Sensemaking and Bias

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http://hci.stanford.edu/courses/cs448g/
Launch?
No!

O-ring damage index, each launch

26-29 range of forecasted temperatures (as of January 22, 1986) for the launch of space shuttle Challenger on January 28

Temperature (°F) of field joints at time of launch

Tufte
Why did that work?

- Aggregates information
- Better representation
- Cue to action
Information Visualization:

“

The use of computer-supported, interactive, visual representations of abstract data to amplify cognition. “
Amplifying cognition

- Sensemaking
- Presentation
- Monitoring

Today we’re going to concentrate on sensemaking.
Behavioral foundations of visualization: Outline

- Basic Problem
- Bounded Rationality
- Rationality: Sensemaking
- Bounds: Proximal mechanisms & their limits
Basic Problem:
The sea (of information) is so big and my (mental) boat is so small.
Solution: The Selective Omission and Re-representation of Information.

[T]here appears to be a general Principle of selective omission of information at work in all biological information processing systems. The sensory organs simplify and organize their inputs, supplying the higher processing centers with aggregated forms of information which, to a considerable extent, predetermine the patterned structures that the higher centers can detect. The higher centers in their turn reduce the quantity of information which will be processed at later stages by further organization of the partly processed information into more abstract and universal forms. 

[Resnikoff, 1987, p. 19]
THE PAOMNNEHAL PWEOR OF THE HMUAN MNID. Aoccdrnig to a rschearch at Cmabrigde Uinervtisy, it deosn't mtaer in wahnt oredr the ltteers in a wrod are, the olny iprmoaatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can stll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.
Errors and Bias

Implications of Principle of Selective Omission and Re-representation of Information:

- Can handle more information, but flip side is
- Bias and Error
Bounded Rationality

An agent behaves as nearly optimal relative its goals as its resources will allow. -Herbert Simon
Simon’s Parable of the Ant
Rationality (Adaptiveness)

- “An ant, viewed as a behaving system, is quite simple. The apparent complexity of its behavior over time is largely a reflection of the complexity of the environment in which it finds itself.”
  –Herbert Simon
Bounded Rationality

RATIONALITY:
- Organisms will do the logical thing to obtain their goals.
- "Economic Man"
  - Completely informed of goals and alternatives
- Optimize utility

BOUNDED:
- There are limits:
  - Problems are complex
  - Perception and cognition are limited
  - Resources are limited
    - Incomplete information
    - Limited decision-making time
  - Conflicting preferences
- Use heuristics
  Satisfice ("good enough")
Interface

Outer Environment
Optimize Adaptation
(conditions for goal attainment)

Proximal Mechanisms
(mechanisms, goals, heuristic)

Rationality

Bounds

Interface
Example of a Proximal Mechanism

Diagram: A diagram illustrating a proximal mechanism's interface with the outer environment and adaptation. The diagram includes symbols for a fly, a sandwich, and a graph showing turning rate and speed over time with feeding intervals.
<table>
<thead>
<tr>
<th>Scale (sec)</th>
<th>Time Units</th>
<th>System</th>
<th>World (theory)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-7}$</td>
<td>months</td>
<td>SOCIAL BAND</td>
<td></td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^{-5}$</td>
<td>days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>hours</td>
<td>Task</td>
<td>RATIONAL BAND</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>10 min</td>
<td>Task</td>
<td></td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>minutes</td>
<td>Task</td>
<td></td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>10 sec</td>
<td>Unit task</td>
<td>COGNITIVE BAND</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>1 sec</td>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>100 ms</td>
<td>Deliberate act</td>
<td></td>
</tr>
<tr>
<td>$10^{-7}$</td>
<td>10 ms</td>
<td>Neural circuit</td>
<td>BIOLICAL BAND</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>1 ms</td>
<td>Neuron</td>
<td></td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>100 µs</td>
<td>Organelle</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 3.3. Time scale of human action.*
Rationality
1. Analysts Work Chains of Entities

FSUS-1
- Peptide regulators (’84-’88)
- Who was the brains?

Collaborators

FSUS-2

FSUS-3

FSUS-4 (Founder of Russian WB program)
- First author 14/49 papers
- Probably born c. 1950
- Probably Ph.D. 1973
- Good work
- Good work but students go to dark program
- Good work, someone else testing

Alibek
- Last author
- 99 Papers
- Party Hack
Web Behavior Graph

Search Pubmed

Searches about individuals

Search about institute
What is in an Expert’s schema?

SME-WMD Task Diagram
Notional Model

- Search for Information
- Search for Relations
- Search for Evidence
- Search for Support
- Search & Extract
- Schematize
- Build Case
- Hypotheses
- Tell Story
- Reevaluate
- Presentation

- External Data Sources
- Shoebox
- Evidence File
- Schemas

TIME or EFFORT

STRUCTURE
Knowledge Assembly Loops

Foraging:
- Skim
- Note-hit
- Follow-pointer
- Search-expand (search term)
- Search-narrow (search term + new term)
- Gather, Read, Annotate, and Question
- Batch Read & Annotate
- Compose

Sensemaking:
- Compose & Gather (search term)
This depicts a zoomed out view of task analyses of both novice and expert intelligence analysts. You can see differences between the novice, who spends the majority of time looking at external sources (grey boxes), and the expert, who spends the majority of time looking at his own familiar sources (purple boxes).
The Loops start at the top and spiral between schemas (to collect evidence for draft) and draft.

In batch mode, the analyst does the same thing over and over repetitively.

BUT IF the Expert Analyst has time...
1. INFORMATION FORAGING THEORY

So much for present input devices and their effect on computer design.
Optimal Foraging Theory

Max \[
\frac{\text{Energy}}{\text{Time}}
\]

Max \[
\frac{\text{Useful info}}{\text{Time}}
\]
Similar to Human & Animal Foraging

**Food Foraging**
- Biological, behavioral, and cultural designs are adaptive to the extent they optimize the rate of energy intake.

**Information Foraging**
- Information access and visualization technologies are adaptive to the extent they optimize the rate of gain of valuable information
Basic Equation

- Human-computer interaction is adaptive to the extent:

\[
\begin{align*}
\text{MAXIMIZE} & \left[ \frac{\text{Net Knowledge Gained}}{\text{Costs of Interaction}} \right] \\
= & \left[ \frac{\text{Net Knowledge Gained}}{\text{Ts} + (\text{Tp} + \text{Th})} \right] \\
= & \left[ \frac{\lambda I - \text{Ts}}{1 + \text{Th}} \right]
\end{align*}
\]

Ts = Search time, Tp = Pursuit time, Th = Handling time
I = Ave Information gained per encounter
Shift of Point of View

- **Information Retrieval**
  - Figures of Merit:
    » Precision - Percentage of stuff you retrieved that's good.
    » Recall - Percentage of good stuff that's out there you retrieved.
  - If you can find it 1000 times faster, it doesn’t count for IR.

- **Information Foraging Theory**
  - Speed (a kind of cost) matters
  - So does quality of result
2. SENSEMAKING THEORY

So much for present input devices and their effect on computer design.
Sensemaking--Creating a Course on Printing

Residue

Version 1

create categories & comparison dimensions

build schemas

encode test case

Generic Printers:

Scanners:

Printers:

version 1
Sensemaking Learning Loop

Learning Loop Complex

- Task Structure
  - Task operations
- Generation Loop
  - Representations
  - Residue
  - Representational Shift Loop
  - Data Coverage Loop
- Search for Good Representations
- Encode Data in Representation
- Processing Requirements of Task
  - Enodons
- Encodons

Russell, Stefik, Pirolli, and Card (1983)
Bounds
Axis Stretching

Microsoft Office Market Share
2008 Data

Which graph shows the worst trend?

COGNITIVE DISTORTION

Judgement Relativity

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Print & web subscription - US $135.00
One-year subscription to the print & web edition of The Economist and online access to all articles from The Economist since 1997.
We’re set up to make relative judgements
Ariely

-A ("the decoy")
Williams-Sonoma Home Bakery

Sales

$275

$412
Anchoring

Introduce at high price. Only available at very exclusive stores. Pair with celebrities and luxury goods.
Arbitrary Coherence

Although initial prices may be arbitrary, once established they will shape present and future prices.
MIT Demonstration

- Jot down last 2 digits of SSN
- Tell whether you would pay this or more for a number of products.
- Bid on products at an auction.
Amazingly, SSN anchors auction price

<table>
<thead>
<tr>
<th>Products</th>
<th>Range of last two digits of SS number</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>00-19</td>
<td>20-39</td>
</tr>
<tr>
<td>Cordless trackball</td>
<td>$8.64</td>
<td>$11.82</td>
</tr>
<tr>
<td>Cordless keyboard</td>
<td>$16.09</td>
<td>$26.82</td>
</tr>
<tr>
<td>Design book</td>
<td>$12.82</td>
<td>$16.18</td>
</tr>
<tr>
<td>Neuhaus chocolates</td>
<td>$9.55</td>
<td>$10.64</td>
</tr>
<tr>
<td>1998 Côtes du Rhône</td>
<td>$8.64</td>
<td>$14.45</td>
</tr>
<tr>
<td>1996 Hermitage</td>
<td>$11.73</td>
<td>$22.45</td>
</tr>
</tbody>
</table>
Heuristics Can Lead to Error

✧ Availability Heuristic
  ✧ Estimate probability by whether examples come to mind.
    ✧ E.g., Nuclear power accidents seem more likely if one has happened recently.
    ✧ Stories and examples used instead of statistics.

✧ Salience Heuristic
  ✧ Estimate probability by vividness.
    ✧ E.g., Terrorist attack on television more salient than attack on TV
• Representative Heuristic
  • Judgments of probabilities influenced by whether A looks like B.
Social Aggregation of Information

Compensate for individual error and limited knowledge by social aggregation and reasoning.
Social Aggregation of Information

Each member of society can have only a small fraction of the knowledge possessed by all, and . . . each is therefore ignorant of most of the facts on which the working of society rests . . . Civilization rests on the fact that we all benefit from knowledge which we do not possess. And one of the ways in which civilization helps us to overcome that limitation . . . is . . . by the utilization of knowledge which is and which remains widely dispersed among individuals.

### Statistical Average: “Wisdom of the Crowds”

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Actual</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow Weight</td>
<td>1,197 lbs</td>
<td>1,198 lbs</td>
<td>-0.08%</td>
</tr>
<tr>
<td>Temperature</td>
<td>72.4°F</td>
<td>72°F</td>
<td>+0.5%</td>
</tr>
</tbody>
</table>

*Galton, Knight*
Suppose we know the correct outcome on some issue.

3 person group
Each correct
p=0.67.

Majority vote
correct
p=0.74.

Better than the average group member.
When a group of “enlightened” decision makers chooses between two options under a majority rule, then as the size of the decision making population tends toward infinity, it becomes a certainty that the best choice is rendered.
Dark Side of Condorect Jury Theorem

- If on average $p<0.5$ believe the correct way, then voting will produce the wrong answer.
- E.g., If groups of voters believe different facts are true about world.
- Condorcet Jury Theorem assumes voters are independent in view and not influence by how others vote.

Bloggers mainly cite bloggers with similar beliefs.
Asch Experiment

Which line on right matches line on left?
On 12 of 18 trials, stooges give the same wrong answer.
Results

- Subject gives wrong conforming answer 37% of time.
- 75% of subjects conformed at least once.
- Larger group, more conforming
Hidden Profiles

- The understanding groups could have, but don’t attain.
- Group members have information they don’t share.
- Why?
The Common Knowledge Effect

- Common information shared by all or most group members has biggest effect on group judgments.
  - Experiment: Selecting a candidate. One obvious best.
    - Cond. 1. 66% of information distributed to all members of 4-person team.
      - Result: 67% favored best candidate before discussion, 85% after.
    - Cond. 2. Information parceled out to individual members, but information given to all favored inferior candidates.
      - Result: 25% favored best candidate before discussion, even fewer after discussion because of influence of common information.
Information Cascades

- People follow the lead of others who have spoken before even when they have a different view.
  - Discussion dominated by common information
  - Low status members increasingly reluctant to share unique information as discussion proceeds.
  - The longer the cascade, the riskier it appears to oppose it.
Reputational Cascades

✦ People don’t contradict the discussion for fear of
  ✦ Seeming stupid
  ✦ Incurring hostility
✦ The more people who go along, the riskier to oppose.
Group Polarization

• Deliberation tends to lead to group polarization.
  • Argumentation. Arguments favoring initial position of group will be more frequent. Have heard more of the arguments.
  • Social influences. People want to be liked by the group.
  • Boost of confidence.
  • Cascade effects
The purpose of Information Visualization is the amplification of cognition not, the creation of pretty pictures.
Summary

* The basic problem is large information, but small mind and resources.
  * A solution is the Principle of Selective Omission and Re-representation of Information.
  * Information visualization uses this principle, often by **aggregating information** in a **better representation** giving **cues to action** relative to a task.
  * But the flip side of the Principle is that the shortcuts may sometimes lead to illusions, biases, or error.
Simon’s theory of Bounded Rationality encapsulates this tension.

On the one hand, behavior is mostly adaptive or “rational”, meaning the organisms does the logical thing to obtain a goal. Much of the complexity of behavior comes from the complexity of the environment.

On the other hand, processing is “bounded”, there is often some proximal mechanism that uses heuristics to satisfice--to do good enough.
For information processing, the **rational** part can be explicated by information foraging theory and sensemaking theory.

- **Information foraging theory** says user maximize the rate of information gain.
- **Sensemaking theory** says that they try to make sense of information by re-representing it relative to some schema, resulting in a more compact and efficient expression of it relative to some task.
The proximal mechanisms used can lead to errors at all levels. Some of these are
- Perceptual: axis spreading
- Cognitive: Judgement relativity, anchoring
- Social: Social distortion of judgment, common knowledge effect, information cascades, reputational cascades, group polarization
- And many more.

Both the facilitative aspect of visualization and the possible routes for error need to be considered in design.
So much for present input devices and their effect on computer design.