fMRI-adaptation evidence of overlapping neural representations for objects related in function or manipulation

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Background

Sensorimotor-based theories of semantic memory:
- Concepts are represented as patterns of activation that are distributed over semantic features, with sensorimotor features situated in sensorimotor regions.
- This means that concepts that share features have overlapping representations.

fMRI evidence of sensorimotor-based representations:
- Retrieving an object’s sensorimotor attributes (e.g., shape, manipulation) activates brain regions in, or near those involved in perception or action.

Indirect evidence of overlapping representations:
- Objects that share sensorimotor features (shape or manipulation) partially activate each other.
- Objects that share non-sensorimotor/abstract feature (function) partially activate each other.

How to obtain neural evidence of overlapping representations? fMRI-adaptation:
- Repeated presentation of same or related stimuli produces reduced fMRI signal in regions that process that stimuli.
  - E.g., for a function-related pair (lightbulb-candle), sequential presentation should produce adaptation in regions representing function, but not shape.

Questions

- Do representations of objects that share sensorimotor features (shape or manipulation) overlap in sensorimotor regions?
  - That is, do they overlap in regions responsible for perceiving visual form or performing action?
- Do representations of objects that share a more “abstract” feature (function/purpose) overlap in multi-modal regions?
  - That is, do they overlap in regions hypothesized to integrate information from multiple modalities?

Methods

Stimuli

- Similarity ratings (60 non-fMRI subjects)

Procedure

- Subject views word pair (sequentially)
- Probe appears (e.g., tasty)?
- Task: Does probe apply to either of the two words?
- Probes (39, randomly ordered) query visual, functional, tactile, etc., properties

Design/Analysis

- Event-related design
- 360 pairs (5 conditions, 36 pairs/condition, each pair seen twice)
- 8 runs, 45 pairs/run
- For item analyses, each pair modeled separately
- fMRI analysis includes only 2sec interval prior to probe

Results: Whole Brain Item Analyses:

Correlating activation with similarity ratings (irrespective of condition)

Manipulation similarity correlates negatively with activation in:
- Left premotor cortex, extending into IFG
- Left intraparietal sulcus (involved in guiding actions)

Function similarity correlates negatively with activation in above two regions plus:
- Left posterior middle temporal gyrus (multimodal integration)

Shape similarity not correlated with activation in any regions
- Poor coverage? Poor coverage highlighted in pink
- Procedure insensitive to rapidly activating and deactivating shape info?

Results: Behavioral Priming & Neural Adaptation in fROIs

Behavioral Priming (response to probe)

ROFI Analysis (7 regions in which task > ITI)

Results: Puzzle

Why “inverse-adaptation” for shape condition in action regions?
- For such pairs we may accentuate differences in manipulation to avoid errors: Don’t eat marbles!
- If true, then after excluding pairs high in shape and function, there should be a positive relationship between shape similarity and activation in areas that represent manipulation
- There is! Shape similarity positively correlated with activation in L premotor/IFG (r = .18, p = .05).

Conclusions

- Objects sharing features have overlapping neural representations
  - Adaptation for manipulation-related objects in dorsal stream regions involved in object-related actions
  - Adaptation for function-related objects in “multi-modal” regions
- Overall, results consistent with sensorimotor-based distributed models of semantic memory that incorporate means to extract higher order features

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