Neuropsychological Evidence for Category Structure
Then:
The Functional Role of Mental Imagery

Psychology 355: Cognitive Psychology
Instructor: John Miyamoto
05/19/2016: Lecture 08-4

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Outline

• Neuropsychological evidence for category representations.

Mental Imagery

• Imagery Debate – Do mental images play a functional role in human cognition?

• Evidence in favor of the functional role of imagery.

• Are perception and imagery similar processes?
  ♦ Behavioral evidence
  ♦ Neuropsychological evidence

Lecture probably ends here
What Is the Neural Representation of Category Knowledge?

- Are there object-specific or person-specific neural representations?
  - Are there specific neurons that are sensitive to specific objects or persons?
    - Are there grandmother cells?

- How is knowledge of categories of objects represented at the neural level?
Evidence for Category-Specific Neurons


- Single-cell recordings from 11 epilepsy patients awaiting surgery.

- Neurons found in the temporal lobe that respond best to specific classes of objects.

- Category-specific neurons for:
  - faces;
  - famous faces;
  - animals;
  - cars;
  - buildings;
  - spatial layouts;
  - abstract patterns
Multimodal Category Representations

• Category knowledge includes knowledge of ....
  ♦ an object's visual appearance, e.g., what a dog looks like;
  ♦ typical sounds, e.g., what kinds of sounds you would expect from a dog;
  ♦ function, e.g., what you would use a hammer for;
  ♦ smell, e.g., what a dog smells like; what a flower smells like; what a fire smells like;
  ♦ taste, especially true of foods
  ♦ typical body actions that relate to it, e.g., we have a representation of the body actions with respect to a hammer, a chair, a chest of drawers

• Multimodal representations involve multiple sensory modes, vision, audition, touch, kinesthesia, and so forth.

Example: The Grasping Circuit
Example of a Multimodal Category Representation: The Grasping Circuit for Manipulable Objects

- The *Grasping Circuit* – a neural circuit associated with use of manipulable objects, like hammers, screwdrivers, tennis rackets, etc.
  - Involves pathways in parietal cortex
- Question: Are the neural circuits involved in handling a hammer part of the category representation of "hammer"?

fMRI Images While Viewing Hammers, Buildings, Animals & People,
Hammer use activates the left ventral premotor cortex & left posterior parietal cortex (grasping circuit).

Subjects are immobile in the scanner so they could not grasp anything.

Nevertheless, viewing a hammer activated the grasping circuit.

- Supports the hypothesis that we activate object-appropriate motor association areas when we access category knowledge.
- Supports the view that category knowledge is multimodal.
Summary – Neural Representations of Category Knowledge

• Some neurons may be specific to particular people or objects. (Controversial Issue)

• Some neural mechanisms are specific to particular kinds of objects.
  ♦ Not necessarily single neurons – the mechanism may involve distributed processing.

• Neural category representations are multimodal.

• As yet, we only have a preliminary understanding of neural representations of category knowledge. *This is a good field for someone with a scientific pioneering spirit.*
Visual Images – What Are They?

• Mental Imagery: Experiencing a sensory impression in the absence of sensory input
  ♦ Visual imagery: “seeing” in the absence of a visual stimulus
# The Debate Over Mental Imagery

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Basic Approach to Arguing for the Functional Role of Mental Imagery

• Find behavioral or neuropsychological evidence that is ...
  ♦ easy to explain if we assume that humans possess and use perception-based representations, but ...
  ♦ hard to explain if we assume that we have only propositional representations.

• In general, these arguments are not air tight, but they can be strong and convincing.
  ♦ Example of Ptolmaic circles in astronomy

• Related Hypothesis: Humans use analog representations. I.e., Humans use representations that are analogous to working with real physical objects.
• TASK: As quickly as possible, decide whether the two figures have the same shape or different shapes.

• Mental rotation experiments: Influential argument for the importance of mental imagery in cognitive processes.
Mental Rotation - Results

- Response time for "identical" figures is a linear (straight-line) function of the angle of rotation between the figures.
  - Result is easy to explain if subjects are rotating a mental image.
  - Result is hard to explain if mental representation is exclusively propositional.
• **Figure 10.4:** Image scanning is discussed in Goldstein, pp. 273 - 274.

• Subjects study the map of the island. Then take it away.

• Using only the mental image of the island, imagine a dot moving from one point to another, e.g., from the mountain to the tree. Push a button when you are done.
**Top**: Imagine a rabbit next to an elephant.

Yes or No: Does the rabbit have whiskers?

**Bottom**: Imagine a rabbit next to a fly.

Yes or No: Does the rabbit have whiskers?
**Top:** Imagine a rabbit next to an elephant.
Yes or No: Does the rabbit have whiskers?

\[ RT = 2,020 \text{ ms} \quad \text{slower} \]

**Bottom:** Imagine a rabbit next to a fly.
Yes or No: Does the rabbit have whiskers?

\[ RT = 1,870 \text{ ms} \quad \text{faster} \]

RT result is hard to explain if you assume that information is retrieved from a semantic network without imagery.
Can Imagery Prime Perception?

- Priming – Stimulus A can prime Stimulus B if A is similar to B.

Why? Theoretical reason is that A and B activate similar brain areas or processes, so the recent activation by A facilitates the processing of Stimulus B.

- Question: Can imagining a visual representation prime the perception of a real visual stimulus?

Images Can Act as Primes for Real Visual Displays

Step (a): Create mental image of H or T while staring at a blank screen.

Step (b): After forming a good image, subject presses a button that causes 2 screens to be displayed one after the other. One screen has an H or a T, the other screen is blank.

Task: Say whether the letter was on the 1st or the 2nd screen.
Images Can Act as Primes for Real Visual Displays

Will priming occur?

Will these responses be slower?

Will these responses be faster?

Results of Farah's Experiment

Psych 355, Miyamoto, Spr '16
Results: Images Act as Primes for Real Visual Displays

Results:
When mental image is same as target, percent correct is higher.

Interpretation:
Forming the mental image requires similar brain activity to actual perception. Therefore forming the mental image primes the perception of the target.

Conclusion: Imagery Plays a Functional Role in Cognition
Yes – Mental Imagery Plays a Functional Role in Cognition

• Lots of evidence –
  ♦ Image scanning (RT pattern consistent with mental image)
  ♦ Zooming in or out with image (RT pattern consistent with mental image)
  ♦ Image can prime detection task

Evidence is easy to explain if we postulate that people use mental imagery; Evidence is hard to explain if we claim that people only use propositional representations.

• Next Question:
  How similar are perception and imagery?
Neuropsychological Evidence for Similarity Between Perception & Mental Imagery

• Neural response is similar when perceiving an object or imagining the object.
  ♦ Single cell studies - neurons that respond to perceiving or imagining an object.
  ♦ fMRI studies - similar brain activity when perceiving an object or imagining the object.
  ♦ Transcranial magnetic stimulation (TMS) has similar effect (slower response) on tasks based on perception and on imagery.
Single-Cell Studies of Perception & Imagery


- Cell is sensitive to perception and mental image of baseballs, but not to faces.

• Cell is sensitive to perception and mental image of baseballs, but not to faces.
Single-Cell Studies of Perception & Imagery


- Cell is sensitive to perception and mental image of baseballs, but not to faces.

- Also found other cells that were selective for perception & imagery of animals, famous people, and food.
fMRI Studies of Perception and Imagery

- Perception of objects and imagining an object produces similar activation in visual cortex.

Goldstein Figure 10.13

Parahippocampal place area (PPA) and Fusiform face area (FFA)

Diagram of Brain From the Side Facing Left

fMRI Study of Face and Place Perception/Imagery

FFA: Fusiform face area. Specialized for faces.

PPA: Parahippocampal place area. Specialized for representing location info.

Subjects either view or imagine a face 😊 or place 🏡.
fMRI Study of Face and Place Perception/Imagery

Subjects view a face 😊 or place 🏡. Face stimulus activates FFA; place stimulus does not.

FFA: Fusiform face area. Specialized for faces.

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Place stimulus activates PPA; face stimulus does not.
face and place stimuli have opposite effects on FFA and PPA.

*Double dissociation when perceiving faces or places.*
FFA: Fusiform face area. Specialized for faces.

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Face and place stimuli have opposite effects on FFA and PPA.

*Double dissociation when imagining faces or places.*
Do Neurological Impairments Have Similar Effects on Perception and Imagery?

- Kosslyn's TMS study supports this hypothesis. (See Goldstein, p. 287 and Figure 10.17 on p. 288)

- What about permanent neurological impairments due to lesions or strokes?
Hemispatial Neglect (Unilateral Neglect):
A deficit of attention in which one entire half of a visual scene is simply ignored.

The cause of unilateral neglect is often a stroke that has interrupted the flow of blood to the right parietal lobe.

Figure to the right: Patient’s copy of an image (model) shows systematic deficits.

The patient’s copy in the right column neglects the left side of the visual field (opposite to the side of brain damage).
Left Unilateral Neglect in Perception & Images


- Patient with left unilateral neglect was asked to imagine himself standing at one end of the Piazza del Duomo in Milan.
- Patient neglected left side of the visual image (in his description) just as he neglected the left side in actual perception.
Are Perception & Imagery Always Similar?

Due to brain injury, Patient CK has visual agnosia (inability to recognize objects)

Figure (a) – incorrect identifications
- Dart labeled “feather duster”
- Tennis racquet labeled “fencer’s mask”
- Asparagus labeled “rose twig with thorns”

Figure (b) – drawings from memory
- Outline of England
- Guitar

Figure (b) – If you show CK his drawings at a later time, he cannot recognize (label) what they are.

Figure 10.19 (p. 284). (a) Pictures incorrectly labeled by CK who had visual agnosia. (b) Drawings from memory by CK. From study by Behrmann, Moscovitch, & Winocur (1994).
## Dissociations Between Imagery & Perception

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• Behrmann et al. (1994) point out that perception is more bottom up; imagery is more top down.
When Are Perception & Imagery Similar? When Are They Different?

- **Hypothesis:**
  - CK's injury blocks the bottom up input for object perception.
  - RM injury blocks the top down construction of a mental image.
• Mental manipulation of images is similar to perception of scenes as they undergo the analogous physical alterations.

• Perception and imagery engage similar cognitive processes, but they are not perfectly equivalent.
  ♦ Perception has more bottom-up influence than imagery.
  ♦ Imagery has more top-down influence than perception.