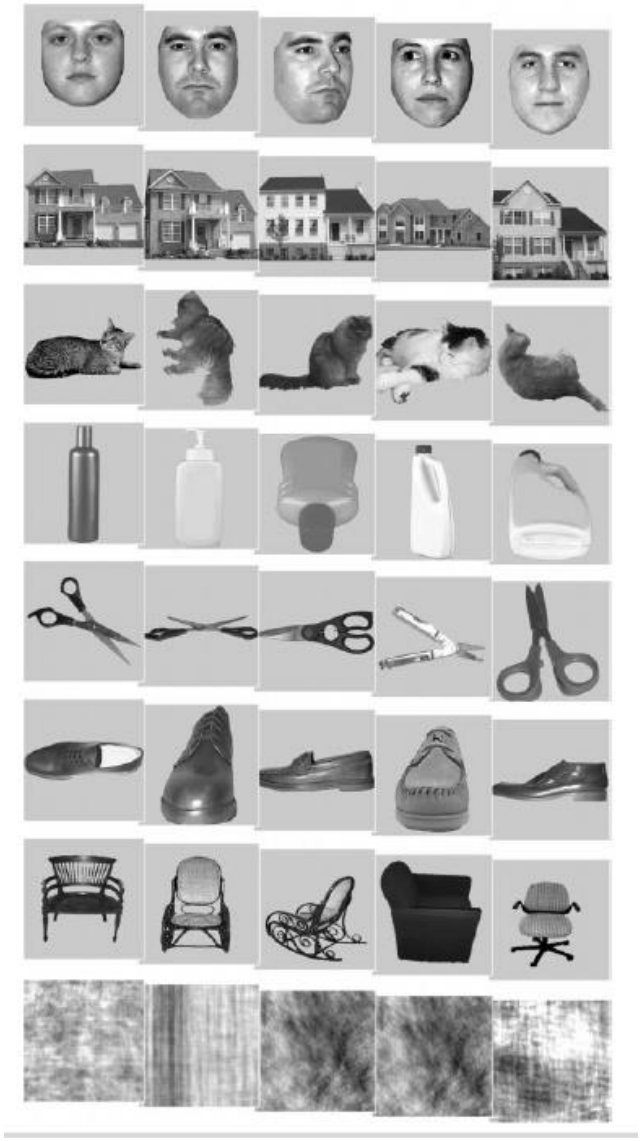
Cognitive Science and AI

fMRI Task Datasets



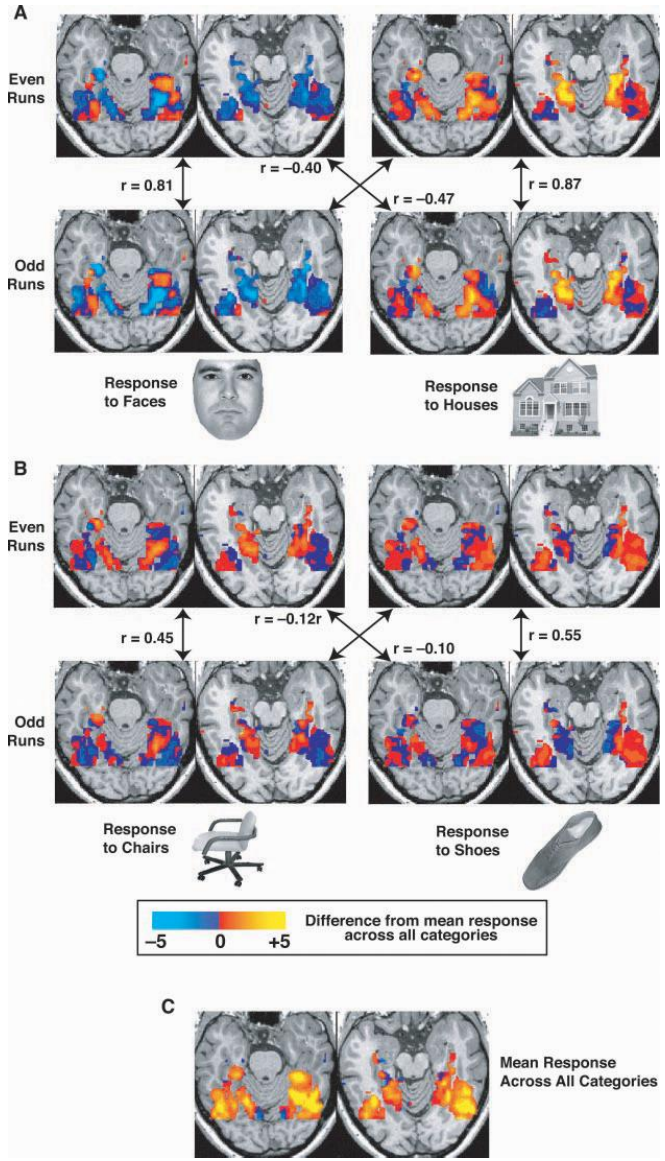
Problem:

Is there an area in the brain for every object category?

Hypothesis:

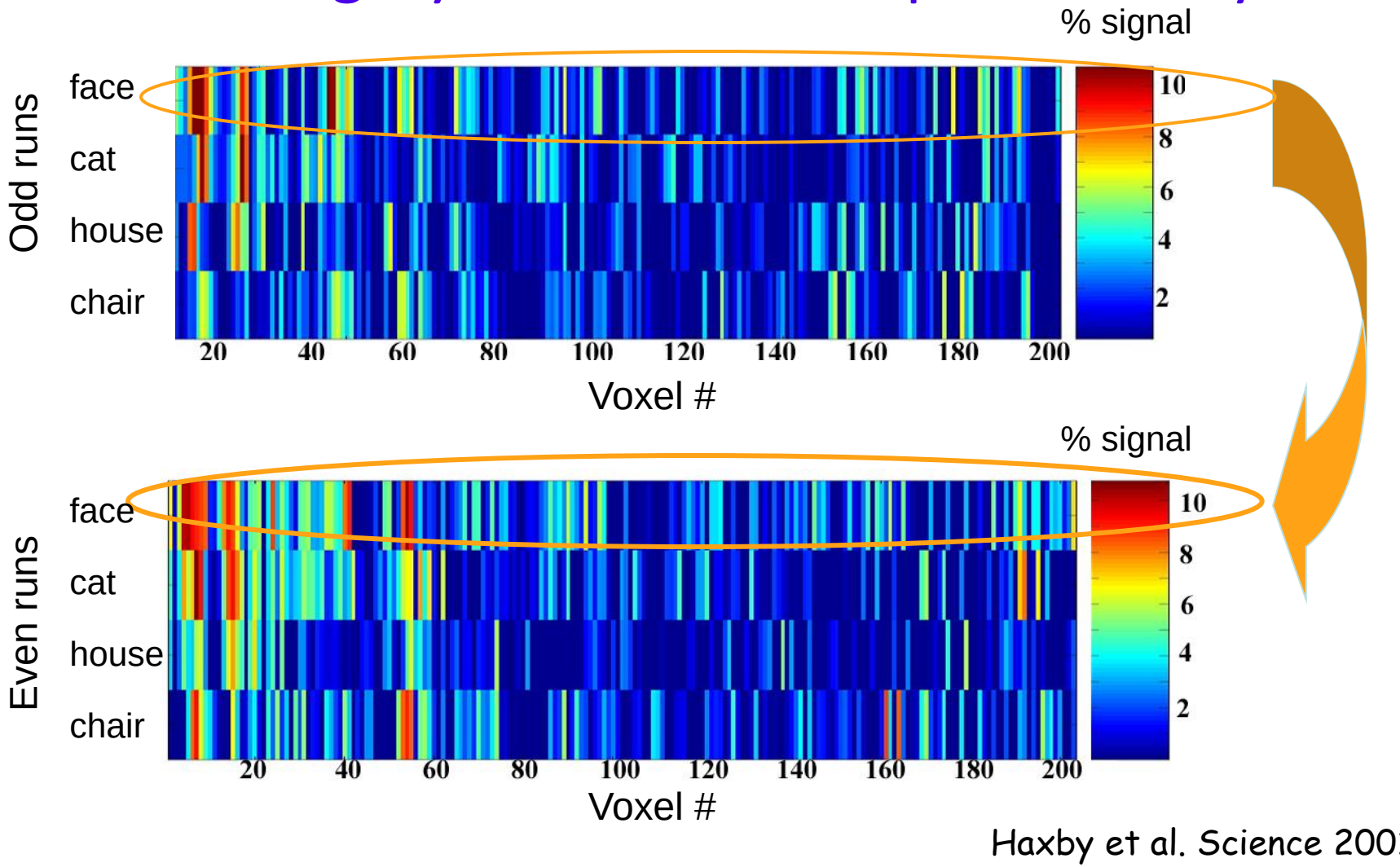
Distributed activation patterns across the ventral stream (rather than other brain areas) code object categories.

Haxby et al. Science 2001



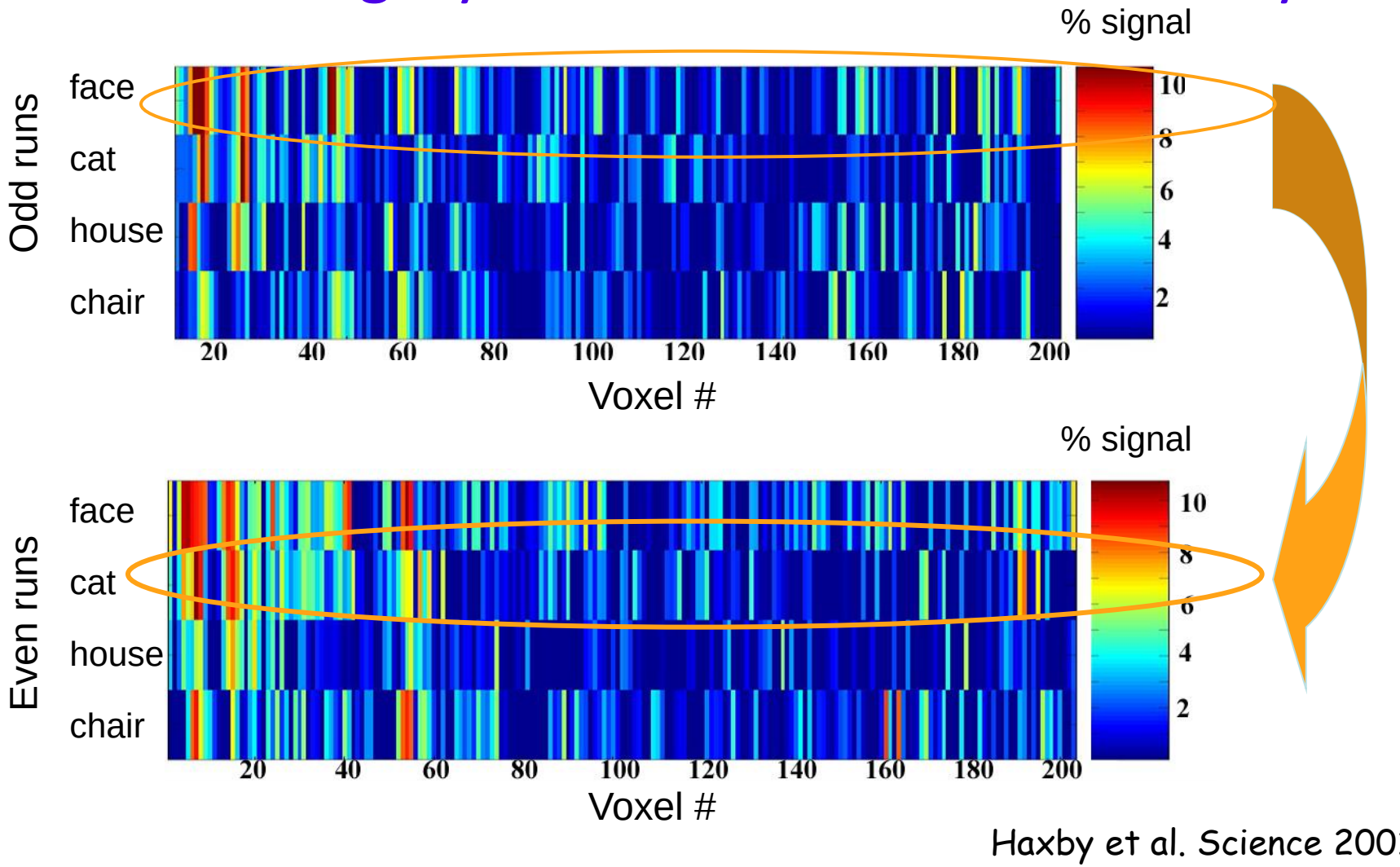
Haxby et al. Science 2001

Split-half analysis of multi voxel patterns: within-category correlation = reproducibility



Haxby et al. Science 2001

Split-half analysis of multi voxel patterns: between-category correlation = discriminability



Haxby et al. Science 2001

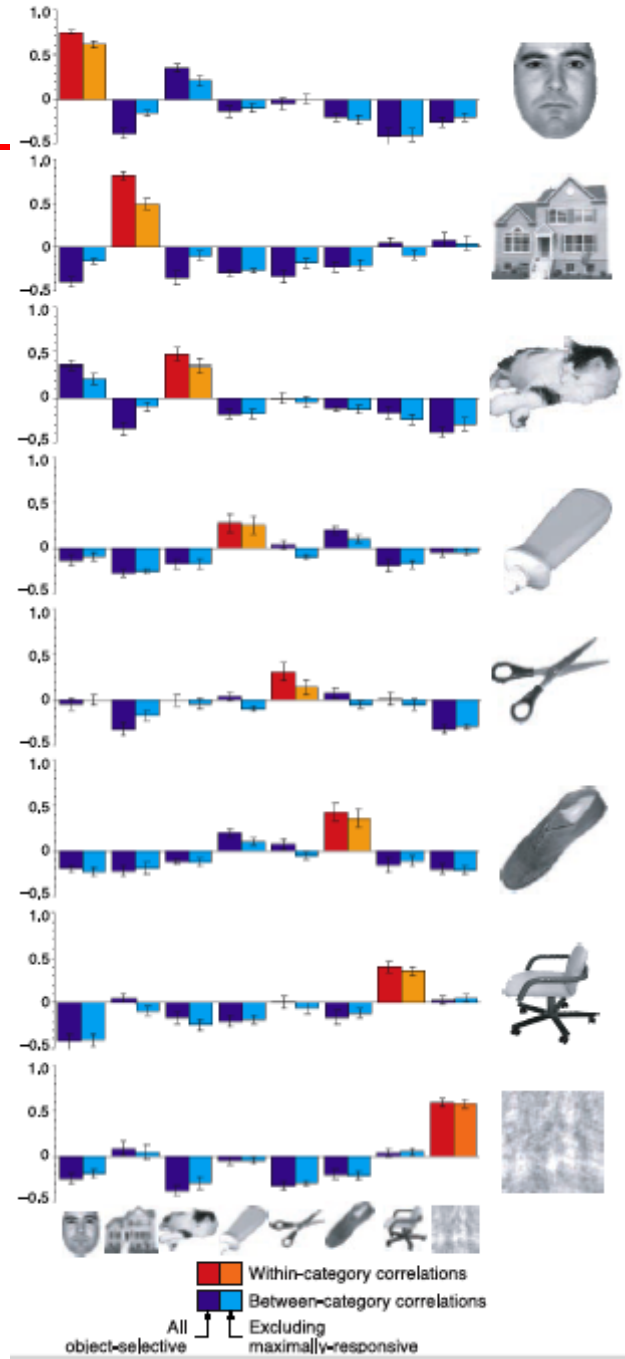


Fig. 4. Mean within-category and between-category correlations (±SE) between patterns of response across all subjects for all ventral temporal object-selective cortex (red and dark blue) and for ventral temporal cortex excluding the cortex that responded maximally to either of two categories being compared (orange and light blue). The SE of within-category correlations after excluding maximally responsive cortex was based on the mean correlation across 14 pairwise comparisons for each subject.

Ventral Temporal cortex activations

Haxby et al. Science 2001

Assignment-1

- ***Predicting fMRI-based task-related activation with Machine Learning***
- Based on Haxby et al. (2001) experiments and data.
- Build Binary Classification models (e.g., face vs house or face vs cat)
  - Consider brain responses at voxels in various regions of the brain (time series signals) as features and build binary classification model. pre-extracted from brain voxels of different brain regions are provided to you as 2D data feature matrix. These features are obtained from the following specifications:
  - Pre & Post-central, Superior Frontal & temporal, Inferior frontal, Cerebellar, and ventral temporal region.
  - All these data matrices are provided to you for 5 subjects.
- ML model can be anything of your choice and use *LeaveOneGroupOut* cross validation strategy to report the mean accuracies.
- Aim is to understand how patterns of fMRI activity time series signals extracted from the brain regions of distinct spatial locations contribute in discriminating various visual stimulus conditions (visual object recognition).

Human Connectome Project (HCP) Dataset

- WashU-Minn-Oxford Consortium
- www.humnconnectome.org
- 1200 healthy adults (22-35 yrs)
- Structural, Diffusion, Resting / Task fMRI
- 100 subjects with MEG
- Genotyping, Extensive behavioral testing

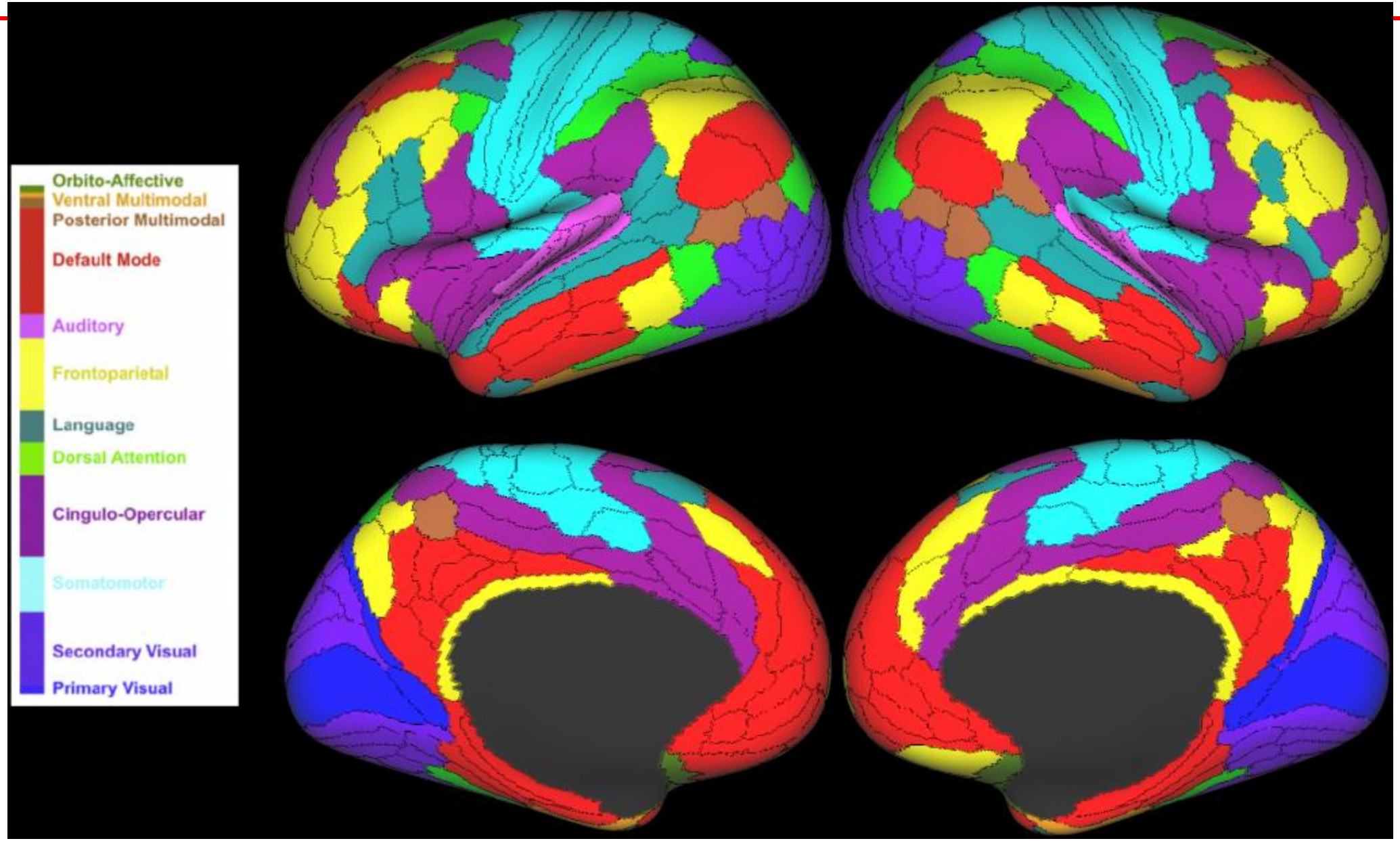
NeuromatchAcademy video of Saad Jbadi:
https://www.youtube.com/watch?v=i30qePz_OGY&ab_channel=NeuromatchAcademy

HCP – Task fMRI Data

Task	Behavioral Domains / Attributes
Emotion	Valence Judgments (faces); Shape Recognition
Gambling	Reward, Punishment, Decision Making
Language	Sentences, Stories, Mental Arithmetic (auditory)
Motor	Hand, Foot, Tongue movements
Relational	Higher-order Cognition
Social	Interpret Social vs Random Interactions
Working Memory (WM)	N-back WM: tools, body parts, places

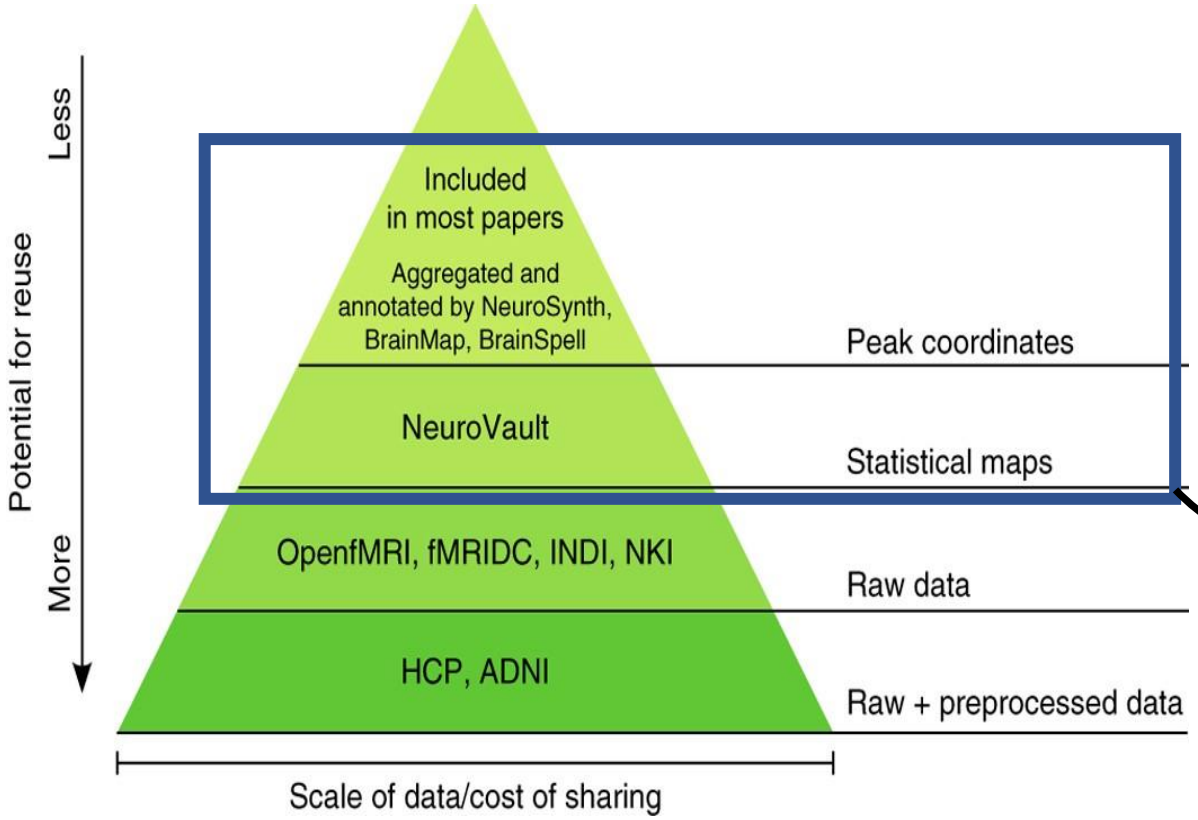
Barch et al. (2013). Function in the human connectome: Task-fMRI and individual differences in behavior. *Neuroimage*, **80**:169–189

Cole-Anticevic Brain Network Parcellation (CAB-NP)

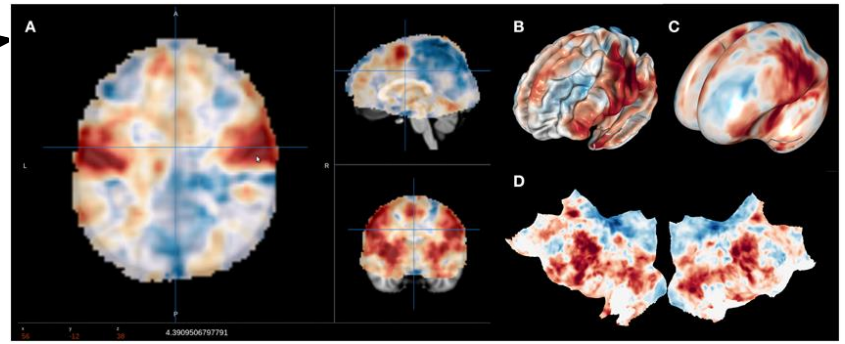


https://balsa.wustl.edu/rrg5v

Cognitive Neuroscience is becoming data-intensive: Statistical maps and its peak activations



X	Y	Z	T
45.0	-15.0	54.0	5.70
39.0	-24.0	66.0	5.64
36.0	-24.0	54.0	4.94
36.0	-12.0	63.0	4.57
9.0	-24.0	48.0	4.22
36.0	-21.0	9.0	4.08
-42.0	-21.0	51.0	-4.78
-36.0	-21.0	63.0	-4.39
-45.0	-12.0	42.0	-4.14
-27.0	-21.0	69.0	-4.08

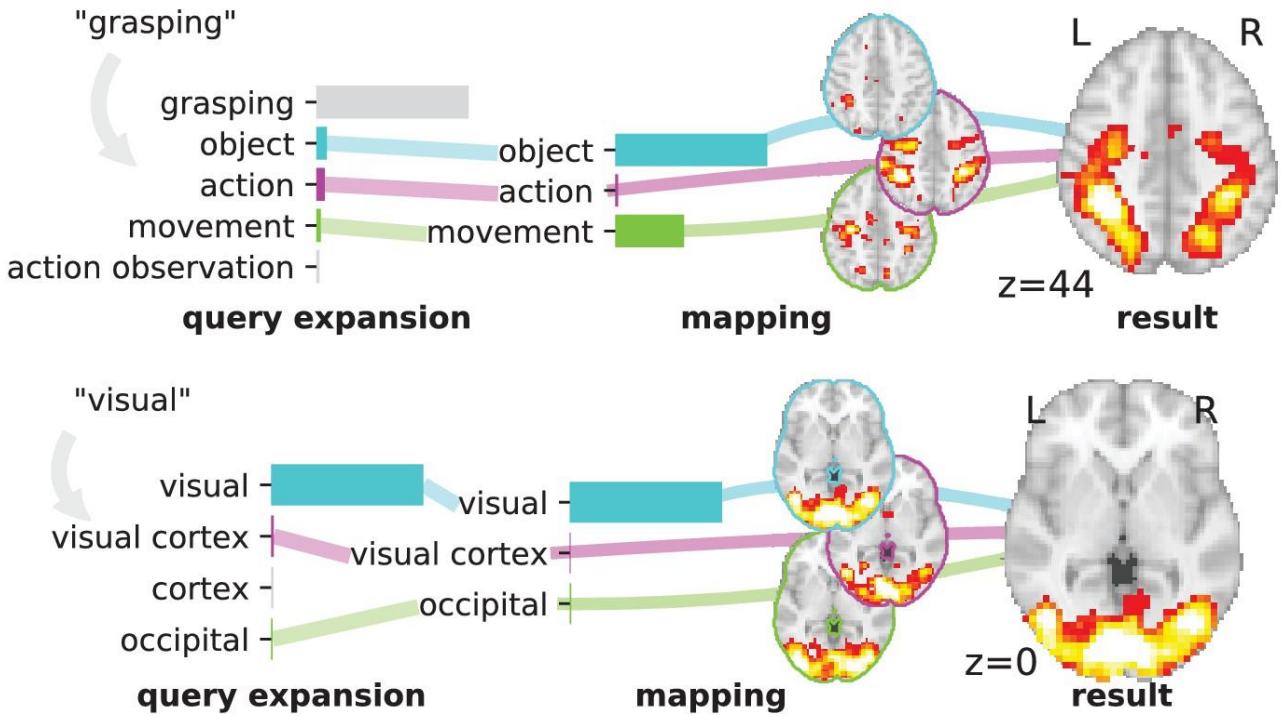


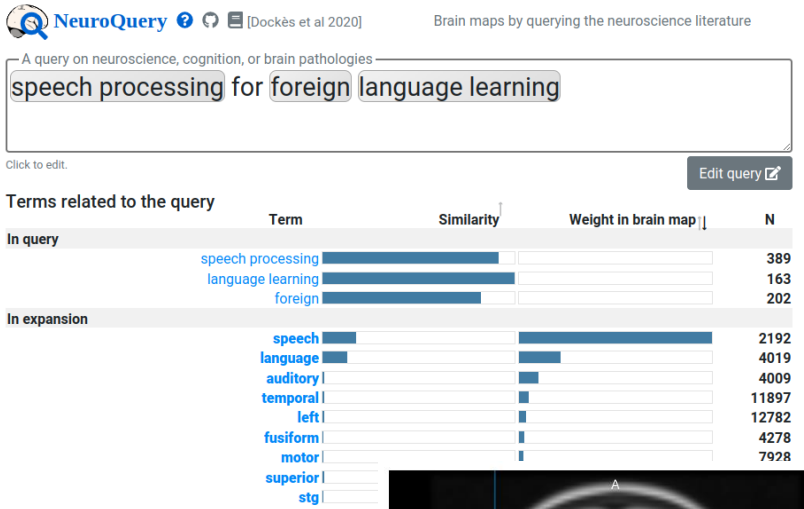
Poldrack, R., Gorgolewski, K. Making big data open: data sharing in neuroimaging. *Nat Neurosci* **17**, 1510–1517 (2014)

Gorgolewski KJ, et al., (2015) NeuroVault.org: a web-based repository for collecting and sharing unthresholded statistical maps of the brain. Front. Neuroinform.

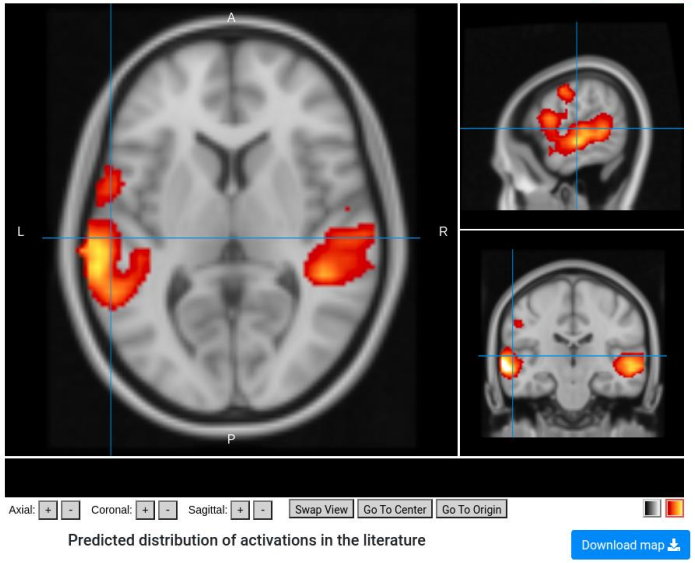
Large-scale study on peak coordinates: mapping text to brain

Extracting spatial information from text and transform it back to brain maps:
NeuroQuery or Neurosynth





https://neuroquery.org/



Jérôme Dockès et al., (2020) NeuroQuery, comprehensive meta-analysis of human brain mapping *eLife* 9:e53385.

HCP – tfMRI (task)

Table 4
Parameters for HCP Phase II task-fMRI.

Parameter	fMRI session 1			fMRI session 2			
Task	Working memory	Gambling	Motor	Language	Social cognition	Relational processing	Emotion processing
Frames per run	405	253	284	316	274	232	176
Run duration (min)	5:01	3:12	3:34	3:57	3:27	2:56	2:16
# of task blocks/run	8 (1/2 0-back, 1/2 2-back)	4 (1/2 reward, 1/2 punish)	10 (2 of each body part)	8 (1/2 story, 1/2 math)	5 (1/2 TOM, 1/2 Random)[b]	6 (1/2 relational, 1/2 control)	6 (1/2 face, 1/2 shape)
Duration of task blocks (s)[a]	25	28	12	See text	23	16	18
# of trials/block	10	8	10	See text	1	4 relational, 5 control	6
Duration of trial (s)	2.5	3.5	1.2	See text	20 (movie), 3 response	4 relational, 3.2 control	3
# of fixation blocks/run	4	4	3	NA	5	3	0
Duration of fixation blocks (s)	15	15	15	NA	15	16	NA
Task cue at start of block	Yes	No	Yes	No	No	No	Yes
Duration of task cue (s)	2.5	NA	3	NA	NA	NA	3
Duration of task initiation countdown at start of run (s)	8	8	8	NA	8	8	8

[a] Duration of task block does not include duration of task cue at start of block if one is present.
[b] Run 1 contains 2 Social and 3 Random motion blocks and Run 2 contains 3 Social and 2 Random motion blocks.

Barch et al. (2013). Function in the human connectome: Task-fMRI and individual differences in behavior. *Neuroimage*, **80**:169–189

Table 1
Candidate task domains for task-FMRI in the Human Connectome Project.

Domain(s)	Task	Regions of interest
Visual, somatosensory motor • Localizer: (Drobyshevsky et al., 2006; Gountouna et al., 2009; Hirsch et al., 2000); reliable across subjects (Drobyshevsky et al., 2006; Hirsch et al., 2000) and time (Warnking et al., 2002)	Retinotopic mapping Finger responses	Primary motor; premotor; striatum; retinotopic visual areas
Category-specific representations • Localizer: (Downing et al., 2001; Fox et al., 2009; Peelen and Downing, 2005; Taylor et al., 2007); reliable across subjects (Downing et al., 2001; Fox et al., 2009) and time (Kung et al., 2007; Peelen and Downing, 2005)	Alternating blocks of 0-back and 2-back working memory; faces, non-living man-made objects, animals, body parts, houses, or words.	Fusiform; occipital face areas; superior temporal sulcus; lateral occipital; parahippocampal gyrus; visual word form area
Working memory; cognitive control • Localizer: (Drobyshevsky et al., 2006); reliable across subjects (Drobyshevsky et al., 2006) and time (Caceres et al., 2009)	N-back task (2-back versus 0-back) embedded in category specific representation task	Dorsolateral + anterior prefrontal; inferior frontal; precentral gyrus; anterior cingulate; dorsal parietal
Dorsal and ventral attention systems • Reliable across subjects and robust activation in fMRI (Doricchi et al., 2010; Engelmann et al., 2009)	Variant of Posner task (compare blocked and event-related versions)	Frontal eye fields; supplementary eye fields; precuneus; intraparietal sulcus: anterior, posterior cingulate
Language processing • Reliable across subjects (Binder et al., 2011) and robust activation in both fMRI and ERP (Ditman et al., 2007; Kuperberg et al., 2008)	1) Auditory sentence presentation with detection of semantic, syntactic and pragmatic violations; versus 2) auditory story presentation with comprehension questions versus math problems	Inferior frontal; superior temporal; anterior cingulate

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Table 1
Candidate task domains for task-FMRI in the Human Connectome Project.

Domain(s)	Task	Regions of interest
Emotion processing • Localizer: (Drobyshevsky et al., 2006; Phan et al., 2004); reliable across subjects (Drobyshevsky et al., 2006; Phan et al., 2004) and time (Manuck et al., 2007), robust activation in fMRI (Hariri et al., 2002)	1) Valence judgments (negative and neutral pictures from IAPS) versus 2) Hariri Hammer Task	Amygdala; hippocampus; insula; medial prefrontal
Memory • Localizer: (Miller et al., 2002, 2009); reliable across subjects (Miller et al., 2002, 2009) and time (Miller et al., 2002, 2009)	Remember, know, new recognition judgments on category-specific task stimuli	Parietal; hippocampus; entorhinal cortex
Reward & decision making • Reliable across subjects and robust activation in fMRI (Delgado et al., 2000; Forbes et al., 2009; May et al., 2004; Tricomi et al., 2004)	Gambling decision making task (compare blocked and event-related versions)	Striatum; ventral medial prefrontal; orbitofrontal
Social cognition • Reliable across subjects and robust activation in fMRI (Castelli et al., 2000, 2002; White et al., 2011)	Frith–Happe animations of social and random interactions	Medial prefrontal cortex; temporal parietal junction; inferior and superior temporal sulcus
Biological motion • Localizer: (Peuskens et al., 2005)	Point light displays of biological motion versus random motion versus static dot displays	MT+; visual cortex
Motor strip mapping • Localizer: (Bizzi et al., 2008; Morioka et al., 1995)	Right versus left toe movements or finger movements; tongue movements	Motor and somatosensory cortex
Higher order relational processing • Localizer: (Smith et al., 2007)	Alternating blocks of judgments about relations among features versus feature matching	Anterior prefrontal cortex

Barch et al. (2013). Function in the human connectome: Task-fMRI and individual differences in behavior. *Neuroimage*, **80**:169–189

Emotion

- Valence Judgments (faces); Shape Recognition

- The participants are presented with blocks of trials that ask them to decide
  - either which of two faces presented on the bottom of the screen match the face at the top of the screen (face matching),
  - or which of two shapes presented at the bottom of the screen match the shape at the top of the screen (shape matching).
  - The faces have either angry or fearful expressions.
- In phase I, we compared this task to one using negative and neutral IAPS pictures.

Gambling

- Reward, Punishment, Decision Making

- The participants play a card guessing game where they are asked to guess the number on a mystery card (represented by a "?") in order to win or lose money.
- They are told that potential card numbers range from 1 to 9 and to indicate if they think the mystery card number is more or less than 5 by pressing one of two buttons on the response box.
- Feedback is the number on the card (generated by the program as a function of whether the trial was a reward, loss or neutral trial) and either:
  - 1) a green up arrow with "$1" for reward trials,
  - 2) a red down arrow next to −$0.50 for loss trials; or
  - 3) the number 5 and a gray double headed arrow for neutral trials.
- All the participants are provided with money as a result of completing the task, though it is a standard amount across subjects.

Language Processing

- Sentences from Stories, Mental Arithmetic (both are auditory)

- The task consists of two runs that each interleave 4 blocks of a story task and 4 blocks of a math task.
- The story blocks present participants with brief auditory stories (5–9 sentences) adapted from Aesop's fables, followed by a 2-alternative forced choice question that asks the participants about the topic of the story.
- The example provided in the original Binder paper (p. 1466) is “For example, after a story about an eagle that saves a man who had done him a favor, participants were asked, ‘That was about revenge or reciprocity?’”
- The math task also presents trials auditorily and requires the subjects to complete addition and subtraction problems. The trials present the subjects with a series of arithmetic operations (e.g., “Fourteen plus twelve”), followed by “equals” and then two choices (e.g., “twenty-nine or twenty-six”).
- The participants push a button to select either the first or the second answer.

Motor

- Hand, foot, tongue movements

- The participants are presented with visual cues that ask them to
  - tap their left or right fingers,
  - squeeze their left or right toes, or
  - move their tongue
- The idea is to map motor areas.
- Each block of a movement type lasts 12 s (10 movements), and is preceded by a 3 s cue.

Relational

- Higher-order Cognition

- The stimuli are 6 different shapes filled with 1 of 6 different textures.
- In the relational processing condition,
  - the participants are presented with 2 pairs of objects, with one pair at the top of the screen and the other pair at the bottom of the screen.
  - They are told that they should first decide what dimension differs across the top pair of objects (shape or texture) and then they should decide whether the bottom pair of objects also differs along that same dimension (e.g., if the top pair differs in shape, does the bottom pair also differ in shape).
- In the control matching condition,
  - the participants are shown two objects at the top of the screen and one object at the bottom of the screen, and a word in the middle of the screen (either “shape” or “texture”).
  - They are told to decide whether the bottom object matches either of the top two objects on that dimension (e.g., if the word is “shape”, is the bottom object the same shape as either of the top two objects).

Social Cognition

- Interpret Social vs Random Interactions.

- The participants are presented with short video clips (20 s) of objects (squares, circles, triangles) either interacting in some way, or moving randomly [Castelli et al. (2000); Wheatley et al. (2007)].
- After each video clip, the participants chose between 3 possibilities:
  - whether the objects had a social interaction (an interaction that appears as if the shapes are taking into account each other's feelings and thoughts),
  - Not Sure, or
  - No interaction (i.e., there is no obvious interaction between the shapes and the movement appears random).
- Each of the two task runs has 5 video blocks (2 Mental and 3 Random in one run, 3 Mental and 2 Random in the other run) and 5 fixation blocks (15 s each).

Working memory (WM) Task

- N-back WM: tools, body parts, places

- Embedded the category specific representations component within the working memory task, by presenting blocks of trials that consisted of pictures of faces, places, tools and body parts.
- Within each run, the 4 different stimulus types are presented in separate blocks within the run.
- Within each run,
  - 1/2 of the blocks use a 2-back working memory task (respond ‘target’ whenever the current stimulus is the same as the one two back) and
  - 1/2 use a 0-back working memory task (a target cue is presented at the start of each block, and
  - the person must respond ‘target’ to any presentation of that stimulus during the block).