Mapping the similarity space of concepts in sensorimotor cortex

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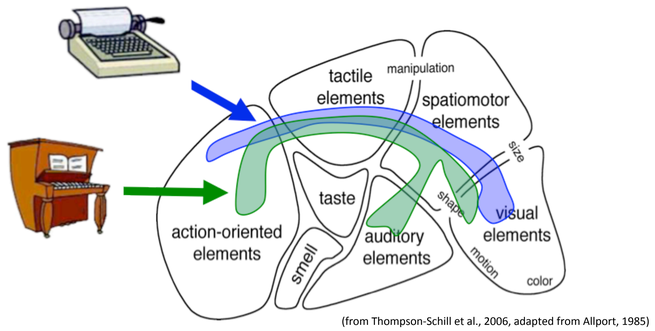
Background

Sensorimotor-based theories of semantic memory:

- Object concepts are represented as a pattern of activation distributed over semantic features
- Because of this architecture, concepts that share features have overlapping representations:



(from Thompson-Schill et al., 2006, adapted from Allport, 1985)

Evidence of sensorimotor-based representations:

- Retrieving an object's sensorimotor attributes (e.g., shape, manipulation) activate brain regions in, or near those involved in perception or action (see Thompson-Schill, 2006 for a review)

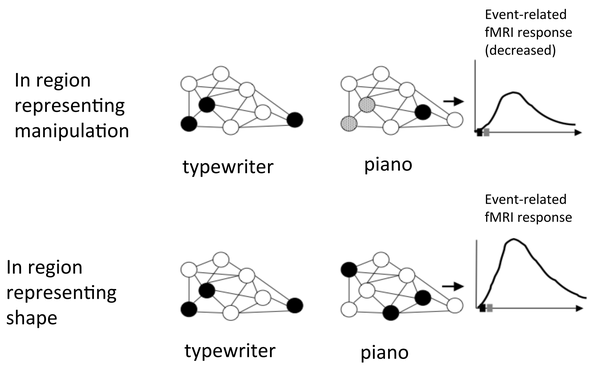
Evidence of overlapping representations:

- Objects that share features partially activate each other:
  - Sensorimotor (shape and manipulation) features (e.g., Schreuder et al., 1984; Myung et al., 2006; Yee et al., 2010)
  - Non-sensorimotor/abstract (function) features (e.g., Schreuder et al., 1984; Yee et al., 2010)

Measuring neural similarity of overlapping representations:

fMRI adaptation

- Repeating two identical or related stimuli sequentially activates the same sub-voxel population of neurons, resulting in a reduced response
- Sequential presentation of two similar stimuli should result in decreased neuronal activity in the regions that represent their similarity



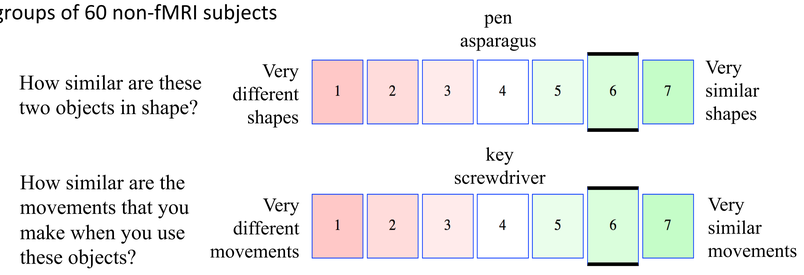
Questions

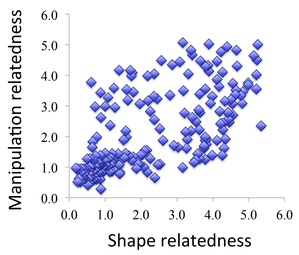
- **Do the representations of objects that share sensorimotor features overlap in sensorimotor regions?**
  - Shape similarity : overlap in areas involved in perceiving visual form?
  - Manipulation similarity : overlap in regions responsible for performing actions?
- **Are there anatomically distinct similarity spaces for representing shape and manipulation? Do they interact?**

Methods

Stimuli

Separate similarity ratings for shape and manipulation (222 item pairs) by two independent groups of 60 non-fMRI subjects

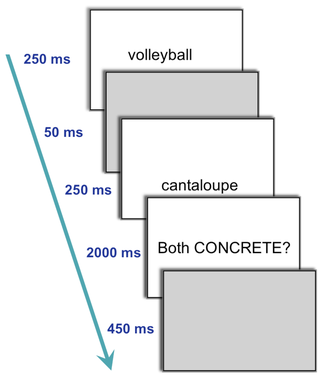




Correlation between shape and manipulation ratings: R^2 = 0.45

fMRI procedure

- Subjects (n=16) view word pair sequentially
- Task: do BOTH of the words refer to concrete entities?
- Catch trials: one or both words are abstract concepts (12% of trials)
- Both words must be processed to perform task on critical trials



References

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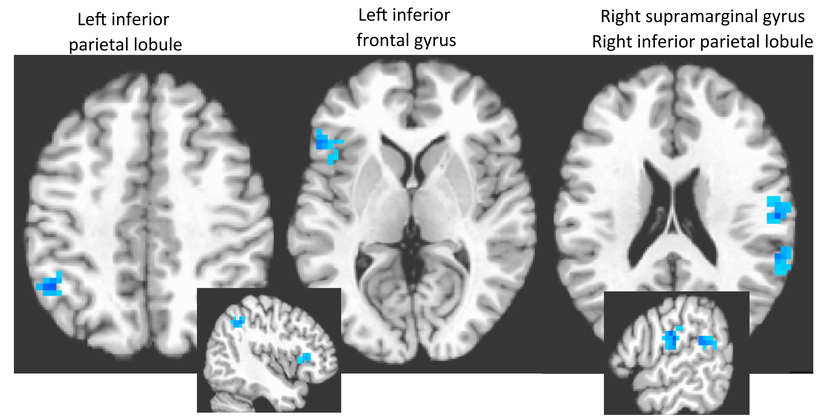
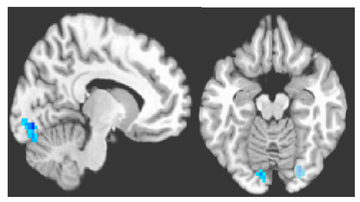
Results: Whole brain analyses

Whole brain analysis (corrected) yielded 7 clusters in which activity was significantly correlated with an item pair's similarity on manipulation or shape.

Manipulation similarity correlates positively with adaptation in:



Shape similarity correlates positively with adaptation in:



Left lingual gyrus
z = -9.5

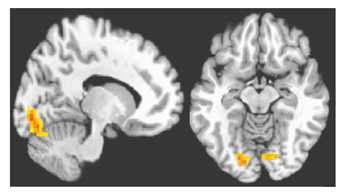
Main Findings

- Adaptation in motor planning and action regions (bilateral IPL and left IFG) is positively correlated with manipulation similarity
- Adaptation in visual form area (left lingual gyrus) is positively correlated with shape similarity (right lingual gyrus cluster appears at p = .20)

Unexpected Findings

- Adaptation in ***visual*** form areas (bilateral lingual gyrus) is ***negatively*** correlated with ***manipulation*** similarity.

  Inverse-adaptation: Greater manipulation similarity produces *more* activation in bilateral lingual gyrus.



Bilateral lingual gyrus
z = -6.5

Discussion

Objects that share features have overlapping neural representations in areas predicted by sensorimotor-based theories of semantic memory

- Adaptation for shape similarity in ventral stream regions involved in visual form, and adaptation for manipulation-related objects in dorsal stream regions involved in object-related actions

Inverse adaptation effects for manipulation similarity in shape regions:

- A contrast enhancement effect to magnify shape differences amidst manipulation similarities?
- Complements Yee et al. (2010), which found inverse adaptation effects for shape similarity in motor regions

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