

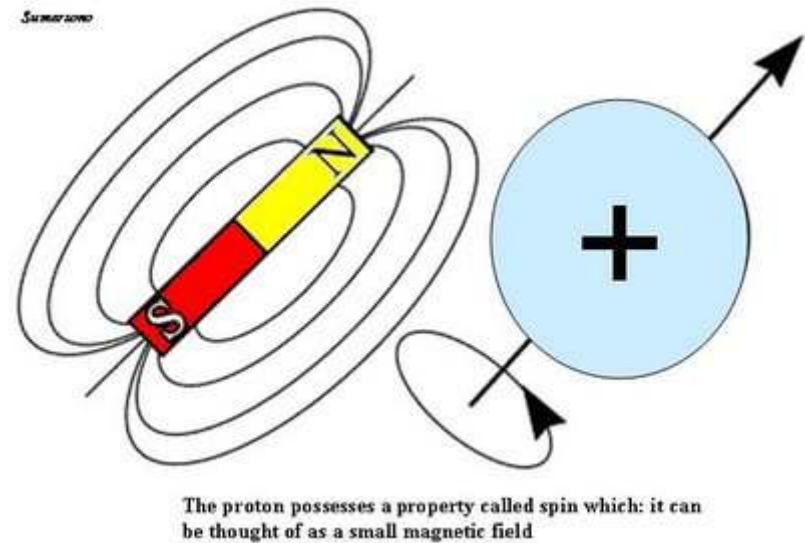
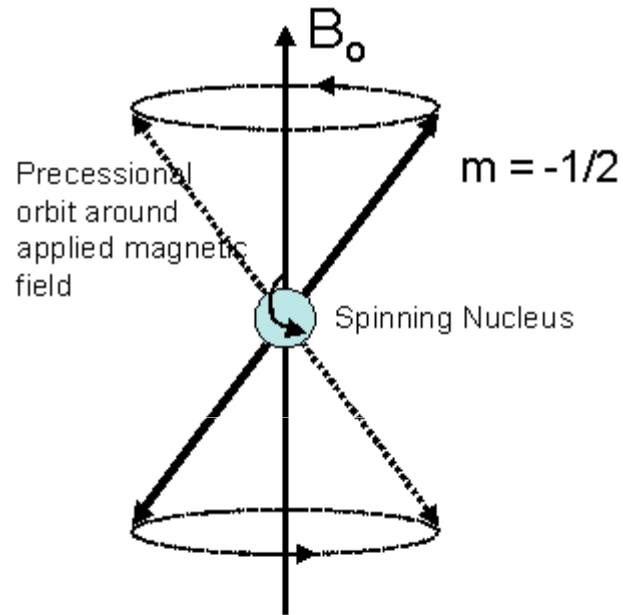
Functional Magnetic Resonance Imaging (fMRI) and Machine Learning

Undergraduate AI Class

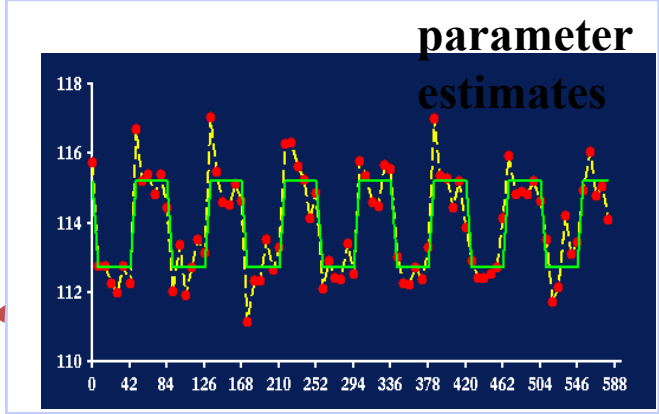
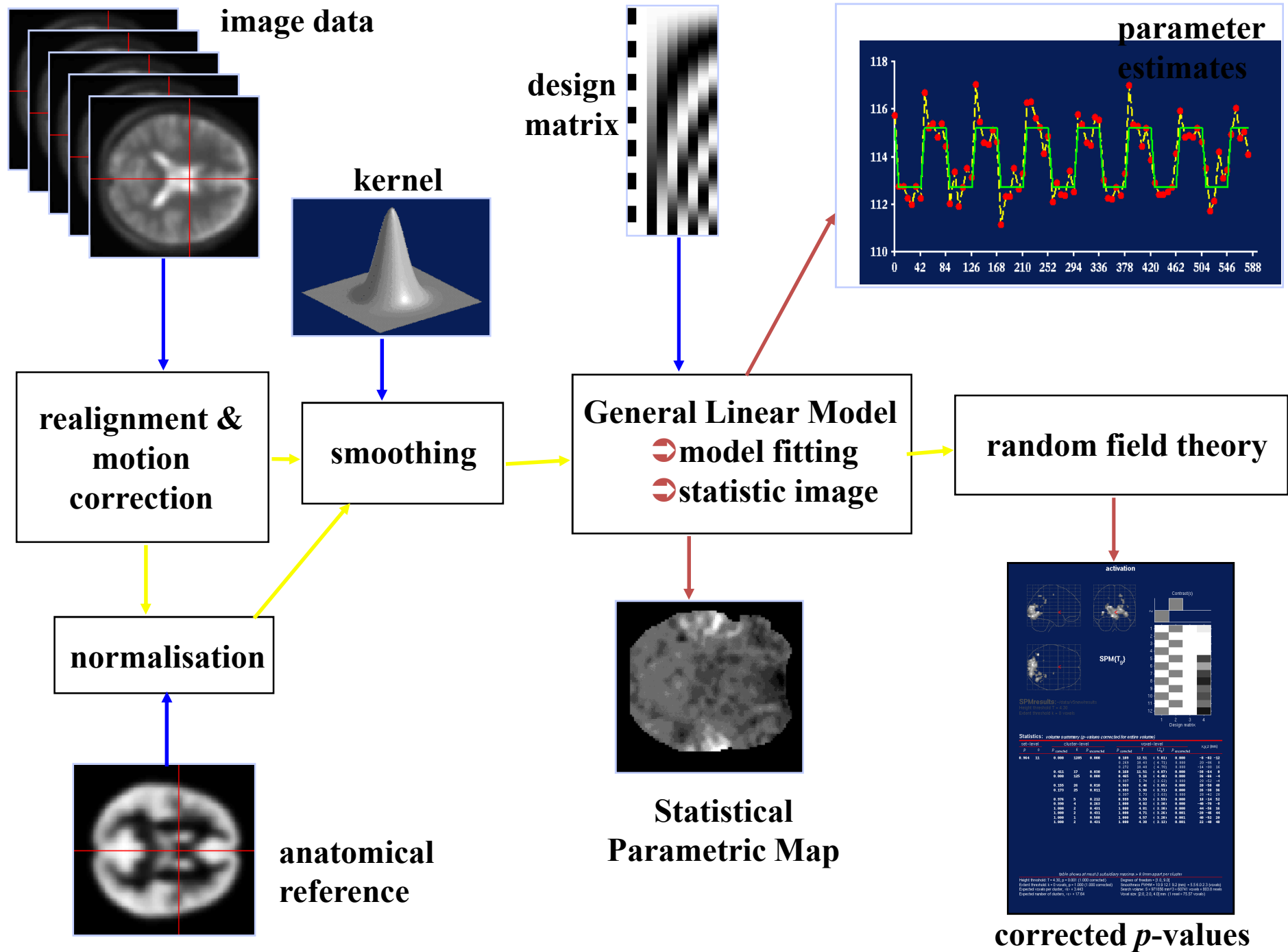
10.10.20.(Wed)

Joon Shik Kim

Spin Precession in Magnetic Field



Blood oxygenation dependent level (BOLD) signal: increased oxygen consumption in neurons is accompanied by the increase of fully oxygenated blood



Statistics: volume summary (p-values corrected for entire volume)

Vol- id	cluster-level		voxel-level		p-value
	Z	p	Z	p	
1	11.000	0.000	8.239	0.000	4.15E-17
2	11.000	0.000	8.239	0.000	4.15E-17
3	11.000	0.000	8.239	0.000	4.15E-17
4	11.000	0.000	8.239	0.000	4.15E-17
5	11.000	0.000	8.239	0.000	4.15E-17
6	11.000	0.000	8.239	0.000	4.15E-17
7	11.000	0.000	8.239	0.000	4.15E-17
8	11.000	0.000	8.239	0.000	4.15E-17
9	11.000	0.000	8.239	0.000	4.15E-17
10	11.000	0.000	8.239	0.000	4.15E-17
11	11.000	0.000	8.239	0.000	4.15E-17
12	11.000	0.000	8.239	0.000	4.15E-17
13	11.000	0.000	8.239	0.000	4.15E-17
14	11.000	0.000	8.239	0.000	4.15E-17
15	11.000	0.000	8.239	0.000	4.15E-17
16	11.000	0.000	8.239	0.000	4.15E-17
17	11.000	0.000	8.239	0.000	4.15E-17
18	11.000	0.000	8.239	0.000	4.15E-17
19	11.000	0.000	8.239	0.000	4.15E-17
20	11.000	0.000	8.239	0.000	4.15E-17

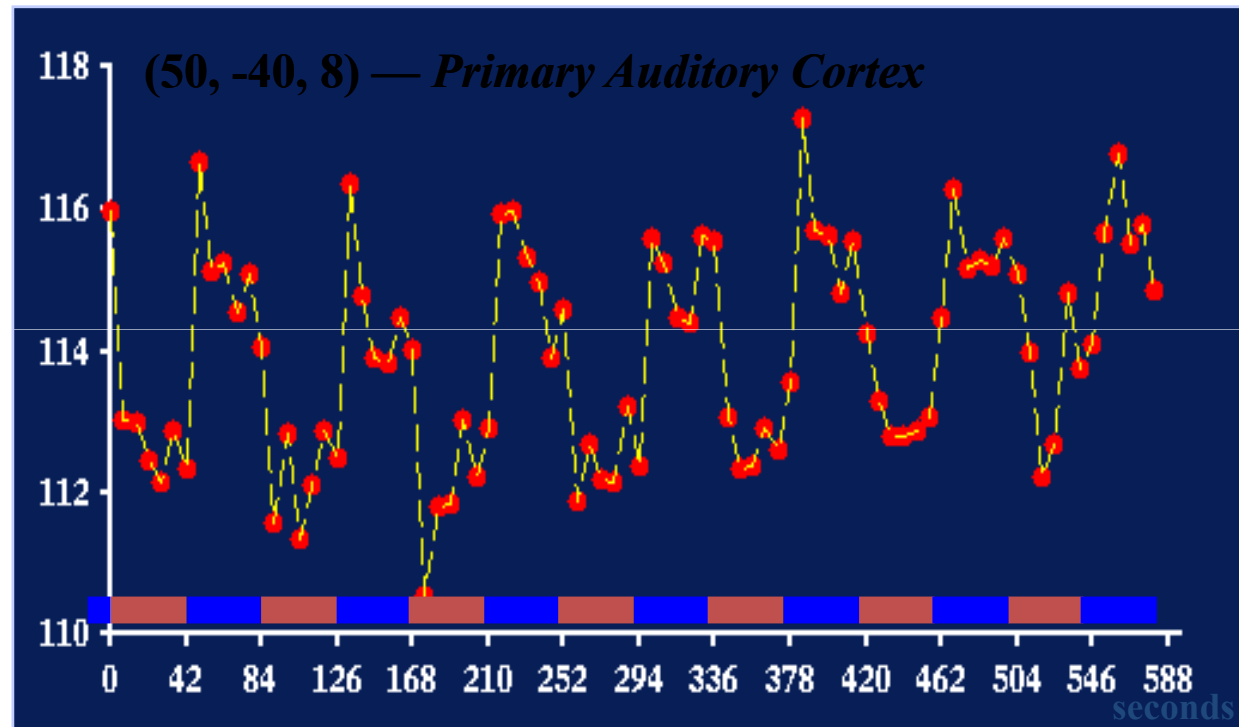
SPM results

Design matrix

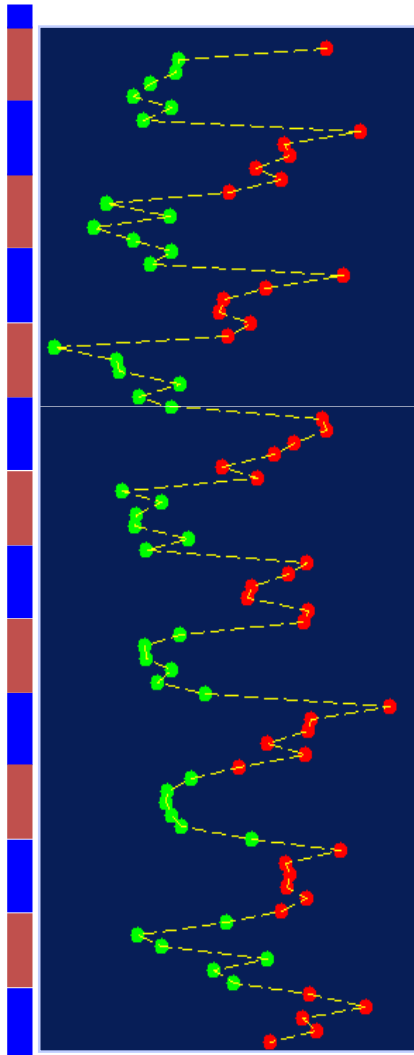
Example epoch fMRI activation dataset: Auditory stimulation

- Single subject
 - RH male
- Conditions
 - Passive word listening
 - Bisyllabic nouns
 - 60wpm
 - against rest
- Epoch fMRI
 - rest & words
 - epochs of 6 scans
 - ⇒ 42 second epochs
 - 7 BA cycles

*experiment was 8 cycles:
first pair of blocks dropped
→ BABABABABABA
⇒ last 84 scans of experiment
images 16–99
→ ~10 minutes scanning time*



...e.g. two-sample t -test?



voxel time series

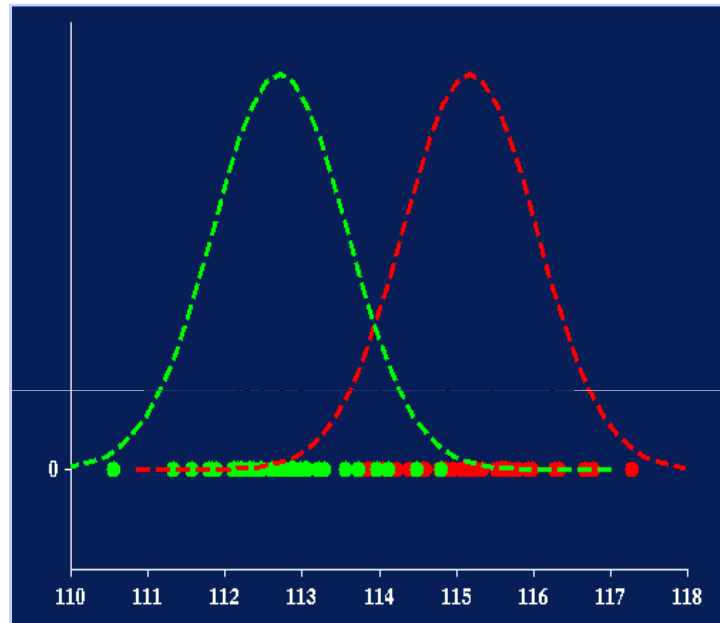
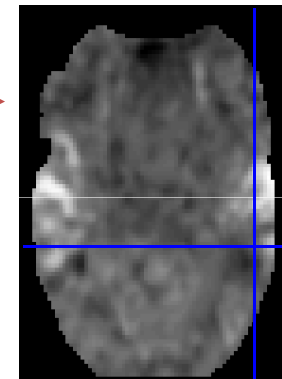


Image intensity



t -statistic image
SPM $\{t\}$
*compares size of
effect to its error
standard deviation*

⦿ *standard t -test assumes independence
⇒ ignores temporal autocorrelation!*



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NeuroImage

www.elsevier.com/locate/ynimg

NeuroImage 24 (2005) 810–821

Functional connectivity in an fMRI working memory task in high-functioning autism

Hideya Koshino,^{a,b,*} Patricia A. Carpenter,^c Nancy J. Minshew,^d Vladimir L. Cherkassky,^a Timothy A. Keller,^a and Marcel Adam Just^a

Task

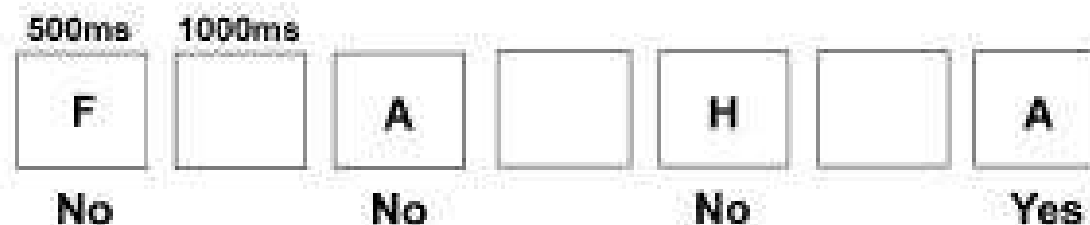
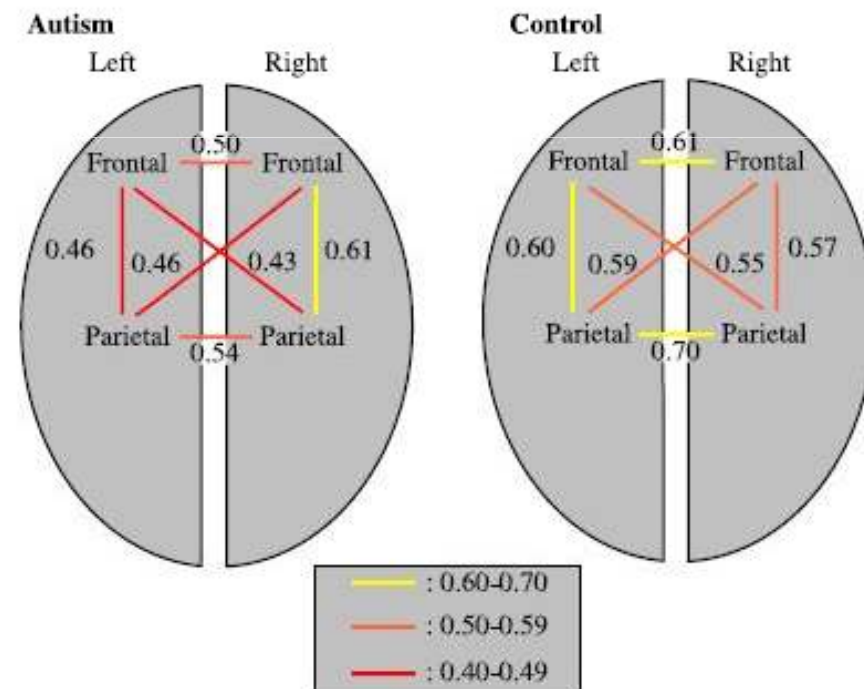
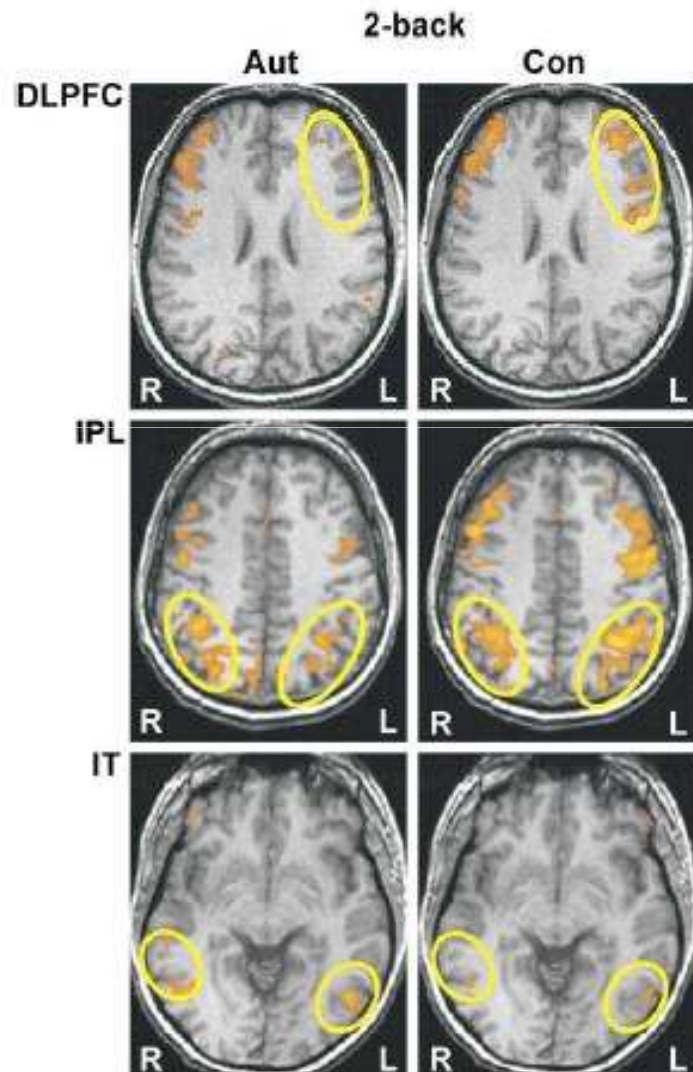


Fig. 1. Schematic representation of the 2-back condition. Each stimulus letter is presented for 500 ms then followed by a blank display for 1000 ms. Participants were asked to judge if each letter is the same as the one that appeared two letters ago.

Activation and Connectivity

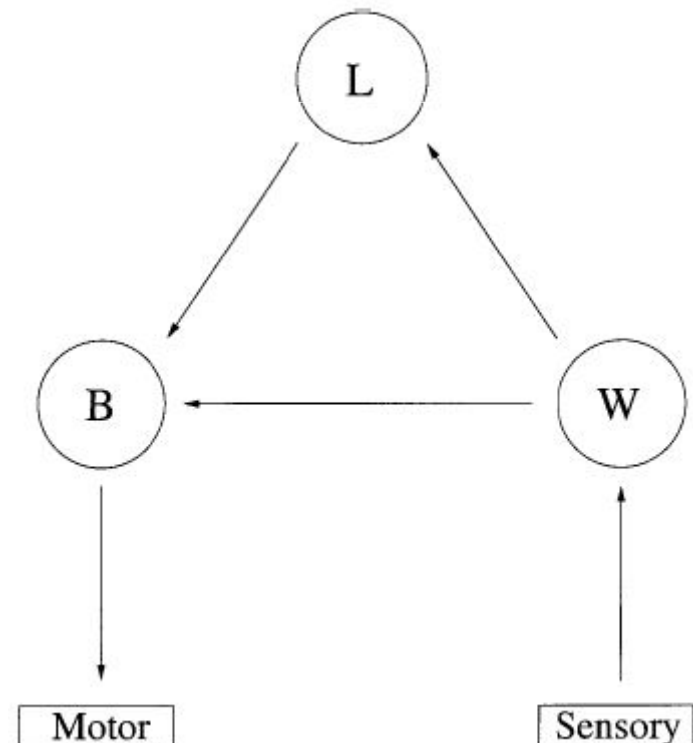


How Good Is Good Enough in Path Analysis of fMRI Data?

Ed Bullmore,*†¹ Barry Horwitz,‡ Garry Honey,* Mick Brammer,* Steve Williams,* and Tonmoy Sharma*

**Institute of Psychiatry, King's College, London, United Kingdom; ‡National Institute on Deafness and other Communication Disorders, National Institutes of Health, Bethesda, Maryland; and †Department of Psychiatry, University of Cambridge, Addenbrooke's Hospital, Cambridge CB2 2QQ, United Kingdom*

Task: after the presentation of a word, the subject speaks internally whether the object is living or nonliving



Structural Equation Modeling (Path Analysis)

$$\begin{pmatrix} \text{VEC} \\ \text{PFC} \\ \text{SMA} \\ \text{IFG} \\ \text{IPL} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & \theta_1 \\ \theta_2 & 0 & 0 & 0 & 0 \\ 0 & \theta_3 & 0 & 0 & 0 \\ 0 & 0 & \theta_4 & 0 & 0 \\ \theta_6 & 0 & 0 & \theta_5 & 0 \end{pmatrix} \times \begin{pmatrix} \text{VEC} \\ \text{PFC} \\ \text{SMA} \\ \text{IFG} \\ \text{IPL} \end{pmatrix} + \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \end{pmatrix}$$

$$v = K v + \psi,$$

Structural equation modeling (SEM)

$$\boldsymbol{v} = (\boldsymbol{I} - \boldsymbol{K})^{-1} \boldsymbol{\Psi}$$

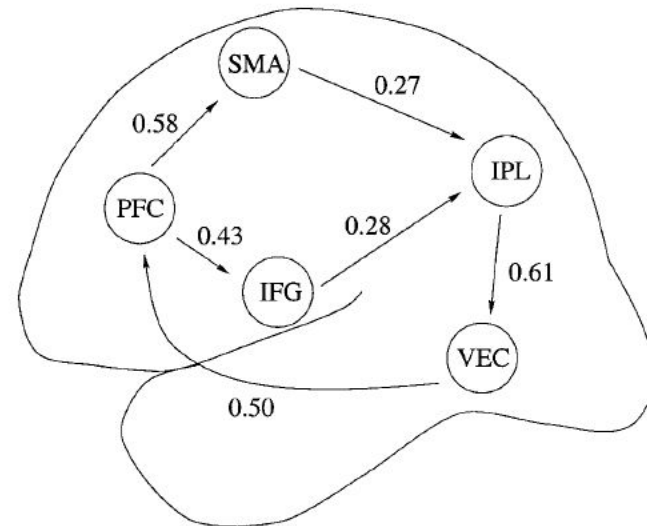
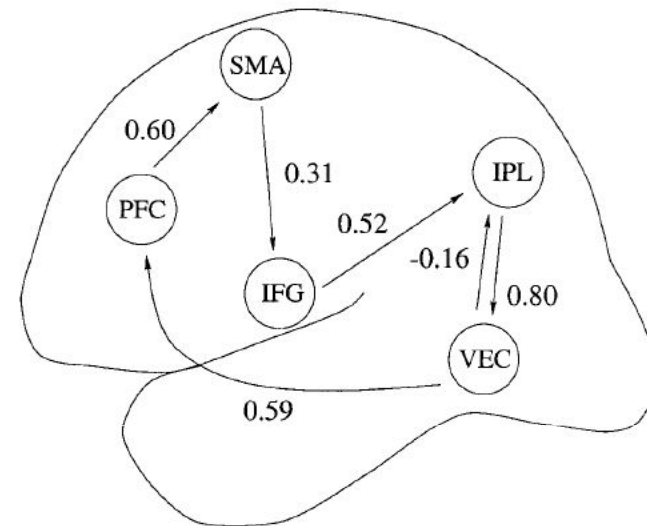
$$\boldsymbol{\Sigma} = (\boldsymbol{I} - \boldsymbol{K})^{-1} \boldsymbol{\Psi} \boldsymbol{\Psi}^T (\boldsymbol{I} - \boldsymbol{K})^{-T}$$

Minimization of a discrepancy function F

$$F = \log |\boldsymbol{\Sigma}(\boldsymbol{\theta})| + \text{tr}(\boldsymbol{C} \boldsymbol{\Sigma}^{-1}(\boldsymbol{\theta})) - \log |\boldsymbol{C}| - q,$$

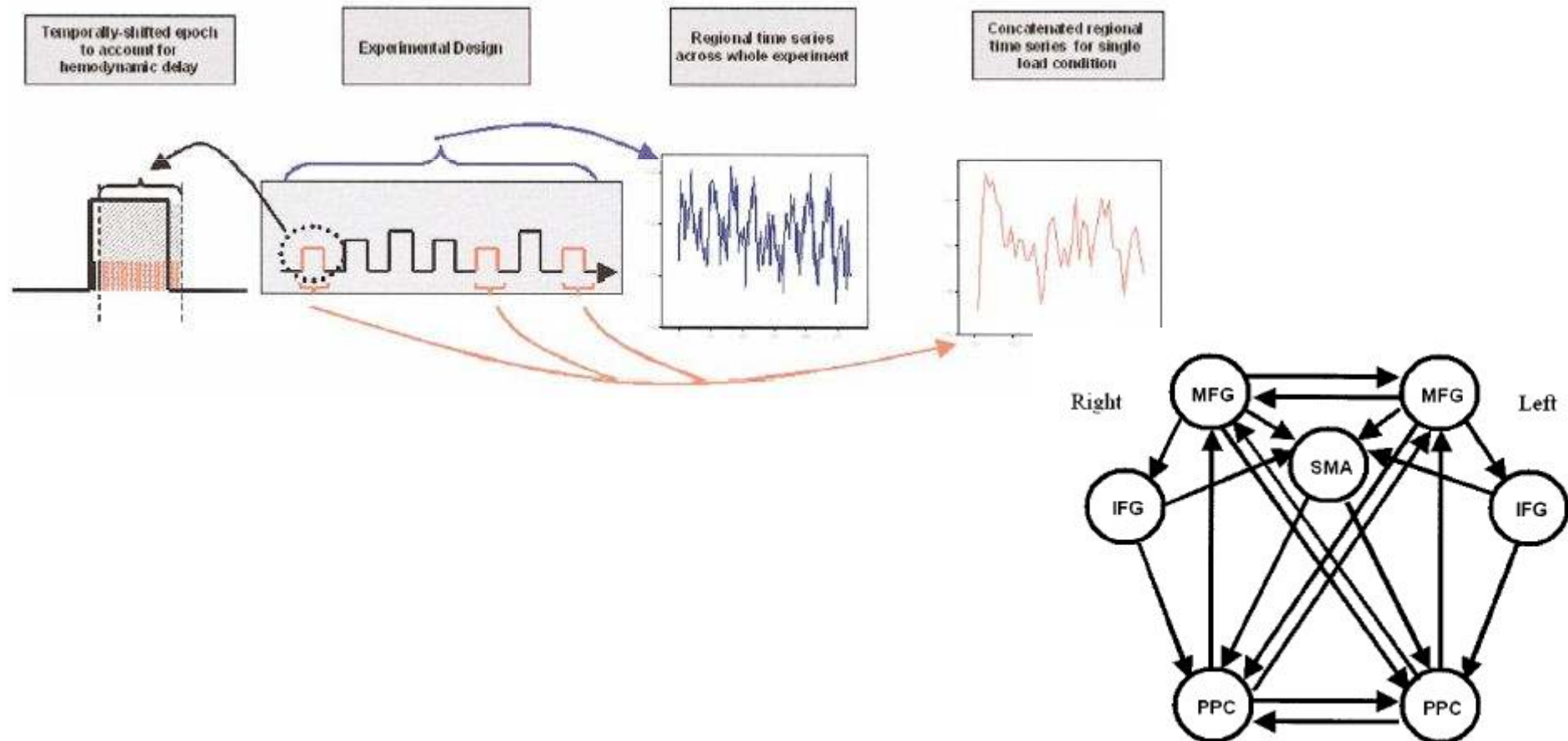
Result of SEM

Top: theoretically preferred path model
Bottom: the best fitting path model



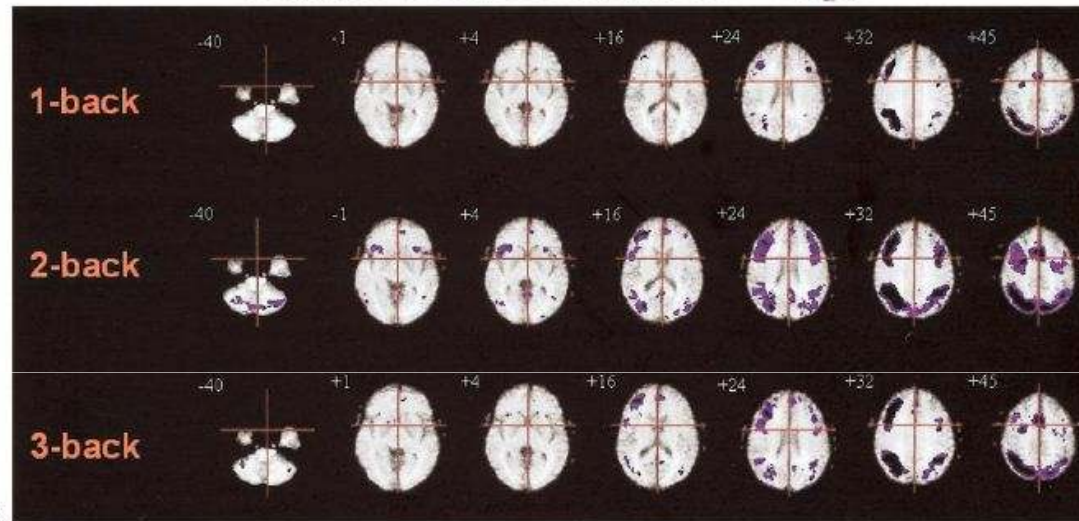
Effects of Verbal Working Memory Load on Corticocortical Connectivity Modeled by Path Analysis of Functional Magnetic Resonance Imaging Data

G. D. Honey,* C. H. Y. Fu,† J. Kim,† M. J. Brammer,† T. J. Croudace,* J. Suckling,† E. M. Pich,‡
S. C. R. Williams,† and E. T. Bullmore*¹

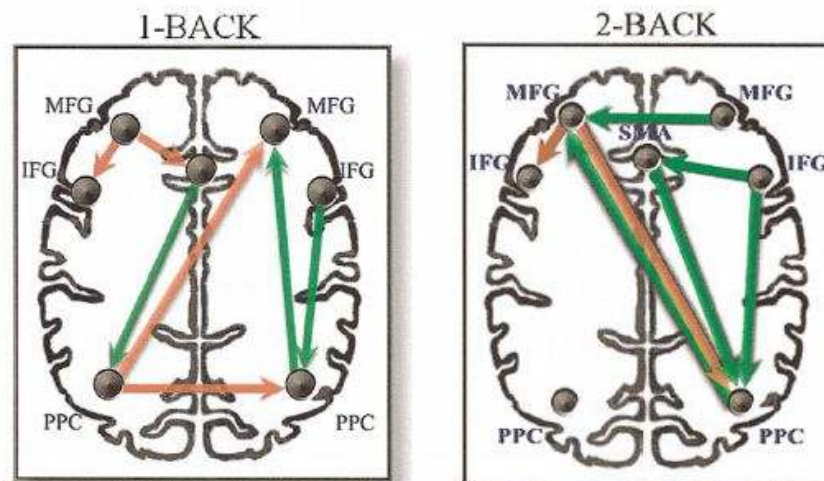


Activation Map and Effective connectivity

Generic Brain Activation Maps



3



4

A Neurosemantic Theory of Concrete Noun Representation Based on the Underlying Brain Codes

Marcel Adam Just^{1*}, Vladimir L. Cherkassky¹, Sandesh Aryal¹, Tom M. Mitchell²

Table 1. 60 stimulus words grouped into 12 semantic categories.

Category	Exemplar 1	Exemplar 2	Exemplar 3	Exemplar 4	Exemplar 5
body parts	leg	arm	eye	foot	hand
furniture	chair	table	bed	desk	dresser
vehicles	car	airplane	train	truck	bicycle
animals	horse	dog	bear	cow	cat
kitchen utensils	glass	knife	bottle	cup	spoon
tools	chisel	hammer	screwdriver	pliers	saw
buildings	apartment	barn	house	church	igloo
building parts	window	door	chimney	closet	arch
clothing	coat	dress	shirt	skirt	pants
insects	fly	ant	bee	butterfly	beetle
vegetables	lettuce	tomato	carrot	corn	celery
man-made objects	refrigerator	key	telephone	watch	bell

doi:10.1371/journal.pone.0008622.t001

Voxel, Factor, and Loading

$$\vec{V}_i = \sum_j \vec{F}_j^1 L_{ij}^1$$

V_i : 60-word mean activation profile of the i -th voxel

F_j^1 : the first-level factor profile of the j -th factor

L_{ij}^1 : a first-level loading of i -th voxel on factor F_j^1

$$\vec{F}_n^1 = \sum_k \vec{F}_k^2 L_{nk}^2$$

F_n^1 : the first-level factor profile

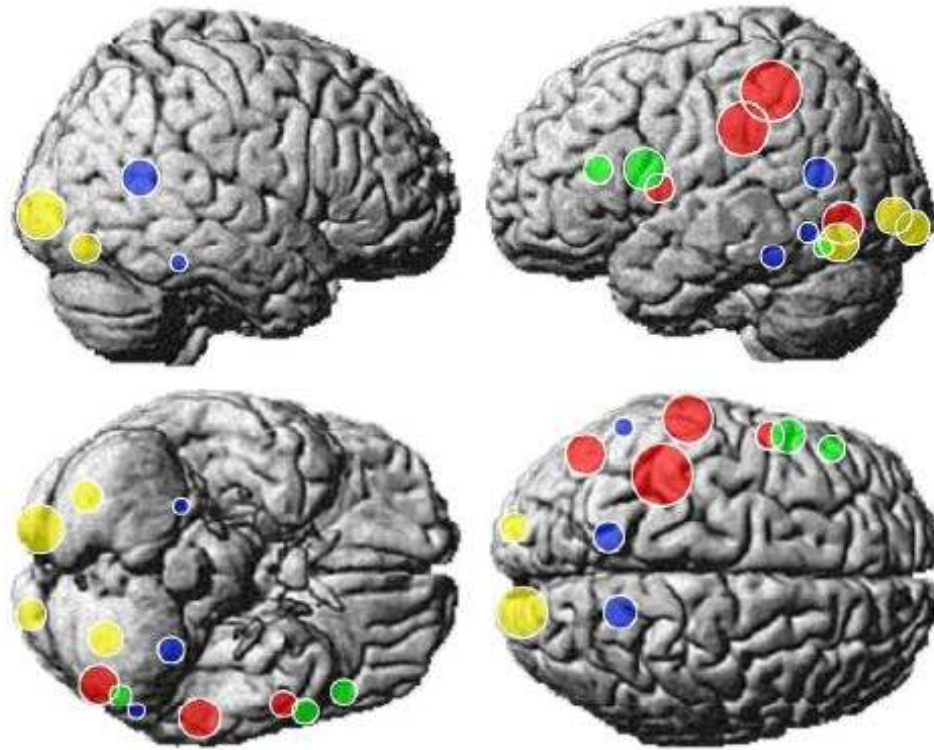
F_k^2 : the second-level factor profile

L_{nk}^2 : load

Gaussian Naïve Bayes (GNB) classifier

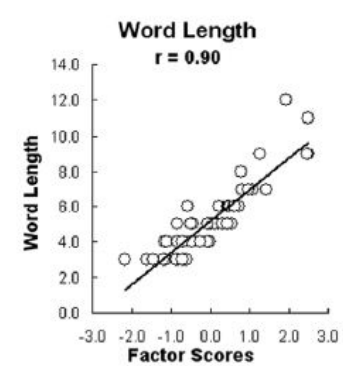
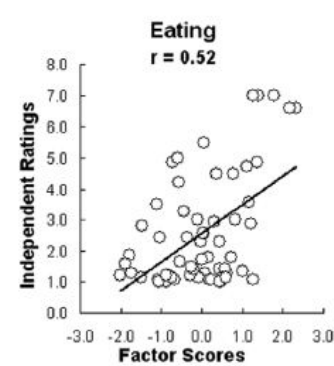
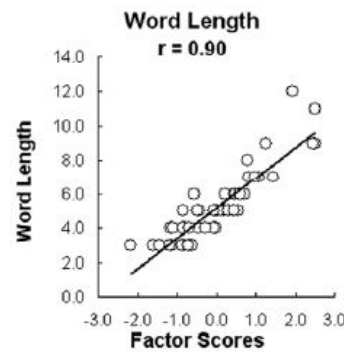
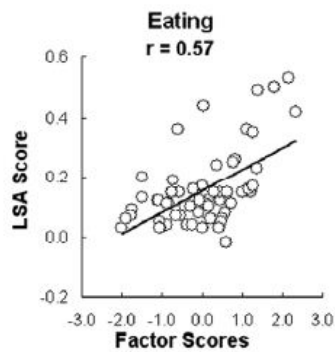
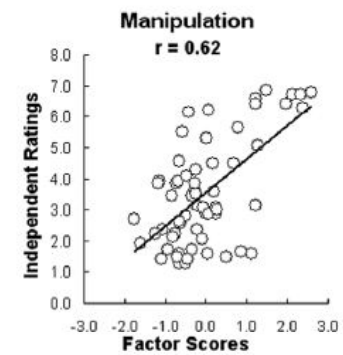
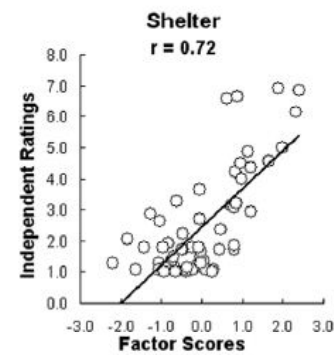
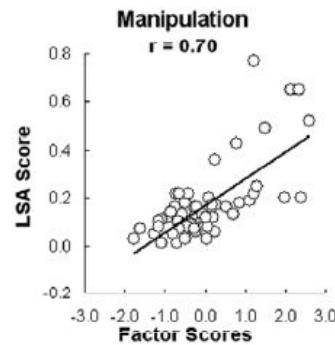
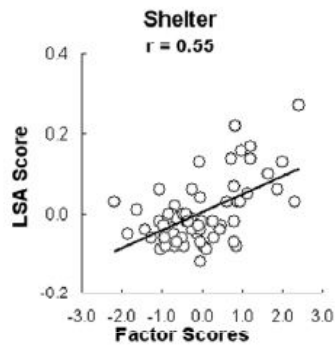
$$Y \leftarrow \arg \max_{y_i} P(Y = y_i) \prod_j P(X_j | Y = y_i)$$

Locations of the Voxel Clusters of Four Factors



- Shelter
- Manipulation
- Eating
- Word length

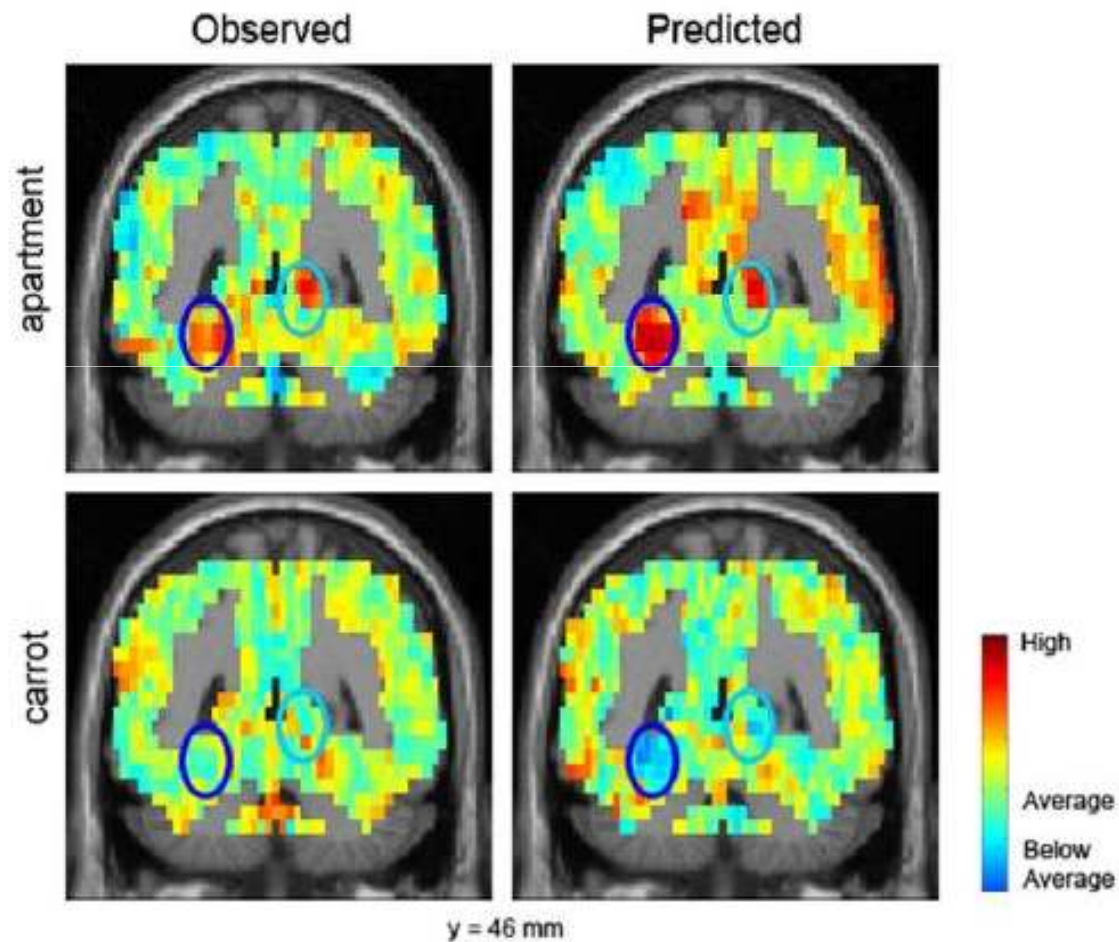
Correlation Between Factor Scores and Ratings



Latent Semantic Analysis (LSA)

Ratings by human

Observed and Predicted Images (Apartment & Carrot)



Marcel Just and Tom Mitchell Interview

http://www.youtube.com/watch?v=JVLu5_hvr8s&feature=player_embedded