Multi Voxel Pattern Analysis (fMRI)

Multi Variate Pattern Analysis (more generally)

Magic Voxel Pattern Analysis (probably not!)

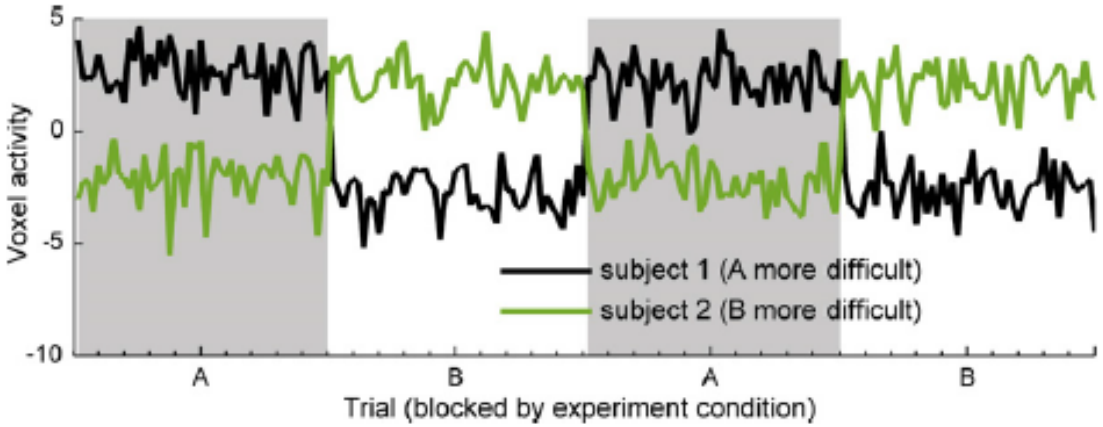
"…all MVPA really shows is that there are places where, in most people's brain, activity differs when they're doing one thing as opposed to another."

Have you decoded something about "orangeness" vs "appleness" or are there potential confounds?

"The mathematics are sound and the method does 'work', but the trouble is what the results *mean.*"

M.T. Todd et al. / NeuroImage 77 (2013) 157–165

Simulated example: experiment condition confounded with difficulty



Individual-Subject Summary Statistics

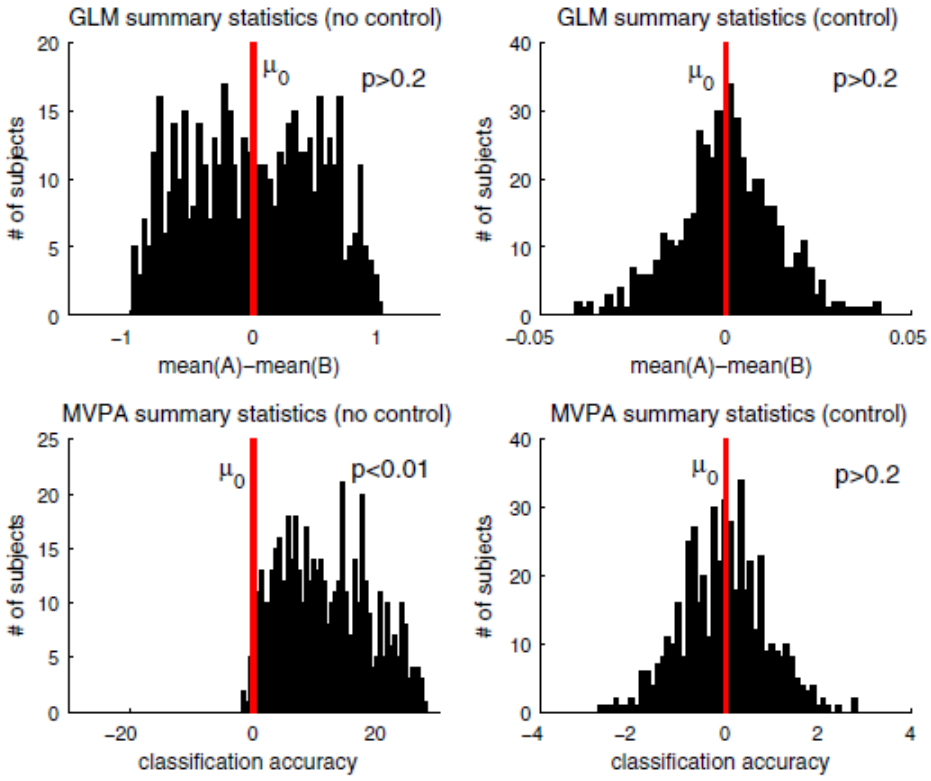
Subject	Experimental Effect (GLM)	Discrimination Success (MVPA)
Subject 1	mean(A)-mean(B) = +4.75	classification accuracy = +13.15, within-minus-across = +3.826
Subject 2	mean(A)-mean(B) = -5.56	classification accuracy = +13.44, within-minus-across = +3.848

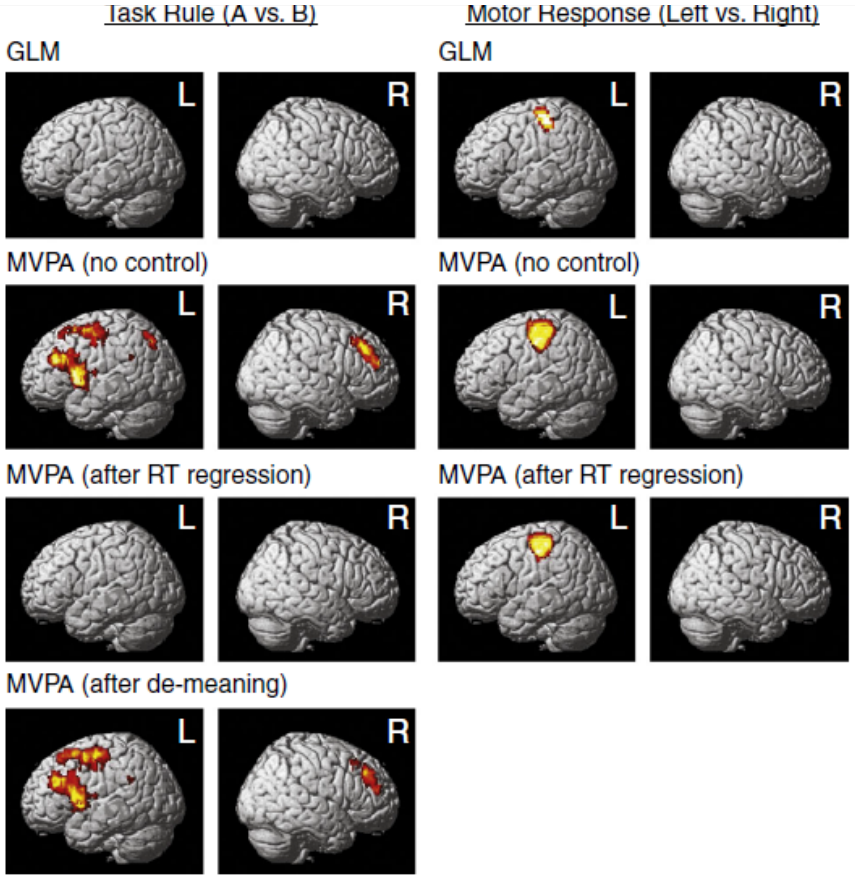
Group Test Statistics (two-tailed *t*-test)

Experimental Effect (GLM)	Discrimination Success (MVPA)
mean(A)-mean(B): t_1=-0.0780, p=0.9504, n.s.	classification accuracy: t_1=94.0, p<0.01, sig. within-minus-across: t_1=348, p<0.01, sig.

GLMA – opposite-signed variations cancel

MVPA – opposite-signed variations sum (unless you do something fancier to make them not do so)


GLM summary statistics (no control)
μ0
p>0.2
# of subjects
mean(A)–mean(B)
GLM summary statistics (control)
μ0
p>0.2
# of subjects
mean(A)–mean(B)
MVPA summary statistics (no control)
μ0
p<0.01
# of subjects
classification accuracy
MVPA summary statistics (control)
μ0
p>0.2
# of subjects
classification accuracy


Task Rule (A vs. B)
Motor Response (Left vs. Right)
GLM
GLM
MVPA (no control)
MVPA (no control)
MVPA (after RT regression)
MVPA (after RT regression)
MVPA (after de-meaning)
L
R

Counteracting?

Better design

Linear regression (e.g., of RT)

Better (more careful) interpretation

Not OK: "Brain region A represents information X"

OK: "Brain region A can predict behavior Y"; "Relationship between brain Region A and behavior Y follows model Z."

Potentially problematic: "distributed" representations with positively and negatively voxel signs

Probably OK: methods that do not discard sign/direction of individual effects

Individual differences and MVPA?

Prediction of Individual Brain Maturity Using fMRI

Nico U. F. Dosenbach,[1*] Binyam Nardos,[1] Alexander L. Cohen,[1] Damien A. Fair,[2] Jonathan D. Power,[1] Jessica A. Church,[1] Steven M. Nelson,[1,3] Gagan S. Wig,[1,4,5] Alecia C. Vogel,[1] Christina N. Lessov-Schlaggar,[6] Kelly Anne Barnes,[1] Joseph W. Dubis,[1] Eric Feczko,[6] Rebecca S. Coalson,[1,7] John R. Pruett Jr.,[6] Deanna M. Barch,[3,6,7] Steven E. Petersen,[1,3,7,8] Bradley L. Schlaggar[1,7,8,9*]

Group functional connectivity magnetic resonance imaging (fcMRI) studies have documented reliable changes in human functional brain maturity over development. Here we show that support vector machine-based multivariate pattern analysis extracts sufficient information from fcMRI data to make accurate predictions about individuals' brain maturity across development. The use of only 5 minutes of resting-state fcMRI data from 238 scans of typically developing volunteers (ages 7 to 30 years) allowed prediction of individual brain maturity as a functional connectivity maturation index. The resultant functional maturation curve accounted for 55% of the sample variance and followed a nonlinear asymptotic growth curve shape. The greatest relative contribution to predicting individual brain maturity was made by the weakening of short-range functional connections between the adult brain's major functional networks.

238 rs-fcMRI scans (3 T; continuous rest) from typically developing participants ranging in age from 7 to 30 years

Blood oxygen level–dependent (BOLD) time courses were generated for 160 regions of interest (ROIs) derived from a series of meta-analyses of task-related fMRI studies that cover much of the brain

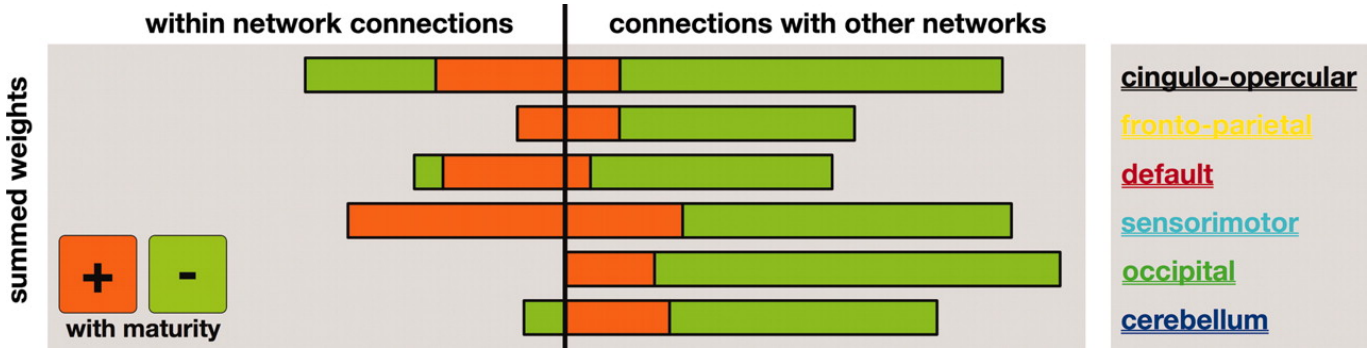
All possible interregional temporal correlations, or functional connections (n = 12,720), were computed for each individual.

reduced the number of features to the 200 functional connections most reliably different between children and adults in each round of leave-one-out cross-validation

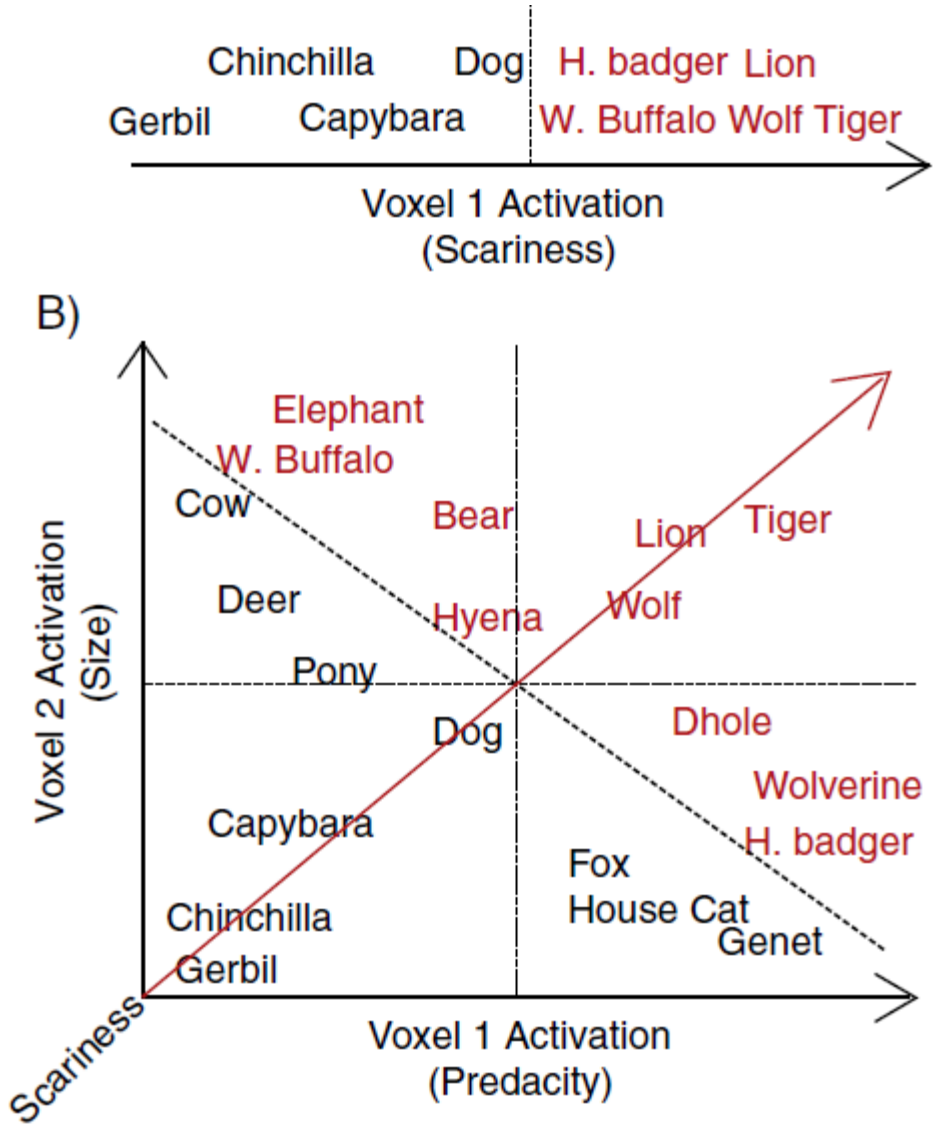
Binary SVM classification of individuals as either children or adults was 91% accurate (permutation test, $P < 0.0001$; 90% sensitive; 92% specific).

For independent replication, the same analyses were also carried out on two other large-scale developmental functional connectivity data sets with somewhat different characteristics.

Turn analysis "inside out" – which brain regions predict maturity?

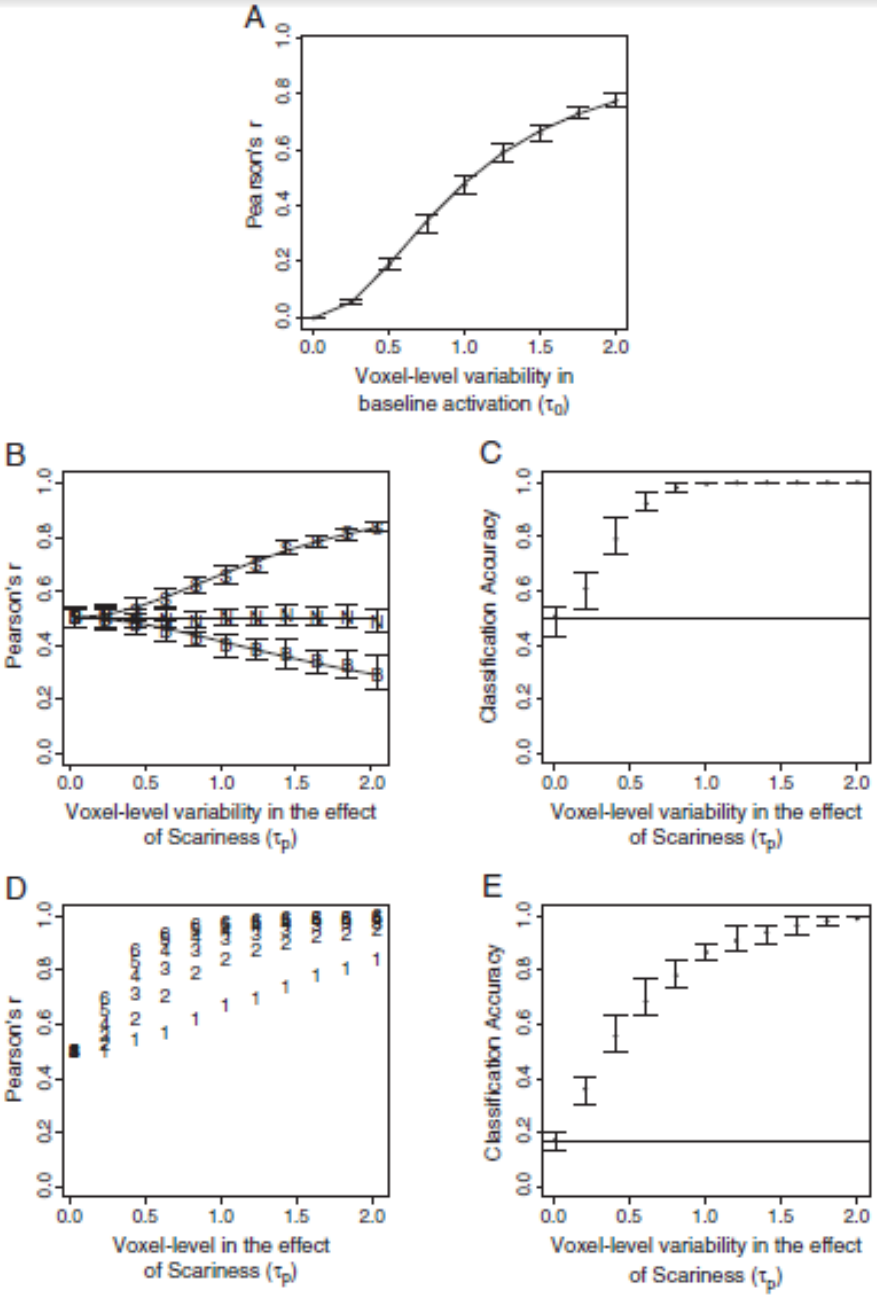


Davis et al.



…but could also get significant MVPA results even if it "really" only varied along one dimension

Davis et al.



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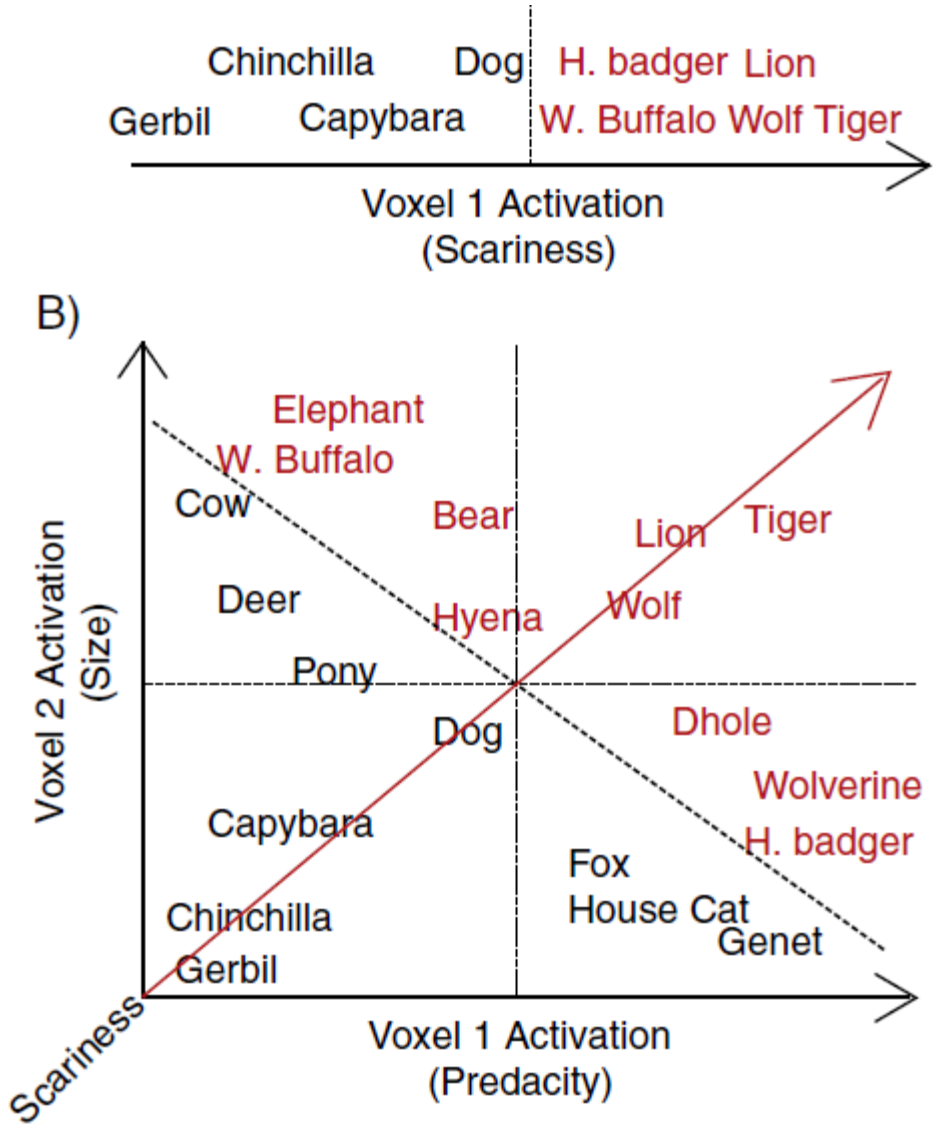

How do you test for multidimensionality?

- Look for effects based on the supposed dimensions (and possibly regress out)
- If including both dimensions improves accuracy, then better evidence for multidimensionality
- Requires models/ hypotheses of what dimensions are

“In many cases,MVPA tests may be providing information that is largely assumed by the group-level statistical maps already reported in most papers (e.g., Rissman et al., 2010): **experimental effects vary across voxels**.

As formal tests of this variability, MVPA results may be more sensitive indicators of heterogeneity of response across regions or voxels within a region. However**, knowledge of this variability does not confer any special theoretical status to the results in and of itself.**

Instead, **to make conclusions about the dimensionality or content** of the activation patterns that stimuli elicit, it is important to incorporate additional methods that **explicitly measure** these aspects of the activation patterns, such as encoding models, classifier-based tests of dimensionality, and multidimensional scaling.”

Or as Frank put it:

“We just can’t throw MVPA at some data, with no hypothesis in mind, and expect it to crack the code for us. In other words, MVPA can’t tell the theory behind the classified patterns.”

GLMA vs MVPA?