The Neural Bases of Mental Imagery

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(additional material from Stephen Kosslyn’s *Image and Brain*)
Aspects of mental imagery

| • The act of forming and examining a “picture in the head” |
| • The subjective experience of mental imagery (akin to the “redness” of a rose) |
| • Cognitive generation and manipulation of nonverbal spatial images (not necessarily “pictures”) |
The Imagery debates

• Do mental images involve the representations used during visual perception?

• Do mental images have a spatial format, or are they propositional in format? (depictive versus propositional)
Depictive Representation

• “A type of picture, which specifies the locations and values of configurations of points in a space” [Kosslyn]

• Conveys meaning via its resemblance to an object, with parts of the representation corresponding to parts of an object”
Propositional representation

- A “mental sentence” that specifies unambiguously the meaning of a sentence. [Kosslyn]

- The sentence need not be expressed in a natural language, but a symbolic language of thought.
Core Issue

There is general agreement that:

• People experience mental images
• Propositional representations are sometimes used in cognition
• Interpretation of images (depictions) usually involves propositional components

Basic disagreement:

• Do visual mental images rely on depictive representations (which are in turn interpreted by other processes) or are they purely propositional representations?
Propositional argument
[Zenon Pylyshyn]

• The pictorial experience of a mental image is epiphenomenal (it has nothing to do with its internal representation)

• Depictive images introduce a problem of infinite regression (need a homunculus to “see” the mental image?!)

• More parsimonious to assume that the same type of representation is used in imagery, language, and in all cognitive processing

• Mental images seem to have visual properties because “Imagination invites you to simulate what would happen in the real world”. The simulation is over propositional representation.
Propositional argument

[Zenon Pylyshyn]

- When children reproduce images, relational (propositional?) properties seem to better reproduced than the actual visual pattern.
Depictive argument  
[Stephen Kosslyn]

- Depictive representations have “privileged properties” that are not shared by propositional representations

- Scanning experiment: Subjects closed their eye and visualize previously memorized drawings of objects.
  - Visualize a motor boat
  - Focus on the motor
  - when you hear a term (e.g. “anchor”, “mast”), look for that part.
  - Press a button when you can “see” the named part

The further the subject had to scan, the longer the response time (linear relation)
Methodological problems with scanning task

- Pylyshyn
  - Asking subjects to use imagery may cause them to mimic the corresponding perceptual situation.
  - The scanning task might be performed using a propositional representation, with a “simulation” layer that determines the response times

- Counter argument:
  - Linear scanning times are obtained even when subjects are not explicitly asked to use mental imagery
Methodological problems with scanning task (contd.)

• Intos-Peterson
  – The experimenters unconsciously led the subjects to produce the expected results
  – Subjects inferred how they are supposed to perform, and tried to cooperate by trying to produce the expected kind of effects

• Counter argument:
  – Effects persist even when experimenter (the person interacting with the subject) and the subject were both misled about what the expected effects are
  – Subjects cannot \textit{a priori} predict whether the scanning times are supposed to be linear or nonlinear
Fundamental problem with behavioral experiments

- Structure-process tradeoff:
  
  Representation (structure) + interpretation (process)

  - Any result can be interpreted as either propositional or depictive representation by making shifting the assumption from structure to process, or vice versa.

- Example: Propositional explanation of linear scanning times
  
  - A scene is represented a network of relationship nodes. Objects further apart in the scene are separated by more propositional nodes.
  
  - Traversal of this network results in linear scan times
Alternative approach: Brain lesion and imaging studies

- Patients with selective impairments of visual perception should manifest corresponding impairments in mental imagery.

Case study 1

- Unilateral brain damage
- Impairment on both color-vision tasks (e.g. color blindness tests) and color imagery tasks (e.g. report color of common objects from memory).
Brain lesion studies (contd.)

Case study 2

• Visual-verbal disassociation syndrome:

• Visual perception
  + purely visual tasks: e.g. match two colors
  + purely verbal tasks: e.g. “color associated with envy?”
  – color naming

• Imagery
  + visual: “select color of an object (peach) shown in black & white”
  – verbal: “what color is a peach?”

• Conclusion: Mental images acted like visual representations
Case study 3

Patients with hemispatial neglect for visual stimuli also neglected the contralesional sides of their mental images.
**Brain lesion studies (contd.)**

**Case study 4**

<table>
<thead>
<tr>
<th>Visual perception problem</th>
<th>Imagery problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual disorientation</td>
<td>unable to describe locations of familiar objects from memory, but able to describe object appearance</td>
</tr>
<tr>
<td>Visual agnosia</td>
<td>able to describe locations of familiar objects from memory, but unable to describe object appearance</td>
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</tbody>
</table>
Case study 5
- Mental images show holes where there is damage to the occipital lobe.
- Homonymous hemianopia (blindness in half of the visual field due to damage after the optic chiasm) => S has a smaller mental image size

Case study 6
- Subject with spared parieto-occipital pathway, and damaged temporo-parietal pathway was
  - able to do spatial imagery tasks (mental rotation, scanning, size scaling, etc.),
  - Unable to do visual imagery tasks (evoke mental pictures of animals, objects)
- Claim: parieto-occipital system => spatial imagery
  ventral temporo-occipital system => visual imagery tasks
Brain-imaging studies in normal subjects

Basic result: mental imagery activity correlates with occipital activity

- Table 62.1 (p. 969)

- Ss asked to visualize large or small alphabet letters. Larger images activated more anterior parts of the visual cortex.

- EEG experiment:
  - Condition 1: present a word, no image
  - Condition 2: present a word, S forms mental image
  - Subtract condition 1 activity from condition 2.

EEG activity centered over occipital regions
Brain-imaging studies
EEG experiment

Figure 62.5  Scalp distribution of potentials synchronized with the generation of a mental image, in 50 ms time slices.
Brain-imaging studies:
fMRI experiment, control condition
Brain-imaging studies:

fMRI experiment, experimental condition

Note long durations (30 seconds).
Results are not due to just iconic memory
Mental images have a depictive representation

Mental images use many of the same representations and processes used during visual perception
Image Generation [Kosslyn]

- Imagery uses the same mechanism as with visual priming (top down influence)

- Higher-level areas project activity onto the visual buffer

- An “attentional window” is used to stitch together different parts of a mental image
The Protomodel
Figure 11.1  The architecture of visual mental imagery.
Image Generation: Single object

Figure 11.1  The architecture of visual mental imagery.
Image Generation: Multiple objects

Figure 11.1 The architecture of visual mental imagery.