Representation and Manipulation of Knowledge
Some Questions of Interest

• What are some of the major hypotheses regarding how knowledge is represented in the mind?

• What are some of the characteristics of mental imagery?
Mental Representations: Pictures vs. Words

- Pictures capture concrete and spatial information analogous to what they represent.
- Words capture abstract and categorical information symbolic of what they represent.
Mental Imagery

• Internal representation of items that are not currently being sensed
  – May be old, new, futuristic, imaginary
  – May involve any of the sensory modalities
    • Imagine a taste, a sight, a touch
  – Majority of research on visual imagery
Mental Imagery

• Individual differences in creating and manipulating mental images
• Use of mental images can help to improve memory
Mental Imagery

• Kosslyn proposes images are used to help solve certain types of problems
  – How many chairs are there in your house?
  – Do bunnies have whiskers?
Dual-Code Theory

• Paivio (1971)
• We use two codes to represent information
  – Analogue (pictoral) codes
  – Symbolic (verbal) codes
  – Two codes are linked
Evidence for Dual-Code Theory

• Paivio compared concrete words (potato, horse) with abstract words (justice, love)
  – Found participants were better able to recall concrete words
  – Concluded that dual code was created for concrete words (analog and verbal label) but not for abstract words
Visual Codes Processed Differently from Symbolic Codes

• Each type of code is affected by different manipulations
  – Visual information interferes with spatial information
  – Verbal labels interfere with spoken words
  – Sequence matters more for words, not so much for unrelated images
Evidence for Dual-Code Theory

• Brooks (1968)
  – One group saw a block diagram of a letter
  – Memorized it
  – Were asked to mentally travel the letter and indicate if the corner was on the extreme top or bottom
Evidence for Dual-Code Theory

• Brooks (1968)
  – Second group saw a sentence
  – Memorized it
  – Were asked to classify each word as a noun by indicating “yes” or “no”
  – Verbal task

A bird in the hand is not in the bush
Evidence for Dual-Code Theory

• Brooks (1968)
  – Participants were then asked to respond in one of two ways
    • Say “Yes” or “No”
    • Point to the answer “Yes or No”
    • Why was this important?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Evidence for Dual-Code Theory

• Brooks (1968) Results

<table>
<thead>
<tr>
<th>Task</th>
<th>Verbal</th>
<th>Pointing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter Diagrams</td>
<td>11.3 sec.</td>
<td>28.2 sec.</td>
</tr>
<tr>
<td>Sentences</td>
<td>13.8 sec.</td>
<td>9.8 sec.</td>
</tr>
</tbody>
</table>

• For image task, RT was slower when pointing
• For the symbolic task, RT was slower for the verbal response
• Different pattern = different processing for different codes
Propositional Theory

• Do not store in form of images
• Instead have a “generic” code that is called “propositional”
• Store the meaning of the concept
• Create a verbal or visual code by transforming the propositional code
Propositional Representations

We may use propositions to represent any kind of relationship, including actions, attributes, spatial positions, class membership, or almost any other conceivable relationship. The possibility for combining propositions into complex propositional representational relationships makes the use of such representations highly flexible and widely applicable.

<table>
<thead>
<tr>
<th>Type of Relationship</th>
<th>Representations in Words</th>
<th>Propositional Representation*</th>
<th>Imaginal Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actions</td>
<td>A mouse bit a cat.</td>
<td>Bite [action] {mouse [agent of action], cat [object]}</td>
<td>![Mice Scene]</td>
</tr>
<tr>
<td>Attributes</td>
<td>Mice are furry.</td>
<td>{external surface characteristic} {furry [attribute], mouse [object]}</td>
<td>![Mice Scene]</td>
</tr>
<tr>
<td>Spatial positions</td>
<td>A cat is under the table.</td>
<td>{vertically higher position} {table, cat}</td>
<td>![Table Scene]</td>
</tr>
<tr>
<td>Class or Category membership</td>
<td>A cat is an animal.</td>
<td>{categorical membership} {animal [category], cat [member]}</td>
<td>![Animal Scene]</td>
</tr>
</tbody>
</table>

*In this table, propositions are expressed in a shorthand form (known as “predicate calculus”) commonly used to express underlying meaning. This shorthand is intended only to give some idea of how the underlying meaning of knowledge might be represented. It is not believed that this form is literally the form in which meaning is represented in the mind. In general, the shorthand form for representing propositions is this: [Relationship between elements] [[subject element], [object element]].
Test Your Visual Imagery Ability!

• Form a mental image of this picture
• Which of the pictures on the next slide are part of this picture?
Try Again with Another Design

- Form a mental image of this picture
- Which of the pictures on the next slide are part of this picture?
Imagery & Ambiguous Figures

• Chambers & Reisberg (1985)
  – Showed ambiguous figures for 5 seconds and asked for first interpretation
  – Removed picture, asked people to form a mental image
Chambers & Reisberg (1985)

• Results
  – People were unable to discover a second interpretation from the image
  – Then drew the figure and could find the other interpretation

• Conclusion
  – A propositional code may override the imaginal code in some circumstances
Carmichael, Hogan, & Walters (1932)

- Participants were shown simple figures with one of two verbal labels:
  - Sun or ship’s wheel
  - Hourglass or table
Carmichael et al. (1932) Results

<table>
<thead>
<tr>
<th>Reproduced figure</th>
<th>Verbal labels</th>
<th>Stimulus figures</th>
<th>Verbal labels</th>
<th>Reproduced figure</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Curtains in a window" /></td>
<td>Curtains in a window</td>
<td><img src="image" alt="Diamond in a rectangle" /></td>
<td>Diamond in a rectangle</td>
<td><img src="image" alt="Diamond" /></td>
</tr>
<tr>
<td>7</td>
<td>Seven</td>
<td><img src="image" alt="Four" /></td>
<td>Four</td>
<td><img src="image" alt="Four" /></td>
</tr>
<tr>
<td><img src="image" alt="Ship's wheel" /></td>
<td>Ship's wheel</td>
<td><img src="image" alt="Sun" /></td>
<td>Sun</td>
<td><img src="image" alt="Sun" /></td>
</tr>
<tr>
<td><img src="image" alt="Hourglass" /></td>
<td>Hourglass</td>
<td><img src="image" alt="Table" /></td>
<td>Table</td>
<td><img src="image" alt="Table" /></td>
</tr>
<tr>
<td><img src="image" alt="Kidney bean" /></td>
<td>Kidney bean</td>
<td><img src="image" alt="Canoe" /></td>
<td>Canoe</td>
<td><img src="image" alt="Canoe" /></td>
</tr>
<tr>
<td><img src="image" alt="Pine tree" /></td>
<td>Pine tree</td>
<td><img src="image" alt="Trowel" /></td>
<td>Trowel</td>
<td><img src="image" alt="Trowel" /></td>
</tr>
<tr>
<td><img src="image" alt="Gun" /></td>
<td>Gun</td>
<td><img src="image" alt="Broom" /></td>
<td>Broom</td>
<td><img src="image" alt="Broom" /></td>
</tr>
<tr>
<td>2</td>
<td>Two</td>
<td><img src="image" alt="Eight" /></td>
<td>Eight</td>
<td><img src="image" alt="Eight" /></td>
</tr>
</tbody>
</table>
Carmichael et al. (1932)  
Results

• Later participants were asked to draw items seen  
• Participants distorted the images to fit the labels  
• This pattern supports the idea that images may be stored propositionally, not as original analog image
Mental Imagery Studies

- **Demonstrate**
  - Active process
  - Response times are proportional to degree of rotation
  - People can rotate images in three-dimensional space as easily as two-dimensional space
  - Images are “mental sculptures”
Functional-Equivalence Hypothesis

• Mental images are internal representations that operate in a way that is analogous to the functioning of the perception of physical objects.
Finke (1989) on Functional Equivalence

- We use similar transformation on objects and mental images
- Spatial arrangements of a mental image are similar to spatial arrangements of actual object
- Images can be used to generate information not explicitly stored during encoding
- Processes of visual system are used on both mental images and visual objects
Neuroscience and Functional Equivalence

• Activation in the frontal and parietal regions occurs when viewing or imagining an image
  – No overlap in the areas associated with vision

• Schizophrenics have difficulty differentiating between internal images and perception of external stimuli
Mental Imagery

• Shepard & Metzler (1971)
  – Participants had to decide whether displays had two similar shapes
  – Some pairs were similar, but rotated to various degrees
Shepard & Metzler (1971) Results
Neuroscience and Mental Rotation

• Using single-cell recordings in the motor cortex, there is physiological evidence that monkeys can do mental rotations.
Johnson-Laird (1983)

• Proposed there are three types of mental representations
  – *Propositional representations* are pieces of information resembling natural language
  – *Mental imagery* are perceptual models from a particular point of view
  – *Mental models* are structural analogies of the world
Characteristics of a Mental Model

• A representation of a described situation rather than a representation of a text itself or the propositions conveyed by a text

• The structure corresponds to the functional relations among entities as they would exist in the world

• A simulation of events in the world, either real or imaginary
Creating Cognitive Maps

• Gain increased spatial knowledge
• Using three types of knowledge
  – Landmark (special buildings)
  – Route-road (procedures to get to one place from another)
  – Survey (global map-like view)
Tversky (1993)

• Cognitive maps more like cognitive collages
• Constructionist view of creating cognitive maps
• Distortions can occur when using heuristics
Draw a map of **campus**, your town, your part of town, your route to the university from home...
Heuristics Affecting Cognitive Maps

• Right-angle bias
  – Streets are drawn at 90-degree angles (even when they are not)

• Symmetry heuristic
  – Irregular geographic boundaries are made regular (e.g., Americans straighten out the Canadian border)

• Rotation heuristic
  – Tend to “regularize” tilted landmarks in maps to appropriate E-W or N-S axis
Heuristics Affecting Cognitive Maps

• Alignment heuristic
  – People distort their mental images to represent landmarks and boundaries as better aligned than they really are

• Relative-position heuristic
  – Relative positions of landmarks and boundaries are distorted in ways consistent with people’s conceptual knowledge
Using Our Minds

• Knowing that…
  – Declarative knowledge

• Knowing how…
  – Procedural knowledge
Declarative Knowledge

• Stored in concepts
  – A mental representation of an item and associated knowledge and beliefs (cat, tools, furniture)
When Do We Use Concepts?

• Create categories
• Make inferences
• Combine to form complex thoughts
• For communication
Organization of Declarative Knowledge

• Concept
  – Unit of symbolic knowledge

• Category
  – Rule used to organize concepts

• Schemas
  – Framework used to organize concepts
Different Types of Categories

• Natural category
  – Occur naturally (e.g., plants, trees, cats)

• Artifact category
  – Created by humans (e.g., hammers, computers)

• Ad hoc category
  – Created individually to suit a need (things you need to be happy, things you do to please parents)
Theories on How People Decide What Objects to Put into a Category

• Defining features (classical view)
• Prototypes
• Exemplars
• Hierarchically semantic networks
Defining Features

• A defining feature
  – *Must* have this to be considered a member
  – What are the defining features of a mime?
Problem with Defining Features

Theory

• Difficult to specify necessary features of some concepts
  – What is the defining feature of a monster?
  – A widow?
  – A family?
Prototype Theory

• Abstracted representation of a category containing salient features that are true of most instances

• Characteristic features that describe what members of a particular concept are like
  – Monster prototype has these characteristics: scary, pale, sharp teeth, evil, lives in odd place (coffins, closets, or graveyards)
  – Vampires, zombies, and bogeymen all fit that prototype well,
  – Can a green, grumpy, lives-in-a-garbage-can monster also fit? Yes, but less well
Prototype Theory

• Deals well with fuzzy concepts
• Fuzzy concepts are categories that cannot be easily defined (monster, games)
• To categorize, simply compare to prototype
Semantic Network Model

- Nodes represent concepts in memory
- Relations represented links among sets of nodes

Robin → Property → Wings
Collins & Quillian’s Model (1969)

• Structure is hierarchical
• Time to retrieve information based on number of links
• Cognitive economy
  – Properties stored only at highest possible level
• Inheritance
  – Lower-level items also share properties of higher-level items
Collins & Quillian’s Model (1969)

Diagram showing relationships between different types of animals, including:
- Bird: Can fly, Has wings, Has feathers, Can sing, Is yellow, Has long thin legs, Is tall, Can’t fly
- Fish: Can swim, Has fins, Has gills, Can bite, Is dangerous, Is pink, Swims upstream to lay eggs
- Animal: Eats, Breathes, Can move around, Has skin
- Canary: Can sing, Is yellow
- Ostrich: Is tall, Can’t fly
- Shark: Can bite, Is dangerous
- Salmon: Is edible, Swims upstream to lay eggs
Support for Collins & Quillian Model

• Sentence verification task
• Indicate if the following sentences are true or false; measure reaction time
  – Salmon are pink
  – Animals breathe
  – A dog has four legs
  – A Dalmatian has skin
• The more links traveled according to model, the longer the reaction time of truth verification
Collins & Loftus (1975) Semantic Model

- Got rid of hierarchy
- Got rid of cognitive economy
- Allowed links to vary in length to account for typicality effects
- Spreading activation
  - Activation is the arousal level of a node
  - Spreads down links
  - Used to extract information from network
Basic Level

- Largest number of features
- Used most often

Superordinate

Furniture, Animal

Basic Level

Chair, Bird

Subordinate

Bean Bag, Robin
Evidence Basic Level Is Special

- People almost exclusively use basic-level names in free-naming tasks
- Children learn basic-level concepts sooner than other levels
- Basic level is much more common in adult discourse than names for superordinate categories
- Different cultures tend to use the same basic-level categories, at least for living things
Schemas

• Schemas are models of the external world based on past experience
• Schemas for concepts underlying situations, events, or sequences of actions
• Abstraction that allows particular objects or events to be assigned to general categories
Schemas

• Organize our knowledge
• May include other schemas
• Help in encoding, storage, and recall
• Allows us to make inferences
Scripts

• Type of schema about events

• Structure captures general information about routine events
  – Eating in a restaurant, attending a movie, visiting a doctor’s office

• Scripts have typical roles
  – (Customers, waiter, cook), (ticket vendor, patrons, refreshments), (doctor, nurse, patient)
Scripts

• When we hear or read about a scripted event, our knowledge of the entire script is activated

• We can fill in or infer the scenes and actions that are not explicitly mentioned
Schank & Abelman (1977)

• Visit a restaurant script
  – Sit down
  – Look at menu
  – Order food
  – Eat
  – Pay
  – Leave

• 73% of subjects produce the above actions
• 48% agreed on a further 9 actions