Generative embedding and model-based classification

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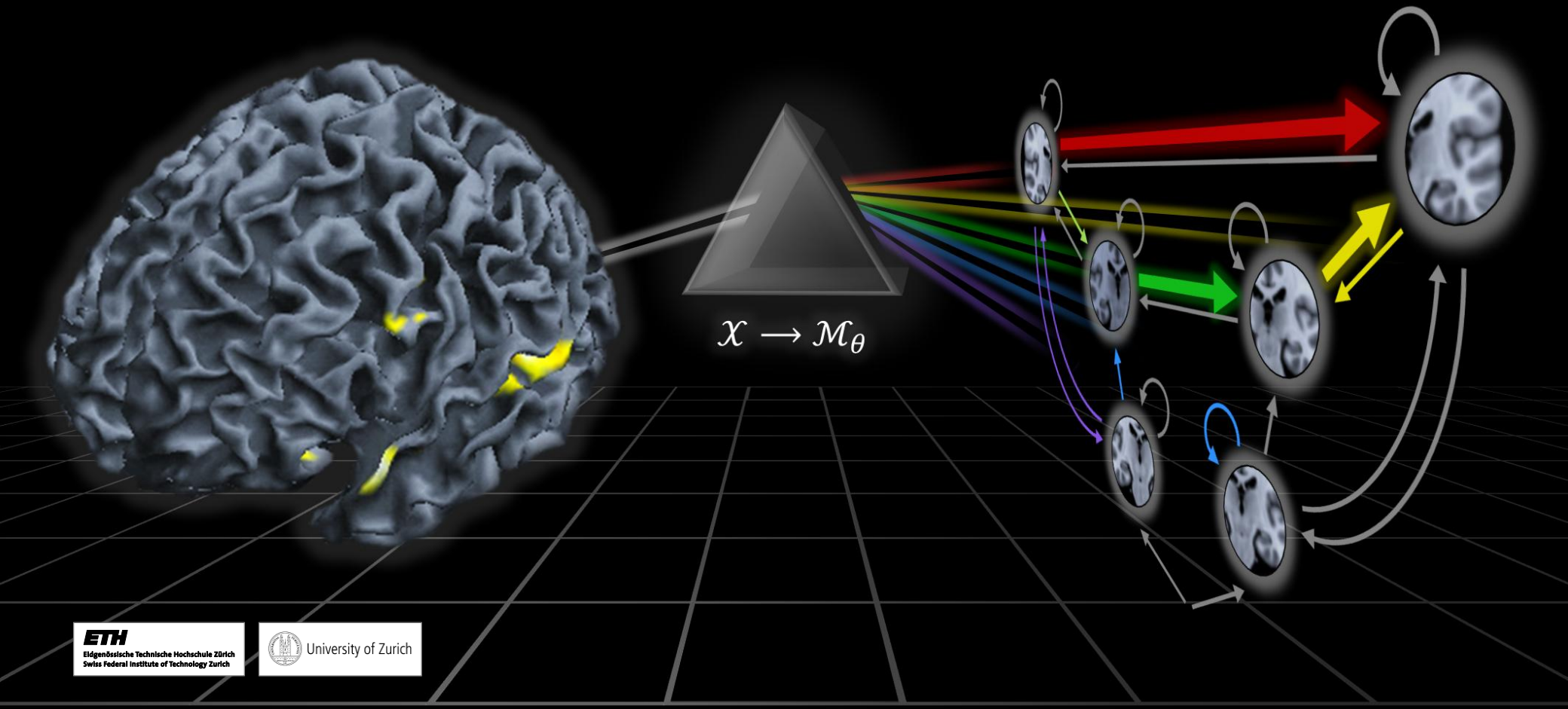


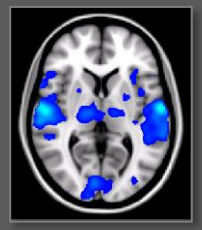
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich
University of Zurich

Classification approaches by data representation

Model-based classification

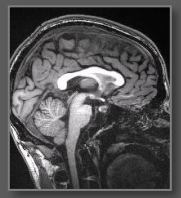
How do patterns of hidden quantities (e.g., connectivity among brain regions) differ between groups?

Activation-based classification



Which functional differences allow us to separate groups?

Structure-based classification



Which anatomical structures allow us to separate patients and healthy controls?

Colleagues & collaborators

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Klaas Enno Stephan
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Christoph Mathys
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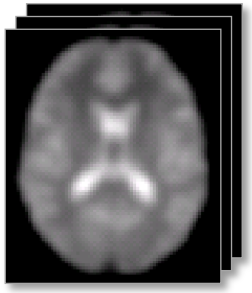
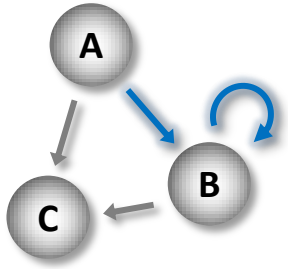
Model-based classification through generative embedding



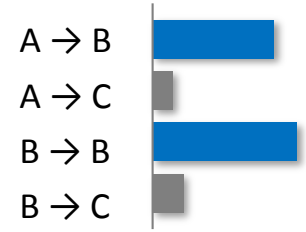
measurements from
an individual subject

**step 1 —
model inversion**



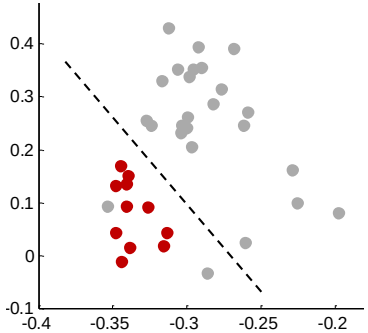
subject-specific
inverted generative model

**step 2 —
kernel construction**



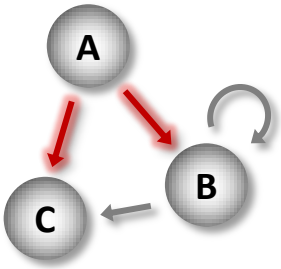
subject representation in the
generative score space

**step 3 —
classification**



separating hyperplane to
discriminate between groups

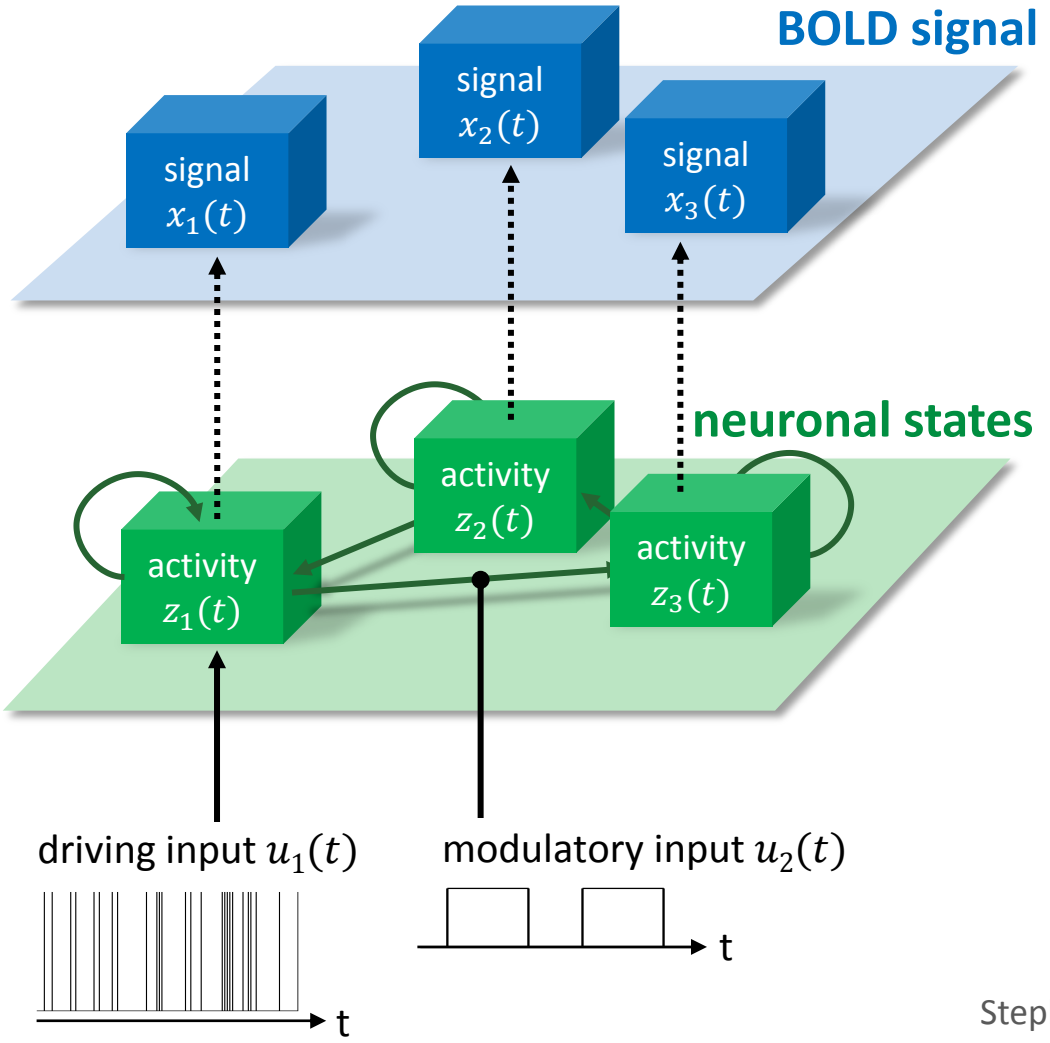
**step 4 —
interpretation**



jointly discriminative
connection strengths

Brodersen et al. (2011) *NeuroImage;* Brodersen et al. (2011) *PLoS Comput Biol*

Choosing a generative model: DCM for fMRI



haemodynamic forward model

$$x = g(z, \theta_h)$$

neural state equation

$$\dot{z} = \left(A + \sum u_j B^{(j)}\right) z + Cu$$

intrinsic connectivity

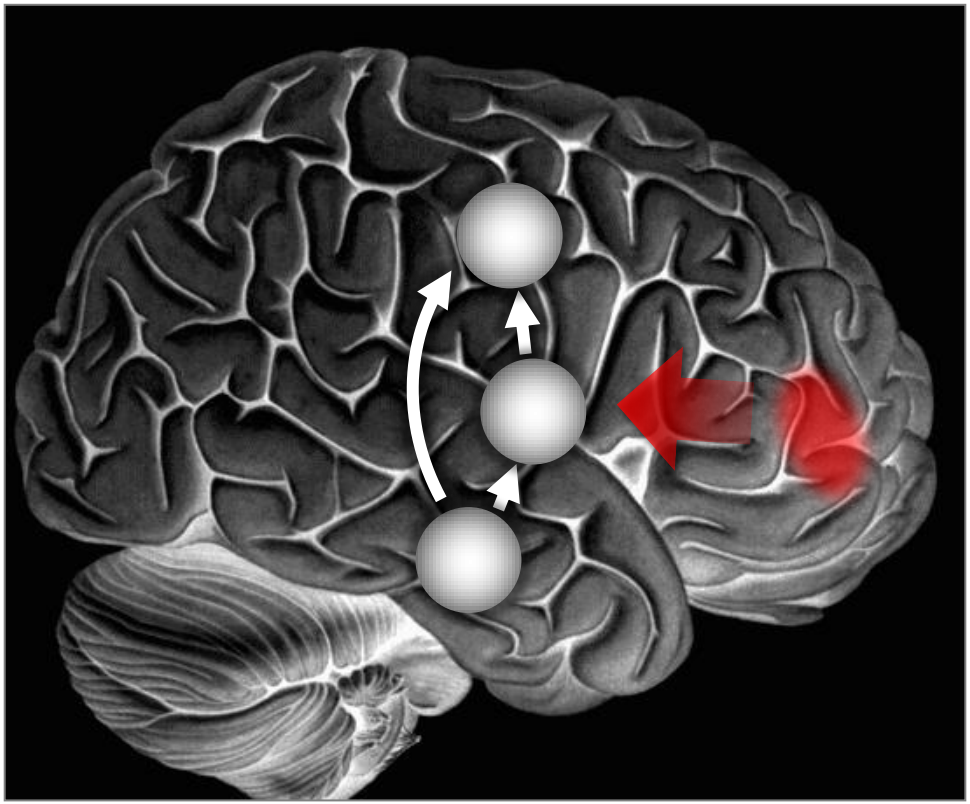
modulation of connectivity

direct inputs

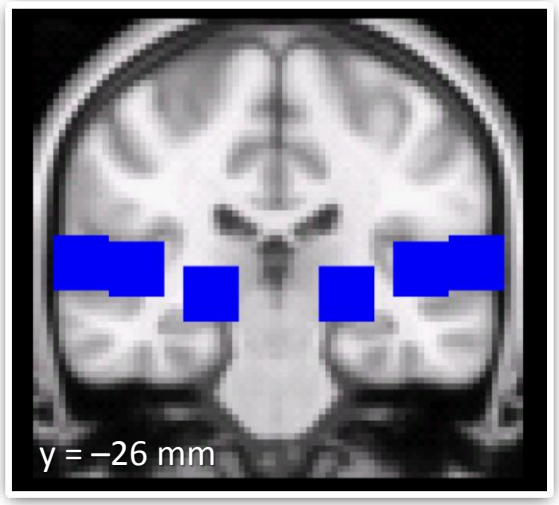
Friston, Harrison & Penny (2003) *NeuroImage*
Stephan & Friston (2007) *Handbook of Brain Connectivity*

Example: diagnosing stroke patients

To illustrate our approach, we aimed to distinguish between stroke patients and healthy controls, based on non-lesioned regions involved in speech processing.

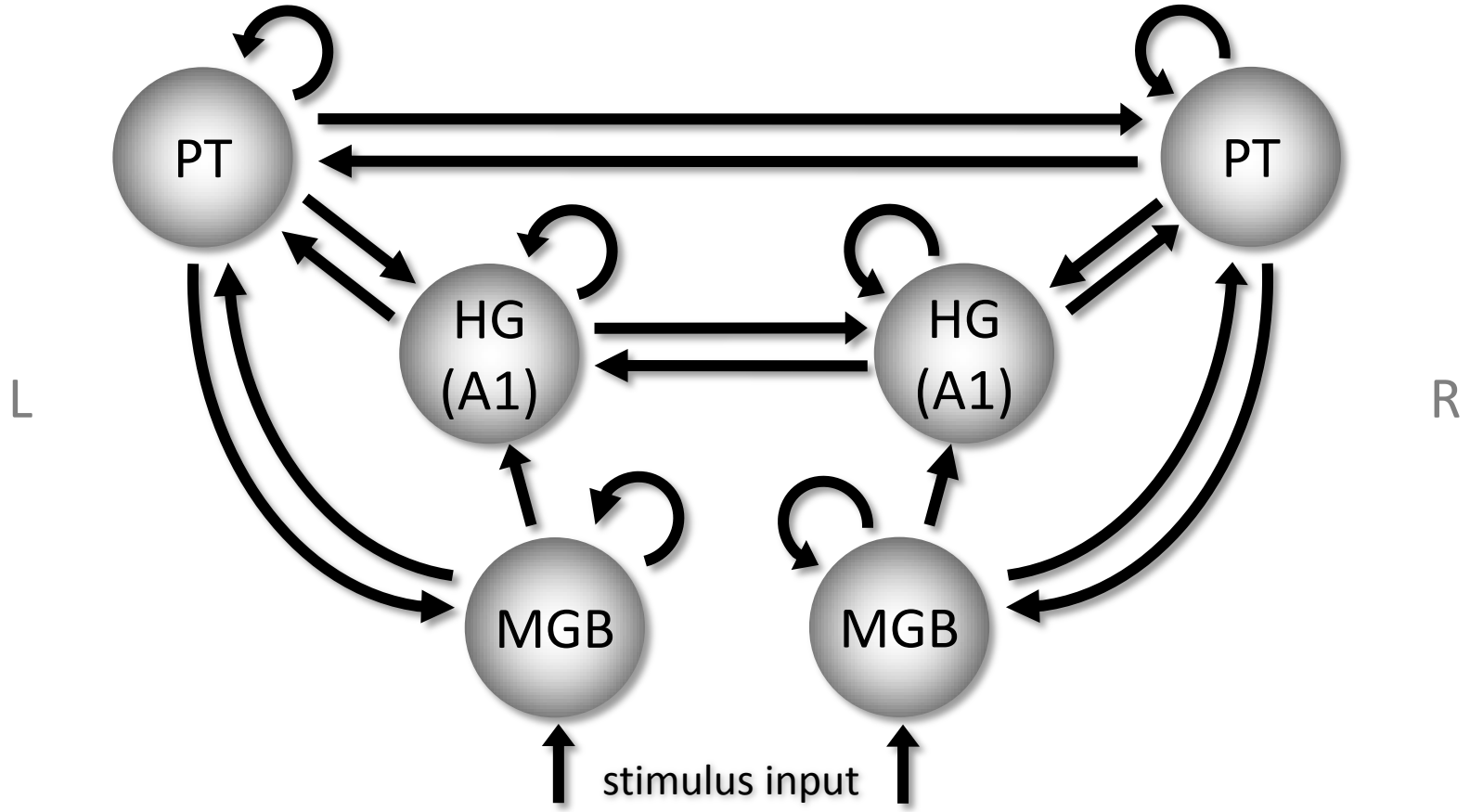


Example: diagnosing stroke patients

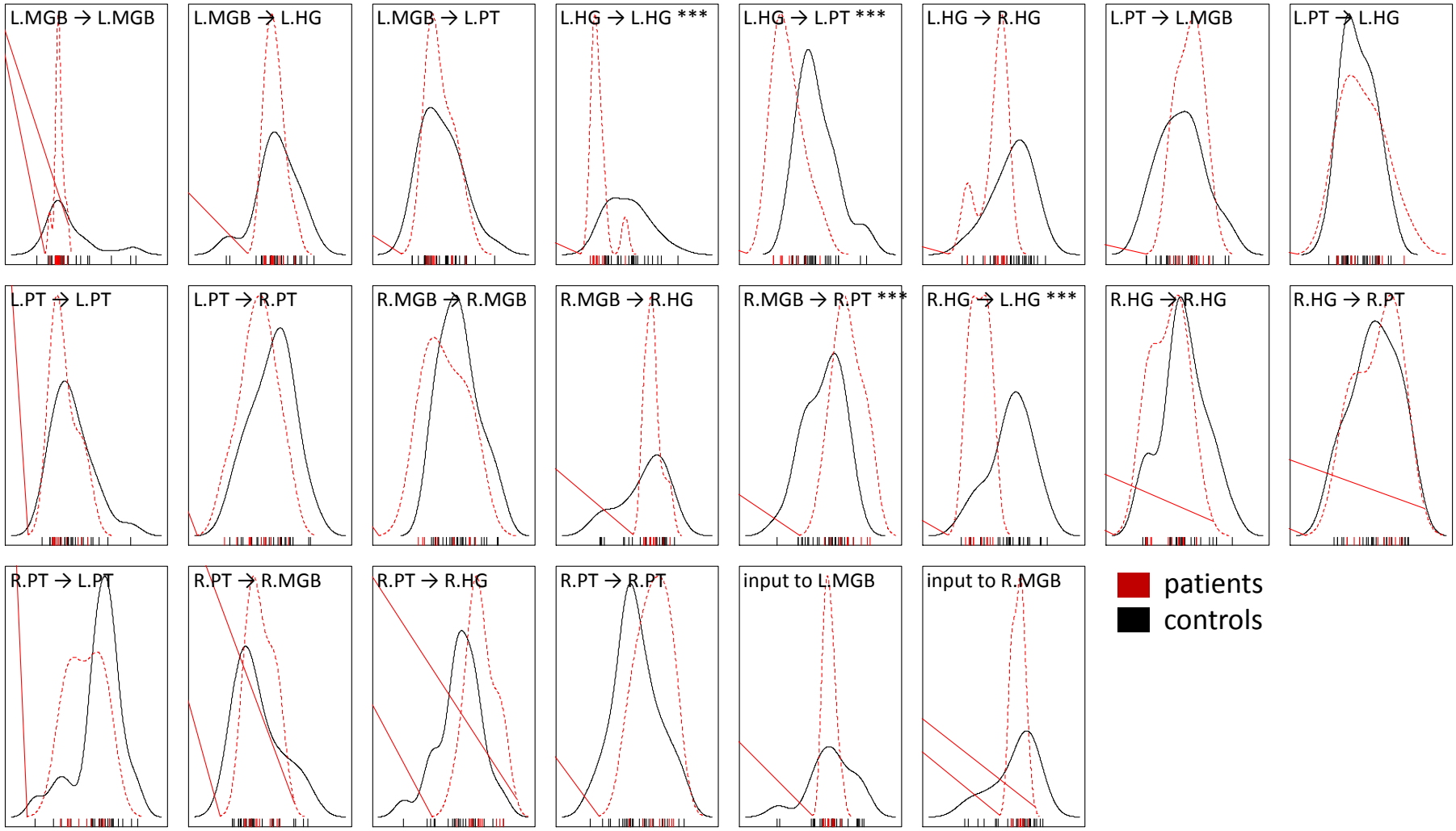


anatomical
regions of interest

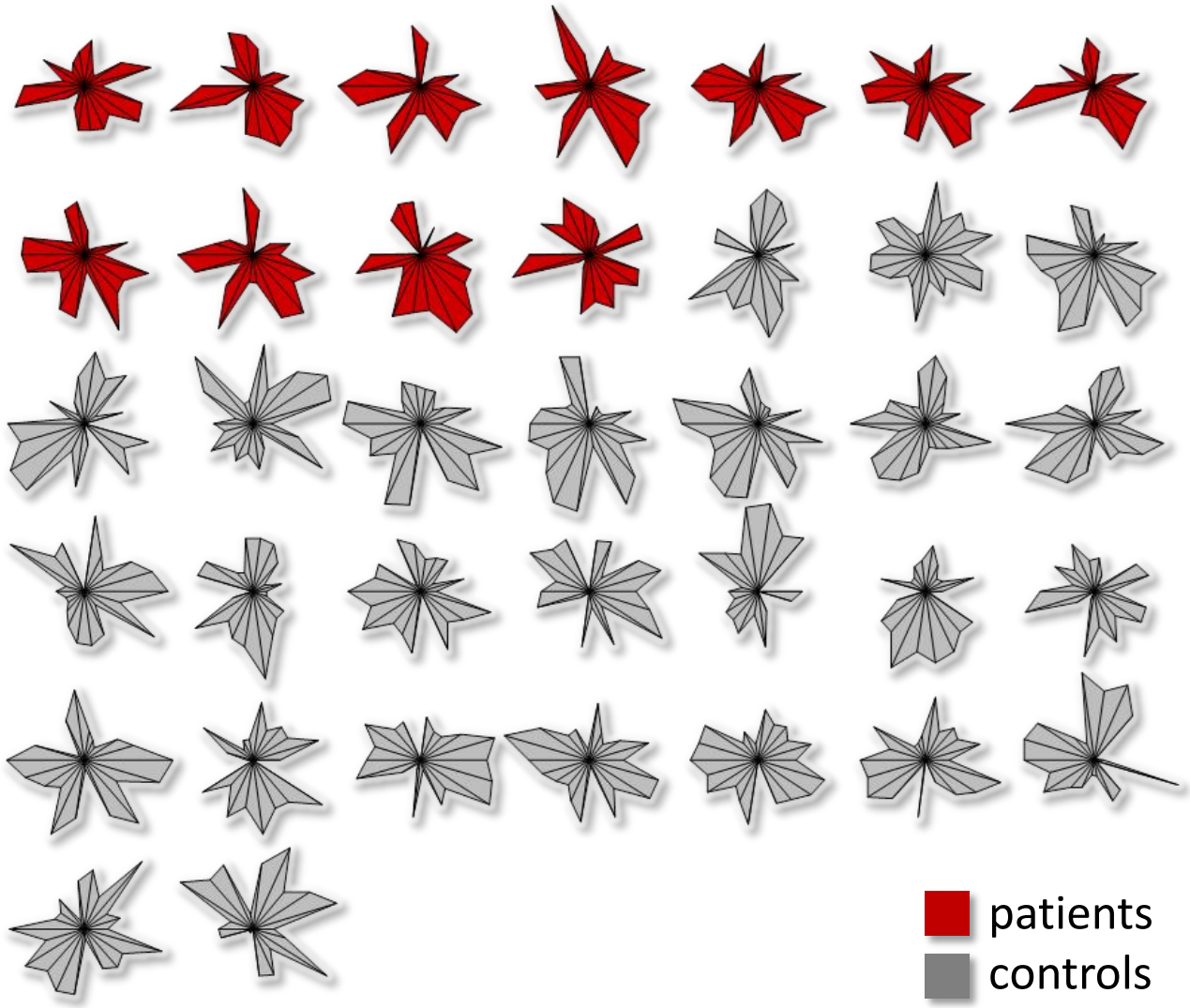
Example: diagnosing stroke patients



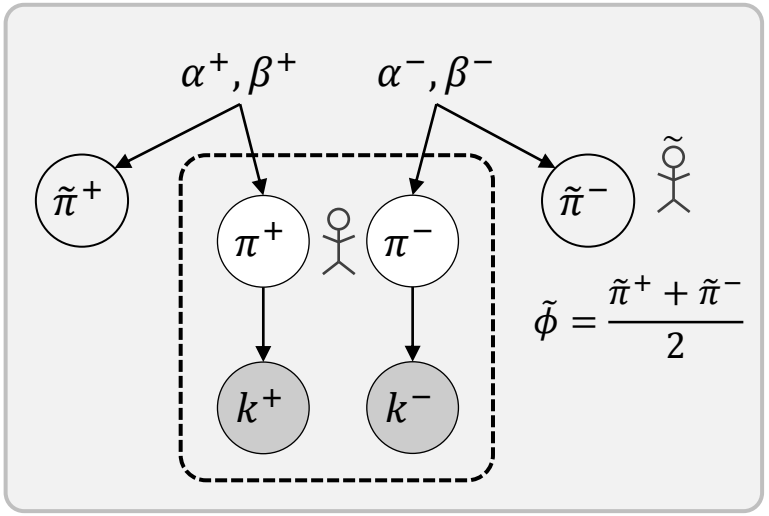
Univariate analysis: parameter densities

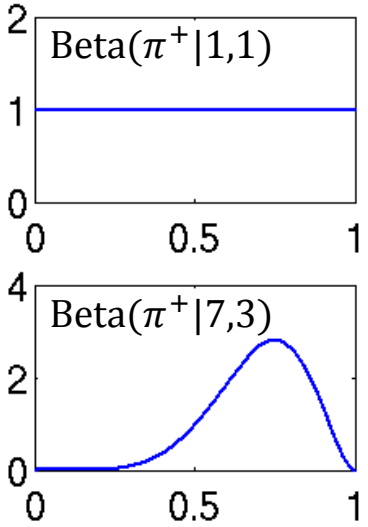


Multivariate analysis: connectional fingerprints



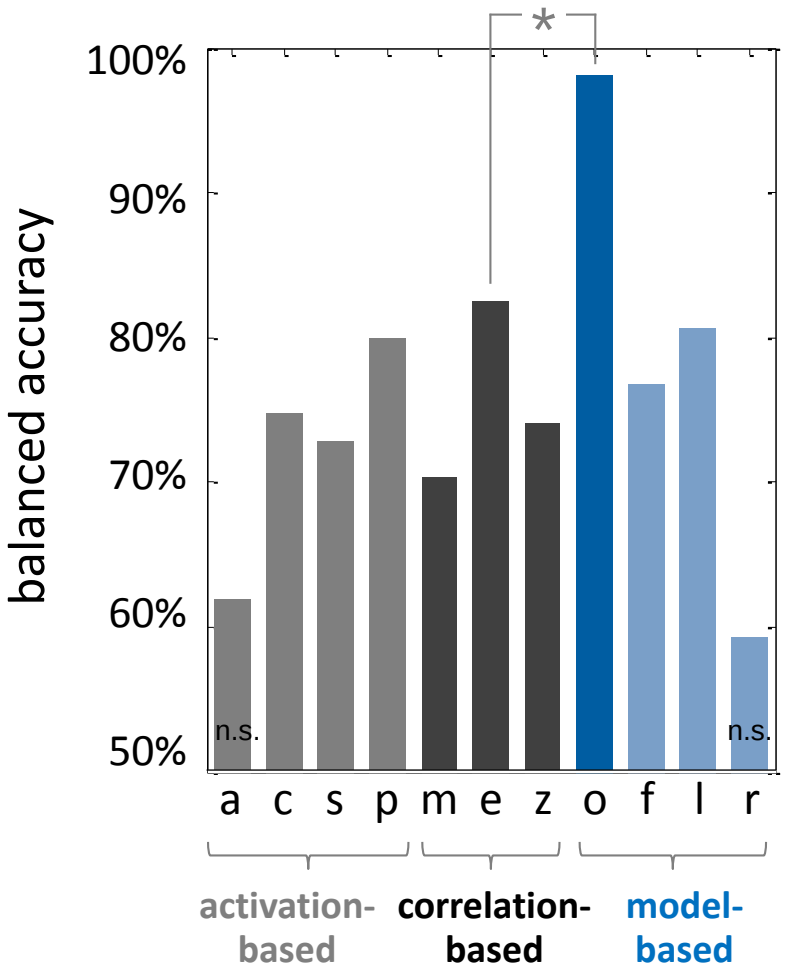
Full Bayesian approach to performance evaluation





Brodersen, Chumbley, Mathys, Daunizeau, Ong, Buhmann & Stephan *(in preparation)*

Classification performance



Activation-based analyses

- **a** anatomical feature selection
- **c** mass-univariate contrast feature selection
- **s** locally univariate searchlight feature selection
- **p** PCA-based dimensionality reduction

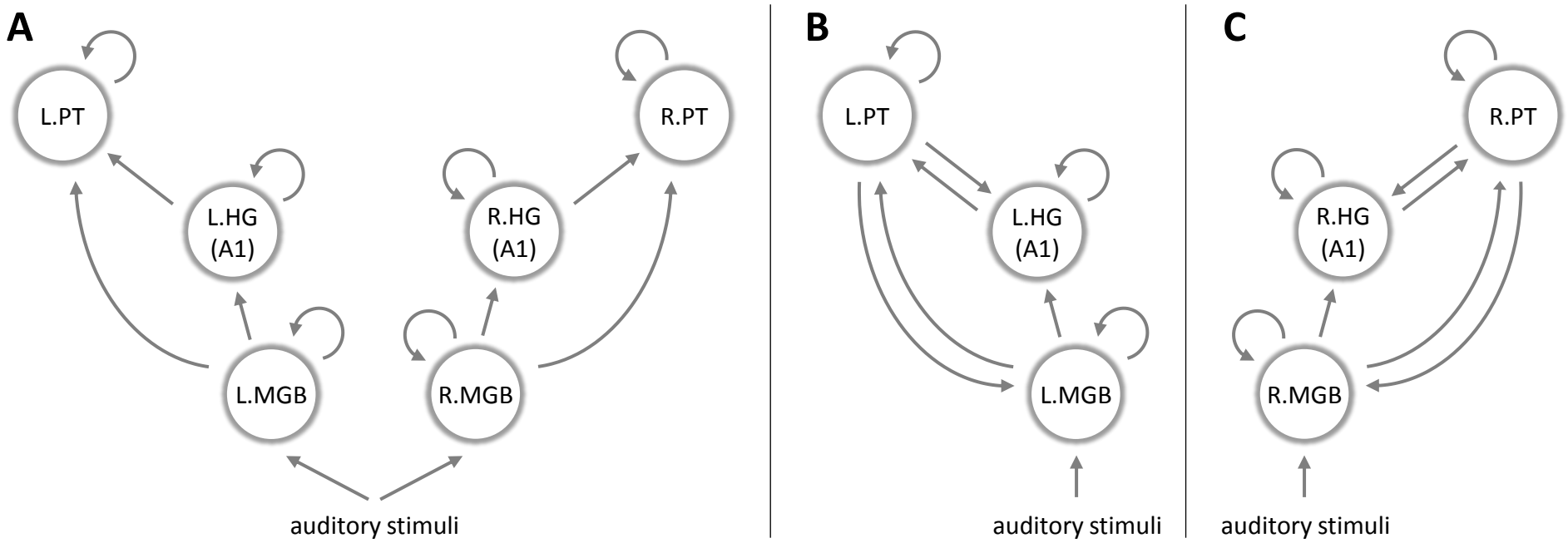
Correlation-based analyses

- **m** correlations of regional means
- **e** correlations of regional eigenvariates
- **z** Fisher-transformed eigenvariates correlations

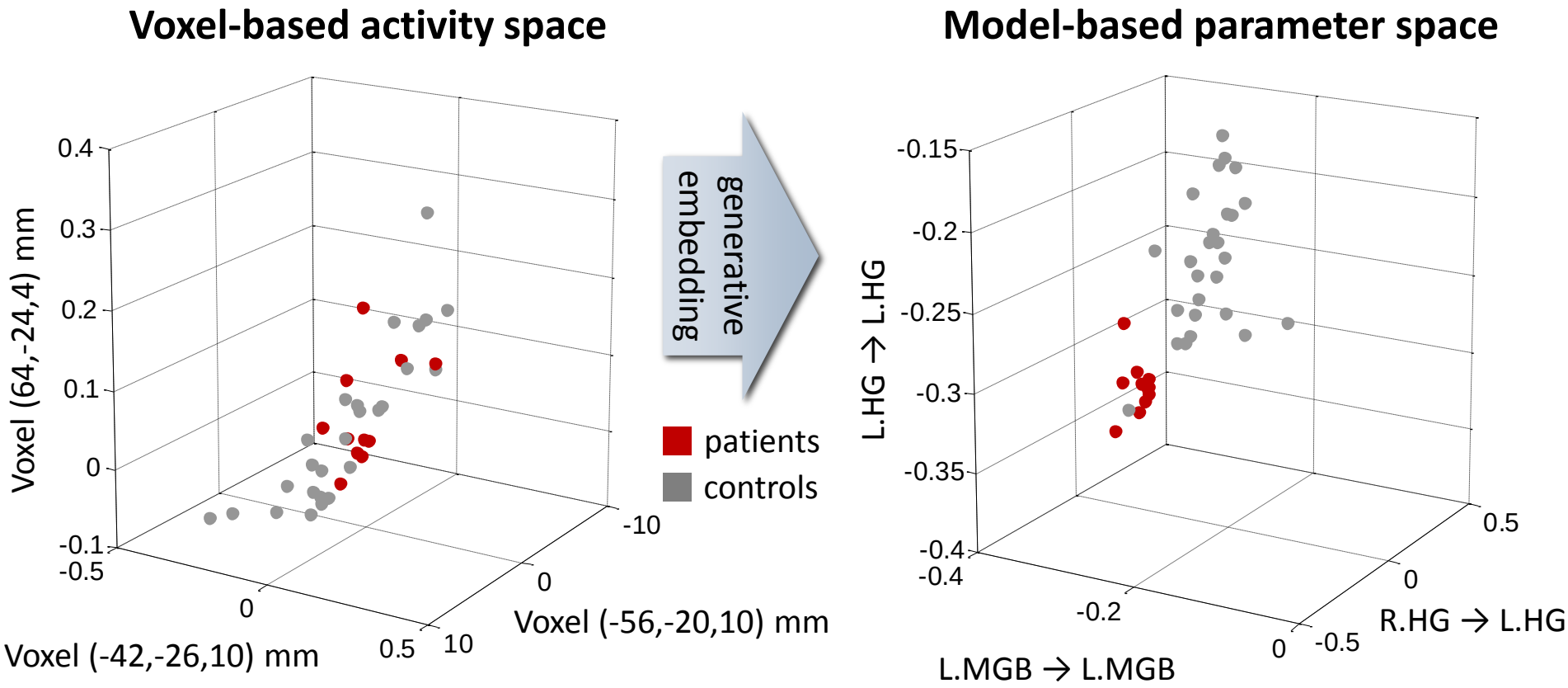
Model-based analyses

- **o** gen.embed., original full model
- **f** gen.embed., less plausible feedforward model
- **l** gen.embed., left hemisphere only
- **r** gen.embed., right hemisphere only

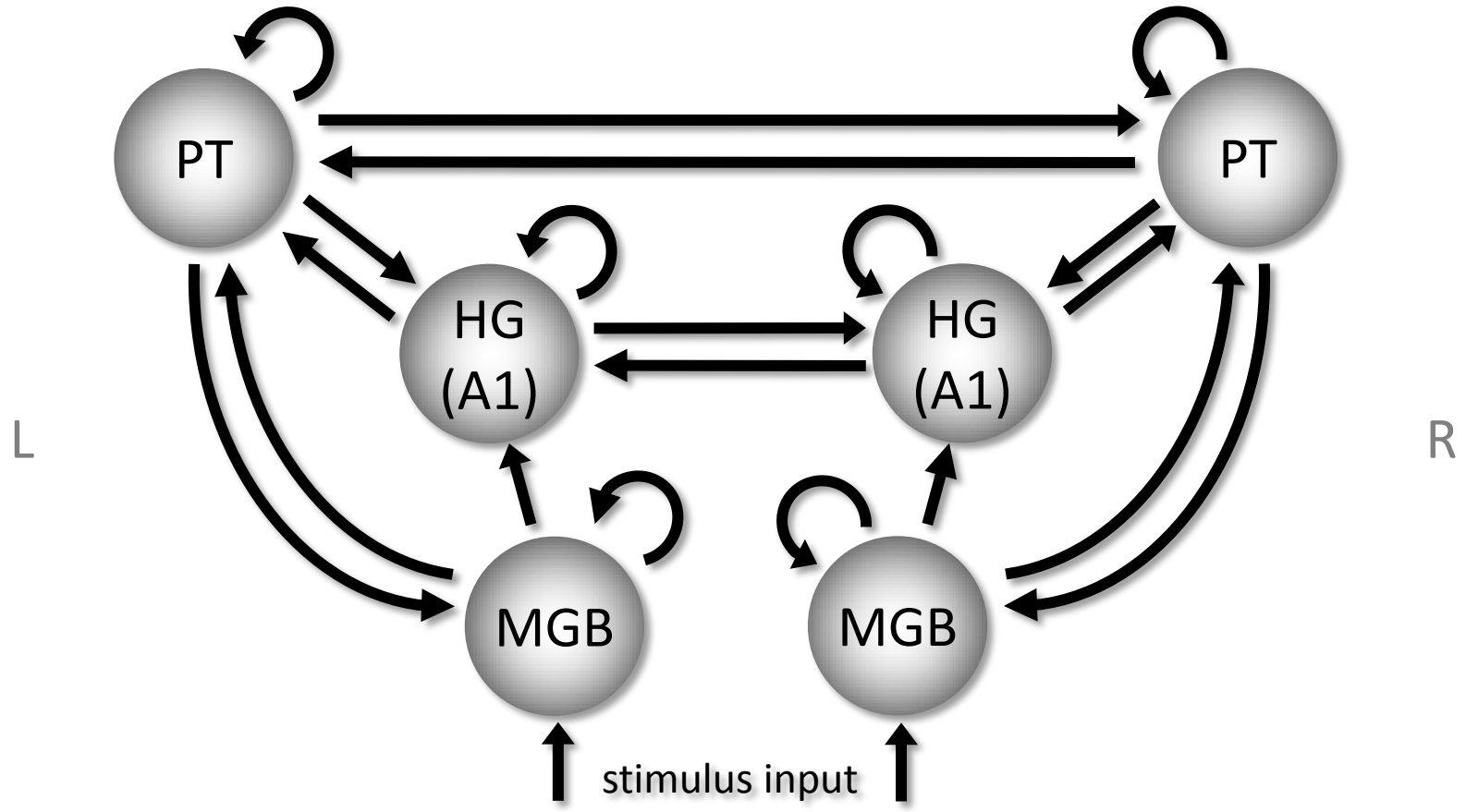
Biologically less plausible models perform poorly



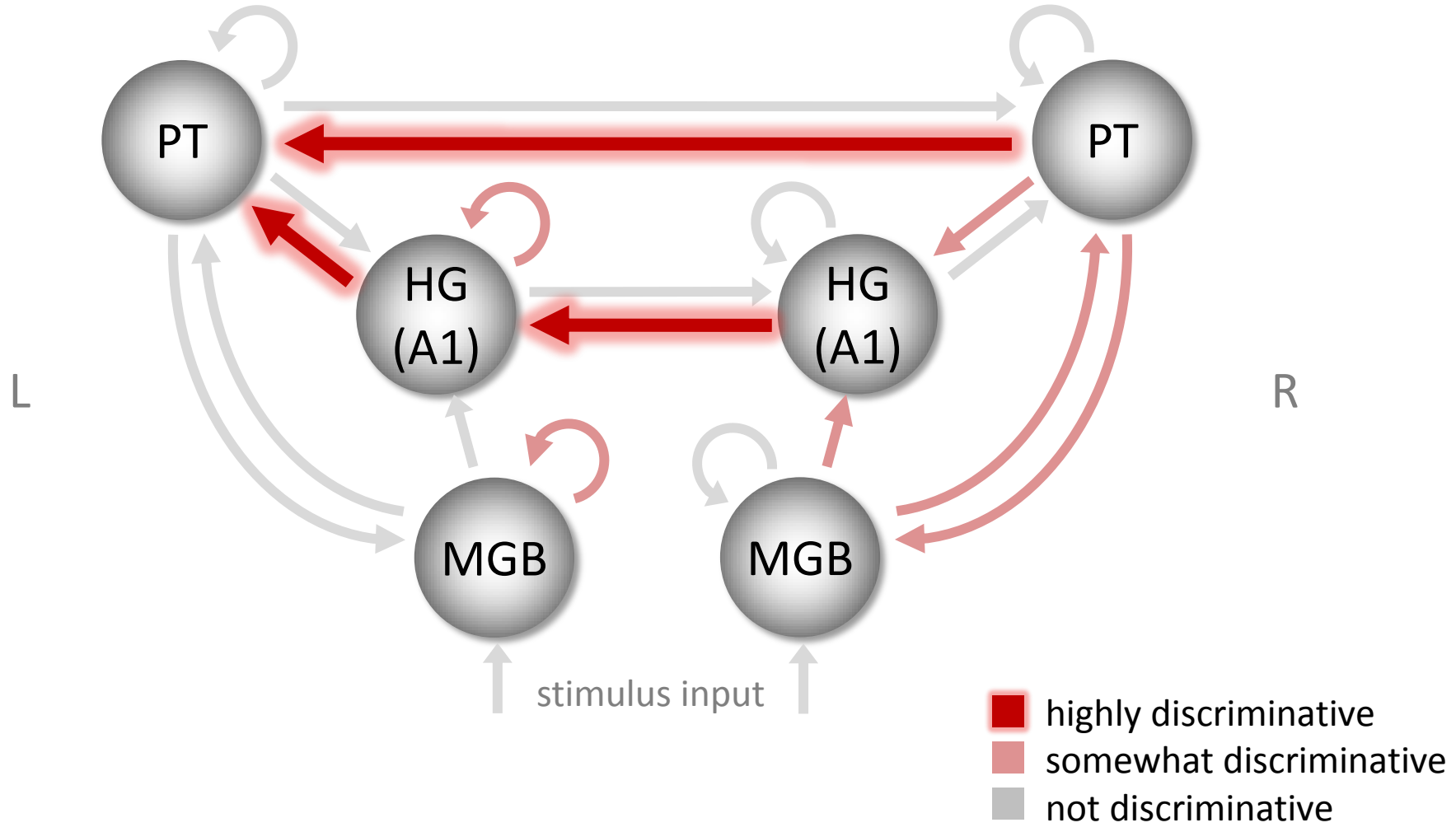
The generative projection



Discriminative features in model space

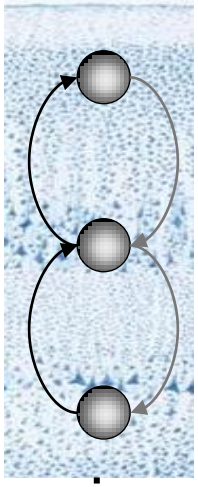


Discriminative features in model space

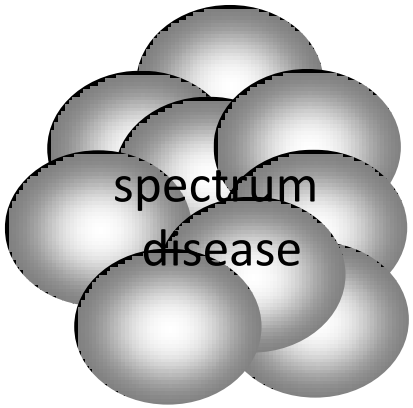


Model-based inference on individual pathophysiology

❶ model of neuronal (patho)physiology



❷ application to brain activity data from individual patients



generative

embedding

❸ diagnostic classification

type 1

type 2

type 3

Summary: generative embedding for fMRI

❶ **Strong classification performance.** Generative embedding exploits the rich discriminative information encoded in 'hidden' quantities, such as coupling parameters.

❷ **Creation of an interpretable feature space.** High-dimensional fMRI data are replaced by low-dimensional subject-specific fingerprints with biologically interpretable axes.

❸ **Future applications.** Generative embedding could help dissect spectrum disorders into physiologically defined subgroups *(in preparation)*.