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
- Right
- Oblique
- Acute
- Obtuse

Quadrilateral (etc.)
- Trapezium
- Trapezoid
- Parallelogram
- Rhomboid
- Rectangle
- 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)

![Diagram showing the classification of animals into birds and mammals. Sparrow and Chicken are classified under birds, and Dog and Pig under mammals.]

![Bar graph showing response latency in seconds for birds and mammals with 1 level and 2 levels of classification.]

- **Response Latency (secs)**
  - Bird: 1.25, 1.5
  - Mammal: 1.25, 1.5

Legend:
- Green bars: 1 Level
- Blue bars: 2 Levels
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)

<table>
<thead>
<tr>
<th>Furniture</th>
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<tbody>
<tr>
<td>Chair</td>
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<tr>
<td>Desk</td>
<td>1.54</td>
</tr>
<tr>
<td>Rug</td>
<td>5.0</td>
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<td>Ashtray</td>
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<tr>
<td>Corn</td>
<td>1.55</td>
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<tr>
<td>Tomato</td>
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<tr>
<td>Pickle</td>
<td>4.57</td>
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</table>

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Sparrow</td>
<td>1.18</td>
</tr>
<tr>
<td>Owl</td>
<td>2.96</td>
</tr>
<tr>
<td>Chicken</td>
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<td>Penguin</td>
<td>4.53</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
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</tr>
<tr>
<td>Cherry</td>
<td>1.82</td>
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<td>Pickle</td>
<td>4.57</td>
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<tr>
<td>Tomato</td>
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### “Typicality” Ratings

Armstrong, Gleitman, & Gleitman (1983)

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<th>Category</th>
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<th>Typicality Rating</th>
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<td>1.7</td>
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<td>18</td>
<td></td>
<td>2.6</td>
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<td>106</td>
<td></td>
<td>3.9</td>
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<tr>
<td><strong>Odd Number</strong></td>
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<td>447</td>
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<td><strong>Female</strong></td>
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<tr>
<td>Mother</td>
<td></td>
<td>1.7</td>
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<tr>
<td>Housewife</td>
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<td>2.4</td>
</tr>
<tr>
<td>Princess</td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>Policewoman</td>
<td></td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Plane Geometry Figure</strong></td>
<td></td>
<td></td>
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<tr>
<td>Square</td>
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<td>1.3</td>
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<tr>
<td>Rectangle</td>
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<td>1.9</td>
</tr>
<tr>
<td>Circle</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>Ellipse</td>
<td></td>
<td>3.4</td>
</tr>
</tbody>
</table>
Typicality Effects in Categorization
Smith, Rips, & Shoben (1974)

Response Latency (msec)

Typicality

- High
- Medium
- Low
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
Algorithms and Heuristics

Lecture 22
Is a Tomato a Fruit or a Vegetable?
Justice Gray writing for the US Supreme Court

Botanically speaking, tomatoes are the fruit of a vine, just as are cucumbers, squashes, beans, and peas.

But in the common language of the people... all these are vegetables... like potatoes, carrots... and lettuce, usually served at dinner in, with, or after the soup, fish, or meats which constitute the principal part of the repast, and not, like fruits, generally as dessert.
Algorithmic Reasoning

• Logical, Systematic Rules
• Application Inevitably Solves Problem
• Guaranteed to Reach Correct Answer
• “Recipe” for Problem-Solving
  – Specifies Necessary Ingredients
  – Amounts
  – Order of Combination

Just Follow the Steps!
Algorithm for Estimation

• Approximate Frequency
  – Count
  – Estimation

• Algorithm for Estimation
  – Draw Representative Sample
    • Random
    • Stratified
  – Extrapolate from Sample to Population
    • Statistical Inference
    • Hypothesis Testing
Means-End Analysis of Problem-Solving
Newell & Simon (1972)

• Elements of Problems
  – Givens
  – Goals
  – Transformations
  – Obstacles

• Means-End Analysis
  – Represent Current State, Goal
  – Calculate Difference
  – Reduce Difference
  – Repeat
The Legend of the Tower of Hanoi
Lucas (1883)

In Hanoi there is a temple in which there is a tower of 64 sacred golden disks, trimmed with diamonds. The disks are stacked on top of each other, with the largest on the bottom and the smallest on the top.

The monks must move the disks from one location to another, one at a time, such that a larger disk is never placed on top of a smaller disk. Besides the original location, and the new location, there is only one other place in the temple sacred enough to hold the disks.

The legend holds that before the monks complete the task, their temple will crumble into dust and the world will end.
Simplification of the Tower of Hanoi
Means-End Analysis of The Tower of Hanoi

- Represent Current State, Goal
- Calculate Difference
- Reduce Difference
- Repeat
The Legend of the Tower of Hanoi

Moving **64** disks in the manner specified will require **18,446,744,073,709,551,615** moves.

At a rate of one move per second, this would take more than **5 billion years**.
The Hobbits and Orcs Problem
Alcuin (d. 804); aka “Missionaries and Cannibals”

On one side of a river are three hobbits and three orcs.
Orcs eat hobbits when they outnumber them.
The creatures have a boat on their side that is capable of carrying two creatures at a time across the river.
The goal is to transport all six creatures to the other side of the river.
At no point on either side of the river can orcs outnumber hobbits (or the orcs would eat them).
Hobbits and Orcs
Alcuin (d. 804)
aka “Missionaries and Cannibals”, “Jealous Husbands”, “Brothers and Sisters”

The problem is to transport all six creatures across the river without the hobbits ever being outnumbered.
Well-Defined Problems

• Completely Specified
  – Initial Conditions
  – Goals
  – Intermediate Operations

\[3x + 3 = 12\]
\[x = ?\]

Only One Possible Representation of Problem
Only One Correct Solution
Ill-Defined Problems

• Incompletely Specified
  – Initial Conditions
  – Goals
  – Intermediate Operations

\[3x + 3y = 12\]
\[x = ?\]

Many Possible Representations of Problem
Many Possible Correct Solutions
Conditions of Uncertainty

- Ill-Defined Problem
- Algorithm Unknown
- Insufficient Information
- Insufficient Opportunity
  - Time
  - Motivation
Judgment Heuristics
Kahneman & Tversky (1973)
Tversky & Kahneman (1974)

- Shortcuts, “Rules of Thumb”
  - Bypass Logical Rules
- Permit Judgments Under Uncertainty
- Also Permit Judgments Under Certainty
  - Use Increases Probability of Error
  - Infer Heuristics From Judgment Errors
Common Judgment Heuristics
Kahneman & Tversky (1973); Tversky & Kahneman (1974)

- Representativeness
  - Categorization
  - Other Judgments of Similarity
  - Probability, Causality
- Availability
  - Frequency, Probability
- Simulation
  - Probability, Causality
- Anchoring and Adjustment
  - Estimation
Applications of the Representativeness Heuristic

• Categorization (Prototype-Matching)
• Similarity Judgments
• Probability of Future Event
• Causality
The Birth Problem

In families of six children, which is the most likely sequence of boys and girls?

- GBGBBBG
- BBBGGGG
- BGBBBBB

marisakamoto.com
Judgment of Likelihood

After Kahneman & Tversky (1972)

Sequence of Births

GBGBBBG

BBBGGGG

BGBBBBB

Judged Probability
The Birth Problem

• The probability of any particular newborn being a boy is 1/2
• Probabilities are independent of each other
• Therefore:

\[ p(\text{GBGBBBG}) = (1/2)^6 = .0156 \]

\[ p(\text{BBBGGG}) = (1/2)^6 = .0156 \]

\[ p(\text{BGBBBB}) = (1/2)^6 = .0156 \]
The Gambler’s Fallacy

On a roulette wheel, half the numbers are “red” and half are “black”.

Which of the following runs is more likely to end with a red?

- RBRRBRB__
- BBBBBBB__
- BBBBBBBBBBBB__
The Representativeness Heuristic

• Judgments are Based on the Extent to Which an Event…
  – Resembles Its Parent Population
  – Reflects Salient Features of the Generating Process

• Representativeness = Similarity

• Problems
  – Failure to Appreciate Baserates
  – Failure to Calculate Prior Probabilities
Is a Tomato a Fruit or a Vegetable?

Justice Gray writing for the US Supreme Court

Botanically speaking, tomatoes are the fruit of a vine, just as are cucumbers, squashes, beans, and peas.

But in the common language of the people… all these are vegetables… like potatoes, carrots… and lettuce, usually served at dinner in, with, or after the soup, fish, or meats which constitute the principal part of the repast, and not, like fruits, generally as dessert.
Representativeness in Judgments of Causality

Causes Should Resemble Effects

• Sex Education, Birth Control  
  – Causes Sexual Behavior to Occur
• Violence in Movies, TV, Videogames  
  – Causes Violent Behavior to Occur
• Arts and Music Education in Schools  
  – Causes Academic Achievement
Applications of the Availability Heuristic

• Judgments of Frequency
• Judgments of Probability
The Word Problem
After Kahneman & Tversky (1973)

• Estimate the Number of Words in English…
  – Beginning with the Letter “K”
  – With “K” as Their Third Letter
• Repeat Estimates for Other Letters
  – L, N, R, V
Letter-Frequency Judgment
Tversky & Kahneman (1973)

Letters K, L, N, R, & V

% Judged More Frequent

Position of Letter

1st Letter

3rd Letter

N = 1957

N = 3310
The Committee Problem

• Given a Group of 10 People…
  – How Many Different Committees of 2 People Can You Create?
  – How Many Different Committees of 8 People?
Number of Committees Created From 10 People

Tversky & Kahneman (1973)
The Committee Problem

• The number of committees of $k$ people that can be formed from a group of $N$ people is given by the binomial coefficient

\[
\binom{N}{k}
\]

For committees of 2: $\binom{10}{2} = 45$

For committees of 8: $\binom{10}{8} = 45$

• From a group of 10 people, the creation of every committee of 2 automatically creates another committee of 8 (10-2)!
The Availability Heuristic

• Judgments are based on the ease with which instances can be brought to mind
• Frequency Affects Availability
• Problem
  – Ignores factors other than frequency that can affect availability
Applications of the Simulation Heuristic

• Estimates of probability
• Judgments of causality
The Undoing Problem

• Two Different Travelers
  – Heading for Airport
    • Different Flights, Leave at the Same Time

• Decide to Share Cab

• Caught in Traffic Jam
  – Expect to Miss Plane

• Get to Airport 30 Minutes Late
  – A’s Plane Left on Time
  – B’s Plane Was Delayed, But Left 5 Minutes Ago

Who is more upset?
Judgments of “Upset”
Kahneman & Tversky (1979)
The Simulation Heuristic

• Judgment is Based on the Ease with which a Plausible Scenario can be Constructed

• Similar to Availability
  – But Ease of Imagination
  – Not Ease of Retrieval from Memory

• Problem
  – No Guarantee that Imagined Scenario Might Have Occurred
Simulation and the “Counterfactual Emotions”

• Compare Actual Outcome with “What Might Have Been”

  Frustration
  Regret
  Grief
  Indignation
Applications of the Anchoring and Adjustment Heuristic

• Estimates
The Extrapolation Problem

• Quickly Estimate the Following Product:

\[ 8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 \]

or

\[ 1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8 \]
Extrapolation Estimates
Tversky & Kahneman (1974)

Median Estimate

40,320

Sequence

Ascending

Descending
The United Nations Problem

• Please Estimate the Percentage of Countries in the United Nations that are From the Continent of Africa
  – Some People Say 10%
    • What Do You Say?
  – Some People Say 65%
    • What Do You Say?
African Countries in United Nations
Tversky & Kahneman (1974)

![Bar chart showing median final estimates for different initial estimates. The initial estimates are 10% and 65%, with median final estimates of 40% and 65%, respectively.](chart.png)
The Anchoring and Adjustment Heuristic

• Final estimates are overwhelmingly influenced by initial estimates
  – Estimates Begin with Initial Value
  – Initial Value Serves as Anchor
• Problems
  – Formulation, Partial Computation Misleading
  – Insufficient Adjustment

The Power of First Impressions
Judgment Heuristics in Problem-Solving

• Problem-Solving Begins with Categorization
  – New Problem Similar to Familiar One

• Representativeness
  – *Einstellung* ("Attitude")
    • Inappropriate Problem-Solving Set

• Availability
  – Functional Fixedness
    • "Inertia" in Problem-Solving
Common Judgment Heuristics
Kahneman & Tversky (1973); Tversky & Kahneman (1974)

• Representativeness
  – Categorization
  – Other Judgments of Similarity
  – Probability, Causality

• Availability
  – Frequency, Probability

• Simulation
  – Probability, Causality

• Anchoring and Adjustment
  – Estimation
Are We Rational?

Lecture 23
“To Err is Human”
Alexander Pope, *An Essay on Criticism* (1711)

- **Categorization**
  - Proper Sets vs. Prototypes and Exemplars
- **Judgment and Decision-Making**
  - Algorithms vs. Heuristics
- **Hypothesis-Testing**
  - Disconfirmatory vs. Confirmatory Strategies
- **Conditional Reasoning**
  - Denying the Antecedent, Affirming the Consequent
  - Prescription vs. Description
Normative Model of Judgment and Reasoning

• Principles of Logic, Probability
• Self-Interest
• Optimality
• Utility (Efficiency)

Rational Choice
Rational Choice Defined
Bentham (1789)
von Neumann & Morgenstern (1947)

• Based on Current Assets
• Based on Possible Consequences
• Uncertain Consequences Evaluated by Probability Theory
• Adaptive within Constraints of Probabilities and Values Associated with Each Possible Consequence

Homo Economicus
The Concert and the Scalper

• Two People Attend a Concert
  – A Bought a Regular Ticket for $75
  – B Bought from a Scalper for $200
• Tickets are Nonrefundable
• Concert is Terrible

Who is More Likely to Leave at Intermission?
The Lost-Ticket Scenario
Tversky & Kahneman (1981)

• Two People Decide to See a Play
• Tickets Cost $10
• As A Approaches the Ticket Booth, He Discovers that He Has Lost a $10 Bill
  – Will He Still Buy the Ticket?
• B Buys a Ticket, but Loses It Before He Enters the Theater
  – Will He Buy Another Ticket?
A Preference Reversal
Tversky & Kahneman (1981)

% of Subjects

$10 Bill

$10 Ticket

Loss

Yes
No
No-Show at the Theatre
Arkess & Blumer (1985)

• Subscriptions to Ohio University Theater
  – Regular Price: $15
  – Discount: $13
  – Deep Discount: $8

• Random Assignment
  – First 60 Purchasers

• Attendance at Performances
  – > 6 Months After Purchase
Attendance at Performances

Arkes & Blumer (1985)
The Problem with Sunk Costs

- Sunk Costs Have Already Been Incurred
  - Cannot be Recovered
- Rational Choices Based on Current Assets
  - Should Ignore Sunk Costs
- Sunk Costs are Part of the Contextual Frame for Decision-Making
Sunk Costs in Public Policy

“To terminate a project in which $1.1 billion has been invested represents an unconscionable mishandling of taxpayers’ dollars.”

Jeremiah Denton (R-Alabama), 1981

“Completing Tennessee-Tombigbee is not a waste of taxpayer dollars. Terminating the project at this late stage of development would, however, represent a serious waste of funds already invested”

James Sasser (D-Tennessee), 1981
Common Violations of Rational Choice
Hastie & Dawes (2001)

• Choosing out of Habit
• Choosing on the Basis of Conformity
• Choosing on the Basis of Authorities
Conditions of Uncertainty

- Ill-Defined Problem
- Algorithm Unknown
- Insufficient Information
- Insufficient Opportunity
  - Time
  - Motivation
Framing in the Disease Problem
Tversky & Kahneman (1981)

• Imagine that You are a Public Health Official Facing the Impending Outbreak of a Deadly Disease
• Based on Past Experience, the Disease is Expected to Kill 600 People
• Two Alternative Programs Available…
The Disease Problem (1)
Tversky & Kahneman (1981)

• Certainty: If A is Adopted
  – 200 People Will Be Saved

• Risky Prospects: If B is Adopted
  – 1/3 Probability that All Will Be Saved
  – 2/3 Probability that None Will Be Saved

Which Program Do You Choose?
Choices in the Disease Problem (1)

Tversky & Kahneman (1981)
Evaluating the Choices with Rational Choice Theory

• Expected Value of a Choice
  – Outcome x Probability

• Program A: Certain that 200 Will Be Saved
  – Value = 1 x 200 = 200

• Program B: Chance that All Will Be Saved
  – Value = 1/3 x 600 = 200

Viewed Rationally, the Outcomes are Identical
Explaining the Effect (1)

- People are Risk-Averse
  - Prefer “Sure Thing” to Any Risk
- But People are Not Necessarily Risk-Averse
  - Will Accept Risks Under Certain Circumstances
Risky Prospects (2)
Tversky & Kahneman (1981)

• Certainty: If C is Adopted
  – 400 People Will Die

• Risky Prospects: If D is Adopted
  – 1/3 Probability that None Will Die
  – 2/3 Probability that All Will Die

Which Program Do You Choose?
Choices in the Disease Problem (2)
Tversky Kahneman (1981)
Evaluating the Choices with Rational Choice Theory

• Expected Value of a Choice
  – Outcome x Probability

• Program C: Certain that 400 Will Die
  – Value = 1 x 400 = 400

• Program D: Chance that All Will Die
  – Value = 2/3 x 600 = 400

Viewed Rationally, the Outcomes are Identical
### Expected Values of the Programs

<table>
<thead>
<tr>
<th>Program</th>
<th>Saved</th>
<th>Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>200</td>
<td>(400)</td>
</tr>
<tr>
<td>B</td>
<td>200</td>
<td>(400)</td>
</tr>
<tr>
<td>C</td>
<td>(200)</td>
<td>400</td>
</tr>
<tr>
<td>D</td>
<td>(200)</td>
<td>400</td>
</tr>
</tbody>
</table>

The Four Programs Are Normatively Equivalent

Why Do People Prefer One Over the Other?
Choices in the Disease Problem
Tversky & Kahneman (1981)

% of Subjects

Saved

Die

Wording

Certain
Risk

23
Framing the Disease Problem

• Programs A and B Focus on Gains
  – People’s Lives to be Saved
  – Prefer Sure Gain, Averse to Risk

• Programs C and D Focus on Losses
  – People’s Lives to be Lost
  – Avoid Sure Loss, Seek Risk

People Are Not Always Risk-Averse
Framing Effects

• Judgment is Not Invariant Over Different Descriptions of a Problem
  – Depends on How Problem is *Framed*

• Violates Normative Rationality
  – Rational Choice Determined by Abstract Representation of Problem
    • Values, Utilities are a Matter of Algebra
  – Judgment Should Not Depend on Wording of Problem
Expected Value Theory
Bentham (1789); von Neumann & Morgenstern (1947)

Value = Outcome x Probability

• Gamble A: 1/3 chance of winning $75
  – Expected Value = $75 x 1/3 = $25

• Gamble B: 1/2 chance of winning $40
  – Expected Value = $40 x 1/2 = $20
Violations of Expected Value Theory

- Lottery
  - 1 in 1,000,000 Chance of Winning $1,000,000
    - Expected Value: $1
    - But People Buy Lottery Tickets Anyway

- Choice Between Gambles
  - 1/3 Chance of $75 vs. 1/2 Chance of $40
  - Choose Gamble with Highest Odds
  - Choose the Gamble with the Highest *Utility*
    - Surplus Value
Expected Utility Theory
Bernoulli (1738); von Neumann & Morgenstern (1947)

• Determinants of Utility
  – Value = Outcome x Probability
  – Risk Aversion
  – Assets and Preferences

• Problems
  – Preference Reversals
    • Utilities Depend on Probability
  – Framing Effects

Subjective Expected Utility Theory
Prospect Theory
Kahneman & Tversky (1979)

Framing as Perception

• People Base Decisions on Subjective Utilities
  – Not Objective Values

• Anomalies of Expected-Utility Theory
  – Losses Loom Larger than Gains
  – First Impressions Shape Final Judgments
    • Anchoring and Adjustment
  – Vivid Examples Overshadow Statistical Summaries
    • Representativeness
Prospect Theory
Kahneman & Tversky (1979)

• People Base Decisions on Subjective Utilities
  – Not Objective Values
• Don’t Multiply Utilities by Objective Probability
  – Rather, Psychological (Subjective) Probability
    • Overweight Very High, Very Low Risks
• Don’t Evaluate Utilities in Absolute Sense
  – Rather, Against Background or Reference Point
  – Framing Alters Reference Point
    • Makes Prospects Appear Better or Worse Than They Really Are
The “People Are Stupid” School of Psychology
Kihlstrom (2004)

• People are Fundamentally Irrational
  – Don’t Follow Logical Principles
  – Don’t Think Very Hard About Anything
  – Let Feelings, Desires Get In the Way of Thinking

• People Usually Operate on “Automatic Pilot”
  – Swayed by First Impressions, Immediate Responses
  – Don’t Pay Too Much Attention to Anything

• People Usually Don’t Know What They Are Doing
  – Behavior is Mostly Unconscious
  – “Reasons” are Post-Hoc Rationalizations
  – Consciousness Gets in the Way of Adaptive Behavior
Bounded Rationality
Simon (1955, 1983)

• Normative Rationality as Idealization
  – Unrealistic

• Real World is Uncertain
  – Problems Not Well Defined
  – Information Available but Uneconomical
  – Algorithm Available but Uneconomical

• Limited Information-Processing Capacity
  – Cannot Attend to All Relevant Information
  – Cannot Perform Complex Computations
Satisficing
Simon (1955, 1983)

• Decision-Makers Do Not *Optimize*
  – Maximize Gains, Minimize Losses

• Rather, *Satisfice*
  – Evaluate Alternatives
  – Identify Those Whose Outcomes are Satisfactory

• Among Satisfactory Outcomes
  – Choose First Available (or Cheapest)
  – Choose Arbitrarily
  – Choose on Basis of Other (Noneconomic) Policy
Bounded Rationality is Based on “Fast and Frugal” Heuristics
Gigerenzer et al. (1999); Gigerenzer (2000)

- Heuristics Are Often the Best Approach
  - Many Problems are Ill-Defined
  - Many Algorithms are Uneconomical

- It is Rational to Inject Economies into Decision-Making
  - So Long as We Can Pay the Price of Error

- Reduce Errors
  - Understanding Normative Principles
  - Understanding Liabilities of Heuristics
Intelligence

Lecture 24
“Psychology’s Most Telling Contribution To Date”
Herrnstein (1973, p. 62)

- Francis Galton
  - *Hereditary Genius* (1869)
  - Anthropometrics
    - Correlation Coefficient
  - Eugenics Movement
- Alfred Binet
  - Binet-Simon Test (1905)
    - Theodule Simon
The Binet-Simon
“Scale for Measuring Intelligence”
Matarazzo (19721), after Binet & Simon (1905)

• Following a Moving Object With the Eyes
• Finding and Eating a Square of Chocolate Wrapped in Paper
• Comparing Two Lines of Unequal Length
• Repeating a Sentence of 15 Words
• Telling How Two Common Objects are Different
• Telling How Two Common Objects are Similar
• Making Rhymes
• Repeating Spoken Digits
• Sentence Completion
• Using Three Nouns in a Single Sentence
• Paper Folding and Cutting
• Defining Abstract Terms
Mental Age and the Intelligence Quotient
Binet & Simon (1908); Stern (1912)

- **Mental Age**
  - Items Arranged in Increasing Order of Difficulty
  - Items Grouped into Clusters by Age Level
    - Ages 3-13
    - Passed by a Majority of Children at That Level

- **IQ = (MA/CA) x 100**
  - Mental Age
  - Chronological Age
The American Scene

• Louis Terman (1916)
  – Stanford-Binet Intelligence Scale
  – Study of “Gifted” Children

• Robert Yerkes (1921)
  – Army “Alpha” and “Beta” Tests
    • Armed Forces Qualification Test

• David Wechsler (1936)
  – Wechsler Adult Intelligence Scale
    • Wechsler Intelligence Scale for Children
The Wechsler Adult Intelligence Scale
Wechsler (1939)

**Verbal Scales**
- Information
- Comprehension
- Memory span
  - 8 Digits Forward
  - 6 Digits Backward
- Arithmetical Reasoning
- Similarities
- Vocabulary

**Performance Scales**
- Picture Arrangement
- Picture Completion
- Block Design
- Object Assembly
- Digit Symbol
Calculating the Deviation IQ

• Norms for Age Groups
  – Age 16-75

• Z-Score: Standard Deviations from Mean
  – Produces “Normal” (Gaussian) Distribution
Assume $M = 40$, $SD = 12$
Transform to $M = 100$, $SD = 15$

<table>
<thead>
<tr>
<th>Test Score</th>
<th>Deviation IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>28</td>
<td>85</td>
</tr>
<tr>
<td>52</td>
<td>115</td>
</tr>
<tr>
<td>16</td>
<td>70</td>
</tr>
<tr>
<td>64</td>
<td>130</td>
</tr>
</tbody>
</table>
Frequency Distribution of IQ
after Wechsler (1939)
“The Bell Curve” of IQ
AFQT administered to National Longitudinal Study of Youth, 1980
Fischer et al. (1996), after Herrnstein & Murray (1994)
The “Forced Curve”

• “Grading on the Curve”
  – \( M = C; \) As and Bs = Ds and Fs

• WAIS, WISC, Stanford-Binet
  – \( M = 100, \) \( SD = 15 \)

• SAT, GRE, GMAT
  – \( M = 500, \) \( SD = 100 \)

• LSAT
  – \( M = 150, \) \( SD = 10 \)
Properties of Psychometric Tests

• Standardization
• Norms
• Reliability
  – Inter-rater
  – Test-Retest
• Validity
  – External Criterion
• Utility
  – Cost-Benefit Ratio
The Structure of Intelligence

• Spearman (1904): General Intelligence
  – Two-factor Theory
    • General Intelligence (g)
    • Specific Factors ($s_n$)

• Thurstone (1941): Primary Mental Abilities
  – Factor Analysis
    • Number
    • Word Fluency
    • Verbal Meaning
    • Memory
    • Reasoning
    • Space
    • Perceptual Speed
The Structure of Intellect
Guilford (1967), as revised
Crystallized and Fluid Intelligence
Cattell (1942)

• Fluid Intelligence ($G_f$)
  – General Ability to Perceive Relationships
  – Neurological Connections
  – Assessed by “Culture Fair” Tests

• Crystallized Intelligence ($G_c$)
  – Product of Experience
    • Education, Environment
  – Assessed by Standard Intelligence Tests

• Components of Performance
  – Fluid Intelligence + Education + Motivation
Raven’s Progressive Matrices
Raven (1938)

Sample Item
The Theory of Multiple Intelligences
Gardner (1983, 1999)

**Multiple Intelligences**
- Linguistic
- Logical-Mathematical
- Spatial
- Musical
- Bodily-Kinesthetic
- Intrapersonal
- Interpersonal

**Evidence**
- Isolation by Brain Damage
- Exceptional Cases
- Identifiable Core Operations
- Psychometric Tests
- Experimental Tasks
Triarchic Theory of Intelligence
Sternberg (1985)

• Analytical Intelligence
  – Meta-Components
  – Performance Components
  – Knowledge Acquisition Components

• Creative Intelligence
  – Novelty Skills
  – Automatization Skills

• Practical Intelligence
  – Adaptation, Shaping, Selection
Intelligence Beyond Cognition

• **Social Intelligence** (Thorndike, 1920)
  
  “The ability to understand and manage men and women, boys and girls – to act wisely in human relations” (p. 228)

• **Emotional Intelligence** (Salovey & Mayer, 1990)
  
  “The ability to monitor one’s own and others’ feelings, to discriminate among them, and to use this information to guide one’s thinking and action” (p. 189)
The “Flynn Effect”

United States
Stanford-Binet and WAIS

Raven Progressive Matrices

Netherlands

1932-Referenced IQ

% Scoring > 24/40

'32 '48 '60 '72 '78

'52 '62 '72 '82

90 80 70 60 50 40 30 20 10 0
Language and Thought

Lecture 25
Language in Cognition

• Language as a Tool for Communication
  – Experience, Thought, and Action

• Language as a Tool for Thought
  – Labels for Objects, Events, Attributes, Concepts
  – Reasoning, Problem-Solving
Social Displays

- Zig-Zag Dance of the Stickleback
- Alarm Reaction in Birds
- “Waggle Dance” in Bees
Birdsong

• Males Sing Characteristic Song
  – Territorial dialects
• “Learned” Through Exposure
• Critical Period
• Female Response to Song
  – Testosterone
• Template Refined Through Experience
Parallels Between Birdsong and Human Speech

- Universal
- No Reinforcement
- Critical Period
  - Isolation Until Puberty
- Second-Language Accent
Properties of Human Language

• Meaning
• Reference
• Interpersonal
• Structure
  – Prescriptive vs. Descriptive
• Creativity
  – $10^{30}$ Sentences in English
  – $10^9$ Seconds in a Century
“Human Language is an Embarrassment for Evolutionary Theory”
Premack (1986, p. 68)
Hierarchical Organization of Language

- Phonemes (40 in English)
- Morpheme (50,000 in English)
  - Roots, Stems, Prefixes, Suffixes
  - Open- vs. Closed-Class
- Word (200,000 in English)
  - Root/Stem + Prefix, Suffix
- Phrases, Sentence (1 Nonillion in English)
  - Language Basics (*Mommy go store*)
  - Language Elaborations (*Mommy goes to the store*)
Phrase Structure Grammar
Rewrite Rules

Noun $\rightarrow$ man, woman, horse, dog, etc.
Verb $\rightarrow$ saw, heard, hit, etc.
Article $\rightarrow$ a, an, the
Adjective $\rightarrow$ happy, sad, fat, timid, etc.
Noun Phrase $\rightarrow$ Art + Adj + N
Verb Phrase $\rightarrow$ V + NP
Sentence $\rightarrow$ NP + VP

The 1st NP verbed the 2nd NP
### The Structure of a Sentence

<table>
<thead>
<tr>
<th>Art</th>
<th>Adj</th>
<th>Noun</th>
<th>Verb</th>
<th>Noun Phrase</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>fat</td>
<td>man</td>
<td>saw</td>
<td>the, timid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dog</td>
</tr>
</tbody>
</table>
"The Jabberwocky"
Lewis Carroll, in *Through the Looking Glass, and What Alice Found There* (1871)

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe;
All mimsy were the borogoves,
And the mome raths outgrabe.

"Beware the Jabberwock, my son!
The jaws that bite, the claws that catch!
Beware the Jubjub bird, and shun
The frumious Bandersnatch!"

He took his vorpal sword in hand:
Long time the manxome foe he sought—
So rested he by the Tumtum tree,
And stood awhile in thought.

And as in uffish thought he stood,
The Jabberwock, with eyes of flame,
Came whiffling through the tulgey wood,
And burbled as it came!

One, two! One, two! and through and through
The vorpal blade went snicker-snack!
He left it dead, and with its head
He went galumphing back.

"And hast thou slain the Jabberwock?
Come to my arms, my beamish boy!
O frabjous day! Callooh! Callay!"
He chortled in his joy.

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe;
All mimsy were the borogoves,
And the mome raths outgrabe.
Phrase Structure and Memory
Epstein (1961), after Osgood (1957)

THE YIG WUR VUM
RIX HUM IN JAG
MIV

THE YIGS WUR
VUMLY RIXING
HUM IN JAGEST
MIV

Trials to Criterion

0 1 2 3 4 5 6 7 8

Syntax  Control
That he was happy was evident from the way he smiled.

80% of judgments were errors.

Direction Relative to Major Break:

- Away: 20% errors
- Toward: 80% errors

Fodor & Bever (1965)
Surface Structure vs. Deep Structure
Chomsky (1957, 1965)

John saw Sally.
John heard Sally.

John is easy to please.
It is easy to please John.

John is eager to please.
It is eager to please John.

John saw Sally.

Sally was seen by John.

It was John who saw Sally.

It was Sally who was seen by John, wasn’t it?
Transformational Grammar
Chomsky (1957, 1965)

• Kernel of Meaning
  – Proposition \(\rightarrow\) NP + VP

• Transformational Rules
  – Attitude \(\rightarrow\) Assertion, Denial, Question Focus on Subject, etc.
  – Sentence \(\rightarrow\) Att + Prop

Kernel as “Gist” or Deep Structure
Transformational Rules Yield Surface Structure
From Deep Structure to Surface Structure
Chomsky (1957, 1965)

- Kernel Proposition
- Assertion
- Denial
- Question
- Focus on Object
- Combination

- The boy hit the ball.
- The boy hit the ball.
- The boy did not hit the ball.
- Did the boy hit the ball?
- The ball was hit by the boy.
- The ball was not hit by the boy, was it?
Psychological Reality of Deep Structure and Transformational Grammar

• Novice Language
  – I no go sleep
  – Why Mommy hit Billy?

• Phrase and Paraphrase
  – He sent a letter to Galileo
    • Galileo sent a letter about it to him.
    • A letter about it was sent to Galileo by him.

• Meaning Verification
  – The boy hit the ball.
    • Has the boy hit the ball?
    • Was the ball hit by the boy?
The Evolution of Generative Grammar

• Standard Theory
  – Extended
  • Revised

• What Makes Us Unique
  – Language Module
  – “Universal Grammar”
  – “Language Acquisition Device”
Semantics

• Types of Reference
  – Denotative
  – Connotative

• Semantic Memory Networks
  – Associative
  – Propositional

• Categorization
  – Prototypes
  – Exemplars

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe;
All mimsy were the borogoves,
And the mome raths outgrabe.
Ambiguous Sentences

• Someone stepped on his trunk.
• Harvey saw a man eating fish.
• They are visiting firemen.
• Visiting relatives can be boring.
• Smoking volcanoes can be dangerous.
• Make me a milkshake.
Pragmatics and Context

• Linguistic
  – Surrounding Sentences

• Nonlinguistic
  – Environmental Context
  – Prosody
    • “What am I doing here?”
  – Gesture
    • Sign Language in the Deaf
  – Facial Expressions, Other “Body Language”
Conversational Rules
Gordon & Lakoff (1971); Grice (1975, 1978); Clark (1979)

Could you pass the salt?

• Common Ground
• The Cooperative Principle
• Conversational Maxims
  – Quantity
  – Quality
  – Relevance
  – Manner

“Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged”
Linguistic Relativity?
Whorf (1940) and Sapir (1941); after Boas (1911)

• “Eskimo Words for Snow”
  – Aput – “Snow on the Ground”
  – Qana – “Falling Snow”
  – Piqsirpoq – “Drifting Snow”
  – Qimuqsuq – “A Snow Drift”

• Linguistic syntax and semantics provide a “program and guide for an individual’s mental activity”…. The relativity of all conceptual systems… and their dependence upon language stand revealed.”
Variants on the Sapir-Whorf Hypothesis
After Au (1983)

• Linguistic Determinism
  – The structure of a language determines the way its native speakers perceive and think about the world.

• Linguistic Relativity
  – Structural differences between two languages are paralleled by non-linguistic cognitive differences between native speakers of those languages.
Space and Time in the Porumpuraaw Tribe
Boroditsky & Gaby (2010)

• Spatial Direction Terms in *Kuuk Thaayore*
  – Left/Right vs. North/South/East/West
  – Spatial Location Ability

• Arrange Pictures in Temporal Sequence
  – English: Left to Right
  – Hebrew: Right to Left
  – Kuuk Thaayore: East to West
    • Facing South: Left to Right
    • Facing North: Right to Left
“How Language Shapes Thought”
Boroditsky (2011, p. 65)

“A hallmark feature of human intelligence is its adaptability, the ability to invent and rearrange conceptions of the world to suit changing goals and environments. One consequence of this flexibility is the great diversity of languages that have emerged around the globe. Each provides its own cognitive toolkit and encapsulates the knowledge and worldview developed over thousands of years within a culture. Each contains a way of perceiving, categorizing, and making meaning in the world….”
Color Perception in the Dani
Rosch Heider & Olivier (1972), after Berlin & Kay (1969; Kay and Moffi, 1999)

• Evolution of Color Terms
  1. All Languages Have Black & White (Light vs. Dark, Warm vs. Cool)
  2. If 3 Color Terms, Add Red
  3. If 4 Color Terms, Add Green or Yellow
  4. If 5 Color Terms, Add Yellow or Green
  5. If 6 Color Terms, Add Blue
  6. If 7 Color Terms, Add Brown
  7. If 8+ Color Terms, Add Purple/Pink/Orange/Gray; then Light Blue

• Two Color Names
  – Mili – Dark and Cold
  – Mola -- Light and Warm

• Experimental Tasks
  – Naming Colors
  – Matching Colors from Memory
Thought Without Language

- Classical and Instrumental Conditioning
  - Expectations, Prediction, and Control
- Natural Concepts in Pigeons
- Curiosity in Rhesus Monkeys
- Problem-Solving in Primates
- Learning in Infants

Kohler, *the Mentality of Apes* (1925)
“We can only talk and understand one another in terms of a particular language. The language or languages that we learn in childhood are not neutral coding systems of an objective reality. Rather, each one is a subjective orientation to the world of human experience, and this orientation affects the ways in which we think while we are speaking.”

• Language Influences Thought “Online”
  – Speaker Must Attend to Some Features of World
Grammatical Gender

• Masculine, Feminine, Neuter
  – Spanish: el vs. la
  – French: le vs. la
  – German: der, die, das

• “My friend Pat”
  – In Spanish
    • Mi amigo Pat if Male
    • Mi amiga Pat if Female
  – In German
    • Mein Freund Pat if Male
    • Meine Freundin Pat if Female

Julia Sweeney as “Pat”
Saturday Night Live
Hopi Sibling Terminology
Eggan (1950); Nerlove & Romney (1967)

- Elder Brother
- Elder Sister
- Younger Sister of Male
- Younger Brother of Male
  – or Younger Sibling of Female
“Language doesn’t have so much to do with words and what they mean as it does with people and what they mean”

Clark (1979)

Any Thought Can Be Expressed in Any Language