IE 545, Human Factors Engineering

Decision Making
Think

(Decision Making, Problem Solving, Trouble-shooting, ...)

Attend

Observe

Remember

Think

calculate
decide
solve
develop alternatives
choose alternative
select response

Act

Environment

stimuli

responses
Some Common Human Decision Making,..., Fallibilities

- **Attend**
- **Observe**
- **Remember**
- **Think**
- **Act**

Environment

- stimuli
- responses

- anchoring, confirmation bias
- recency bias
- tendency to treat all sources as equally reliable
- bias against absence of cues
- asymmetric valuation (gain/loss)
- overconfidence
- erroneous mental model
Decision Making

- Choice among hypotheses/alternatives (known or to-be-generated)
- Conscious (attentive, not pre-attentive)
- Some information available, but not complete
- Time frame: seconds to hours
- Uncertainty about cues, outcomes
- Risk
  - potential that something unwanted or harmful may occur
  - $= f$ (uncertainty, consequences)
- Phases
  1. Receive and use cues
  2. Generate hypotheses and choose
  3. Select action to implement choice
Decision Making Models

- Normative Decision Models
  - Utility = subjective value, “goodness”
  - Multi-Criterion Decision Making Theory
    - e.g., choose a printer
## MCDM Example: Selecting a Printer

**Inkjet Printer Comparison Multi-Criterion Decision Matrix**

*November 2004 (but the principles remain!)*

<table>
<thead>
<tr>
<th>Criteria &amp; Weights</th>
<th>Scores</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternatives</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MCDM Example (2)

Inkjet Printer Comparison Multi-Criterion Decision Matrix

1. Alternatives, i = 1, 2, ...

2. Criteria j = 1, 2, ...
   (and rating functions)

3. weights w_j, j = 1, 2, ...
   (and sum, for formulation purposes)

4. Alternative Ratings r_{ij}

5. Alternative Scores S_i, i = 1, 2, ...
   \[ S_i = \sum_{j} w_j r_{ij} \]
### Inkjet Printer Comparison Multi-Criterion Decision Matrix

*November 2004 (but the principles remain!)*

#### Criteria & Weights

<table>
<thead>
<tr>
<th>Criteria &amp; Weights</th>
<th>Text Quality</th>
<th>Text Speed</th>
<th>Text Cost</th>
<th>Photo Quality</th>
<th>Photo Time</th>
<th>Photo Cost</th>
<th>Graphics Quality</th>
<th>Extra Features</th>
<th>Usability</th>
<th>Printer Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

#### Alternatives

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Scores</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Deskjet 995c</td>
<td></td>
<td>$250 @ Staples</td>
</tr>
<tr>
<td>HP Deskjet 6127</td>
<td></td>
<td>$250 @ OfficeMax</td>
</tr>
<tr>
<td>Epson Stylus Photo R800</td>
<td></td>
<td>$400 @ OfficeMax</td>
</tr>
<tr>
<td>Epson Stylus Photo R200</td>
<td></td>
<td>$100 @ Staples &amp; OfficeMax</td>
</tr>
<tr>
<td>Canon Photo Printer i800D</td>
<td></td>
<td>$240 @ Staples</td>
</tr>
<tr>
<td>Canon Photo Printer i860</td>
<td></td>
<td>$150 @ OfficeMax</td>
</tr>
</tbody>
</table>
MCDM Example (4)

MCDM Decision Criteria and Rating Functions

<table>
<thead>
<tr>
<th>Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>9</td>
</tr>
<tr>
<td>Very Good</td>
<td>7</td>
</tr>
<tr>
<td>Good</td>
<td>5</td>
</tr>
<tr>
<td>Fair</td>
<td>3</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
</tr>
</tbody>
</table>

Text Speed

![Text Speed Graph](image)

Text Cost

![Text Cost Graph](image)

Photo Time

![Photo Time Graph](image)

Photo Cost

![Photo Cost Graph](image)
MCDM Example (5)

Features (LCD viewer, Individual color tanks, Swap black/photo ink, Memory cards, Prints from camera, Borderless photos)

<table>
<thead>
<tr>
<th>Features</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 4</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Printer Cost

Cost vs. Rating
## MCDM Example (6)

### Inkjet Printer Comparison Multi-Criterion Decision Matrix

*November 2004 (but the principles remain!)*

<table>
<thead>
<tr>
<th>Criteria &amp; Weights</th>
<th>Text Quality</th>
<th>Text Speed</th>
<th>Text Cost</th>
<th>Photo Quality</th>
<th>Photo Time</th>
<th>Photo Cost</th>
<th>Graphics Quality</th>
<th>Extra Features</th>
<th>Usability</th>
<th>Printer Cost</th>
<th>Scores</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Deskjet 995c</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>4</td>
<td>705</td>
<td>$250 @ Staples</td>
</tr>
<tr>
<td>HP Deskjet 6127</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>4</td>
<td>705</td>
<td>$250 @ OfficeMax</td>
</tr>
<tr>
<td>Epson Stylus Photo R800</td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>660</td>
<td>$400 @ OfficeMax</td>
</tr>
<tr>
<td>Epson Stylus Photo R200</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>635</td>
<td>$100 @ Staples &amp; OfficeMax</td>
</tr>
<tr>
<td>Canon Photo Printer i800D</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>9</td>
<td>690</td>
<td>$240 @ Staples</td>
</tr>
<tr>
<td>Canon Photo Printer i860</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>795</td>
<td>$150 @ OfficeMax</td>
</tr>
</tbody>
</table>

Data adapted from *Consumer Reports*, September 2004, p. 27
Decision Making Models

● Normative Decision Models
  – Utility = subjective value, “goodness”
  – Multi-Criterion Decision Making Theory
    • e.g., choose a printer
  – Expected Value Theory
  – Subjective Expected Utility
    \[ \max \forall i \ E(x_i) = p \cdot \text{val}(x_i) \]
    \[ \max \forall i \ U(x_i) = p \cdot \text{util}(x_i) \]

● Descriptive Decision Models
  – Satisficing
  – Naturalistic decision making (complex, dynamic, often intuitive)
Heuristics and Biases

- Information Processing Limits in Decision Making: See Fig. 7.2, p.163, AORTA/Stage model (next slide)

1. Heuristics and Biases in Receiving and Using Cues
2. Heuristics and Biases in Hypothesis Generation, Evaluation, and Selection
3. Heuristics and Biases in Action Selection
Information Processing Model of Decision Making

**Attend**
- Focus on decision task
- Attend to relevant stimuli

**Observe**
- Receive and use cues: stimuli, perceptions

**Remember**
- WM working hypotheses & actions:
  - H1 → A1
  - H2 → A2
- LTM hypotheses & actions:
  - H H H H H H H H H H H H...
  - A A A A A A A A A A A A A...

**Think**
- Hypothesis generation, evaluation, selection
- Action selection

**Act**
- Action implementation: reach, grasp, move/manipulate, speak, walk/run

**Environment**
- Stimuli: inputs to the model
- Responses: outputs from the model
Heuristics and Biases

• Information Processing Limits in Decision Making: See Fig. 7.2, p.163, AORTA/Stage model.

1. Heuristics and Biases in Receiving and Using Cues
2. Heuristics and Biases in Hypothesis Generation, Evaluation, and Selection
3. Heuristics and Biases in Action Selection
Heuristics and Biases in Receiving and Using Cues

- Attention to limited number of cues
- Cue primacy and anchoring
- Inattention to later cues
- Cue salience
- Overweighting of unreliable cues
Heuristics and Biases in Hypothesis Generation, Evaluation, and Selection

- Generation of a limited number of hypotheses
- Availability heuristic
- Representativeness heuristic
- Overconfidence
- Cognitive tunneling (fixation)
- Anchoring and confirmation bias
... The human understanding, when any proposition has been once laid down (either from general admission and belief, or from the pleasure it affords), forces everything else to add fresh support and confirmation; and although most cogent and abundant instances may exist to the contrary, yet either does not observe or despises them, or gets rid of and rejects them by some distinction, with violent and injurious prejudice, rather than sacrifice the authority of its first conclusions. ...

Francis Bacon

*Novum Organum, 1620*
Heuristics and Biases in Action Selection

- Retrieve a small number of actions
- Availability heuristic for actions
- Availability of possible outcomes
- Framing effect / framing bias
  - People tend to incur greater risks to avoid losses
  - Sunk cost bias ("throw good money after bad")
  - To discourage risky behavior*, frame decisions WRT gains

* not always best!
Two Opportunities

1. Gamble?
   • 10% chance to win $95
   • 90% to lose $5
Two Opportunities

2. $5 lottery?
   • 10% chance to win $100
   • 90% chance to win nothing
Two Opportunities

1. Gamble?
   - 10% chance to win $95
   - 90% to lose $5

2. $5 lottery?
   - 10% chance to win $100
   - 90% chance to win nothing
Two Opportunities

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In study by Kahneman & Tversky\(^1\), more picked 2:

Framing Effect

Framing Effect Example (experiment)\(^1\)

- US preparing for disease outbreak
- 600 expected to die
- Two alternative programs proposed:

<table>
<thead>
<tr>
<th>Alternatives framed as gains:</th>
<th>Alternatives framed as losses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: P (save 200 people) = 1</td>
<td>C: P (400 die) = 1</td>
</tr>
<tr>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td>B: P (save 600 people) = (\frac{1}{3})</td>
<td>D: P (none die) = (\frac{1}{3})</td>
</tr>
<tr>
<td>P (save none) = (\frac{2}{3})</td>
<td>P (600 die) = (\frac{2}{3})</td>
</tr>
</tbody>
</table>

Framing Effect Example (experiment)¹

- US preparing for disease outbreak
- 600 expected to die
- Two alternative programs proposed:

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</tr>
<tr>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td>B: P (save 600 people) = ⅓</td>
<td>D: P (none die) = ⅓</td>
</tr>
<tr>
<td>P (save none) = ⅔</td>
<td>P (600 die) = ⅔</td>
</tr>
</tbody>
</table>

Of 152 participants:
72% picked A
28% picked B

Of 155 different participants:
22% picked C
78% picked D

Benefits of Heuristics, Costs of Biases

- Heuristics simplify decision making
- Work most of time ...
- ... but not all: lead to systematic biases*

*bias: tendency to decide one way or the other
Dependency of Decision Making on Decision Context

- Most people make pretty good decisions most of the time: heuristics work.
- Automatic vs control processing
- Skill-, Rule-, and Knowledge-Based Behavior
  - See Fig. 7.3, p. 171
  - Signals → **Skill-based Behavior** [automatic, fast]
  - Signs → **Rule-based Behavior**
    [IF condition Then action]
  - Symbolic knowledge (symbols) → **Knowledge-based Behavior**
    [attention-, WM-intensive, slow]
  - Personal driving example
- Recognition-Primed Decision Making
  - Familiar pattern → standard response
  - NB: Experts can recognize subtle differences in a pattern that make it novel & therefore require care & reason
Common Theme In Theories of Decision Making

Two-/Three-Process Decision Making

<table>
<thead>
<tr>
<th>Automatic Processing</th>
<th>Control Processing</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill-Based Processing</td>
<td>Rule-Based Processing</td>
<td>Schneider, W., &amp; Shiffrin, R. M. (1977) [psychology]</td>
</tr>
<tr>
<td>System 1</td>
<td>System 2</td>
<td>many sources, summarized in Kahneman (2011) [psychology]</td>
</tr>
</tbody>
</table>
Factors Affecting Decision Making

- See Table 7.4, p. 174
- Decision Making Factors/Limitations
  - Inadequate cue integration
  - Inadequate / poor quality knowledge
  - Tendency to adopt single course of action
  - Incorrect/incomplete mental model
  - Working memory limits
  - Poor awareness of changing situation (poor SA)
  - Inadequate metacognition
  - Poor feedback WRT past decisions
Improving Decision Making

- Task redesign
  - Better than trying to change person

- Decision Support Systems
  - Displays
  - Flowcharts
  - Decision matrices (MCDM)
  - Spreadsheets
  - Simulations

- Training
  - Anti-bias training
  - Metacognition training
  - Development of accurate/useful mental models
  - Perception/pattern recognition training
  - Relevant cue training
  - **Limitations to training**