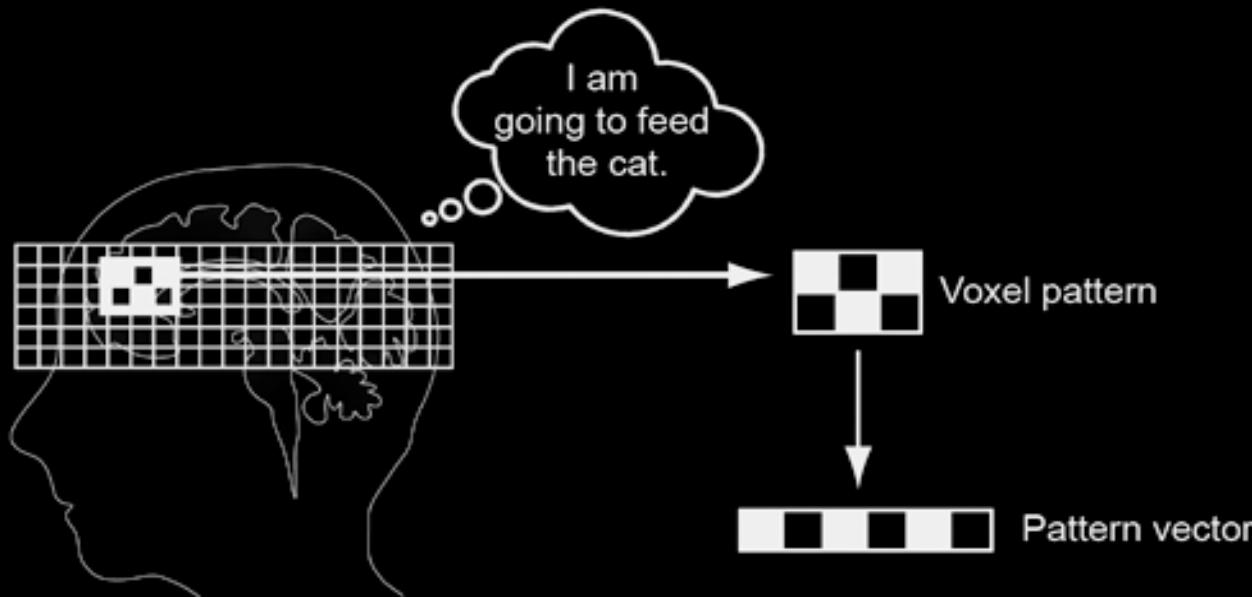


Carsten Allefeld John-Dylan Haynes

Bernstein Center for Computational Neuroscience Berlin  
Charité – Universitätsmedizin Berlin

Decoding and predicting intentions:  
A case study for MVPA applications

# Decoding intentions



Training data

„Feed cat“	
„Prepare lecture“	
„Book flight“	
„Go shopping“	
„Post letter“	
„Cook dinner“	

Pattern classifier  
(e.g. SVM)

Test data



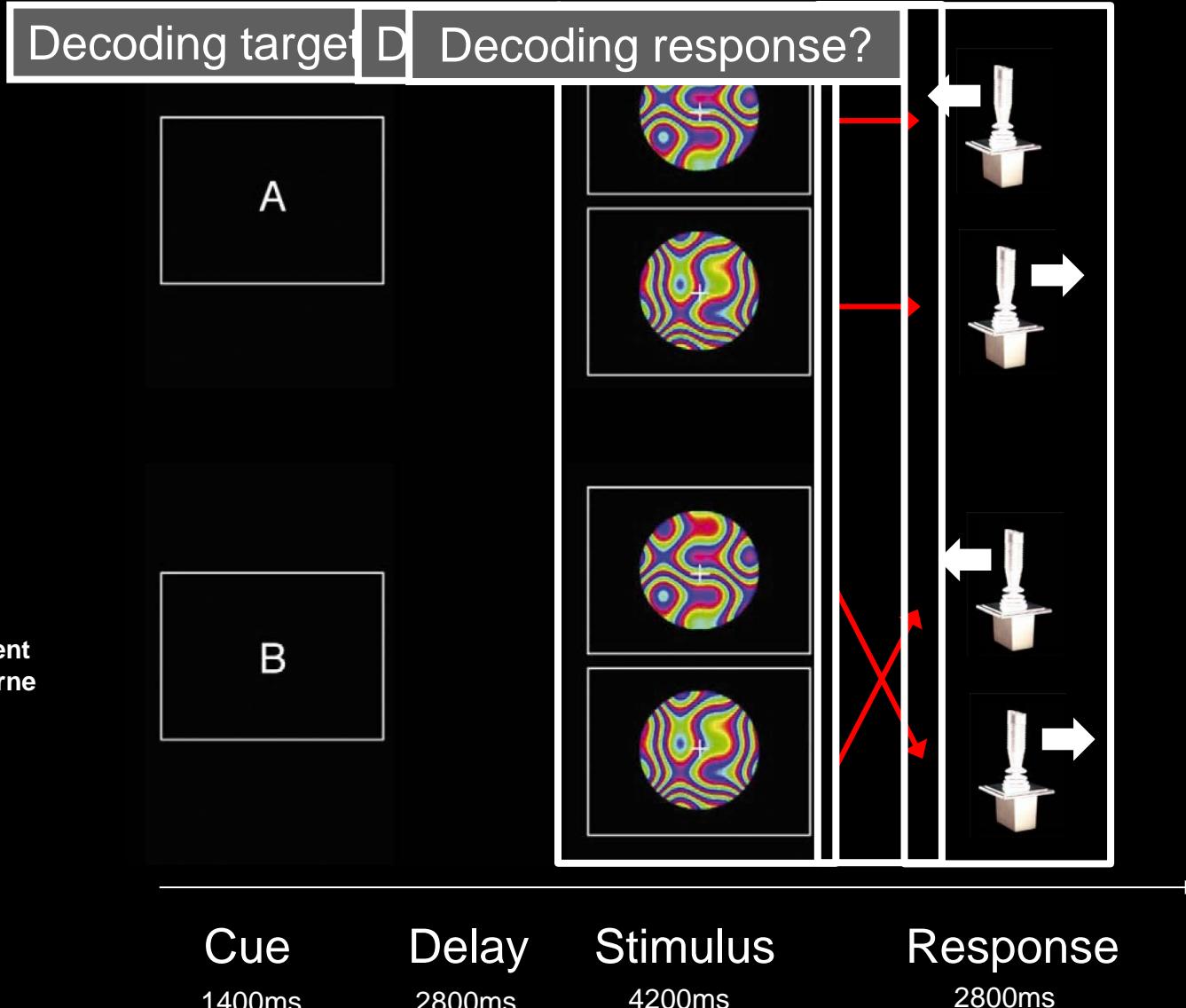
„Prepare lecture“

Decoded label

# Experimental paradigm “task sets”

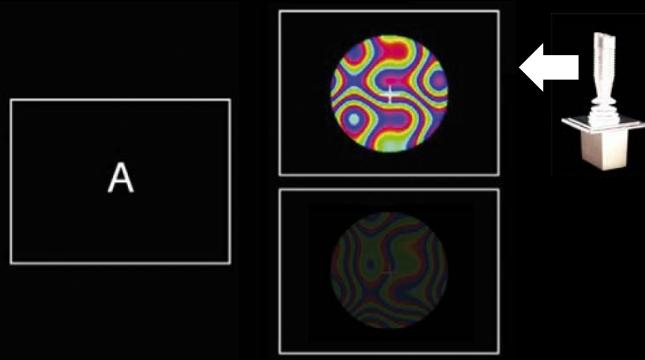


**Stefan Bode**  
former PhD student  
now at U. Melbourne

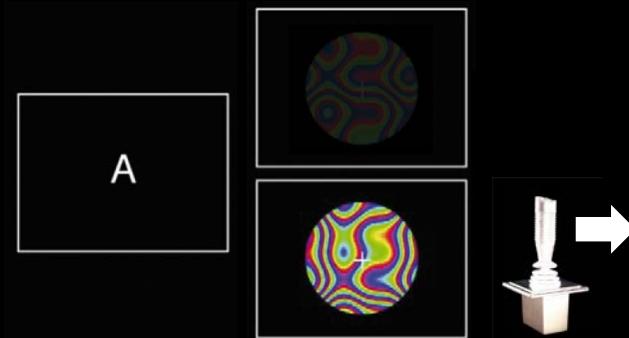


# Trial types

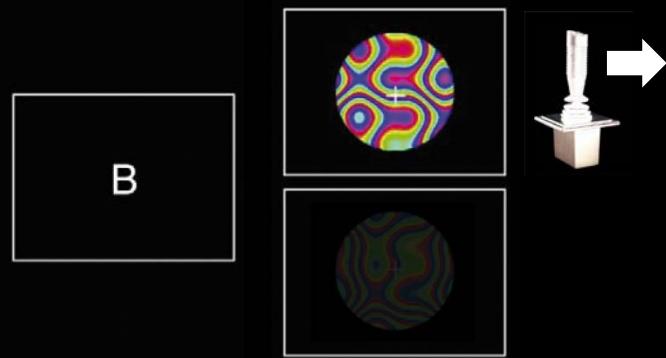
TT1



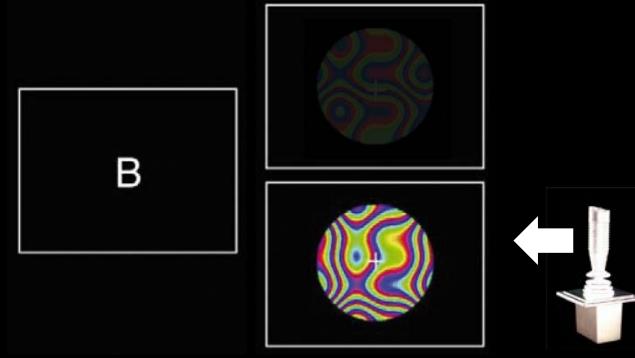
TT2



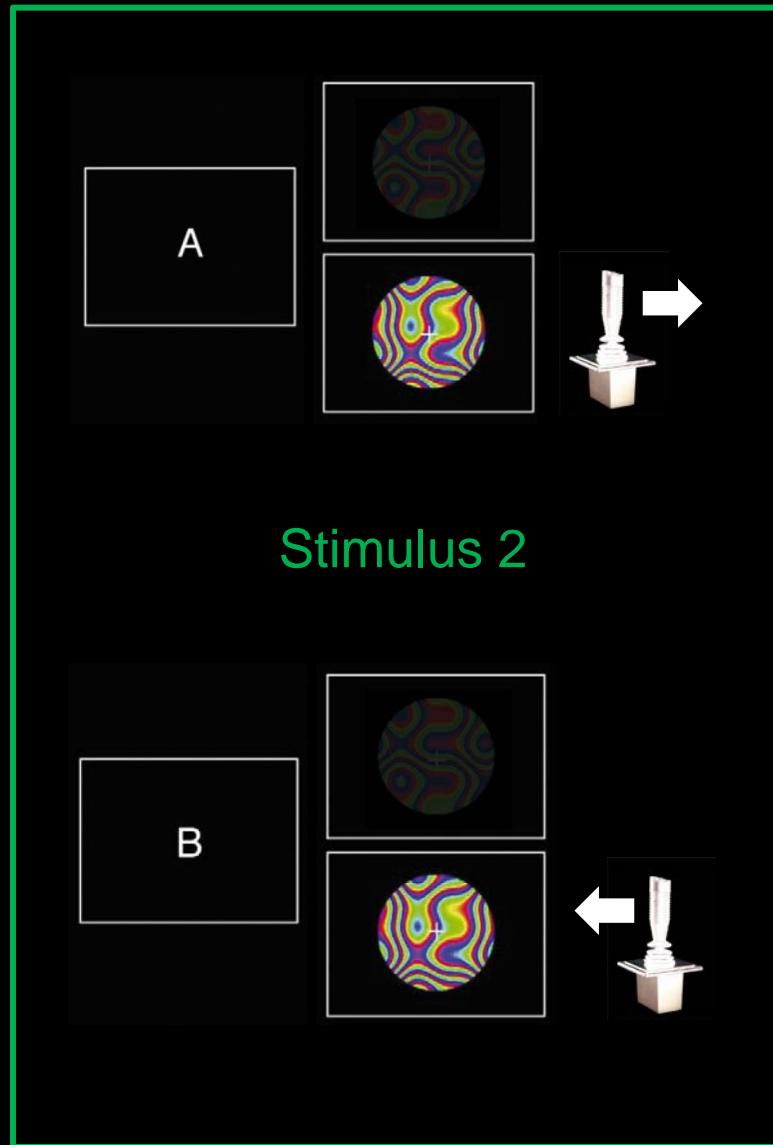
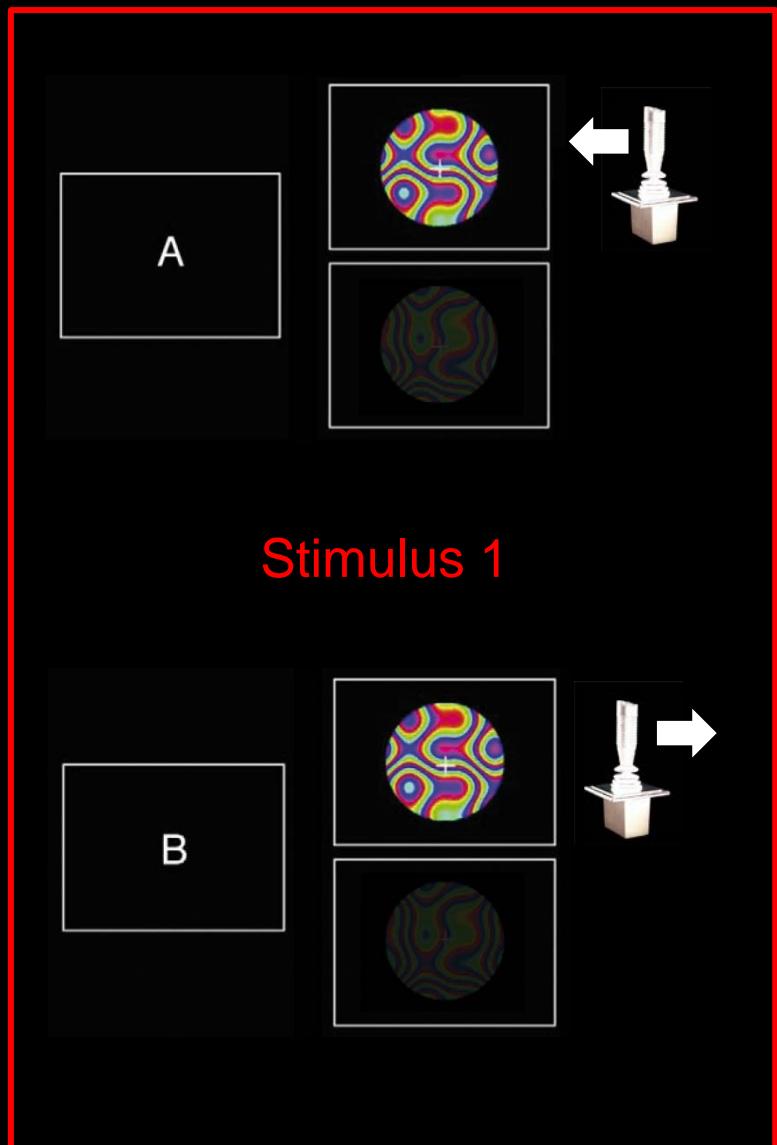
TT3



TT4

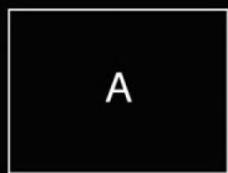


# Labels for decoding stimuli

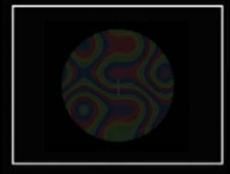


# Labels for decoding responses

Response „L“



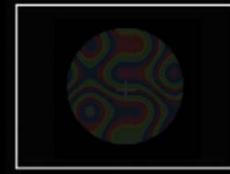
Response „R“



Response „R“

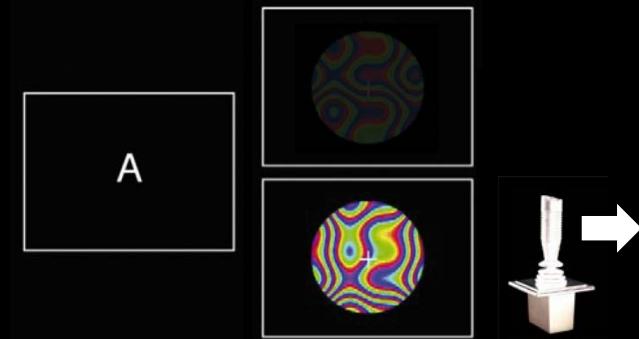
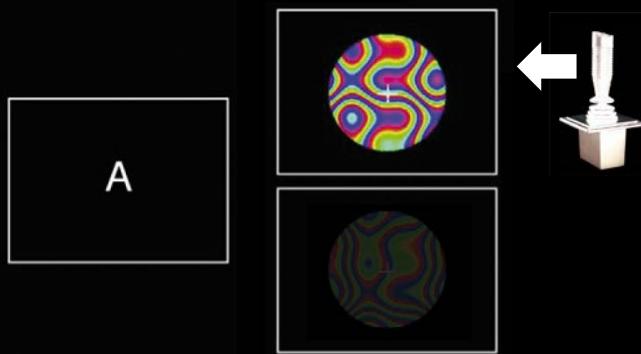


Response „L“

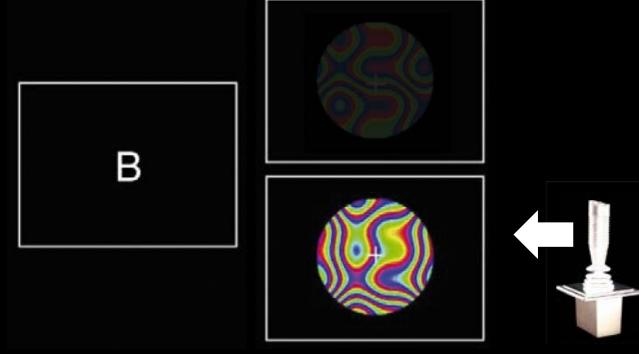
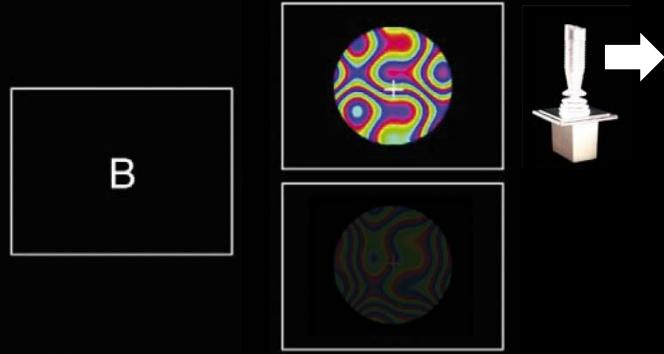


# Labels for decoding task sets

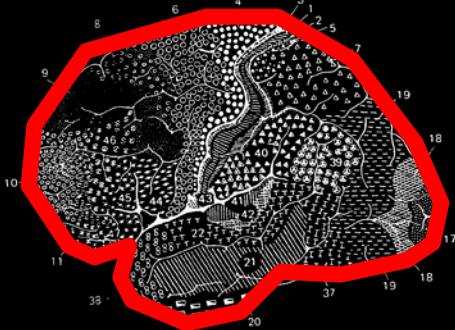
Task set A



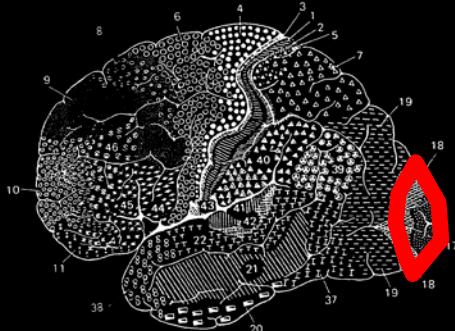
Task set B



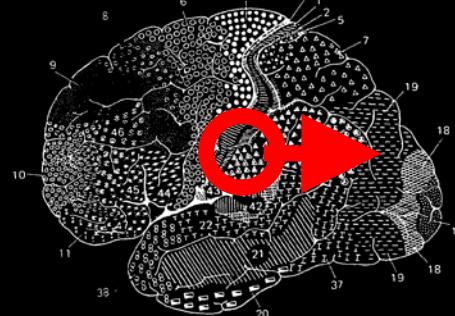
# What to put into your classifier: space



Whole-brain decoding  
Curse of dimensionality  
Biological plausibility?

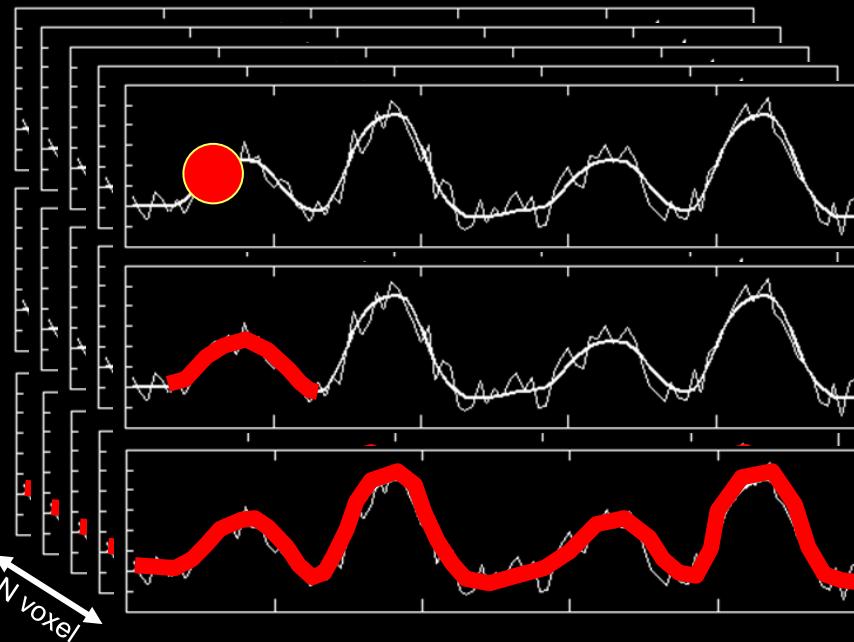
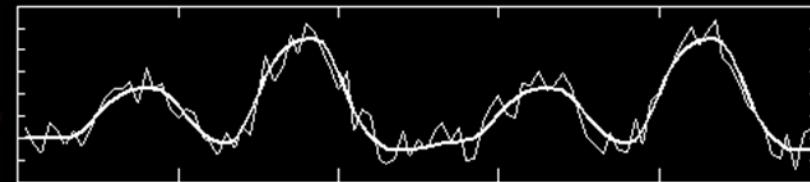


Region of interest



Searchlight decoding  
Specific subspace  
Locality assumption  
Spatially unbiased

# What to put into your classifier: time



Single volume activity  
(typically baseline corrected)

HRF-fitted single-trial parameter estimate

Runwise GLM parameter estimates

# Practical implementation

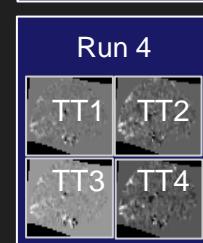
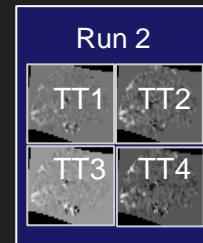
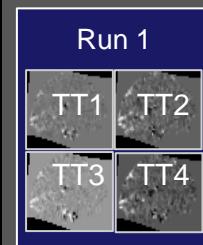
Raw data



Preprocessed data



GLM parameter estimates



This you can do e.g. in SPM

Test

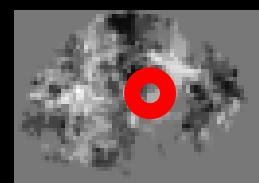
„Leave one run out“ cross-validation

Train

3 label groupings

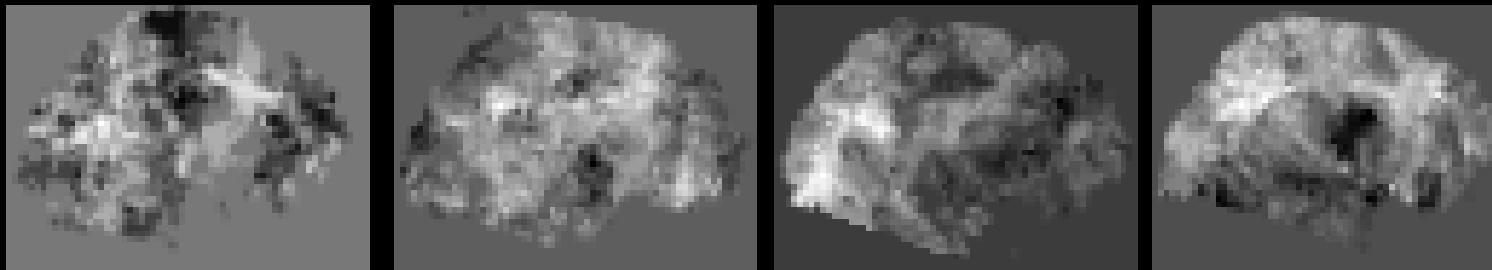
For each searchlight center

Single subject local decoding accuracy map



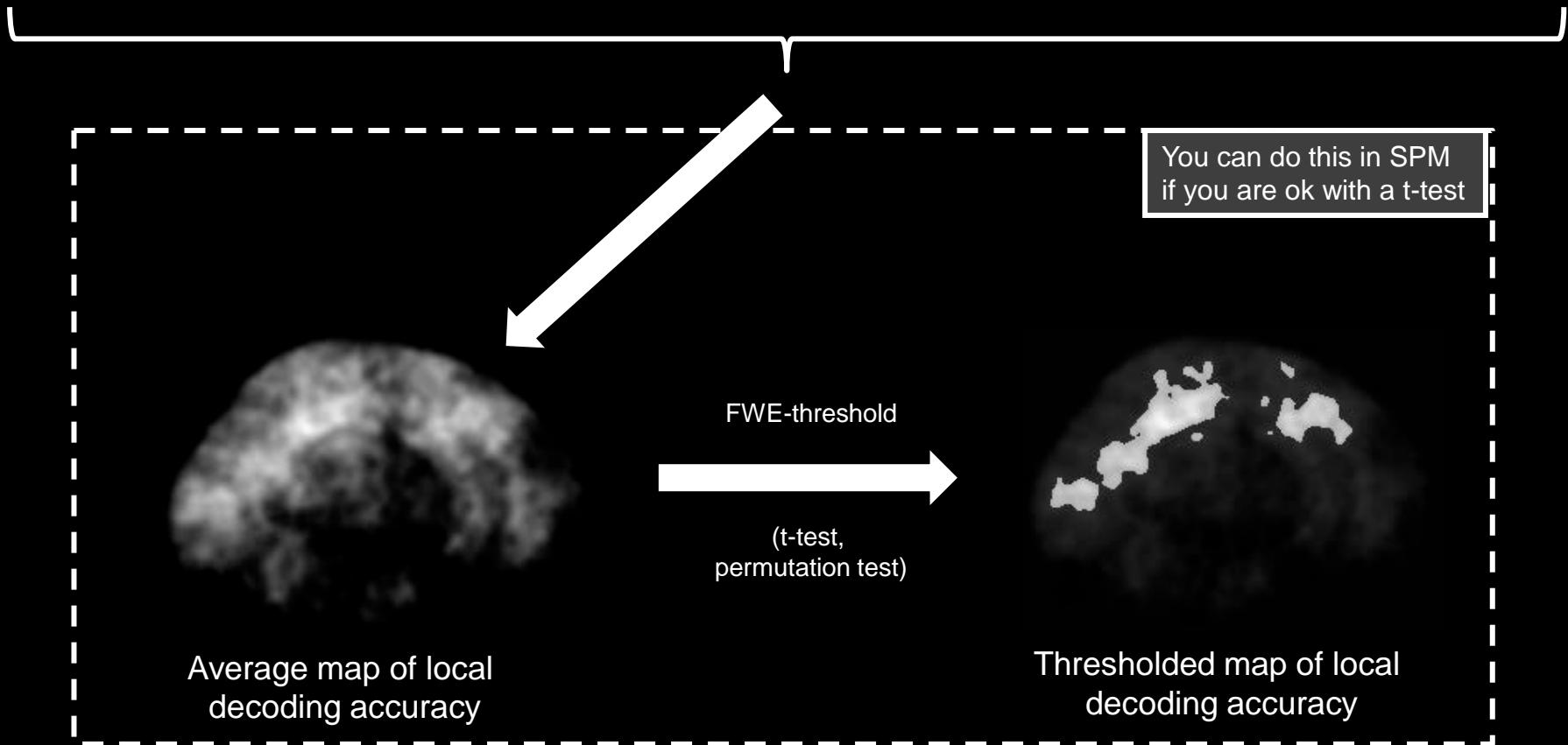
Spatial normalization can occur before or after classification. This flow chart shows “early” normalization.

# Averaging accuracy / information across subjects

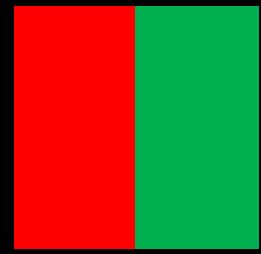
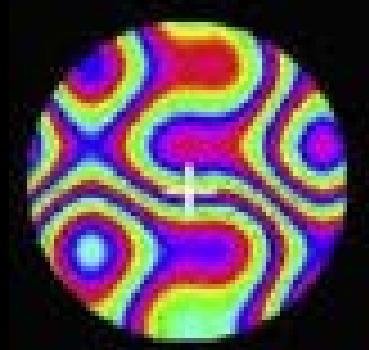
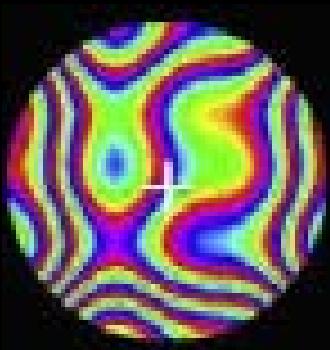


...

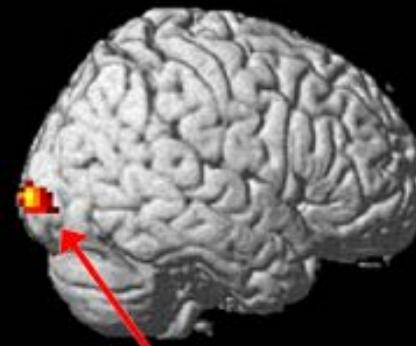
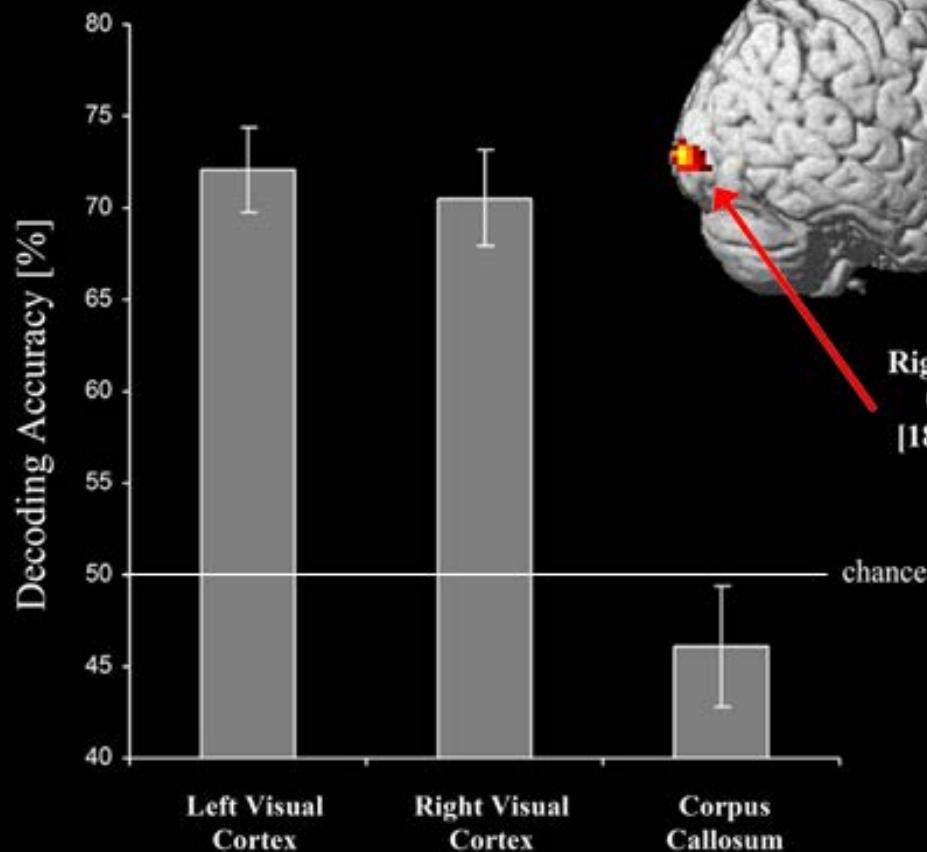
One decoding accuracy map per subject



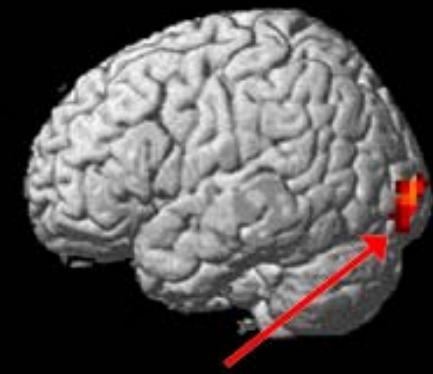
# Stimulus decoding



**Caution:**  
These are  
biased  
estimates!  
cf. Vul et al.  
(2009)

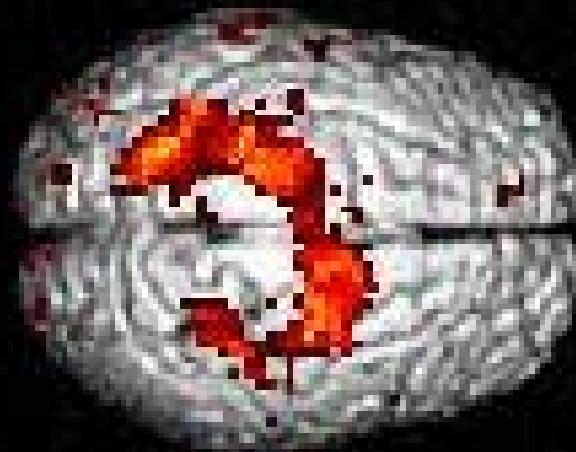
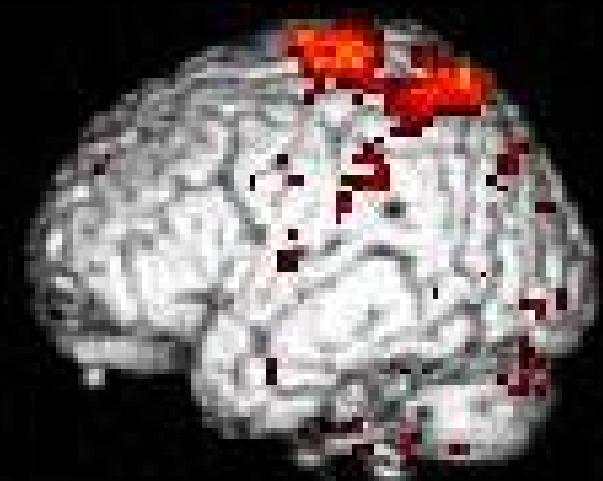
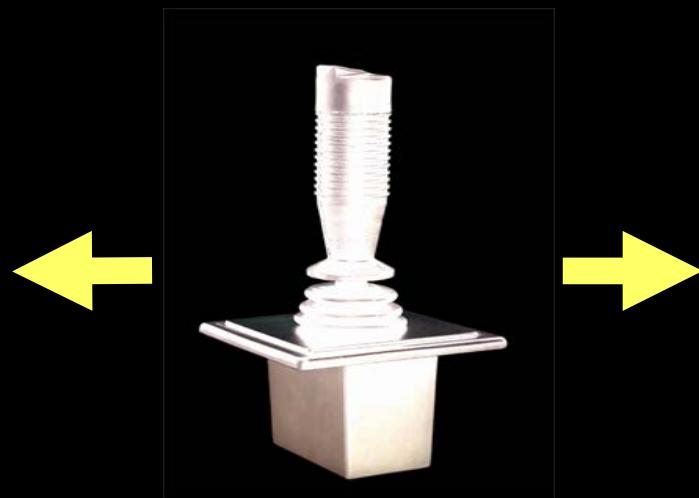
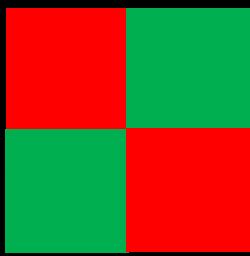


Right Visual Cortex  
[18 -105 -3]

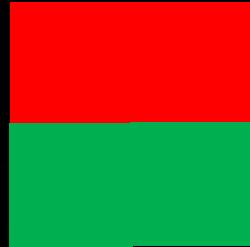
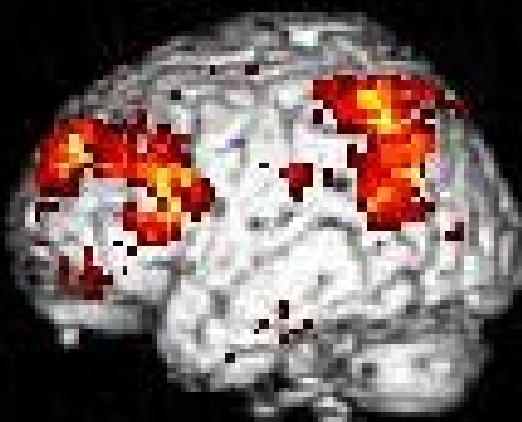
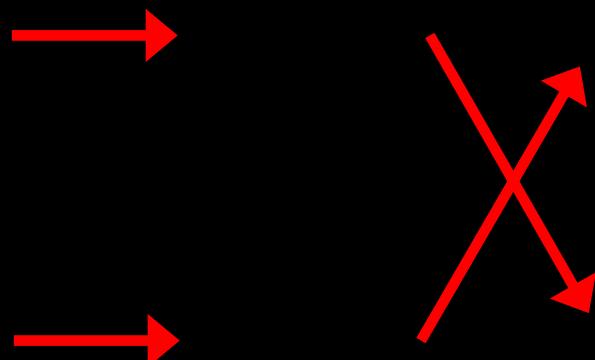


Left Visual Cortex  
[-18 -93 0]

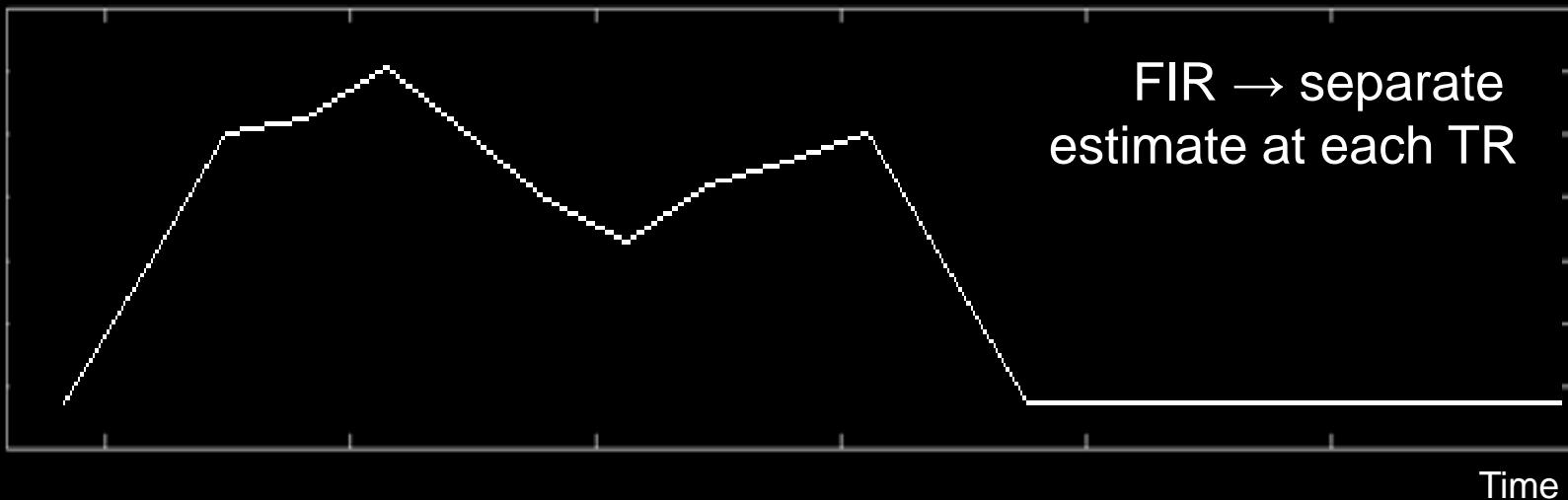
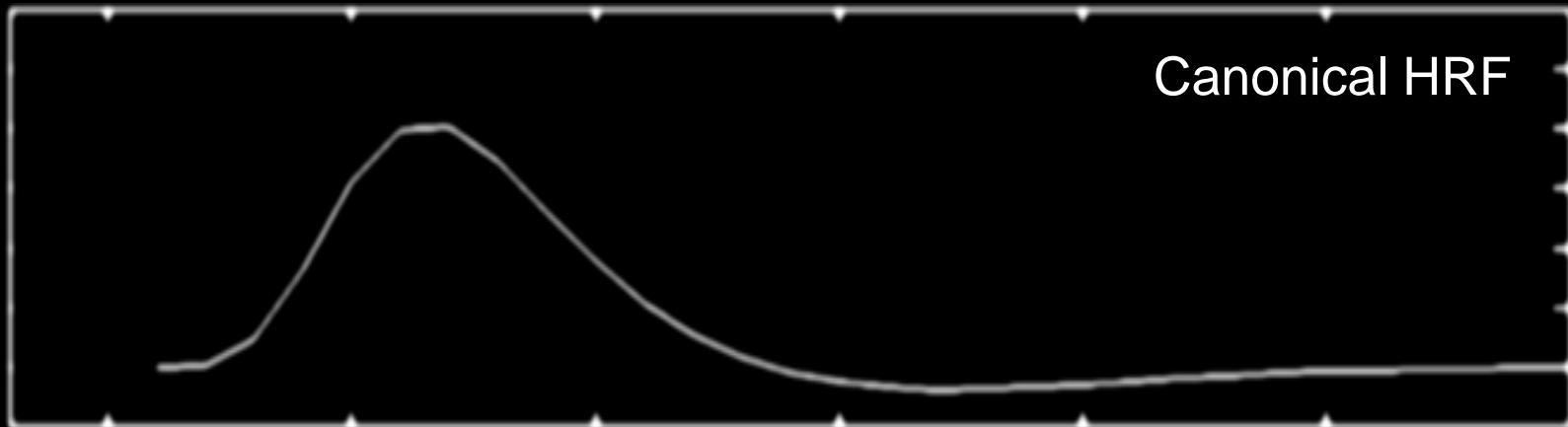
# Response decoding



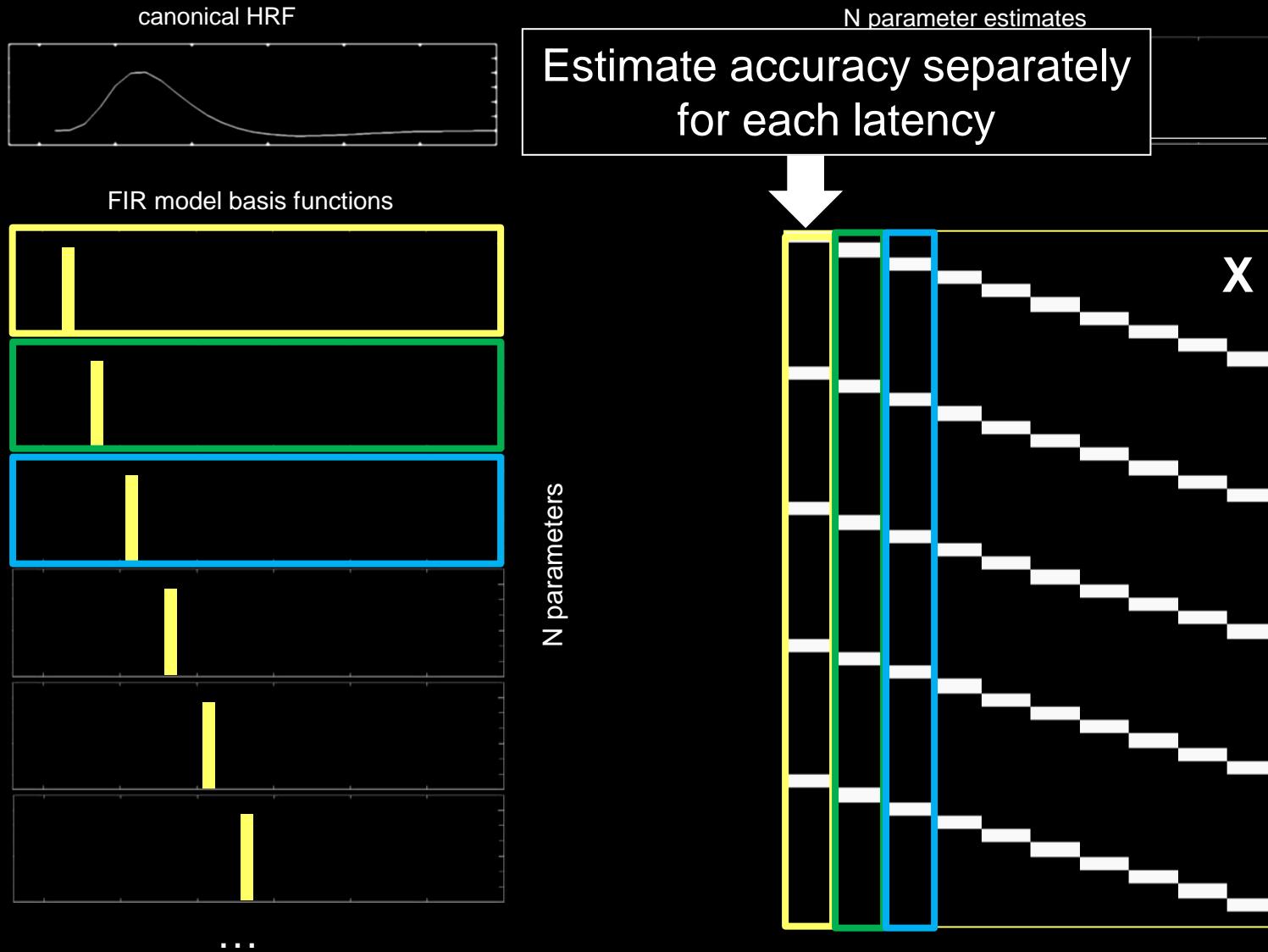
# Task-set decoding



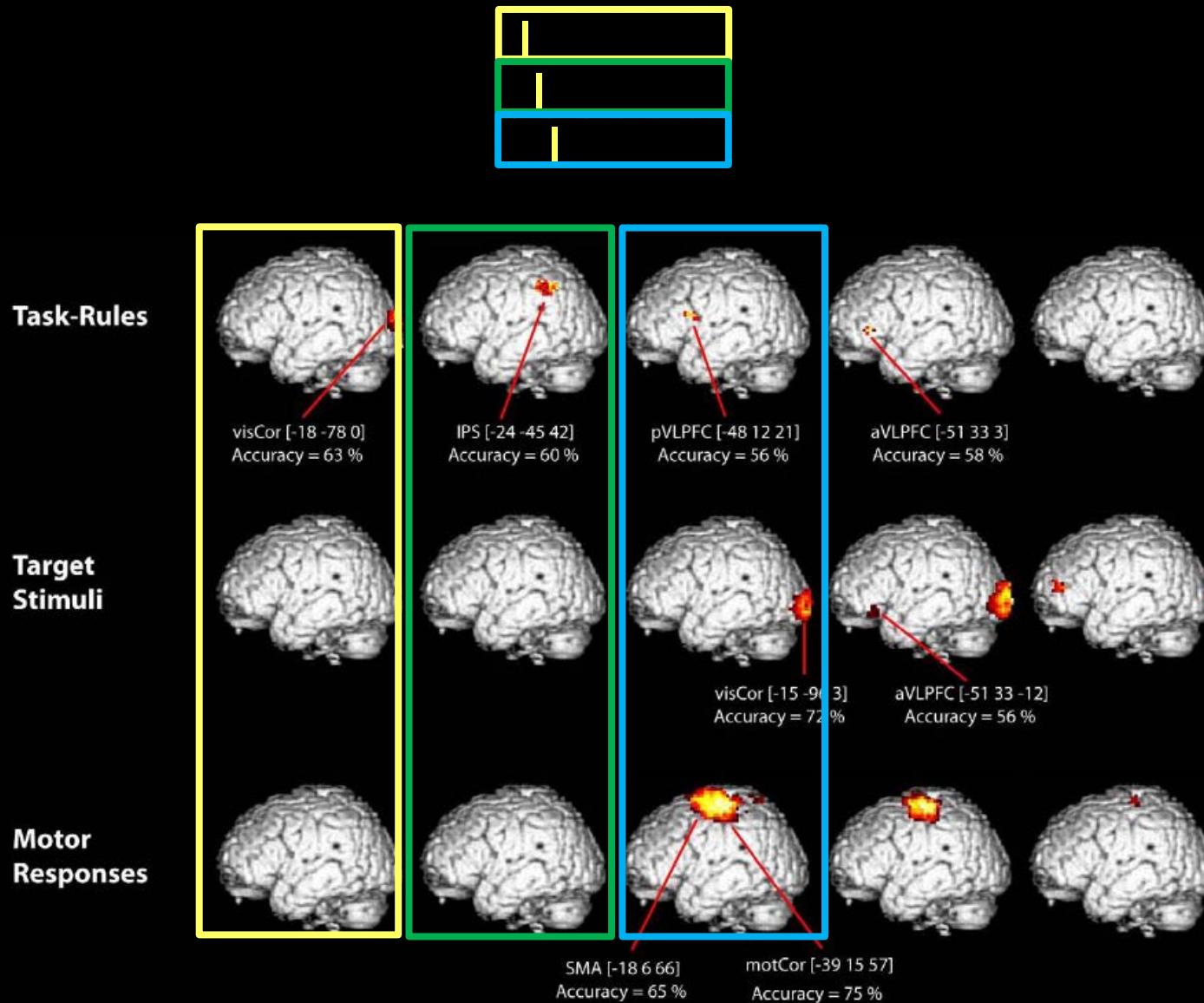
# Decoding across time: Finite Impulse Response Functions



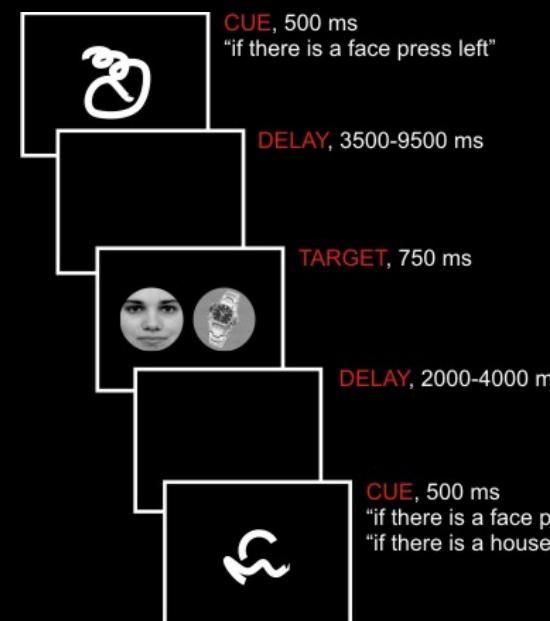
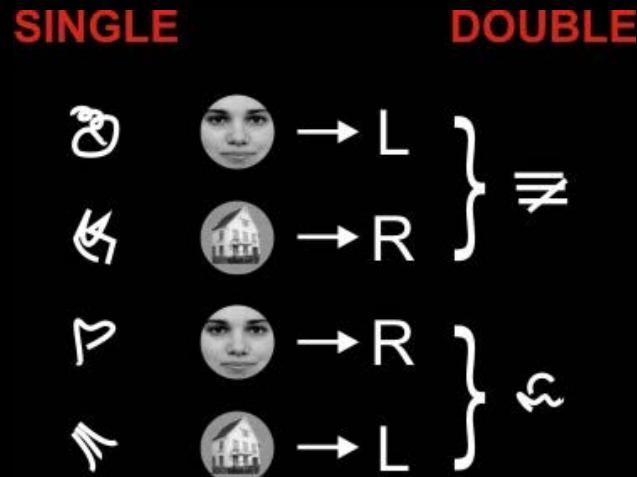
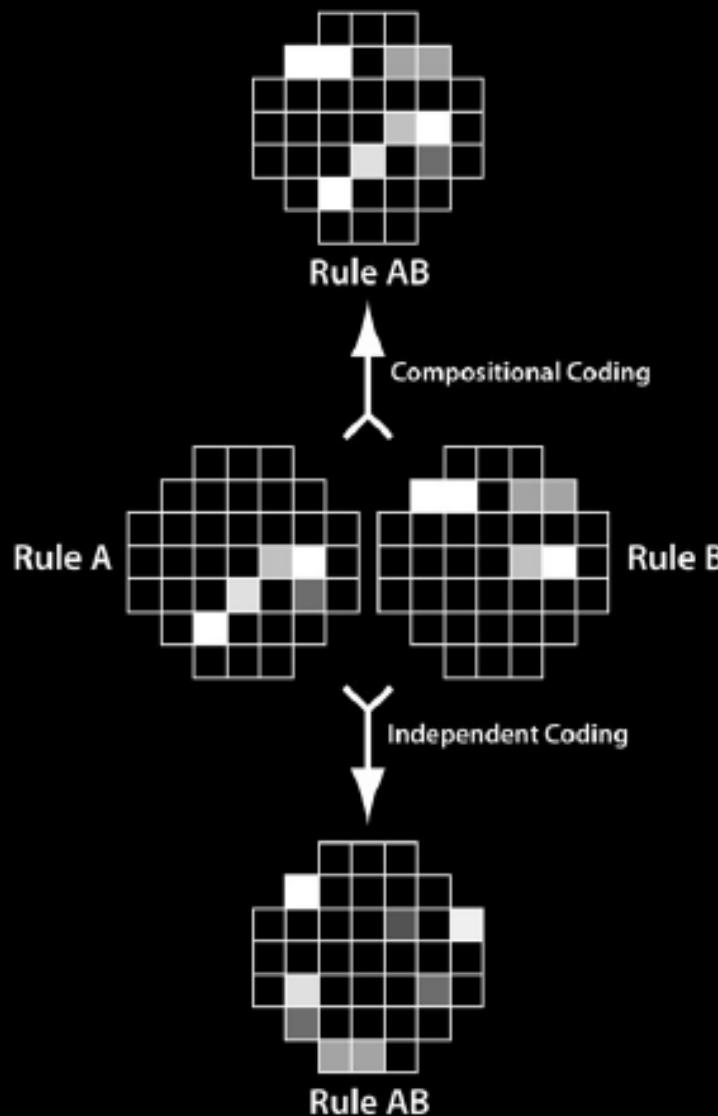
# Decoding across time: Finite Impulse Response Functions



# Decoding across time

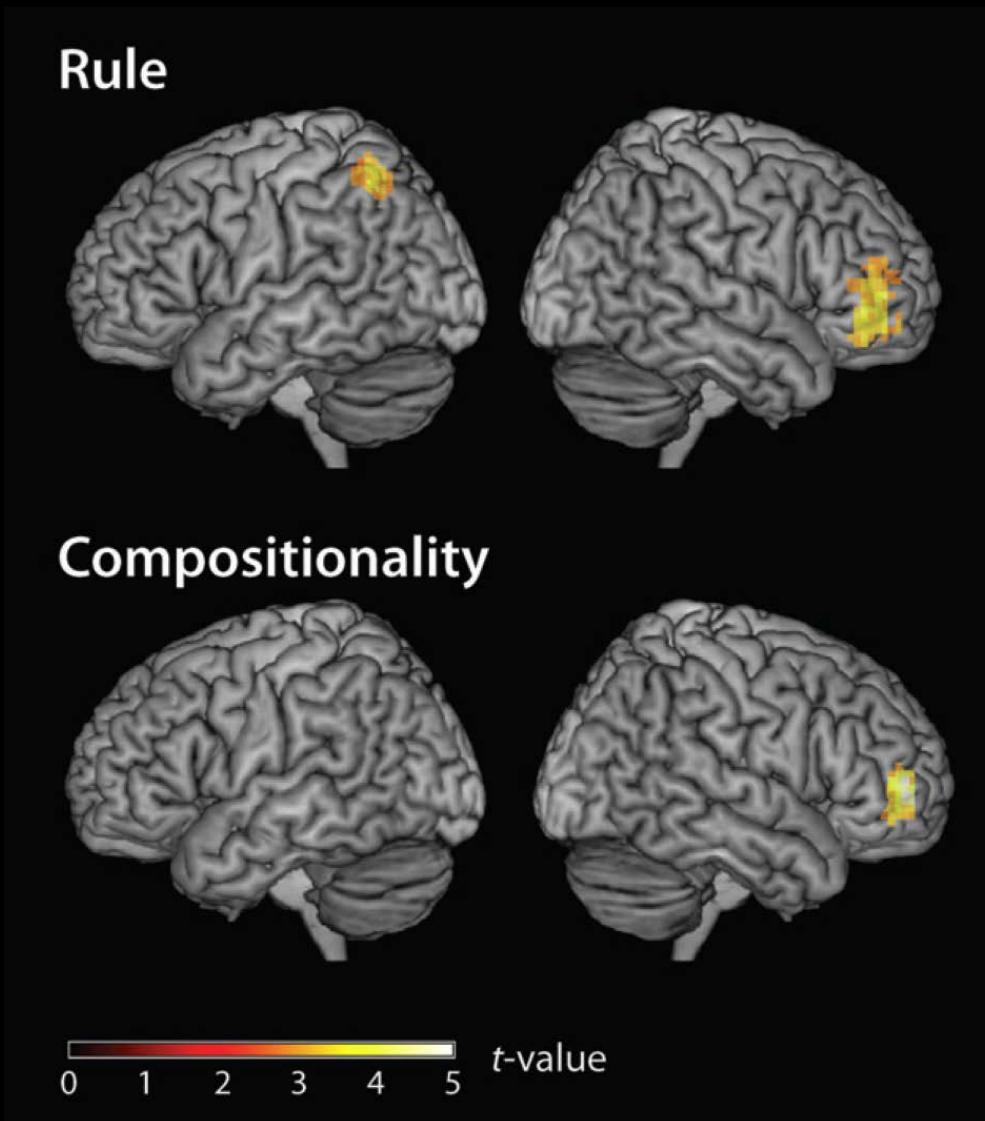


# Hierarchy and compositionality: Cross-classification

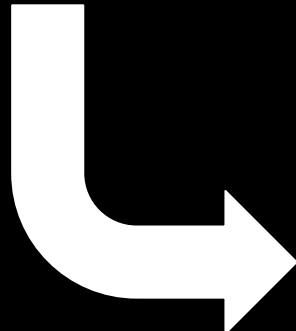
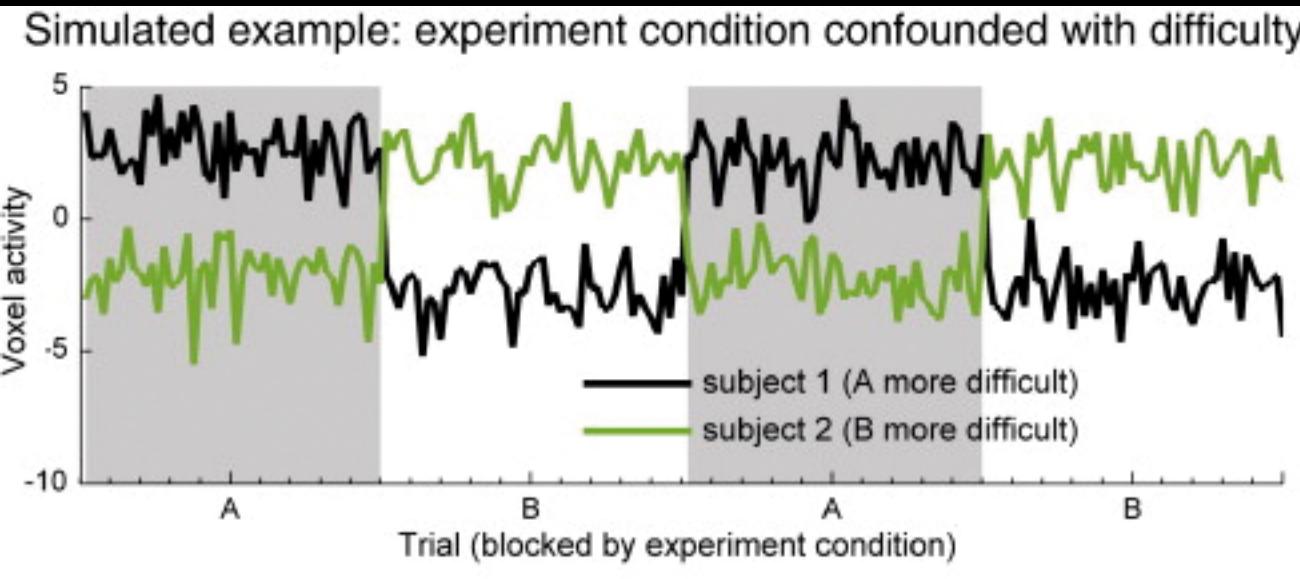


Carlo Reverberi  
former Postdoc  
now at U. Milano

# Hierarchy and compositionality: Cross-classification



# Pitfalls: Confounds



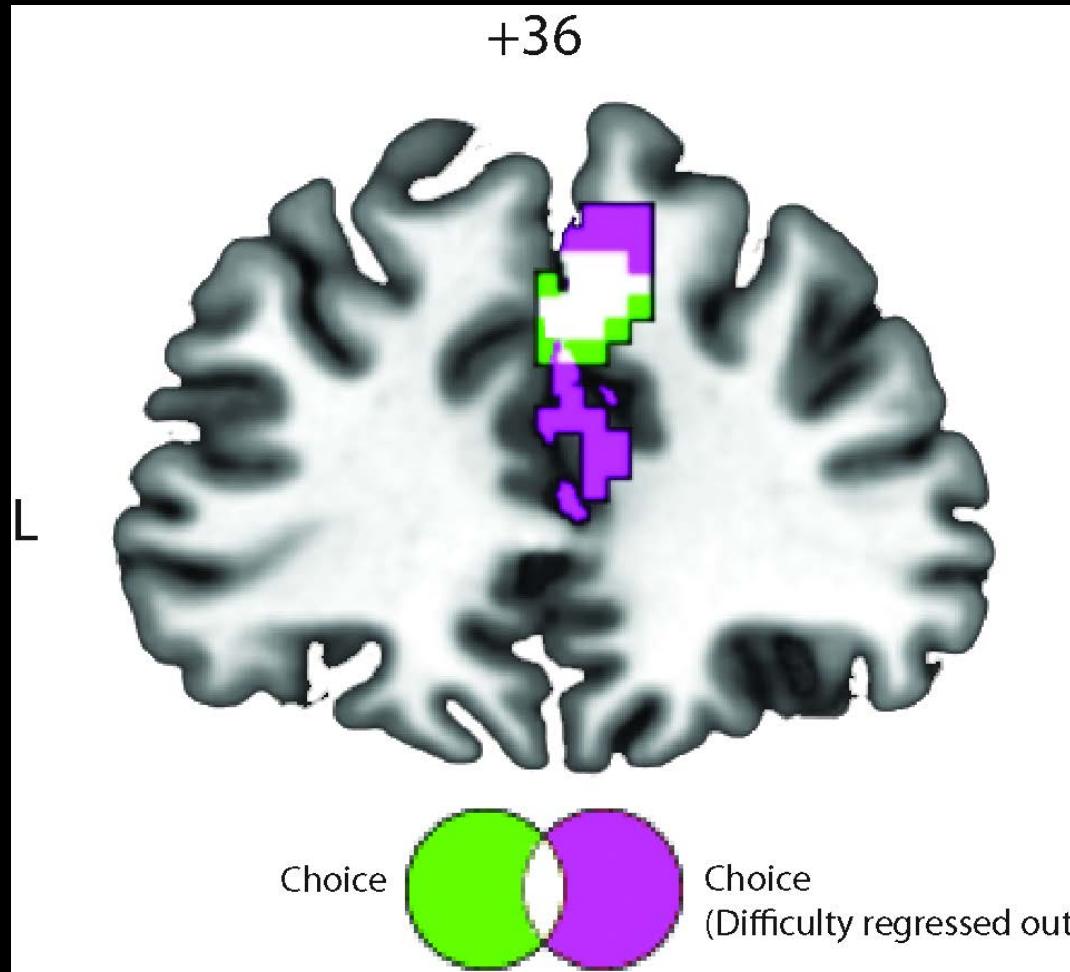
One possible „fix“: Regress out reaction times before classification

# Pitfalls: Confounds

Choice decoding with and without regressing out reaction times



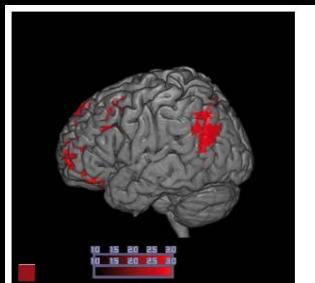
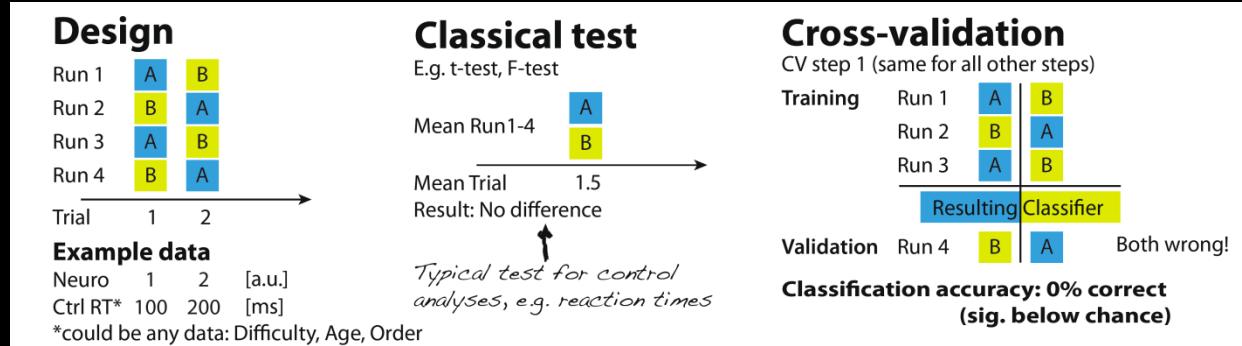
David Wisniewski  
Postdoc



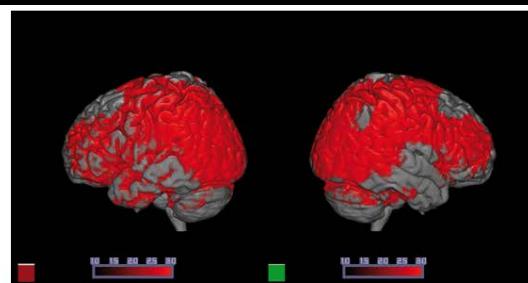
# Pitfalls: Other confounds



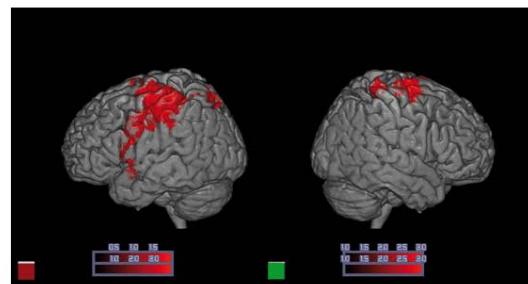
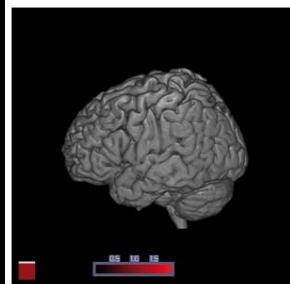
Kai Görgen  
PhD Student



0-2s  
(expected: nothing)



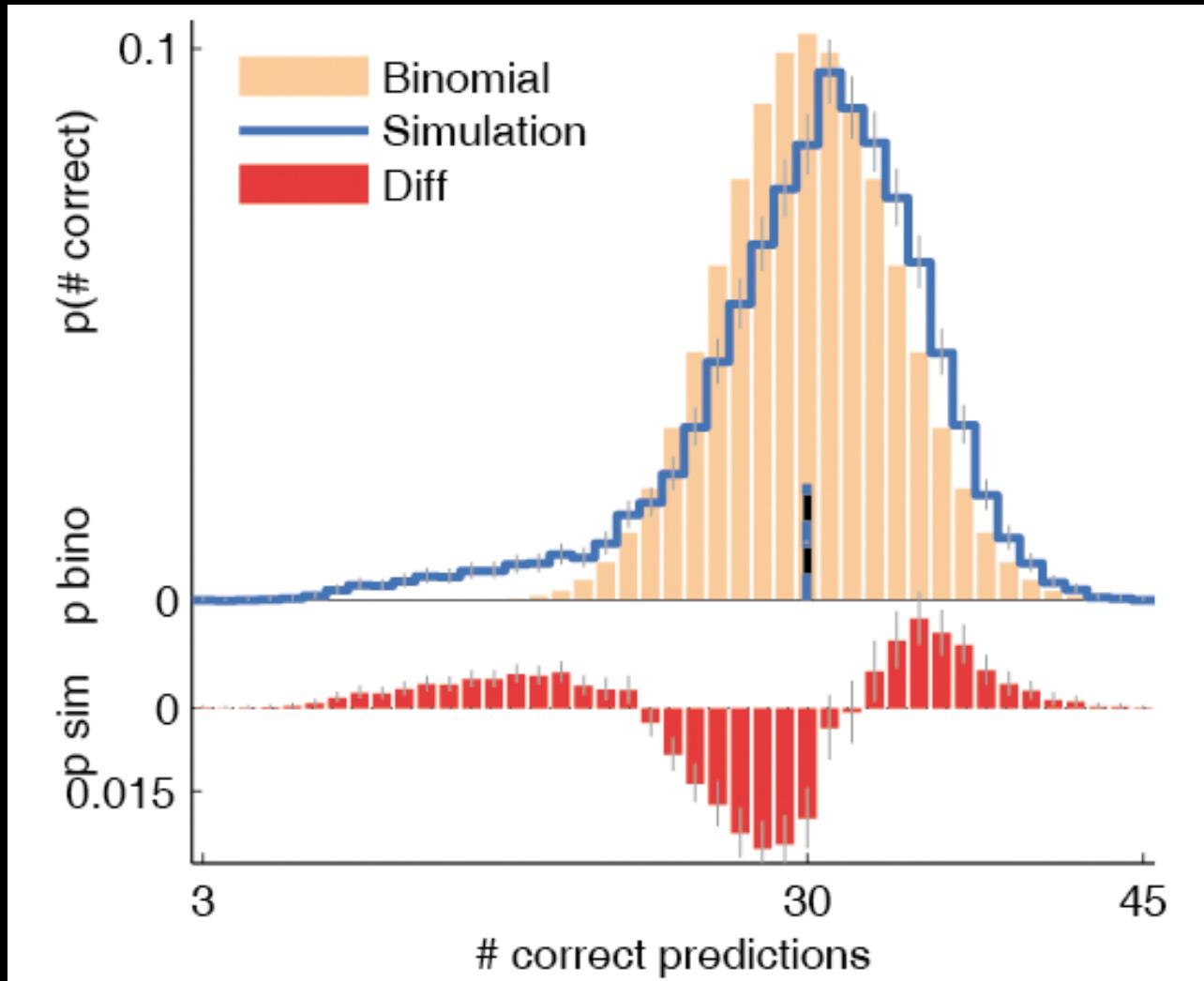
6-8s  
(expected: M1, Parietal, some PFC)



# Pitfalls: Statistical testing

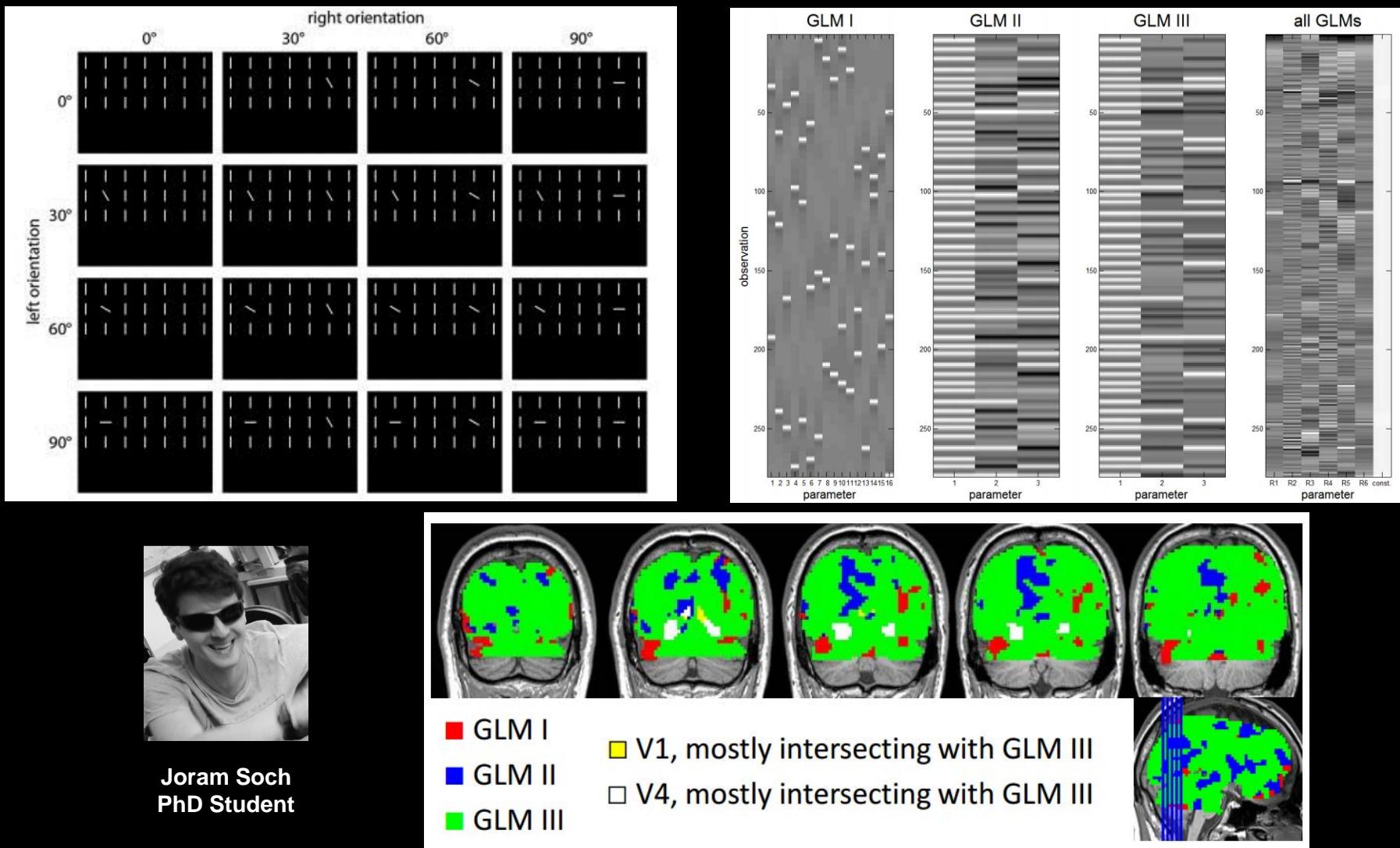


Kai Görgen  
PhD Student



Cross-validated classification accuracy is not binomially distributed!

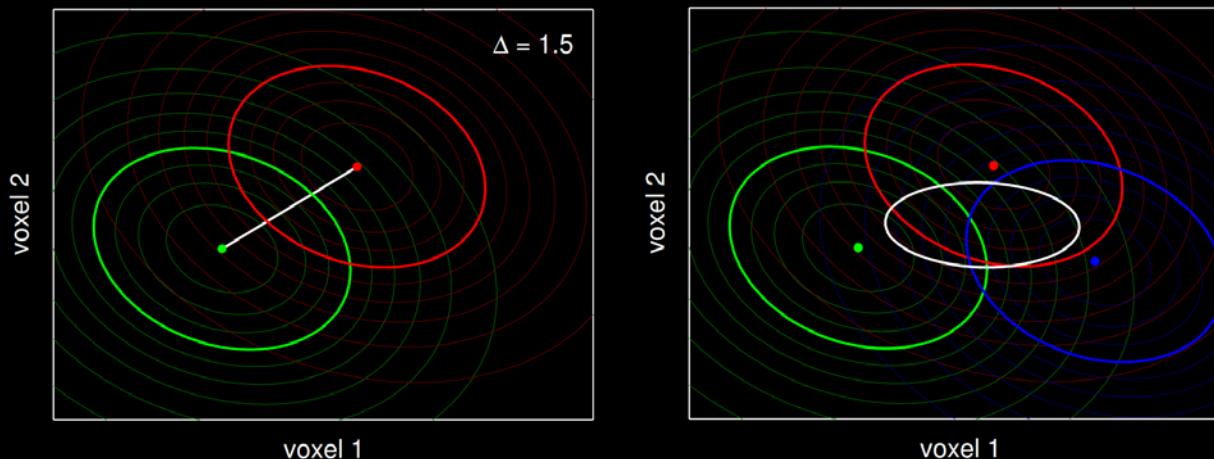
# Pitfalls: Overfitting



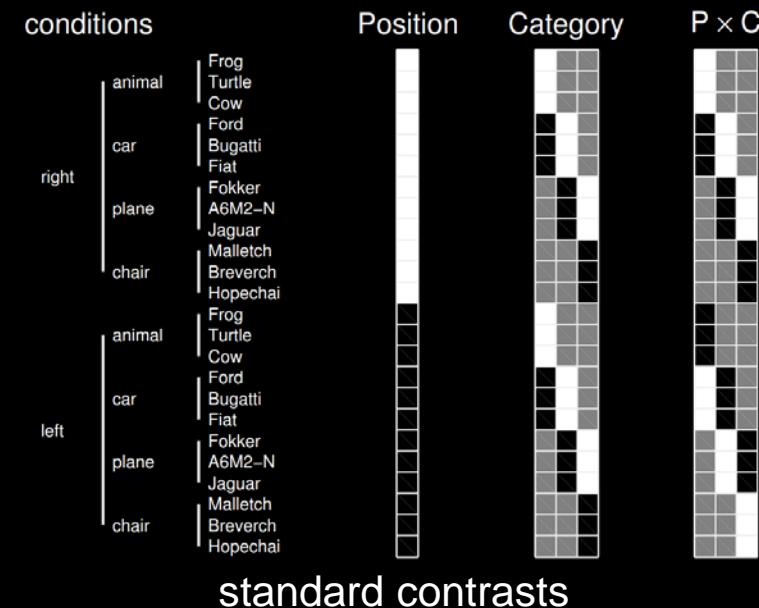
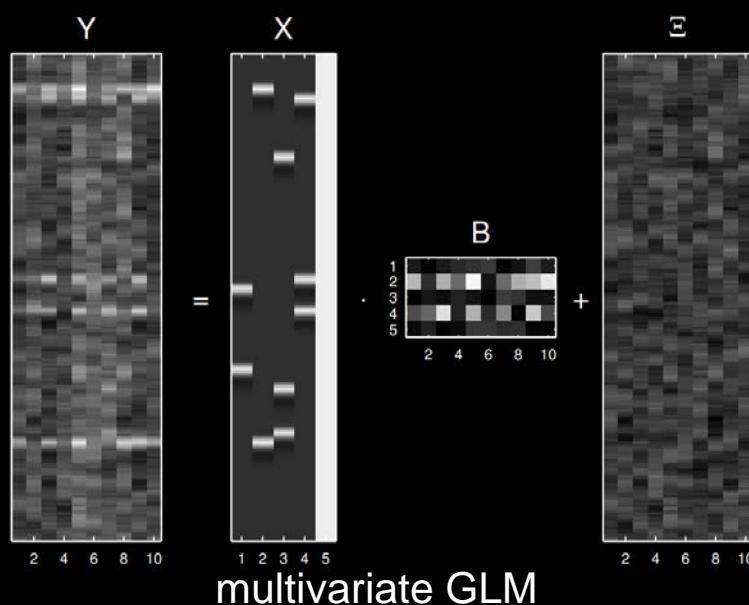
Joram Soch  
PhD Student

OHB M Poster Nr. 2190  
Solving the Problem of Overfitting in Neuroimaging?  
Monday June 15, 12:45–14:45

# Alternative to decoding: Cross-validated MANOVA



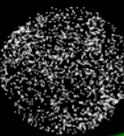
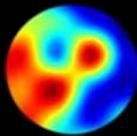
pattern distinctness D: estimate multivariate variance, *explained by effect vs error*



# cvMANOVA applied to visual working memory

three different studies:

紫 級



memory signal

task

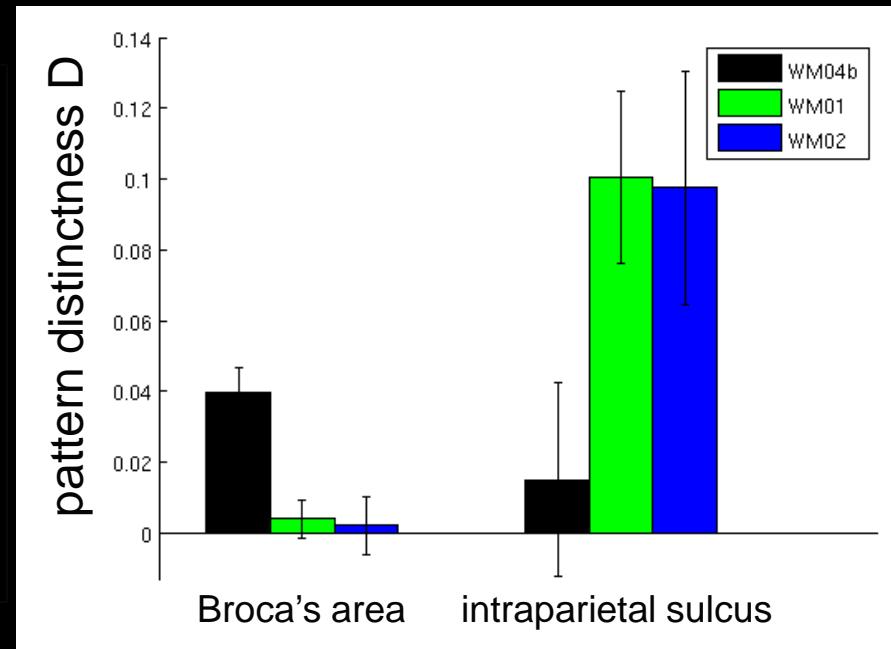
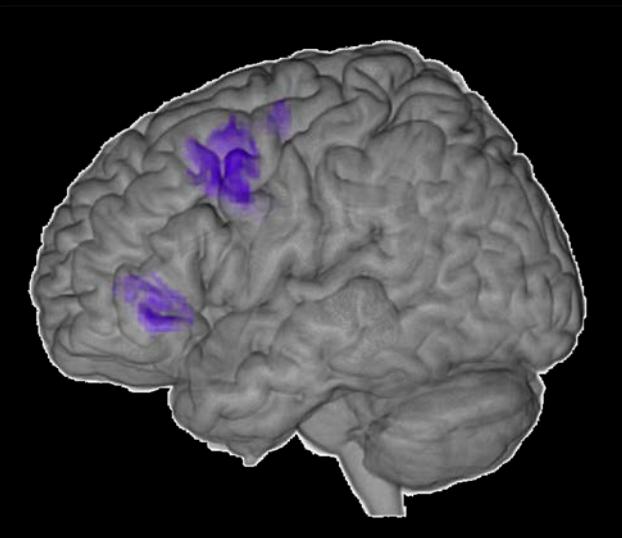
time



Thomas Christophel  
Postdoc



Chang Yan  
PhD student



OHBM Poster Nr. 2177

Decoding neural representations of Chinese characters stored in working memory

Tuesday June 16, 2015 12:45–14:45

Yan, Christophel, Allefeld & Haynes, in prep.

Christophel, Hebart & Haynes *Journal of Neuroscience* 2012, Decoding the contents of visual short-term memory ...

Christophel & Haynes *Neuroimage* 2014, Decoding complex flow-field patterns in visual working memory

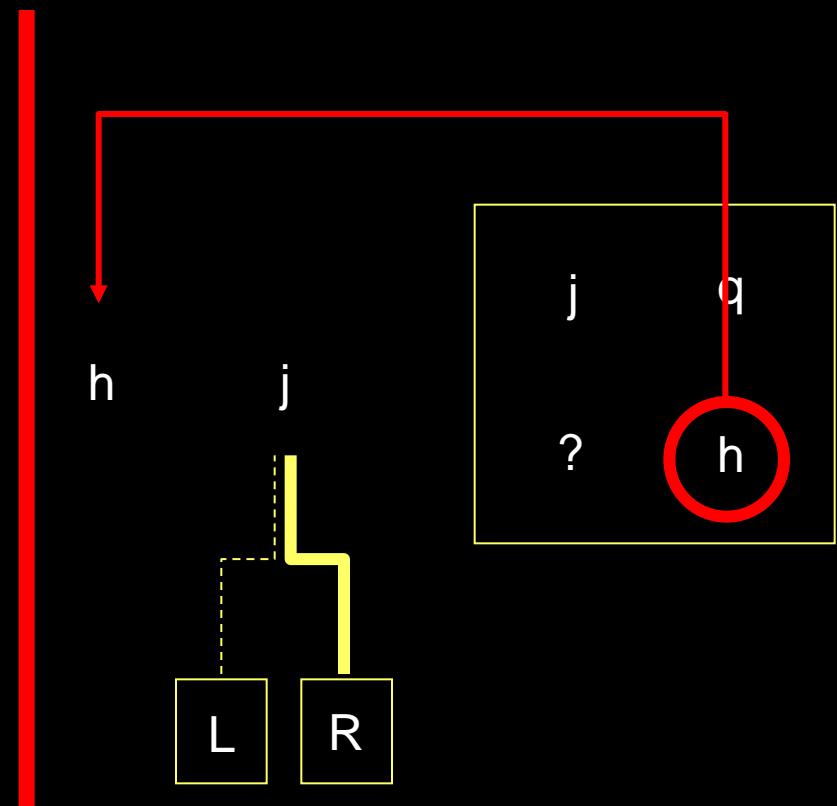
# Predicting decisions



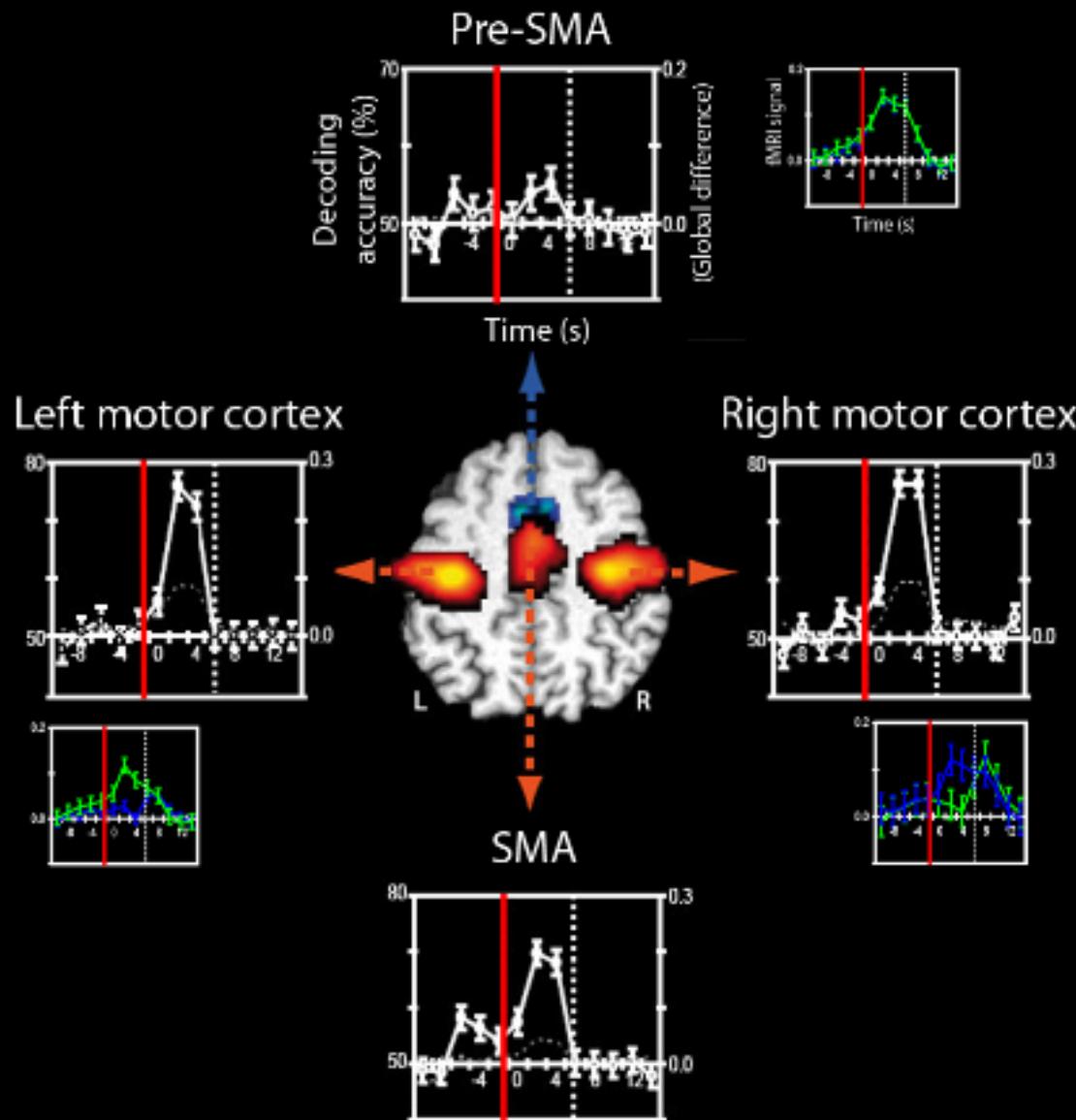
Chun Siong Soon  
former PhD student  
now at Duke-NUS Singapore

b        k        y        p        q

... potential predictors ...

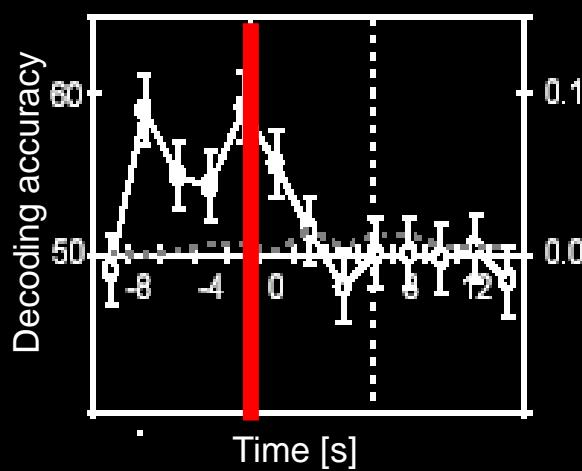


# Decoding choice *after* decision

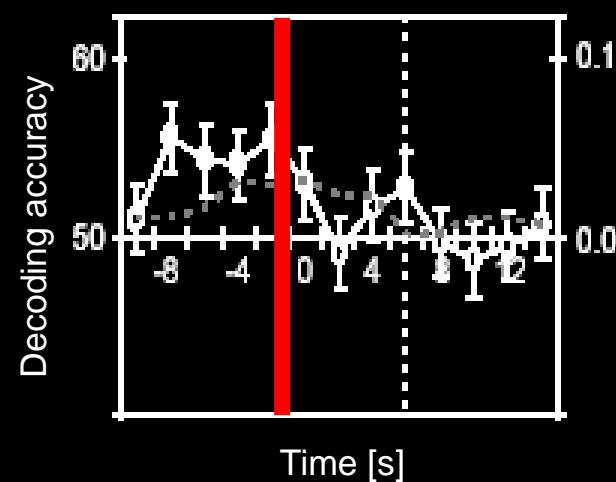


# Decoding choice *before* decision

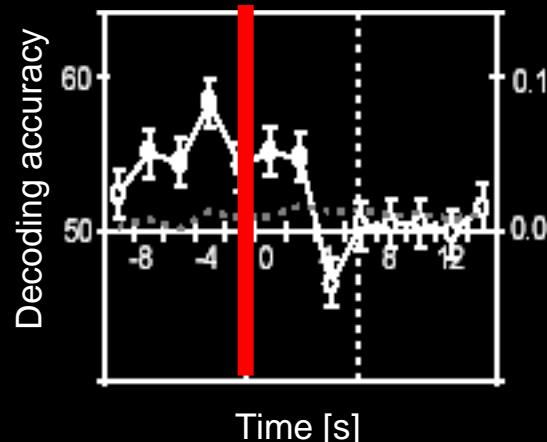
Lateral frontopolar cortex



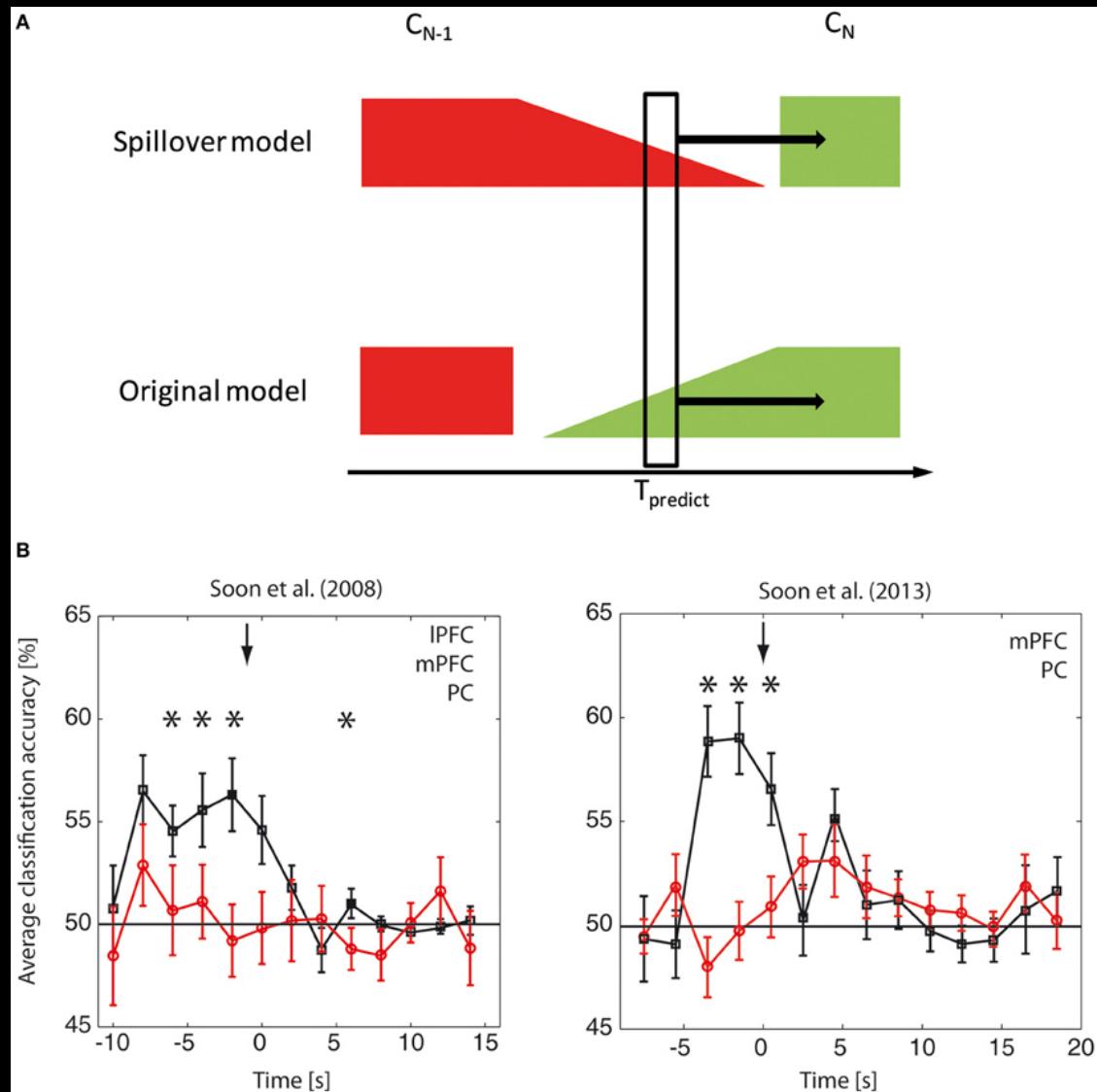
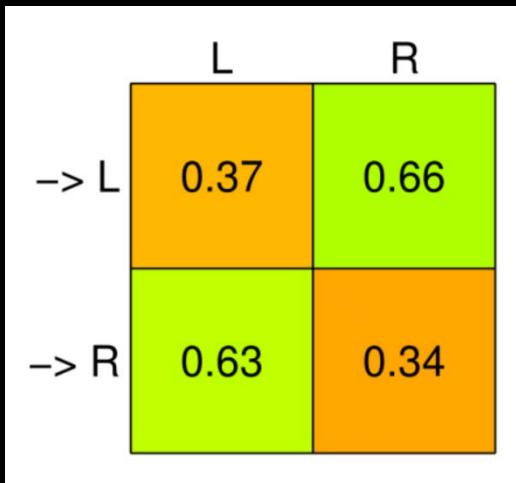
Medial frontopolar cortex



Precuneus / posterior cingulate cortex



# Early decoding because of sequential dependencies?



# Summary

MVPA and decoding can be used to investigate the neural representations of intentions, even of decisions before they become conscious.

Important techniques:

- training and testing of classifiers to assess information in the form of accuracy
- associate experimental conditions with different classification labels  
to access different kinds of information
- use the searchlight for localization of information
- leave-one-run-out cross-validation for well-defined pattern estimates
- FIR modeling for time-resolved analysis
- cross-classification to examine commonality or invariance of representations

Potential pitfalls:

- confounds
- errors in statistical testing
- overfitting

Alternative to decoding: Cross-validated MANOVA  
as a natural framework for MVPA in the context of complex factorial designs.



Bernstein Center for  
Computational Neuroscience Berlin



Berlin Center for  
Advanced Neuroimaging

**Members of the J.-D. Haynes lab:**  
Carsten Allefeld, Carsten Bogler, Thomas Christophel,  
Robert Deutschländer, Kai Görgen, Lasse Loose,  
Achim Meyer, Kerstin Ritter, Joram Soch,  
Martin Weygandt, David Wisniewski, Ahmet Yalcin,  
Chang Yan, Chen Yi

Contact: [haynes@bccn-berlin.de](mailto:haynes@bccn-berlin.de), [carsten.allefeld@bccn-berlin.de](mailto:carsten.allefeld@bccn-berlin.de)