Kishan Salian, Msc Interaction Design

MENTAL MODELS

MENTAL MODELS

Structure of the presentation:

- Introduction to mental models
- Why and how?
- Past and Current research areas
- Types of mental models
- Methods used to extract mental model
- Construction of mental model
- Mental model and HCI
- Problems, challenges and confusions

MENTAL MODELS

Questions:

How do we think?

How do people understand some domain of knowledge?

What is the result of perception?

How do we anticipate the world and make sensible decisions about what to do?

What triggers thinking and reasoning?

Answer:

The answer is simple we rely on "**Mental Models**".

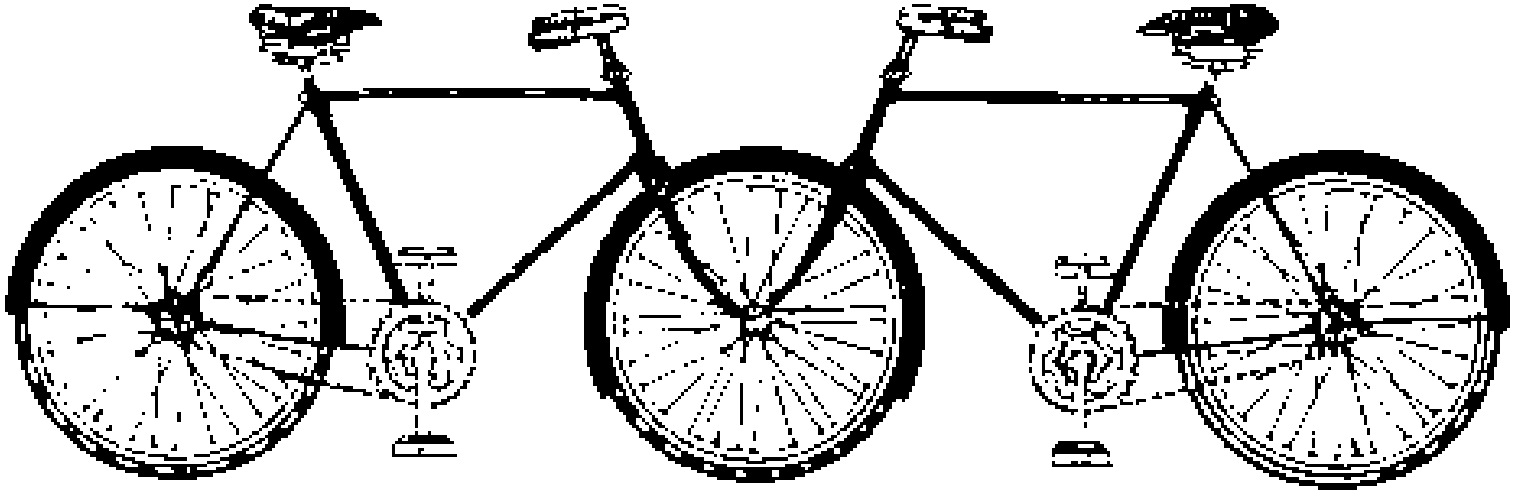
Perception and linguistic comprehension yield mental models and **thinking and reasoning** are the internal manipulations of mental models. - Phil Johnson-Laird.

(Johnson-Laird, 2004)

MENTAL MODELS

What are Mental Models?

A persons thought process of understanding the world. It allows people to make assumption about how things work and unconsciously influence our behaviour and decision making.



Our mental models of how bicycles work can "simulate" this to know it won't work

(Slide adapted from Saul Greenberg)

MENTAL MODELS

The term “Mental Models”

The Scottish psychologist Kenneth Craik (1914–45) was the first person to propose the term "Mental Models" (1943) and believed that the mind constructs “small-scale models” of reality that it uses to anticipate events, to reason, and to underlie explanation.

Mental models are representations in the mind of real or imaginary situations - Ruth Byrne and Phil Johnson-Laird (born 12 October 1936).

Reasoning is a process by which a human “examines the state of things asserted in the premises, forms a diagram of that state of things, perceives in the parts of the diagram relations not explicitly mentioned in the premises, satisfies itself by mental experiments upon the diagram that these relations would always subsist, or at least would do so in a certain proportion of cases, and concludes their necessary, or probable, truth. ” (1896) - Charles Sanders Peirce (1839–1914).

Example of everyday thoughts: (Deductive reasoning)

How do you solve the following reasoning problem?

Adam is taller than Bob.
Bob is taller than Dan.
so what do you know about Adam and Dan?

Answer:
Adam is taller than Dan.

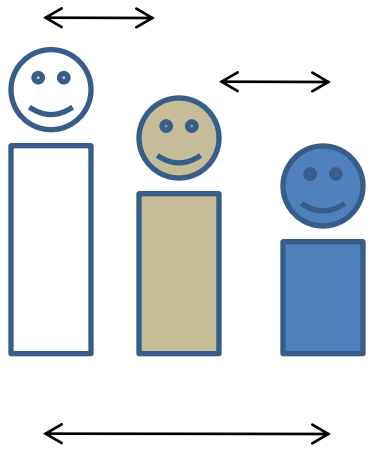
How we conclude it? Mental calculation

We apply **logical rules** of universal instantiation and modus ponens, to **translate** the given information into **predicate** calculus

Adam as **taller than** Bob Bob as **taller than** Dan

We use their encoding of the transitivity of "**taller than**" to infer that Adam is taller than Dan.

Image or model of the world



(Paul Thagard - How brain makes mental model)

Why research on Mental Models?

Patrick Hayes' (1979) extensive study on the behaviour of liquids.
The understanding enables people to predict when a liquid will flow, stand still and fall from the surface.

This theory would be useful any substance in liquid form and it would be helpful in understanding why operators of nuclear plants misinterpret their instruments.

The better our understanding (models) of the knowledge involved, the better we would be able to simulate, teach and test it.

(Dedre Gentner, Albert L. Stevens - Mental models)

Use of “Mental Models”

The concept of mental model has been used extensively in the psychology (reasoning), artificial intelligence , linguistics , sociology , learning science and human computer interaction field.

Some theorists and psychologists explored their respective domains to prove the **existence** of mental models while others suggested **refinement** in existing mental model theory.

Does mental model exists? If yes then how is it extracted, represented and analysed?

(Dedre Gentner, Albert L. Stevens - Mental models)

In search of Mental Model

Qualitative reasoning about space and motion – Kenneth D. Forbus
He simulated a well-defined sub-domain of spatial knowledge and proposed more refined theory and made it more compatible.

Flowing waters or teeming crowds: Mental models of electricity - Gentner's
They proposed a theory of the way in which analogies are psychologically processed and claimed that different analogies help in predicting and understanding of the topic domain.

Understanding Micronesian Navigation – Edwin Hutchins
He compared spatial navigation in Solomon islands with western theories and found huge differences in usage.

(Dedre Gentner, Albert L. Stevens - Mental models)

The mental model theory in thinking and reasoning

According to the model theory, everyday reasoning depends on the simulation of events in mental models. It rests on simple principle assumptions:

Each model represents a possibility

Models are iconic as far as possible

Models explain deduction, induction, and explanation

The principle of truth: mental models represent only what is true

Procedures for reasoning with mental models rely on counterexamples

The greater the number of alternative models needed, the harder it is

The meanings of terms such as 'if' can be modulated by content and knowledge

(Johnson-Laird, 2006 - http://mentalmodels.princeton.edu/about/what-are-mental-models/)

Types of Mental Models

Young (1983) suggests eight tentative types of mental models:

- Strong analogy
- Surrogate
- Mapping
- Coherence
- Vocabulary
- Problem Space
- Psychological Grammar
- Commonality

Laird cautions that all model distinctions maybe artificial for they may represent the same reality.

(Richard Young - Mental models)

MENTAL MODELS

Methods used

- Novices and experts studies
- Comparing users' performance on a system
- Protocol analysis
- Field observation
- Comparison across culture and historical comparison
- Content analysis
- Procedural mapping (Think aloud)
- Card sort

How are mental models constructed?

Cognitive scientists have argued that the mind constructs mental models as a result of perception, imagination and knowledge, and the comprehension of discourse

Perception:
Becoming aware of something by seeing, hearing or by using other senses.

Imagination:
Forming new ideas, or images or concepts of external objects.

Knowledge:

What is known perceptual experience and reasoning.

Comprehension of discourse:
The action of understanding something by written or spoken communication.

How are mental models constructed?

One notion is that analogies or metaphors function as tools of thoughts which help structure unfamiliar domain (Gentner and Gentner, 1983)

Example: (Analogies)
Flowing waters simulates the flow of electricity and any other liquid substances.

Example: (Metaphor)
More is up/good is up
I'm feeling up. That boosted my spirits
Get up. Wake up. She rises early
He's at the peak of health
I am on top of the situation. He is under my power
My income rose last year

How are mental models constructed?

- Affordances
- Constraints
- Mappings
- Positive transfer
- Cultural associations/standards
- Instructions
- Interactions

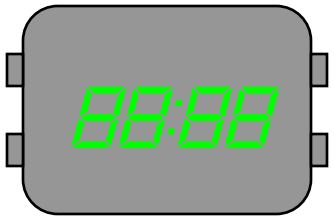
(Slide adapted from Saul Greenberg)

Wheel Bag

- Affordances:
  - Handle to carry or lift the bag.
  - Big compartments for clothes and small for accessories.
- Constraints:
  - Moving zip in one direction to open and close the bag.
- Mappings:
  - Placement of the side handle to use the wheel for moving.
- Positive transfer:
  - Learnt easily when in contact

(Slide adapted from Saul Greenberg, Image copyright: Reebok)

Wheel Bag



- Affordances:
  - Four push buttons, not clear what they do.
- Constraints and mapping:
  - No visible relation between buttons and the end-result of their actions.
- Negative transfer:
  - Little association with analog watches.

(Slide adapted from Saul Greenberg)

MENTAL MODELS

“Mental Models” in HCI

"In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction.“
- Norman, D

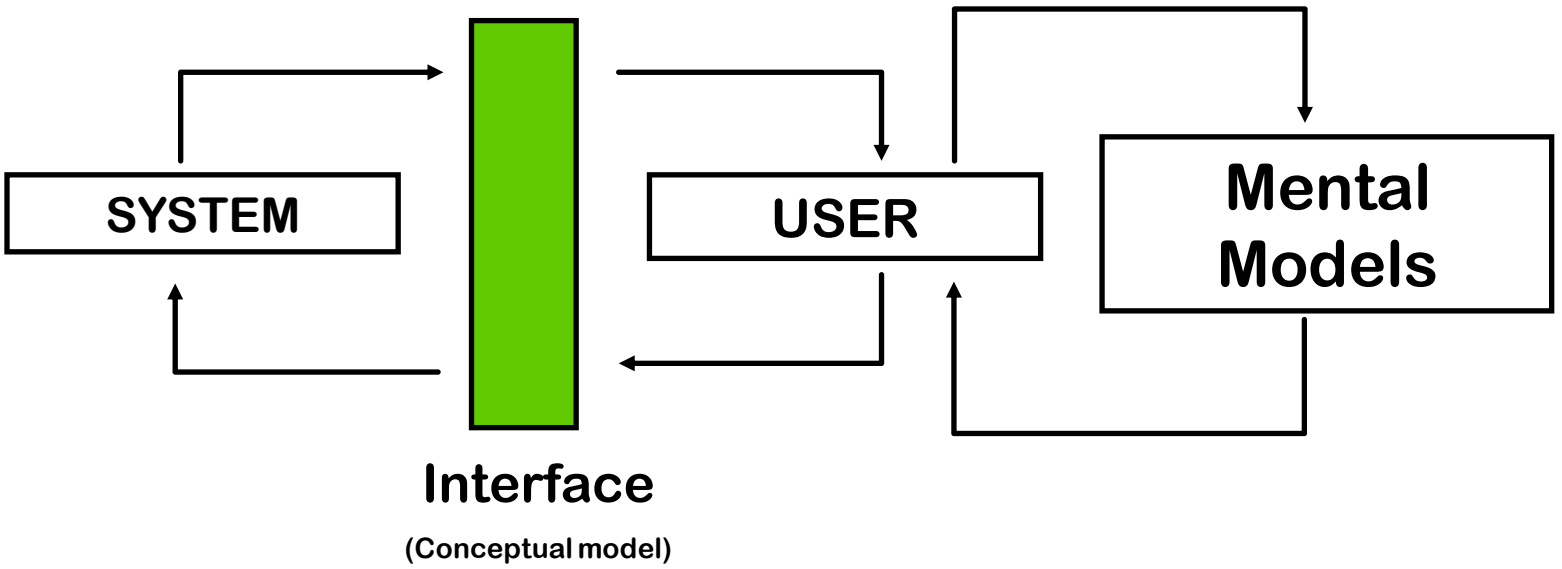
Term Distinctions:

Norman (1983) offers some differentiation between the terms conceptual and mental models and suggests considerations:

- The target system
- The conceptual model of the target system (teachers, designer’s)
- The system image
- The users’ mental model of the target system
- The scientist’s conceptualisation of the mental model

"Mental Models" in HCI

- Users develop an understanding of a system through learning & using it
- This type of understanding is often described as a mental model
  - How to use the system (what to do next)
  - What to do with unfamiliar systems or unexpected situations (how the system works)
- People make inferences using mental models of how to carry out tasks



(Slide Adapted from Philip Barker, ENABLE99 Presentation)

Why research of mental model in HCI?

Developing better system conceptual model leads to:

- Easy Learning
  - Increase motivation to use the system
  - Better understanding the complexity of the system and task
- Better Performance
  - Problem solving skills
  - Efficiency
  - Accuracy

(Staggers, N and Norcio, A. F)

MENTAL MODELS

Guidelines for Design

Provide a good conceptual model

- ❖ Allows users to predict consequences of actions
- ❖ Communicated through the image of the system

Make things visible

- ❖ Relations between user's intentions, required actions, and results should be
  - ▪ Sensible
  - ▪ Consistent
  - ▪ Meaningful (non-arbitrary)
- ❖ Make use of visible affordances, mappings, and constraints
- ❖ Remind person of what can be done and how to do it

To conclude, designer's should be aware of users' mental model.

(Slide adapted from Marti Hearst)

Problems, Challenges and Confusions

Norman (1983) reports some problems during this observation:

- Mental models are incomplete (Laird, 2000): Can lead to incorrect mental representation and wrong decisions
- Models are unstable
- People's ability to run their models are severely limited
- Mental models are parsimonious: Often people do extra physical operation rather then the mental planning

Byrne, R (2000) points that few areas are still a challenge like strategic thinking that occurs in making decisions and in reasoning about another individual's inferences.

Different authors different terms: mental models, conceptual models, cognitive models and casual models.

MENTAL MODELS

Overall View

Even though it is hard to capture and evaluate mental models and many times are incomplete or weak, but it is worth the effort of understanding human knowledge in any domain and improves our capability to design better theories and systems on any domain.

MENTAL MODELS

Questions?

Further Reading:

For detailed information on the topic please visit:

http://www.designimpacts.com/?cat=17

Bibliography:

Byrne, R. 2006. *Mental Models* [Online]. Available: http://www.tcd.ie/Psychology/other/Ruth_Byrne/mental_models/ [Accessed].

Forrester, J. W. 1971. Counterintuitive Behavior of Social Systems. *Technology Review.* Alumni Association of the Massachusetts Institute of Technology.

Gentner, D. & Stevens, A. L. 1983. *Mental Models*, Lawrence Erlbaum Associates. Inc.

Johnson-Laird, P. N. 2004. The history of mental models. *In:* MANKTELOW, K. & CHUNG, M. C. (eds.) *Psychology of Reasoning: Theoretical and Historical Perspectives.* New York: Psychology Press.

Kurtz, A. 2004. *Mental Models - A Theory Critique* [Online]. The Open University. Available: http://mcs.open.ac.uk/yr258/ment_mod/ [Accessed].

Lab, M. M. a. R. 2010. *Mental Models* [Online]. Mental Models and Reasoning Lab. Available: http://mentalmodels.princeton.edu/ [Accessed].

Magnani, L., Pizzi, C., Carnielli, W. & Thagard, P. 2010. How Brains Make Mental Models. *Model-Based Reasoning in Science & Technology.* Springer-Verlag Berlin Heidelberg.

Staggers, N. & Norcio, A. F. 1993. Mental models: Concepts for human-computer interaction research. *International Journal of Man-Machine Studies*, 587-605.