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COGNITION

Chapter 7: Knowledge Representation

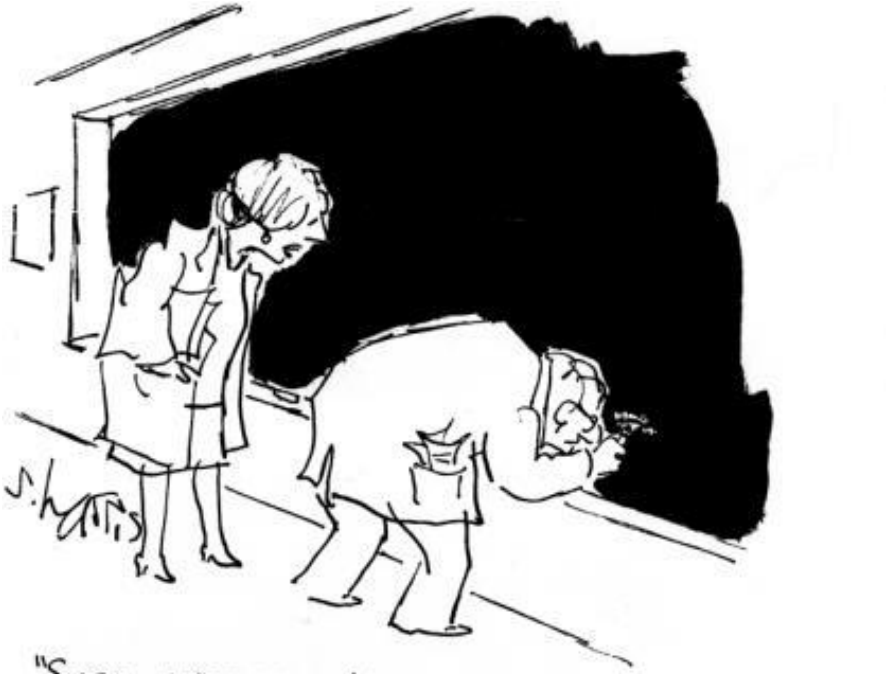
Fundamentals of Cognitive Psychology

(Kellogg)

Fall 2013

Semantics

- Semantics is the study of meaning. Any theory of Semantic memory must explain how people mentally represent concepts and ideas.
- Semantic Memory stores knowledge of concepts and facts.



Categorization

A Category is a kind of thing…

The type of representation of knowledge in semantic memory has necessary implications for 'categorization'

e.g., Make a List 12 Farm Animals

(e.g., if the list was "jobs" you might include lawyer, doctor, professor, candlestick maker, …)

Categorization

- Rate each item with regards to how “GOOD” the item is as an exemplar of a “FARM ANIMAL”

1 2 3 4 5

(good exemplar) (poor exemplar)

Bottom-Up Processing
(data driven processing)

Template matching: use of an exact match (goodness of fit test) to classify a new pattern
  - Bank number checking account number recognition
  - A **template** in the context of human pattern recognition refers to an internal construct that, when matched by sensory stimuli, leads to the recognition of an object.
- needs a set of templates against which to compare objects (all possible chairs)
  - storage?
- the system will need to create (via experience) the entire set of templates against which to compare the stimulus.
- the templates will be very particular and need good alignment in order to identify
  - machine vision is historically very bad at this

This will be a very large problem for auditory processing.

- The "problem of invariance" is that humans are very good at picking out and understanding speech despite huge amounts of variability within and between speakers. Computerized voice recognition systems are only now beginning to be marginally reliable (with a restricted vocabulary and speaker training, etc.)

Bottom-Up Processing
(data driven processing)

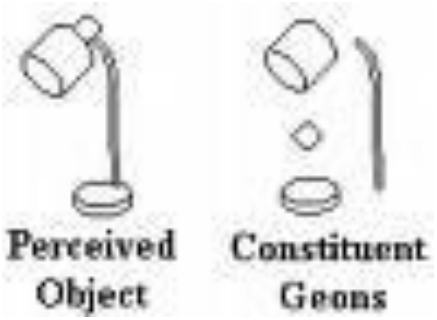
Feature Analysis

- Pandemonium [Selfridge]
  - Feature analysis model of bottom-up letter recogntion
    - Image demon
    - Feature demon
    - Letter demon
    - Decision demon
- Hubel & Weisel
    - Orientation specific cells
    - Feature specific cells (page 141)

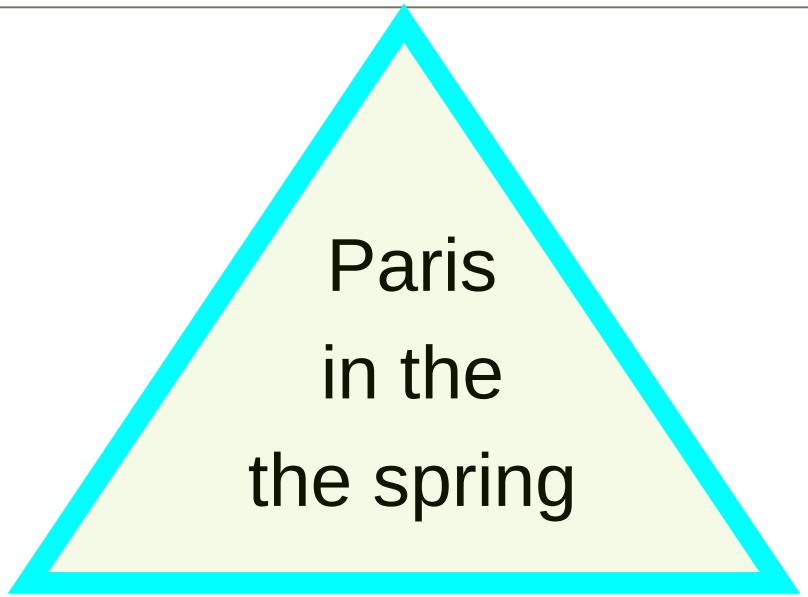
Structural Description Theory

Recognition by Components *[Biederman]*

- Break down visual objects into GEONS
- People cannot identify objects which are missing their intersections
- Number of basic features is relatively small



Top-Down Processing
(Conceptually Driven Processing)



WELCOME TO IIIINOIS

vs.

WELCOME TO IIINOIS

RULE-GOVERNED CONCEPTS (Kellogg)

- The classical view of categories, dating back at least to Aristotle, and showing up again and again in philosophy and psychology, is that categories are defined by a set of necessary and sufficient conditions.

  - For example, to qualify as a BACHELOR, a person must be an unmarried adult male. Each of these four features (human, unmarried, adult, male) is necessary. An unmarried adult male dog is not a bachelor, nor is an unmarried adult woman. Together, the four features are sufficient. Thus, any unmarried adult man is a bachelor, regardless of the kind of car he drives, the kind of food he eats, and so on.

Fuzzy Categories

It turns out to be surprisingly difficult to identify the necessary and sufficient features for many (most?) of the categories we use.

- The philosopher Ludwig Wittgenstein (1953) argued that there are no necessary and sufficient features that make a *game* a *game*.
  - Some involve competition, but not others.
  - Some involve multiple participants, but others can be played alone.
  - Some are fun, some are not.

- The category GAME cannot be defined by a set of necessary and sufficient features (Labov, 1987)

Fuzzy Categories

Another problem with the classical view is that it does not mesh well with observations about how people actually behave.

- The classical perspective provides no basis for distinguishing among members of a category. Anything that meets the criteria ought count as a member.
  - Among members there are no criteria for being a "better" member.
- If categories are defined by necessary and sufficient features, they should be "crisp“ with clear and well-defined boundaries.
  - They are not.

Fuzzy Categories

Experimental observation suggests that the categories we use have a graded structure with fuzzy boundaries.

People tend to think that some members of a category are better members than others, and moreover, they do not act as if there are clear-cut boundaries determining whether something belongs to a category or not.

- It seems clear that a 35-year old unmarried man is a bachelor,
- how about a 21-year old? A 17-year old? If the 17-year old is not a bachelor, does he become one when he turns 18?
- Is a divorced man a bachelor? A priest? The Pope? What about an unmarried man who has been living with the same woman for over 10 years? What if they have been living together for 10 days?

Fuzzy Categories

- Eleanor Rosch was one of the early proponents for the view that categories have a fuzzy and graded structure.

- Rosch used a variety of tasks to investigate how people use categories.

- In one experiment Rosch (1975) asked people to simply rate on a 7-point scale how good particular instances are as exemplars of a given category.

Fuzzy Categories

Rosch observed that people found this to be a perfectly natural task, which produced consistent category ratings yielding a graded category structure.

- For the category “VEGETABLE”:
  - PEA and CARROT were rated as very good exemplars (1.07 and 1.13, respectively, on the 7-point scale),
  - ONION (2.52) and YAM (3.31) were rated as moderately good exemplars, and
  - PEANUT (5.36) and RICE (5.59) were considered poor exemplars (perhaps not even vegetables at all).

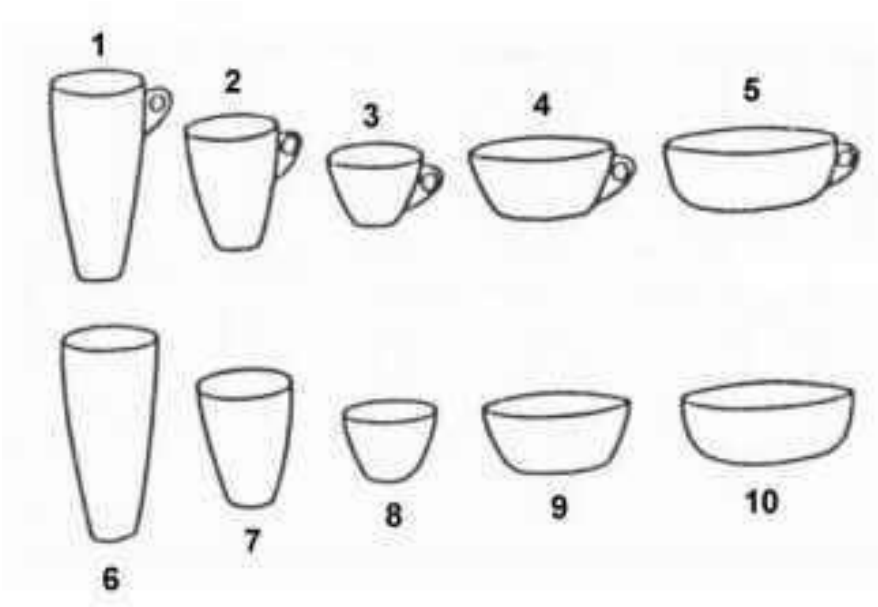
Fuzzy Categories

- Importantly, Rosch (and others) have demonstrated that these category ratings are excellent predictors of behavior in a variety of other tasks.
  - Rips et al. (1973) found that it takes a shorter amount of time to decide that a **PEA is a VEGETABLE** than to decide that an **ONION is a VEGETABLE**. This finding is known as the **Typicality Effect**.

- If category judgments are based solely on a fixed set of necessary and sufficient features, there is no reason to suppose that typical category members would be classified any more quickly than less typical members.

OBJECT CONCEPTS

- Refer to “Natural Kinds” and “Artifacts”
  - Natural Kinds: Biological objects (depend on constitution)
  - Artifacts: Human-made objects (depend on function)

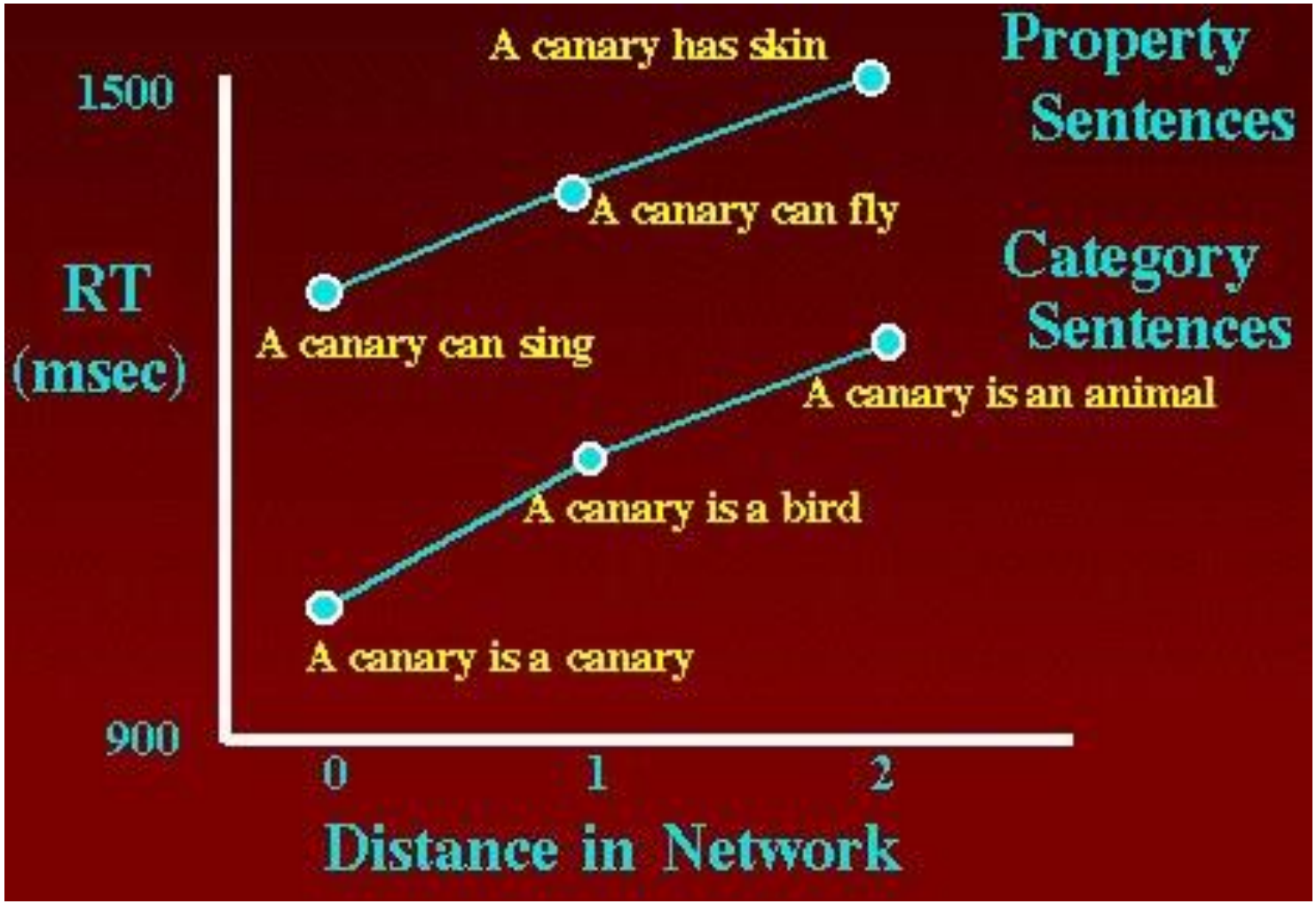


•Labov’s work (1973) demonstrates that object categories can have fuzzy boundaries and that the boundaries can depend on context (e.g., hunger, recent activation).

A Hierarchical Model of Semantic Memory

Collins and Quillians' Semantic Network Model

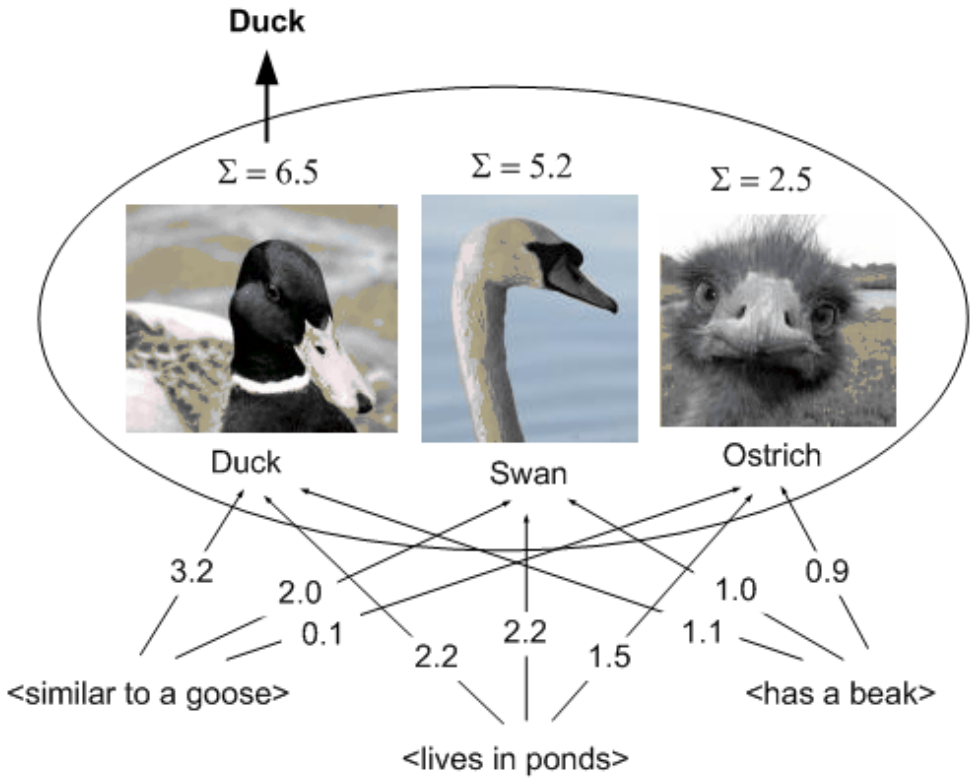
Support for Hierarchical Representation



Feature Comparisons?

- Collins and Quillian's Hierarchical Semantic Network Model could not account for the Typicality Effect
- A Feature Comparison Model (e.g., Smith, 1974) could account for Typicality, but only at the cost of cognitive economy
  - Move to non-hierarchical pathways
  - Allow different connection strengths

Weighted Paths Can Account for Typicality Effects



PROTOTYPE

The best or “most typical” member of a category

Objects most similar to the prototype are the “best” exemplars beyond which there is a gradient of membership

- the category of bird is represented by an ideal bird (or birds), which constitute the exemplars for the category
- If one mentions a bird, the category invokes an exemplar that connotes wings, a certain wing shape, a certain color, a certain kind of beak, flight patterns, food preferences, etc.
  - In North America, the “best” exemplar is the robin.
  - In Australia, the ideal bird may be the canary.
  - in Brazil, it best exemplar may be the parrot.

Although one would like to believe that these categories refer to the real world, categories are phenomenological. They reflect the perceptual structure of the perceiver. Even though categories harbor prototypes, what constitutes a prototype is usually culturally defined.

Family Resemblance Structure

- A category is defined not by a small set of defining features (per Smith, 1973, etc.) but rather a large number of features that apply to some (but not all) instances
- The “Family resemblance score” predicts the typicality effect

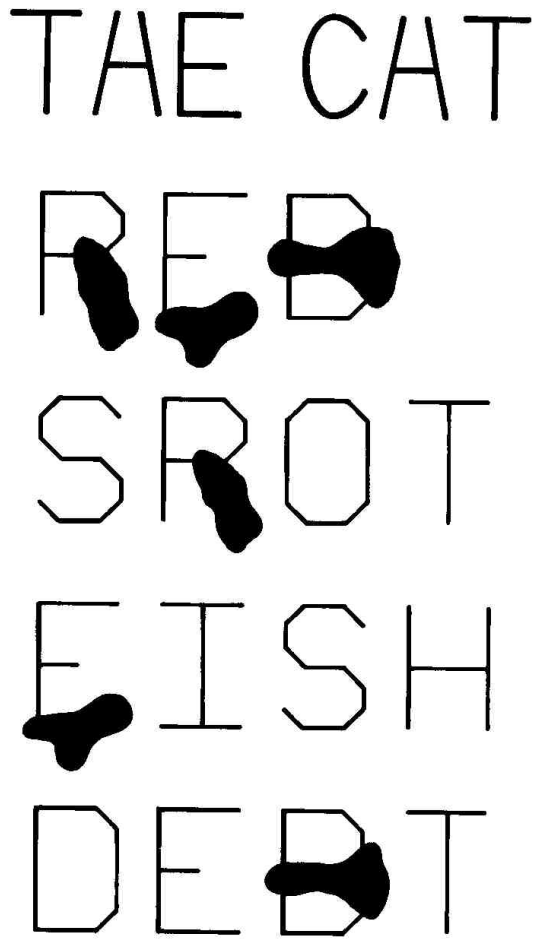
Parallel Distributed Processing / Connectionism

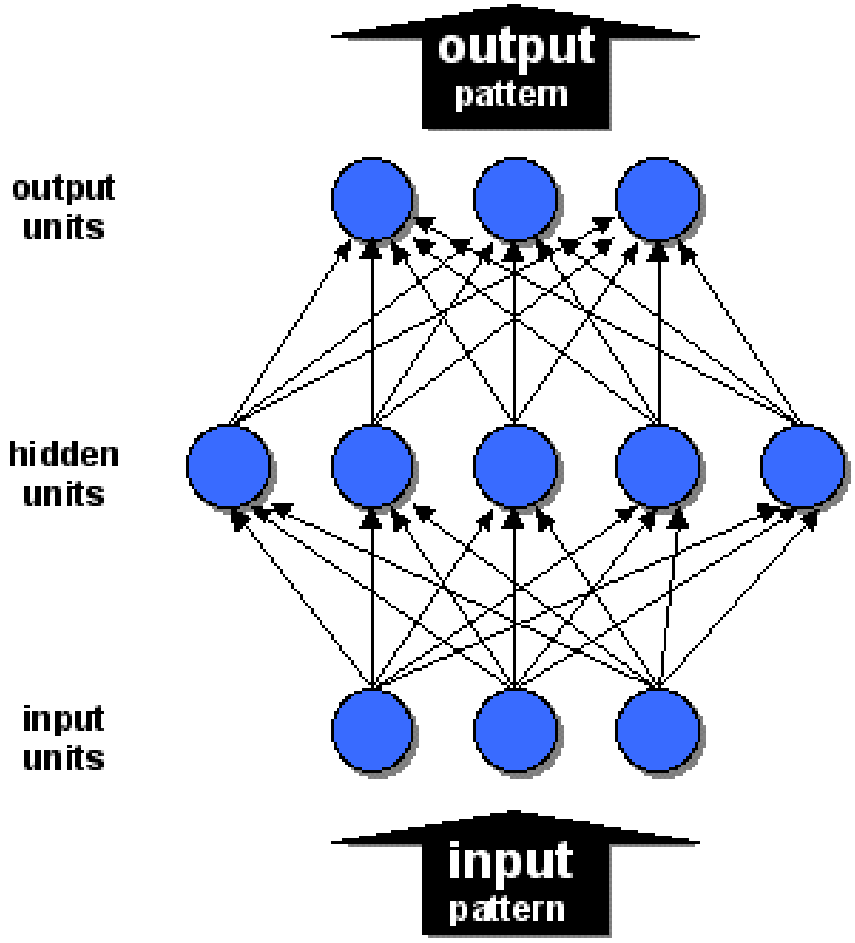
Early computer architecture (Von Neuman architecture) specified that the system (the computer) could only do one thing at a time. This reflected 1940s beliefs about how the brain worked. This, in turn, led to the computer analogy of the information processing view.

Newer computer systems have parallel processing. With this kind of parallel processing, the architecture turns to distributed, rather than localist, representations. (i.e., distributed representations). These representations basically encode multiple correlations (regularities) into a network of connections.

The regularities can be used to decode ambiguous inputs

Connectionist Models (PDP)





Neurology (Categorization)

- Categorization is heavily dependent on Temporal lobe functions
- Dissociations between artifact and object categorization abilities correspond to different locations of temporal lobe damage (see page 191)

Three major themes of Representation

- dual-coding (encoding and storage)
- conceptual-propositional hypothesis
- functional equivalence (e.g., in vision)

Dual-Coding Hypothesis

- 2 codes, 2 storage systems (Imaginal + verbal storage)
- People show a memory recall advantage if information is processed both verbally and visually
- This suggests an advantage for “dual-coding”
  - evidence: concreteness advantage in word recall
  - evidence: Brook's F task (w/ visual or auditory second task)

Conceptual-Propositional Hypothesis

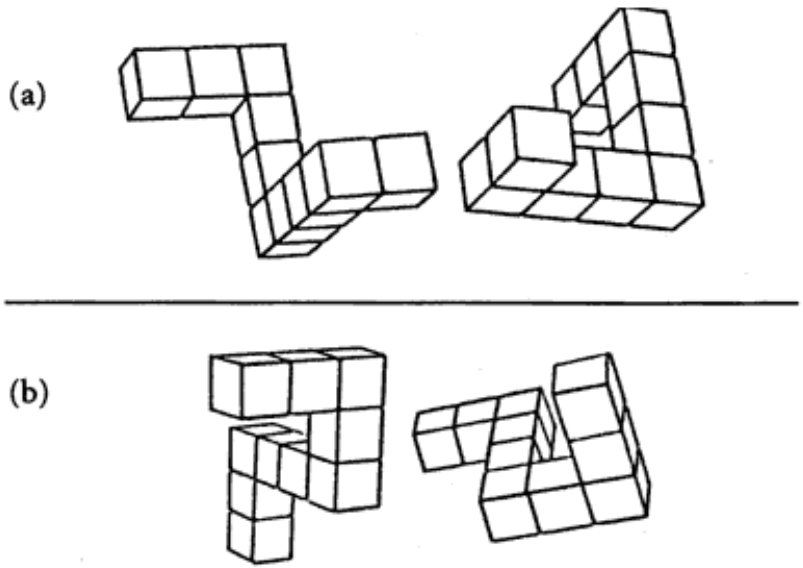
- Brandsford & Franks (from last week)
  - Semantic Integration
- People store information as inter-related abstract mental concepts (propositional codes)
  - e.g., story sentence verbatim recall very poor (just content)
- reject isomorphism
  - isomorphism: iso = same morph = shape;
  - "picture in the head"

Functional Equivalency

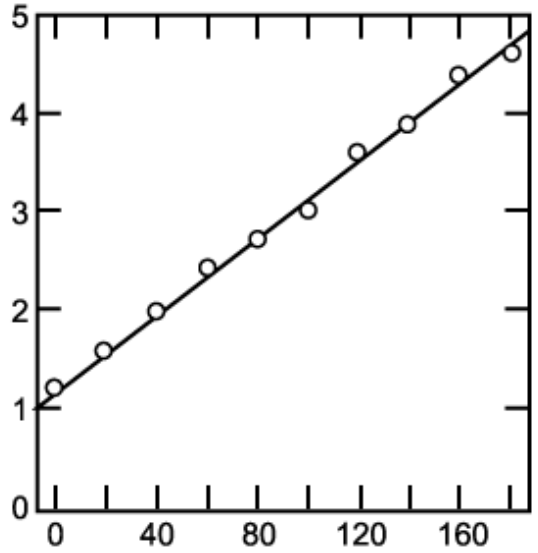
imagery & perception are highly similar

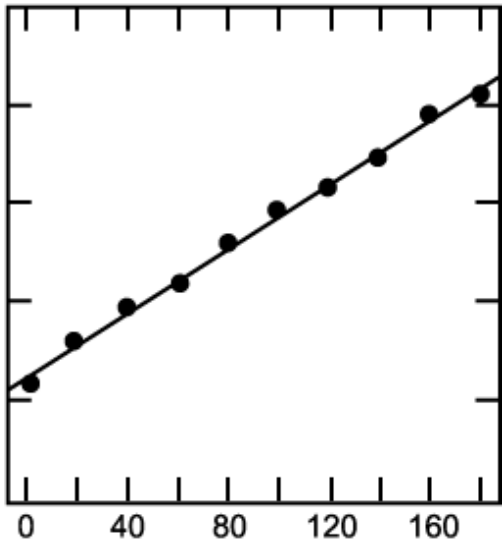
- consider mental rotation
  - Task
  - Theory
  - Data
- Jolicoeur, Corballis.. Letter Rotation, Object Identification, top/bottom, left right facing..
- Shepard & Metzler cubes
- Neurophysiology: Georgopolis (monkey motor cortex)
- Mental Maps (Kosslyn)
  - further apart, longer time
  - Island, Speedboat, Ear comparison
- Podgorny & Shepard (inside/outside) w/ real/imagined letter on grid

MENTAL ROTATION



Mental Rotation Test—Are these two figures the same except for their orientation?



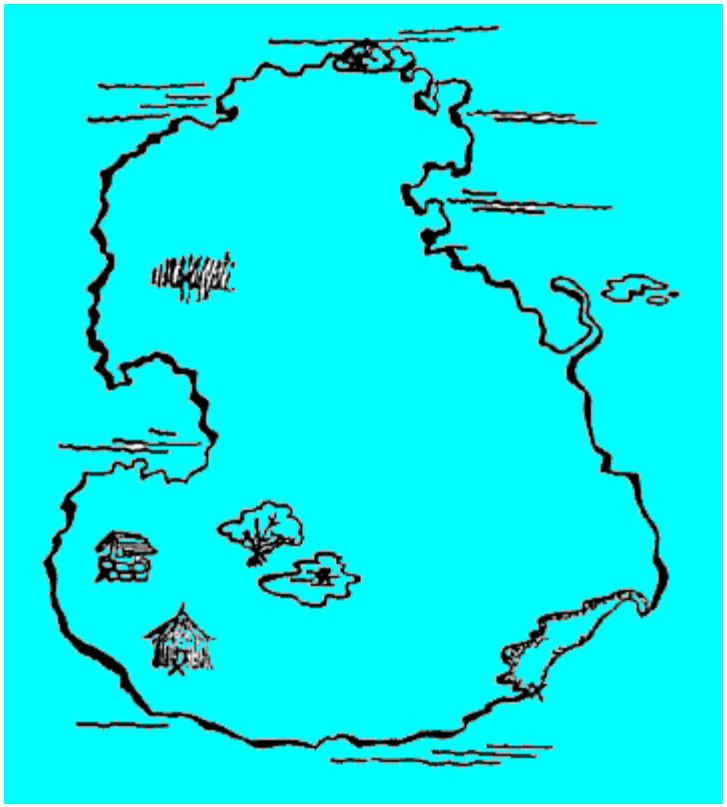


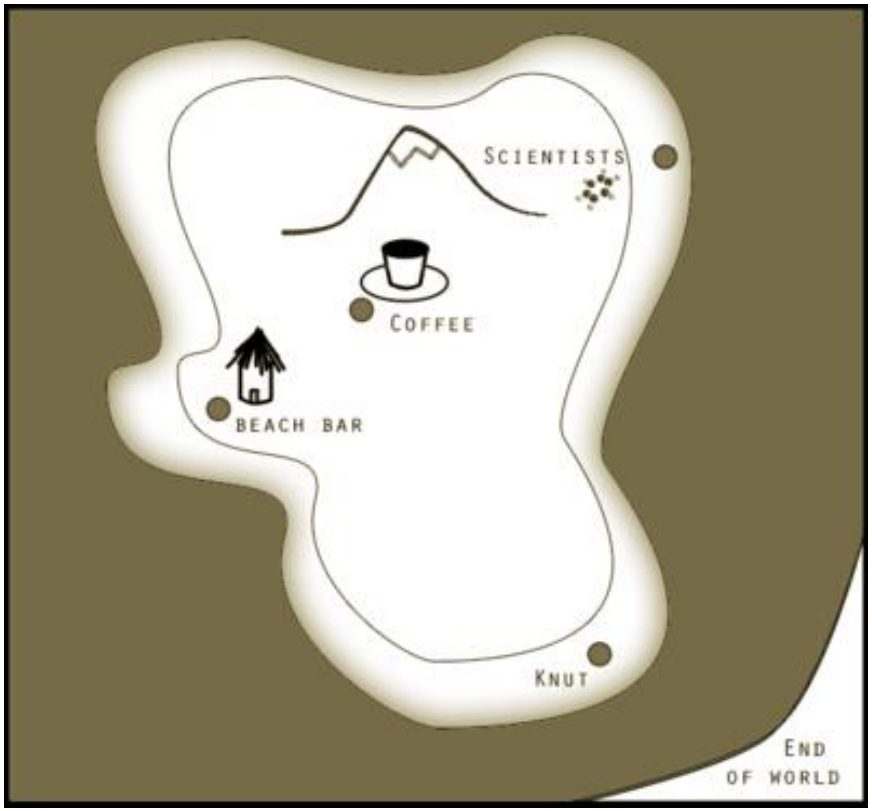
•Different

Same

•Mentally aligning the two “sugar cube shapes” (Shepard & Metzler cubes) takes time proportional to the angular disparity of their presentation.

ANALOG MENTAL SCANNING

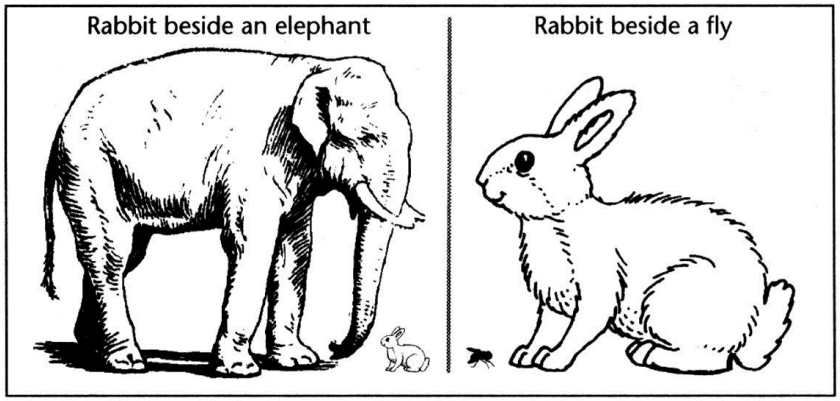




- Mentally moving takes time proportional to the distance travelled on the map

MENTAL IMAGERY

In one experiment, Kosslyn (1975) asked subjects to imagine animals standing next to one another, such as a rabbit next to an elephant or a rabbit next to a fly. Then subjects were asked questions such as, "Does the rabbit have two front paws?" People took longer to answer such questions when the rabbit was imagined next to an elephant, because the rabbit's image was so small. When the rabbit was imagined next to a fly, its imagined image was large, and subjects were quicker to answer questions about the image. Kosslyn concluded that visual imagination produces "little models, which we can manipulate much like we do actual objects."

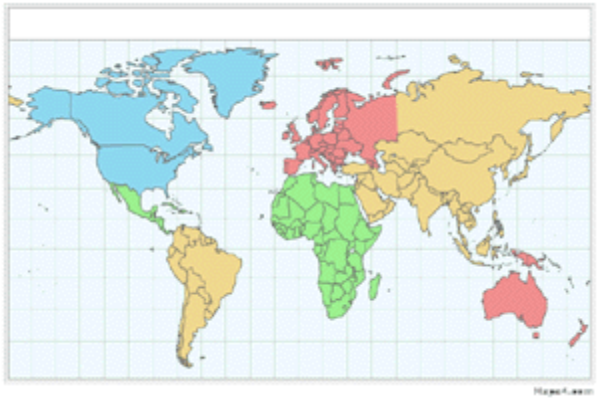


Mental Maps

Alignment Heuristic:

Which is further North:

Holland or **NY** ?



Rotation Heuristic:

Which is further West:

San Diego or **Reno** ?

Important Terminology

- Meta-representation
- Mindblindness (inability to understand that other people have mental representations)
- Rule Governed Concepts
- Object Concept
- Prototype
- Family resemblance structure
- Cognitive economy
- Feature comparison model
- Category size effect
- Synset
- Typicality effect
- Folk theories
- Frames
- Scripts
- Meta-representation
- Imaginal code
- Functional equivalency
- Conceptual-propositional hypothesis
- Propositional Code
- Dual-coding theory
- Semantic network model

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Assignment #7 (Functional Equivalency)

Your assignment is to

1) Define the term '**functional equivalency**' and
2) Describe at least one piece of evidence suggesting the functional equivalency of imaginal and perceptual processing.

The report should be two pages long and should include at least one quote (e.g., a definition or clarification of a concept) from an original source article (e.g., work by such luminaries as Shepard, Kosslyn, or Georgopolis).

I am particularly interested in your demonstrating insight into the connection between data and theory and some of the thinking behind theoretical proposals that describe human information processing. I do anticipate that there will be parts of the original source articles than you will not fully understand. Further, I expect that you will check with a number of secondary sources (including the textbook) to help clarify the concepts for yourself.

While this paper may be challenging, I am more interested in your level of understanding than the use of technical jargon.

- Include a photocopy or printout of the title page of the journal article (not PsycInfo Abstract) with your assignment.

Due Date: start of class, Monday, November 18th

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