Semantic object grouping in the visual cortex seen through MVPA

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Semantic encoding in perception of visual objects

- The hierarchy of semantic information encoded in the brain is unclear
- Huth (2012) proposed a subset of categories to predict voxel-level firing for semantic properties; Sudre (2012) proposed a larger set of semantic properties to predict MEG activity in broader cortical regions
- We study semantic properties of Sudre (2012), using representational dissimilarity analysis (Kriegeskorte 2008) and more fine-grained BOLD MVPA
- We identify more spatially-localized ROIs in mid-level vision with a subset of studied semantic representations, partially consistent with Sudre (2012)

fMRI study

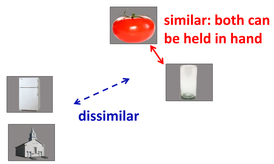
- Participants shown photos of 60 real-world objects, 6 x each, passive viewing

- BOLD signals recorded with slow event-related design (2 sec TR, partial coverage) for 3 subjects

Data from Leeds et al., Journal of Vision 2013

Representational dissimilarity analysis

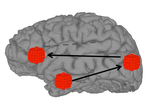
- Representational dissimilarity: use pairwise distance matrix to show how stimuli are grouped by each neural and computational representation



Pairwise distance matrix

0	.7	.8
.7	0	.1
.8	.1	0

- **Neural:** 123-voxel sphere of responses at each location across the cortex



- **Semantic models:**

Disagree/agree (scale of 1-5) responses to 218 "semantic" questions

- Identity
- Emotion
- Action
- Location

Micah Lawrence, The Noun Project

Can it fly?

Is it friendly?

Luc Viator/www.Lucnix.be

Would you find it in a house?

Questions from Sudre et al., 2012

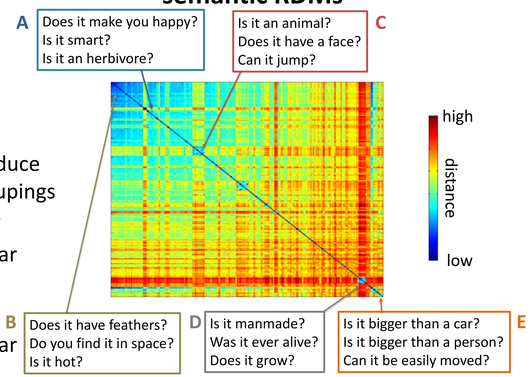
- **Neural vs model comparison:** Spearman correlation between elements of neural and model distance matrices

Comparing semantic groupings

Representational distance matrix (RDM) computed for comparing 60 objects using each of 217 semantic questions

We compute the pairwise correlation among RDMs (compare pairs of semantic questions; matrix to the right)

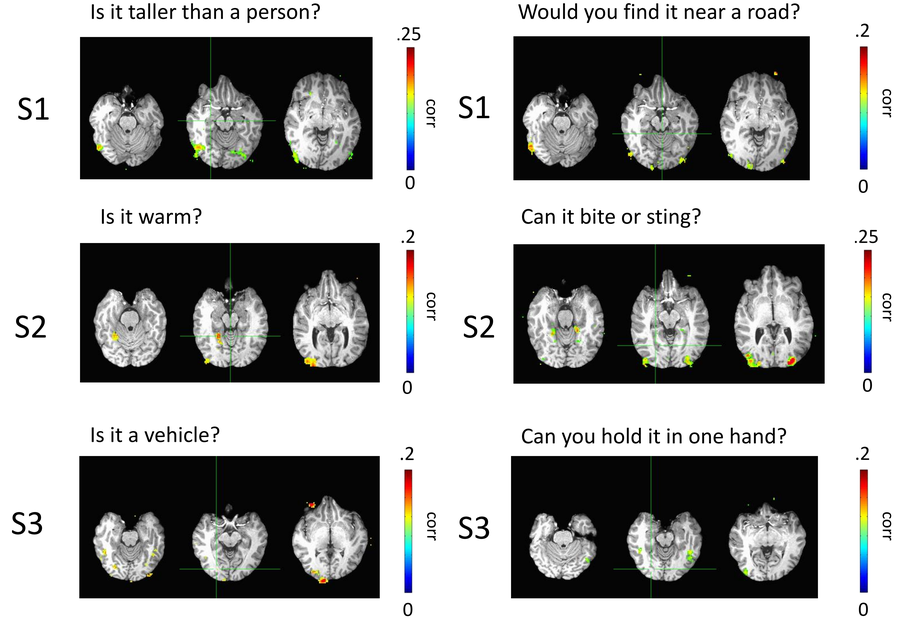
Pairwise comparisons among semantic RDMs



- Over 100 semantic questions produce mutually distinct RDM object groupings
- Several "non-intuitive" clusters of semantic questions produce similar RDMs (boxes **A**, **B**)
- Several "intuitive" clusters of semantic questions produce similar RDMs (boxes **C**, **D**, **E**)

Same semantic groupings in multiple regions of mid-level vision

Permutation testing for q<0.01



ROIs with semantic groupings

Often associated with mid-level vision

- Lateraloccipital (LO)
- Fusiform (Fus)
- Inferoparietal (IP)
- Inferotemporal (IT)

ROI varies by semantic question

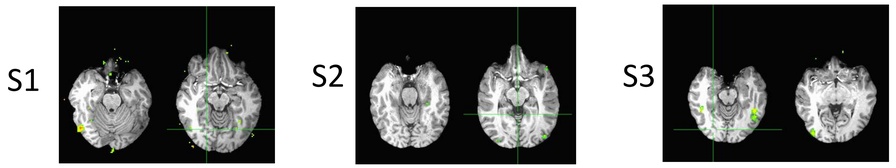
Significant semantic groupings

Diverse classes of semantic properties

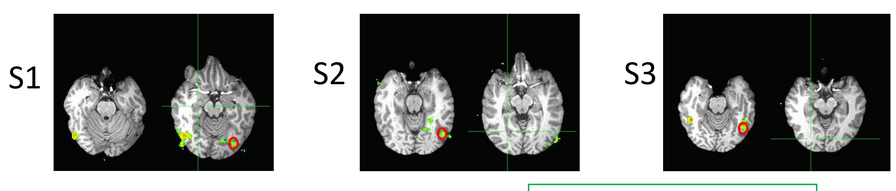
- Physical (size, 3D structure)
- Action
- Somatosensory
- Location
- Identity

Cross-subject consistency

Can you hold it in one hand? – INCONSISTENT



Is it taller than a person? – "CONSISTENT"



We test for anatomical regions with more than 6 voxel spheres showing semantic match of q<0.01

- Few semantic properties consistent in regional match across all three subjects
- Most consistent region is lLO
- "Consistent" anatomical match varies in exact location on Talairach brain

Consistent properties (from 20 tested)

- Is it taller than a person?
  lFus, lLO, rIP
- Is it tasty?
  lIP
- Is it hollow?
  lLO, rLO
- Is it a vehicle?
  lLO

Common **MEG** semantic regions:

- l/rLO
- l/rFus
- l/rIP
- l/rIT

Comparison with prior MEG data

- Regions consistently predicted in MEG were common match regions for single MVPA subjects
- 50% of consistent match regions in MVPA were consistently predicted in MEG
- Under 50% of consistently predicted MEG regions were consistent matched in MVPA

Number of semantic model matches per region

	LO	Fus	IP	IT
Only MVPA	3	1	1	1
Only MEG	8	9	10	9
MVPA & MEG	4	2	5	0

Discussion

- Lateral-occipital cortex groups objects consistent with diverse semantic properties
- Semantic property groupings observed in other mid-level visual regions
- Noun-category, size, and action groupings prominently match cortical groupings, emotional and touch-sensation groupings less prominent
- RDM MVPA results only partially consistent with analysis of prior MEG data

References

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Acknowledgments

Fordham University Faculty Research Grants; **Carnegie Mellon University** Shared data from labs of Michael Tarr (Leeds et al. 2013) and Tom Mitchell (Sudre et al., 2012)