Mental Models (1)

- Johnson-Laird (1983) *Mental Models*
- Gentner & Stevens (1983) *Mental Models*
- Definitions of Mental Models
  - Term used in diverse ways by theorists, can refer to memory or dynamically created structure in consciousness
  - Norman (1988) *Psychology of Everyday Things*
    - "The model people have of themselves,others, the environment, and the things with which they interact. People form mental models through experience, training, and instruction"
  - Johnson-Laird

Mental Models (2)

- Johnson-Laird's Mental model theory
  - Grew out of research on imagery
  - Mental models are related to images, may contain propositional (linguistic, factual) information
  - Combination of analogical and propositional representations
  - Mental models (unlike images) are *constructed* in order to make an *inference* or prediction about a particular state of affairs
  - Image is specific, has one viewpoint, mental model more general
- Mental models are related to analogies and learning by analogies
  - Example in book: Erikson, 1990: views of voice mail system mailboxes (answering machine vs. answering service)

Mental Models Examples

- Research (Psychology)
  - People's mental models of electricity

- Application / Design (Engineering)
  - Thermostat
  - Norman (1988) Refrigerator
  - Mental models of the telephone system

Mental Models of Electricity (1)

- Gentner & Gentner (1983)
- Mental models as analogies
  - Compare simple, familiar system with complex system
  - More than just language "shorthand", analogies have real conceptual effects in people's understanding
    - Phrase "stopping the flow" of electricity
  - Analogies are often used in teaching
  - Scientists report using analogies in theory development
- Generative Analogy hypothesis: Analogies are used in generating inferences about a domain
  - Mental models affect users understanding and, therefore, behavior toward a system (for us: a device or technology…)

D. Genter & D. R. Gentner. (1983) Flowing waters or teeming crowds: Mental models of electricity. In D. Gentner & A. L. Stevens (Eds.) *Mental Models*, Hillsdale, NJ: Erlbaum. Pp. 99-129.

Mental Models of Electricity (2)

- Electricity as Water Flow
  - Systems of relationships can be "imported" from hydraulics to electricity
  - Water flows through pipes, electricity flows through wires
    - Battery $\Rightarrow$ pump or reservoir
    - Voltage $\Rightarrow$ water pressure
    - Current (milliamperes) $\Rightarrow$ flow rate of water
    - Narrowness of pipe $\Rightarrow$ resistance

Mental Models of Electricity (3)

- Moving-Crowd Model
  - Electric current $\Rightarrow$ masses of objects racing through passageways
    - Cars on a highway, devils running though hallways
  - Provides analogy for same set of relationships as previous model:
    - Voltage $\Rightarrow$ how powerfully entities push
    - Current (milliamperes) $\Rightarrow$ number of entities passing by a point
    - Resistance $\Rightarrow$ gate through which entities must pass through
    - Battery $\Rightarrow$ *no real useful analogy*

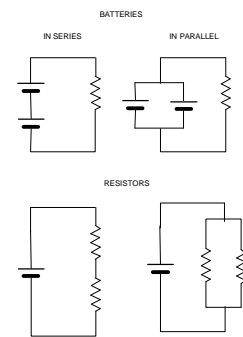- Analogy works much better in predicting properties of resistors

What happens to the speed of electrical flow
when you add a [battery / resistor] ?

Mental Models of Electricity (4)

- "Generative analogies" or surface terminology?
  - Serial versus parallel batteries and resistors distinguish models
    - More batteries in serial $\Rightarrow$ more current
    - More resistors in serial $\Rightarrow$ less current
    - More batteries in parallel $\Rightarrow$ same current as a single battery
    - More resistors in parallel $\Rightarrow$ more current than a single resistor
  - Water model
    - Two reservoirs stacked (serial) $\Rightarrow$ more flow, pressure
    - Reservoirs side by side (parallel) $\Rightarrow$ same height, therefore same flow and pressure
  - Moving-Crowd model
    - Two gates in sequence (serial resistors) $\Rightarrow$ flow lower than one gate
    - Side-by-side gates (parallel resistors) $\Rightarrow$ flow splits and moves through two gates, therefore, overall flow rate is twice that of one gate

Mental Models of Electricity (5)

- Prediction:
  - People with Flowing-Water model
    - More likely to see difference between serial-parallel battery combinations
  - People with Moving-Crowd model
    - More likely to see difference between serial-parallel resistor combinations
- Experiment:
  - Subjects given different circuit combinations asked to say whether current and voltage greater than, equal to, or less than a reference simple circuit
  - Subjects then were asked about their mental models
  - Results: Subjects with Moving-Object model did better with resistors, subjects with Water Flow model did better with batteries
  - Further experiments taught one model or another, to get away from problems with subjective reports, results were more complicated

Mental Models: The Thermostat (1)

- The room is cold, the heat turns on
- The thermostat is at its usual setting
- Do you
  - Do nothing?
  - Turn up the thermostat so it'll get warmer faster?

Mental Models: The Thermostat (2)

- Thermostat = Gas Pedal
  - Turning it up makes the boiler work faster
- Thermostat = Switch
- Thermostat = Feedback System
  - Feedback system with sensors
  - Thermostat controls set point

  - ➤ Discrepancy between user's model of system and actual system (designer's model) can cause errors and usability problems
  - ➤ Room becomes too hot

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Mental Models: Refrigerator

- Norman (1988) *The Psychology of Everyday Things*
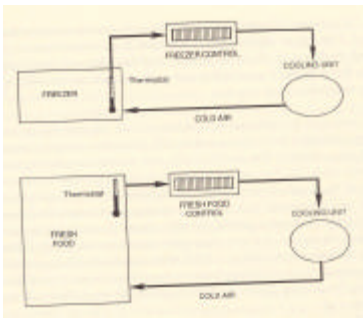
User Confusion → User's Model ¹ Designer's Model
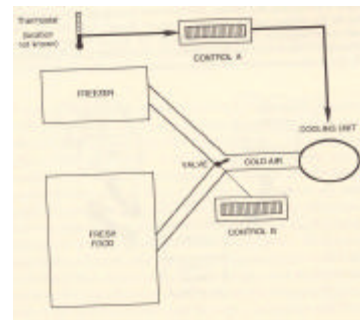
Slide 14

Slide 15

Slide 16

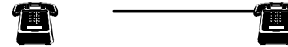## Mental Models of the Telephone System (1)

- Bennett & Klinger, 1990
  - Understand why people do not used advanced features of telephone systems (premise-based PBXs)
  - Advanced features: conference, transfer, forward, call redirection, call park, etc.
  - Build user interface prototypes which are consistent with understanding of users' mental models of how telephone work
- Interviews with business users of PBX ("key") systems
  - Users were heavy user 6-40 calls per business day
  - Saw very little use of phone beyond simple calling
  - Users reported using very few advanced features and were unaware of many features

Mental Models of the Telephone System (2)

- Mental Models
  - In depth structured interviews with users who were not telecommunications engineers or hobbyists
  - Four categories of mental models:
    - No model or one that could not be understood
    - Simple model ("paper cups and string")
    - Model recalling distributed packet system
    - Automated operator-like model

- Simple Model
  - Telephones and wire, little recognition of anything in between
  - Did not recognize difference between busy and "fasy busy" (network congestion)
  - Interpreted working of calling features as having second telephone line
  - Completely confused by switchhook flashes, work by magic

Mental Models of the Telephone System (3)

- Distributed system model
  - Some common facilities, telephones are "smart" and know how to send their voice to other telephones
  - Understood busy versus "fast busy"
  - Seriously misunderstood some telephone features
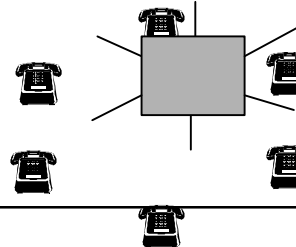   - E.g. assumed that they couldn't forward calls if phone was in use

Mental Models of the Telephone System (4)

- Automated operator model
  - Believed system of some number of automated systems sent calls to telephone based upon dialed digits
  - Understanding fundamental idea of switching, their understanding and use of telephone features were accurate

Mental Models of the Telephone System (5)

- Use made of the understanding of people's models
  - Simple mental model of telephone network stands in the way of understand how telephone system needs to work to make conference calls
  - Simple model begs to just dial multiple phone numbers, but must signal to network a multi-point calls
  - Prototyped directed manipulation user interface based upon separate metaphor from telephone system: "The personal visit"
  - Re-designed button names and call procedures on conventional multi-button phone based upon personal visit metaphor
  - Good results from usability testing

How Does a User Form a Mental Model?

- Acquire knowledge of system and its behavior and form a 'theory' of how system works
- Mental models formed by
  - Using the system
  - Observing other users
  - Reading documentation
  - Preconceptions and background knowledge
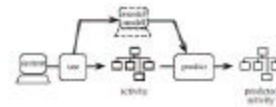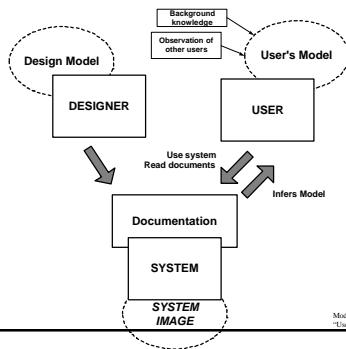- Model is 'runable' – user predicts system behavior

Fig – TCD Computer Sciences Dept.

Norman (1986) – "System Image"

Modified From Norman (1986)
"User-Centered System Design"