

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. Gentner & 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

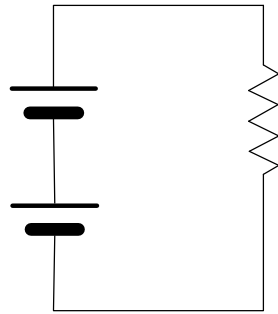
Mental Models of Electricity (3)

- Moving-Crowd Model
 - Electric current \Rightarrow masses of objects racing through passageways
 - Cars on a highway, devils running through 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

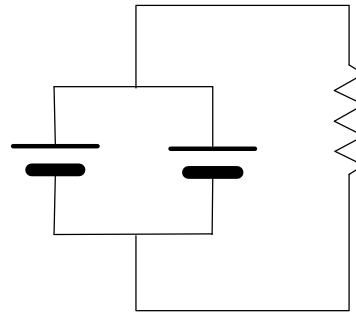
What happens to the speed of electrical flow
when you add a [battery / resistor] ?

BATTERIES

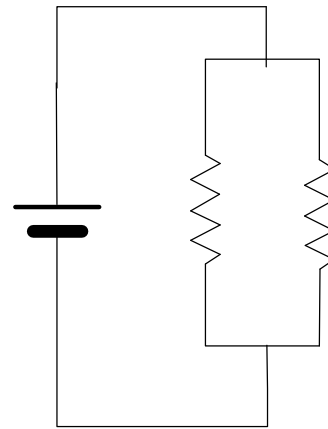
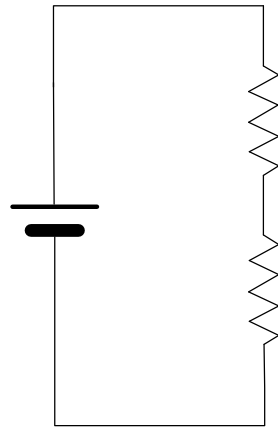
IN SERIES



IN PARALLEL



RESISTORS



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

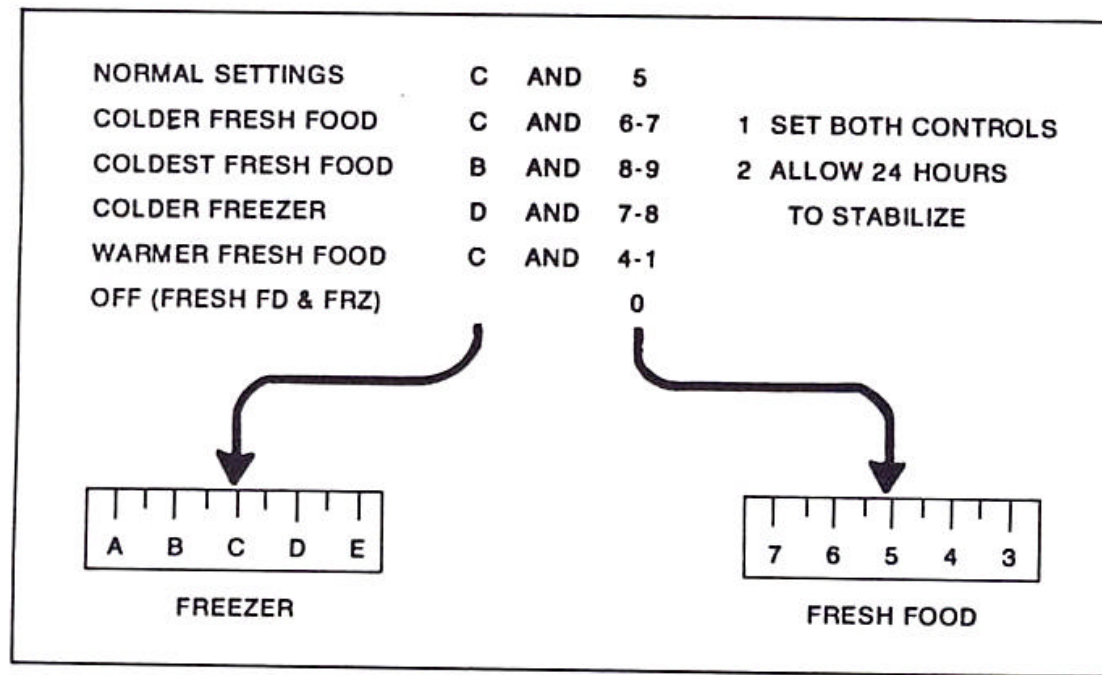


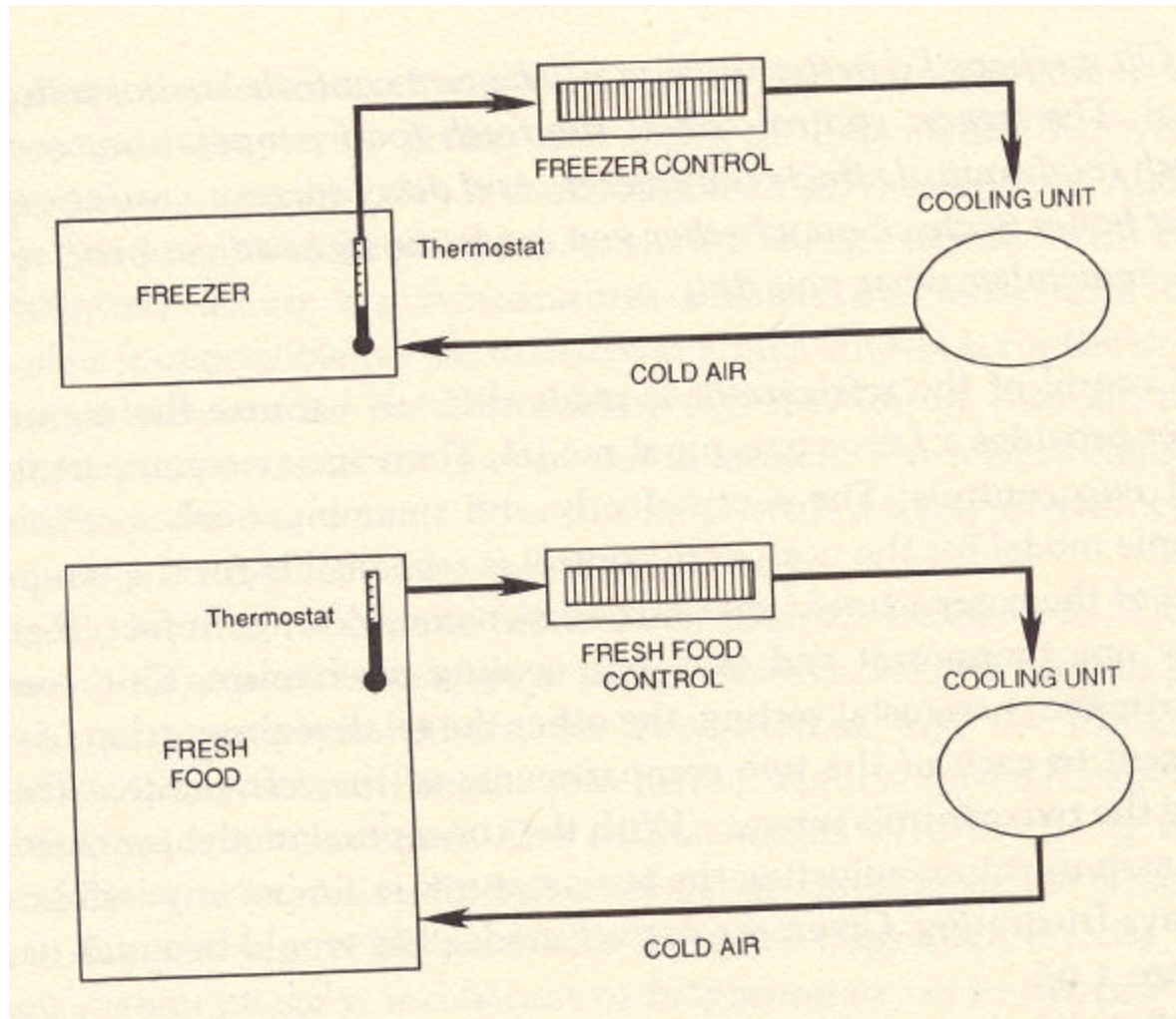
Mental Models: Refrigerator

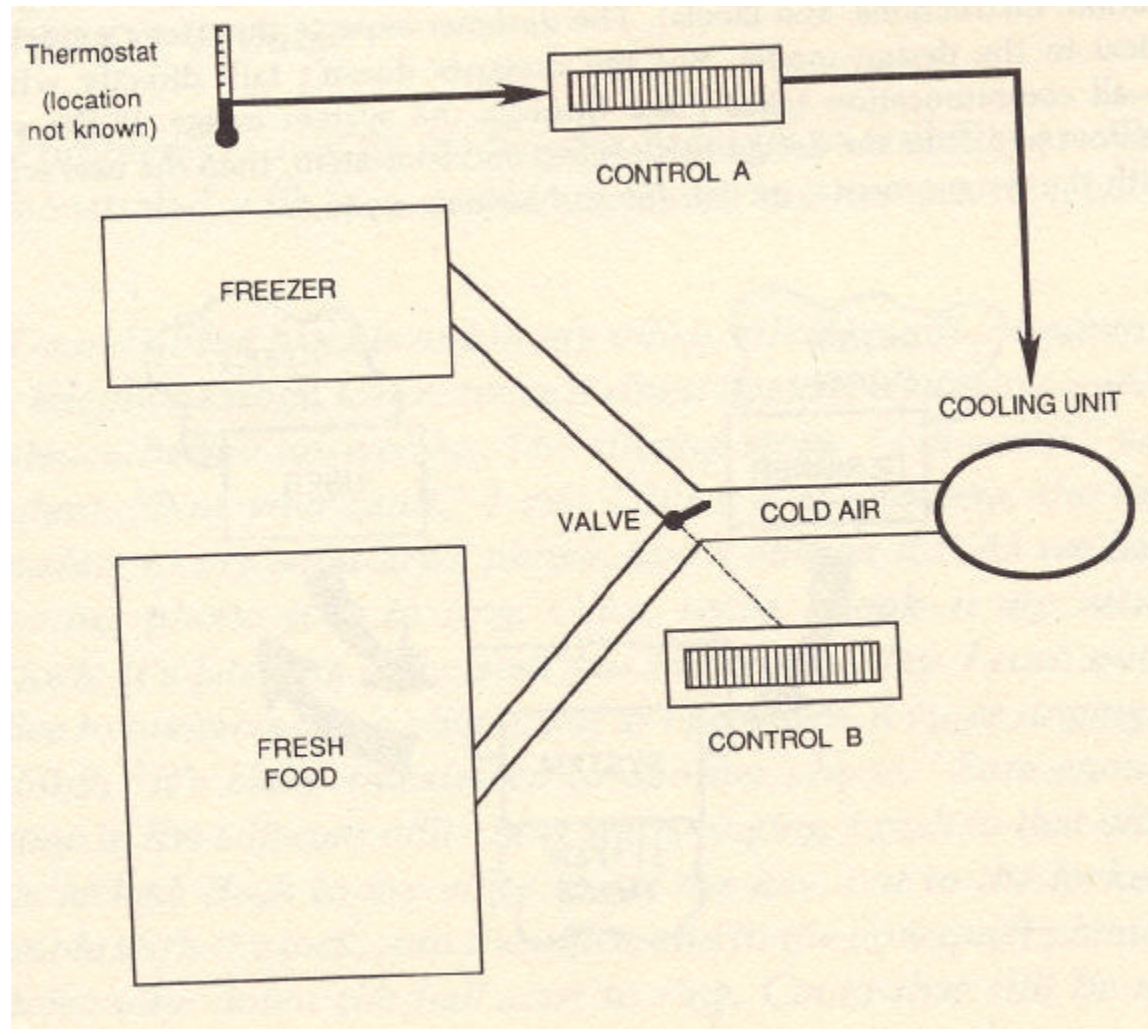
- Norman (1988) *The Psychology of Everyday Things*

User Confusion → User's Model ¹ Designer's Model

1.8 My Refrigerator. Two compartments—fresh food and freezer—and two controls (in the fresh food unit). The illustration shows the controls and instructions. Your task: Suppose the freezer is too cold, the fresh food section just right. How would you adjust the controls so as to make the freezer warmer and keep the fresh food the same? (From Norman, 1986.)







Slide 14-16 Fig s – Norman (1988).

Mental Models of the Telephone System (1)

- Bennett & Klinger, 1990
 - Understand why people do not use 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)

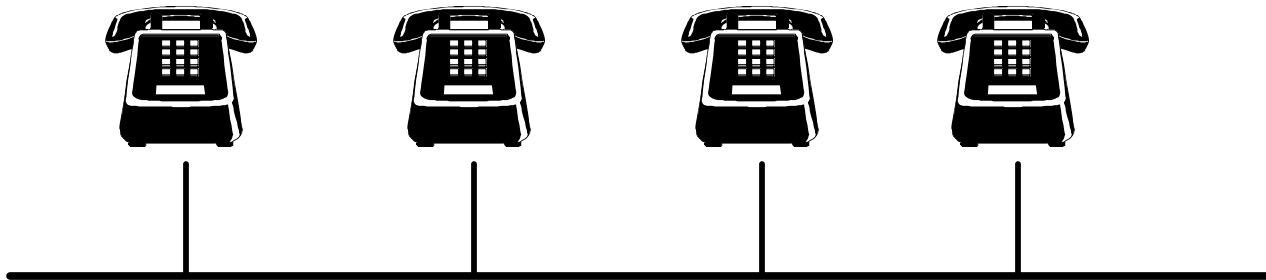
- Mental Models
 - In depth structured interviews with users who were not telecommunications engineers or hobbyists
 - Four categories of mental models:
 - No model or one that could not be understood
 - Simple model (“paper cups and string”)
 - Model recalling distributed packet system
 - Automated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

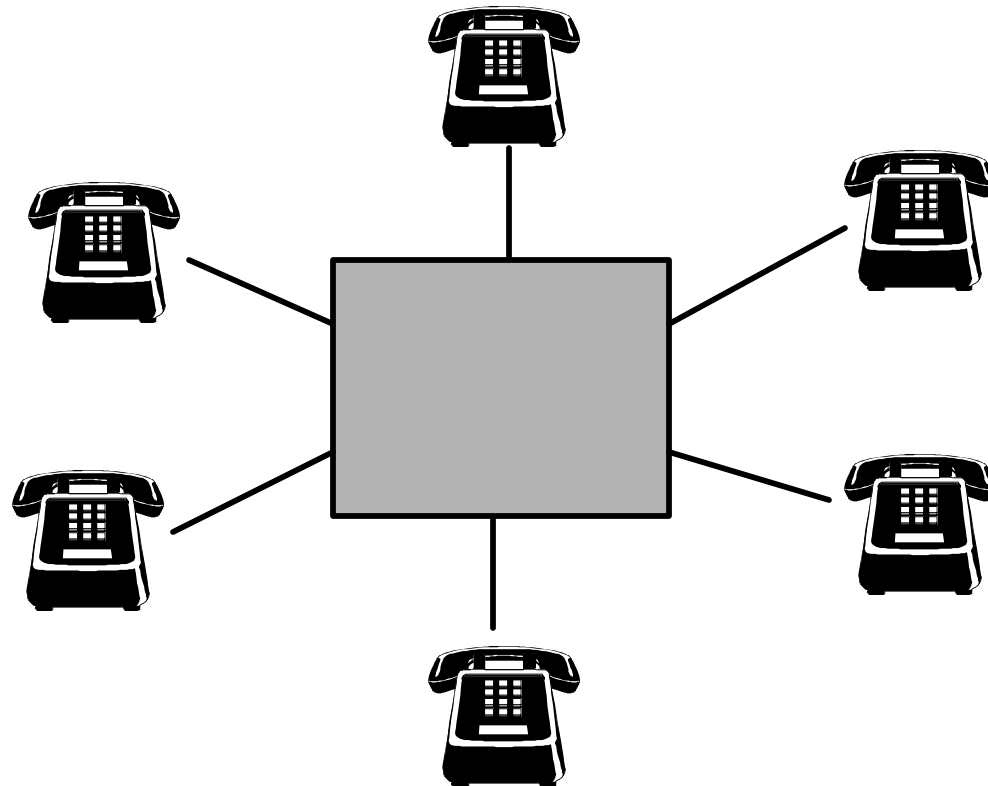
Mental Models of the Telephone System (3)

- 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

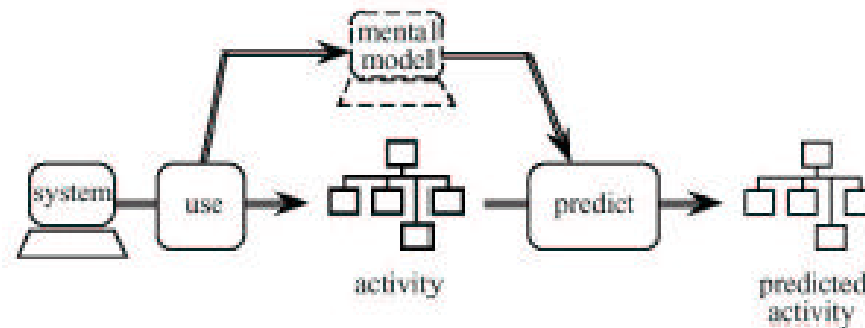
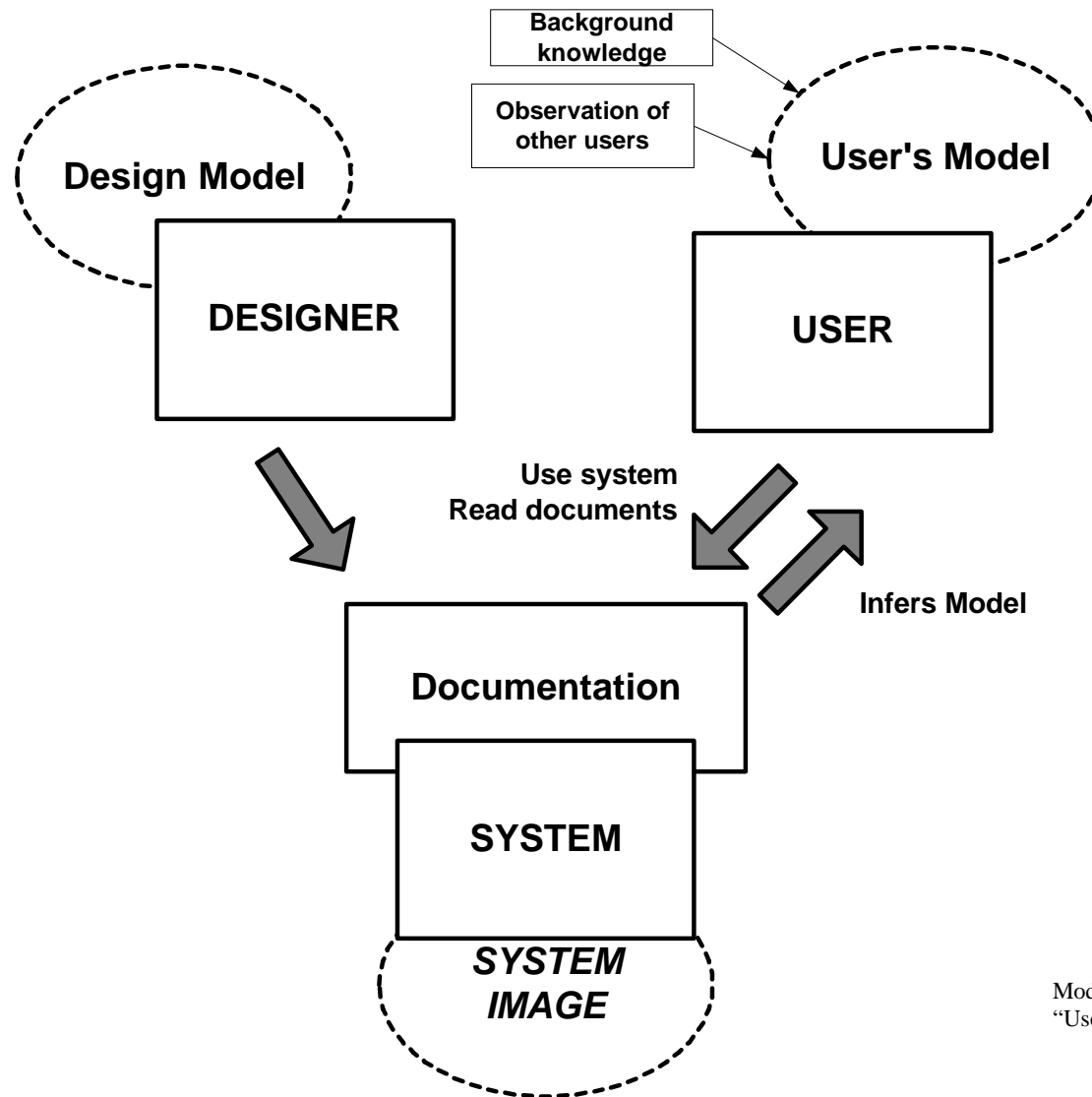


Fig – TCD Computer Sciences Dept.

Norman (1986) – “System Image”



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