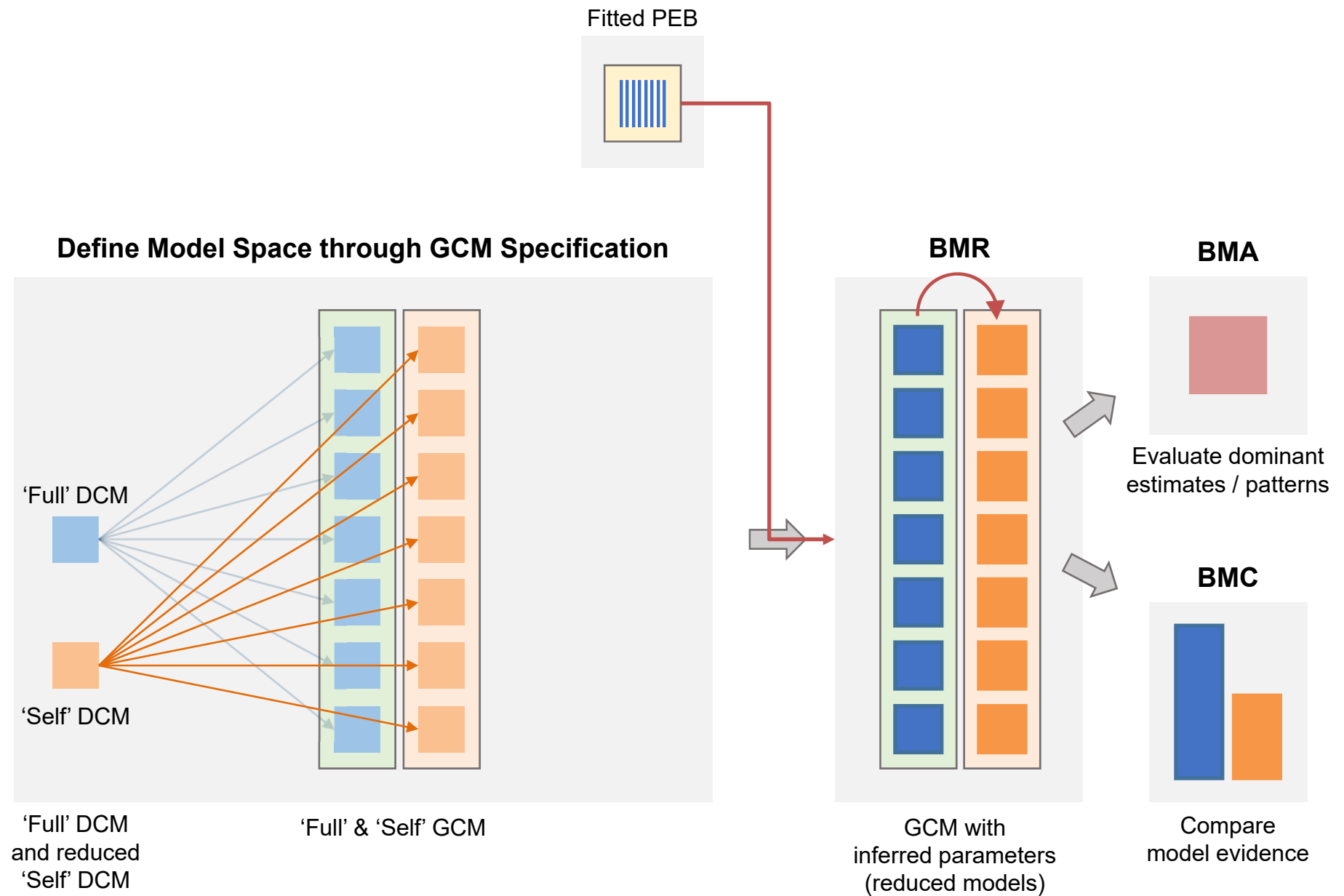
Batch Processing Steps for Comparison



Batch Processing Steps for Comparison

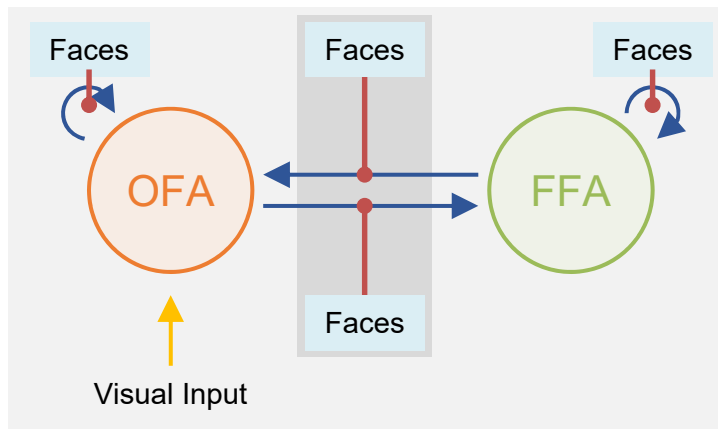


Batch Processing Steps for Comparison



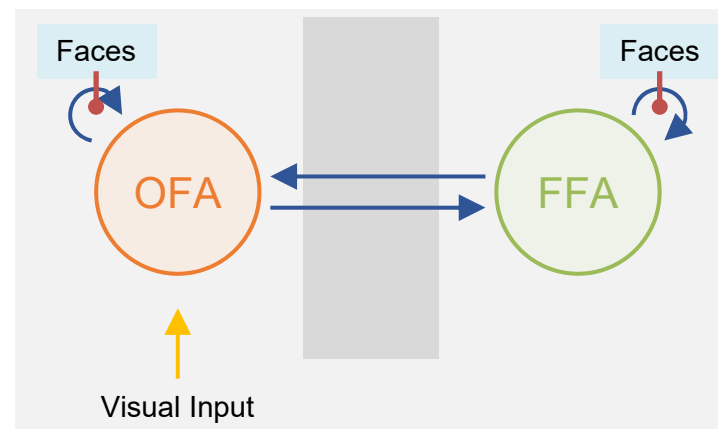
'Full' model

Faces modulate bw-region & self-connections



'Self' model

Faces modulate only self-connections (no bw-region)



BMC

Are between-region connections modulated?