Concepts and Categories

Lecture 21
Learning, Perception, and Memory Rely on Thinking

• Learning
  – Classical Conditioning
    • How can I predict some event?
  – Instrumental Conditioning
    • How can I control that event?

• Perception
  – What is out there? Where is it? What is it doing?

• Memory
  – What happened in the past?
“Every act of perception is an act of categorization”
Bruner (1957) [paraphrase]

• Fundamental Cognitive Process
  – Perceptual Identification...
    • Of Individual Object
  – Categorization...
    • As Belonging in Same Class as Other Objects

• Categorical Knowledge is Part of Semantic Memory
Categories and Concepts

• Enumeration
• Rule
• Attributes
  – Perceptual
  – Functional
  – Relational
Classical View of Categorization
Aristotle, *Categories* (in the *Organon*, 4th C. BCE)

*Categories are Proper Sets*

- **Defining Features**
  - Singly Necessary
  - Jointly Sufficient
Defining Features

• Geometrical Figures
  – Triangles
    • 2 Dimensions, 3 Sides, and 3 Angles
  – Quadrilaterals
    • 2 Dimensions, 4 Sides, and 4 Angles

• Animals
  – Birds
    • Vertebrate, Warm-Blooded, Feathers, Wings
  – Fish
    • Vertebrate, Cold-Blooded, Scales, Fins
Categories as Proper Sets
Aristotle, On Categories, etc.

- Defining Features
- Vertical Arrangement into Hierarchies
  - Perfect Nesting
    - Superordinate (Supersets)
    - Subordinate (Subsets)
Geometric Figures
Subcategories of Triangles

• Classified by Length of Sides
  – Equilateral
  – Isosceles
  – Scalene

• Classified by Internal Angles
  – Right
  – Oblique
    • Obtuse
    • Acute
Subcategories of Quadrilaterals

• Trapeziums

• Trapezoids

• Parallelograms
  – Rhomboids
    • Rhombuses
  – Rectangles
    • Squares
Biological Taxonomy
Linnaeus (1758)

- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- Species
- Subspecies

- Animalia
- Chordata
- Mammalia
- Primates
- Hominidae
- Homo
- Sapiens
- Sapiens

Pioneer 10
Categories as Proper Sets
Aristotle, *On Categories*, etc.

- Defining Features
- Vertical Arrangement into Hierarchies
- Horizontal Relations
  - “All or None”
  - Sharp Boundaries
Geometrical Figures

Point          Line          Plane          Solid

Triangle
- Equilateral
- Isosceles
- Scalene

Quadrilateral (etc.)
- Trapezium
- Trapezoid
- Parallelogram

- Right
- Oblique

- Acute
- Obtuse

- Square
- Not-Square
Categories as Proper Sets
Aristotle, *On Categories*, etc.

- Defining Features
- Vertical Arrangement into Hierarchies
- Horizontal Relations “All or None”
- Homogeneous Internal Structure
  - All Instances Are Equally Good
    - All Share Same Set of Defining Features
Quadrilaterals

Wikipedia
Algorithms for Categorization

• Defining a Category
  – Determine Defining Features
    • Shared by All Members

• Categorize an Object
  – Analyze Features of Object
    • Perception
  – Retrieve Defining Features of Category
    • Memory
  – Match Object Features to Defining Features
    • If Match, Assign Object to Category
Problems with Classical View of Categories as Proper Sets

- **Disjunctive Categories**
  - Baseball Strike
    - Swing and Miss
    - Pitch in Strike Zone
    - Foul Ball
    - Called Strike
  - Jazz
    - Blues
    - Swing (Standards)
Problems with Classical View of Categories as Proper Sets

• Disjunctive Categories
• **Unclear Category Membership**
  – Is a Rug an Article of Furniture?
  – Is a Pickle a Vegetable?
Is a Tomato a Fruit or a Vegetable?

*Nix v. Hedden* (1893)

- Tariff Act of 1883
  - Duty on Vegetables “In Natural State”
  - No Duty on Fruits
- Customs Collector for Port of New York
  - Declared Tomatoes to be Vegetables
- International Tomato Cartel
  - Sued, Took Case to US Supreme Court
- Justice Gray, for a Unanimous Court
Problems with Classical View of Categories as Proper Sets

- Disjunctive Categories
- Unclear Category Membership
- Difficult to Specify Defining Features
  - Required to Define Category
  - Required to Assign Category Membership

The Concept of GAME

(Wittgenstein (1953))
Problems with Classical View of Categories as Proper Sets

- Disjunctive Categories
- Unclear Category Membership
- Difficult to Specify Defining Features
- Imperfect Nesting
  - “Tangled Hierarchy”
Category Verification
Smith, Shoben, & Rips (1973)

Sparrow/Chicken  
Dog/Pig

Response Latency (secs)

Bird/Mammal  
Animal

Sparrow  Chicken  Dog  Pig
Problems with Classical View of Categories as Proper Sets

- Disjunctive Categories
- Unclear Category Membership
- Difficult to Specify Defining Features
- Imperfect Nesting
- Variations in Typicality
  - Birds: Sparrow vs. Chicken
“Typicality” Ratings
Rosch (1975)

- **Furniture**
  - Chair, 1.10
  - Desk, 1.54
  - Rug, 5.0
  - Ashtray, 6.35

- **Vegetable**
  - Pea, 1.07
  - Corn, 1.55
  - **Tomato**, 2.23
  - Pickle, 4.57

- **Fruit**
  - Orange, 1.07
  - Cherry, 1.82
  - Pickle, 4.57
  - **Tomato**, 5.58

- **Bird**
  - Sparrow, 1.18
  - Owl, 2.96
  - Chicken, 4.02
  - Penguin, 4.53
“Typicality” Ratings
Armstrong, Gleitman, & Gleitman (1983)

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Typicality Effects in Categorization

Smith, Rips, & Shoben (1974)

Typicality

Response Latency (msec)

High
Medium
Low

Typicality
Implications of Problems with Classical View of Categories

• These problems would not occur if categories were represented as proper sets
• Therefore, people must do something else when they induce concepts or deduce category membership
• Apparently, concepts are not structured like proper sets after all!
“Prototype” View: Categories as Fuzzy Sets
Rosch (1975)

• No Defining Features
  – Probabilistic Relationship
    • Central vs. Peripheral

• Family Resemblance

• Category Based on Similarity to Prototype
  – Many Features Central to Category Membership
  – Few Features Central to Membership in Contrasting Categories

• Permits Heterogeneity Within Category
  – Typicality Effects
Problems with the Classical View of Categories Solved by the Prototype View
Rosch & Mervis (1975); Rosch et al. (1976)

- Disjunctive Categories
- Unclear Category Membership
- Difficult to Specify Defining Features
- Imperfect Nesting
- Variations in Typicality
Alternative “Exemplar” View
Medin & Schaffer (1978)

• Abandons Features
  – No Defining or Characteristic Features

• Concept as List of Members
  – Salient Examples of Category

• Compare Object to List of Exemplars
  – Categorization Still Based on Similarity
Problems with Similarity
After Medin & Shoben (1988); see also Medin et al. (1993)
The Theory (Knowledge-Based) View
Murphy & Medin (1985); Murphy (2002)

Concept : Instance :: Theory : Data

• Instances Not Bound Together by Similarity
  – At Very Least, “Similarity” is Flexible
  – Categorization Explains Similarity Judgments

• Concepts Organized by Theory of Domain
  – “Explanatory Relationship” Between Concept, Instance

• Categorization Based on Knowledge, Not Similarity
Implications of Categorization

• **Logically**, Categories are Structured as Proper Sets
  – Represented by Defining Features
• **Psychologically**, Categories are Structured as “Fuzzy” Sets
  – Represented by Prototypes, Exemplars
  – Representations Differ by Expertise
• **Principles of Reasoning Do Not Necessarily Follow the Principles of Formal Logic**
  – Cannot be Discovered by Reason Alone