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# IPM 12/13 – T1.4

## Mental Models

Licenciatura em Ciência de Computadores

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**Acknowledgements:** Most of this course is based on the excellent course offered by Prof. Kellogg Booth at the British Columbia University, Vancouver, Canada. Please acknowledge the original source when reusing these slides for academic purposes.

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# Summary

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- Mental models vs. Conceptual design
- Human goal-oriented action
- Structural and functional models

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# Recall: Design Concepts

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design concept is highest level and open to interpretation;  
*It is a starting point*

- Affordance
  - visible constraints
- Mapping
- Feedback
  - Causality (true and false kinds)
  - Understandable action

Other factors:

- Transfer effects
- Cultural associations
- Individual differences

• Visibility

• **Conceptual models**

“Psychology of everyday things”,  
Don Norman, 1988

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# Conceptual models: learning goals

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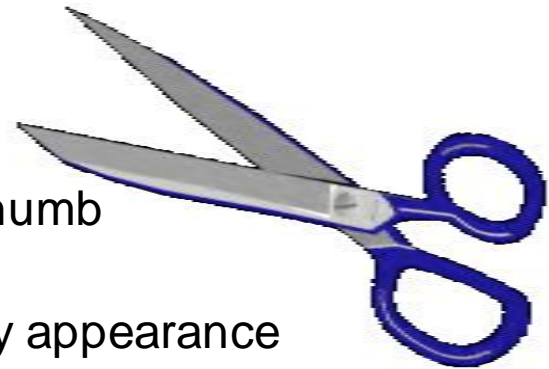
- People have “**mental models**” of how things work
- We **build** our conceptual models from **many things**, inc:
  - affordances
  - causality
  - constraints
  - mapping
  - positive transfer
  - population stereotypes/cultural standards
  - instructions
  - interactions (inc. w/ other people)
  - familiarity with similar devices (positive transfer)
- Models **may be wrong**, esp. if attributes are misleading
- Models allow us to **mentally simulate** device operation
- The designer has control over the **system image**

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# An object that **helps** you form a conceptual model: **Scissors**

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- **Affordances:**
  - Holes for something to be inserted
- **Constraints:**
  - Big hole for several fingers, small hole for thumb
- **Mapping:**
  - Holes-for-fingers suggested / constrained by appearance
- **Positive transfer and cultural idioms:**
  - Learnt when young; constant mechanism
- **Conceptual model:**
  - Physical object implies how the operating parts work



The object implies a **reasonable conceptual model**.

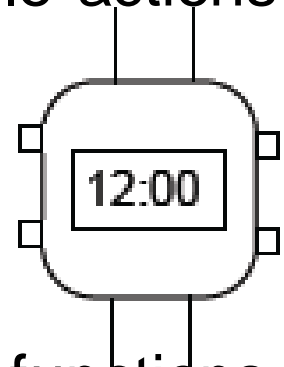
- Some things you don't understand you do anyway: why big blade down?
- Model's not perfect: what about "glide" style of cutting?

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# An object that **hinders** conceptual model formation: **Digital watch**

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- **Affordances:**
  - Four buttons to push, but not clear what they will do
- **Constraints and mapping unknown:**
  - No visible relation between buttons, possible actions and end result
- **Transfer of training:**
  - Little relation to analog watches
- **Cultural idiom:**
  - Somewhat standardized core controls and functions
- **But still highly variable conceptual model:**
  - Must be taught



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# Mental models

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"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 (in Gentner & Stevens, 1983)

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# Mental models vs. Conceptual Design

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## Mental models: *something the user has (forms)*

- Users “**see**” the system through mental models
- Users **rely** on mental models during usage
- There are various **forms** of mental models
- Mental models can **support** users’ interaction

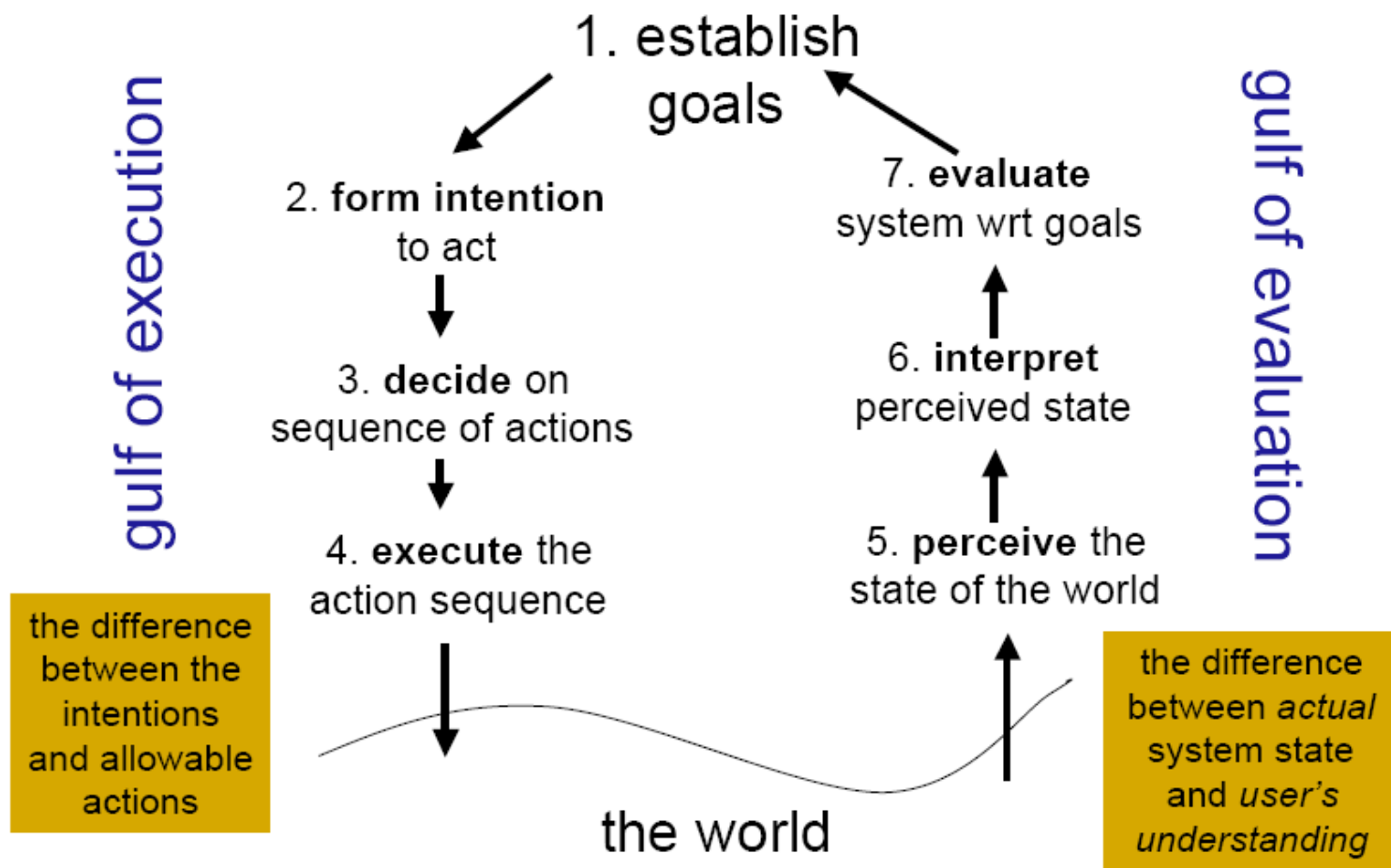
## Conceptual design: *something the designer does*

- **Defining** the *intended* mental model
  - Hiding the technology of the system
- **Designing** a suitable system image
  - Applying appropriate design guidelines
- **Analysis** using “walkthroughs”



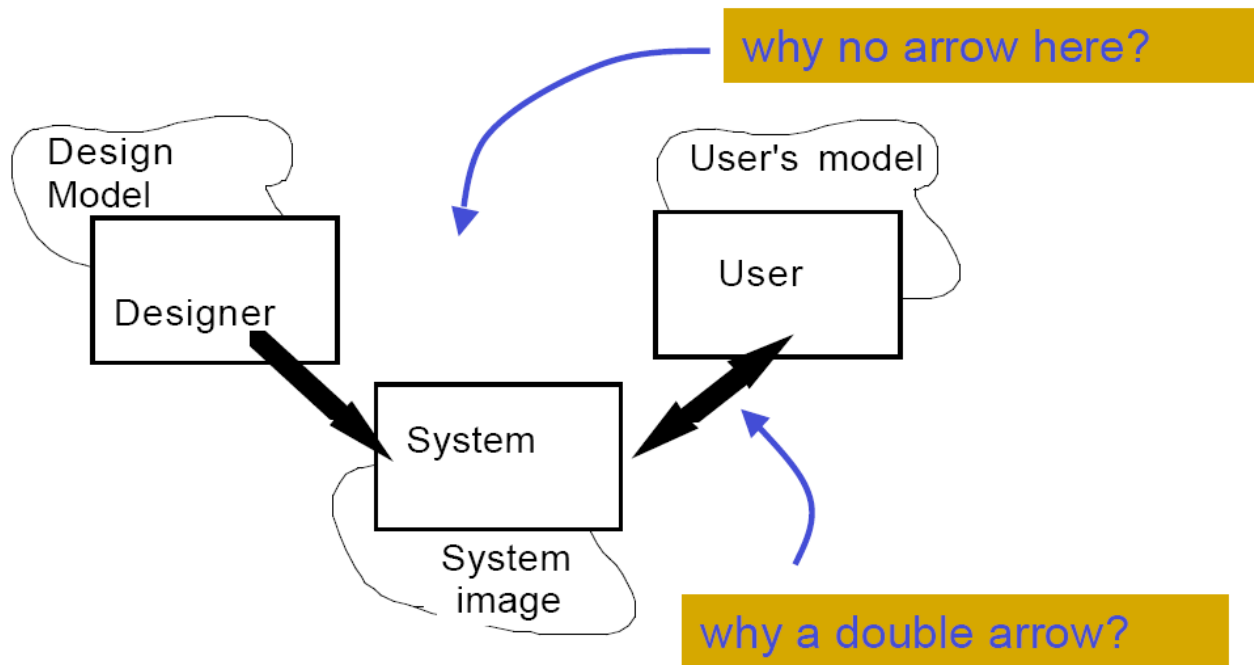
# Norman's seven-stage model

*a description of human goal-oriented action*



# Conceptual Design

- Designing systems so users can understand them
- Assisting the user to build useful mental models



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# Various models

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- **Design model** is the designer's conceptual model
- **System model** is a model of the way the system works
- **System image** results from the physical structure of what has been built (including documentation, instructions, labels) – it is what the user “sees”
- **User's model** is the “**mental model**” developed by the user through interaction with the system
  - User tries to match the mental model to the system model

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# Conceptual mismatch

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- **Misconceptions** happen when user's model differs from the system model
  - Document sizes measured in bytes, not pages or words
    - Sun and SGI Unix use different measures for files
  - Dates may be in non-standard formats
    - Whose birthday is 09-06-46 (what country are we in)?
  - Userids (and files) may be constrained by system design
    - userid hmitchel@cs.ubc.ca
  - Error message may use system-specific codes
    - Error 404 in HTTP

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# Some characteristics of mental models

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- Incomplete
- Constantly evolving
- Not accurate representation
  - (contain errors and uncertainty measures)
- Provide a simple representation of a complex phenomena
- Can be represented by a set of if-then-else rules

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# Acquiring mental models

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- **During system usage:**
    - The user's own activity leads to a mental model
    - Explanatory theory, developed by the user
    - Often used to predict future behavior of the system
  - **Observing others using the system:**
    - Casual observation of others working
    - Asking someone else to “do this for me”
    - Formal training sessions
  - **Reading about a system**
    - Documentation, help screens, “for Dummies” books
- This is done by the user (not the designer)**

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# Runnable models: 'perturb' system to figure out how it works

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- These are **dynamic models**
  - Includes a notion of **causality**
  - “doing this will result in this”
- Used for **explanation**
  - To understand why the system responded as it did
  - Part of Norman’s model of behavior (interpretation)
- Used for **prediction**
  - To select an appropriate action
  - Also part of Norman’s model (intention)

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# Runnable models: 'doing $x$ will result in $y$ '

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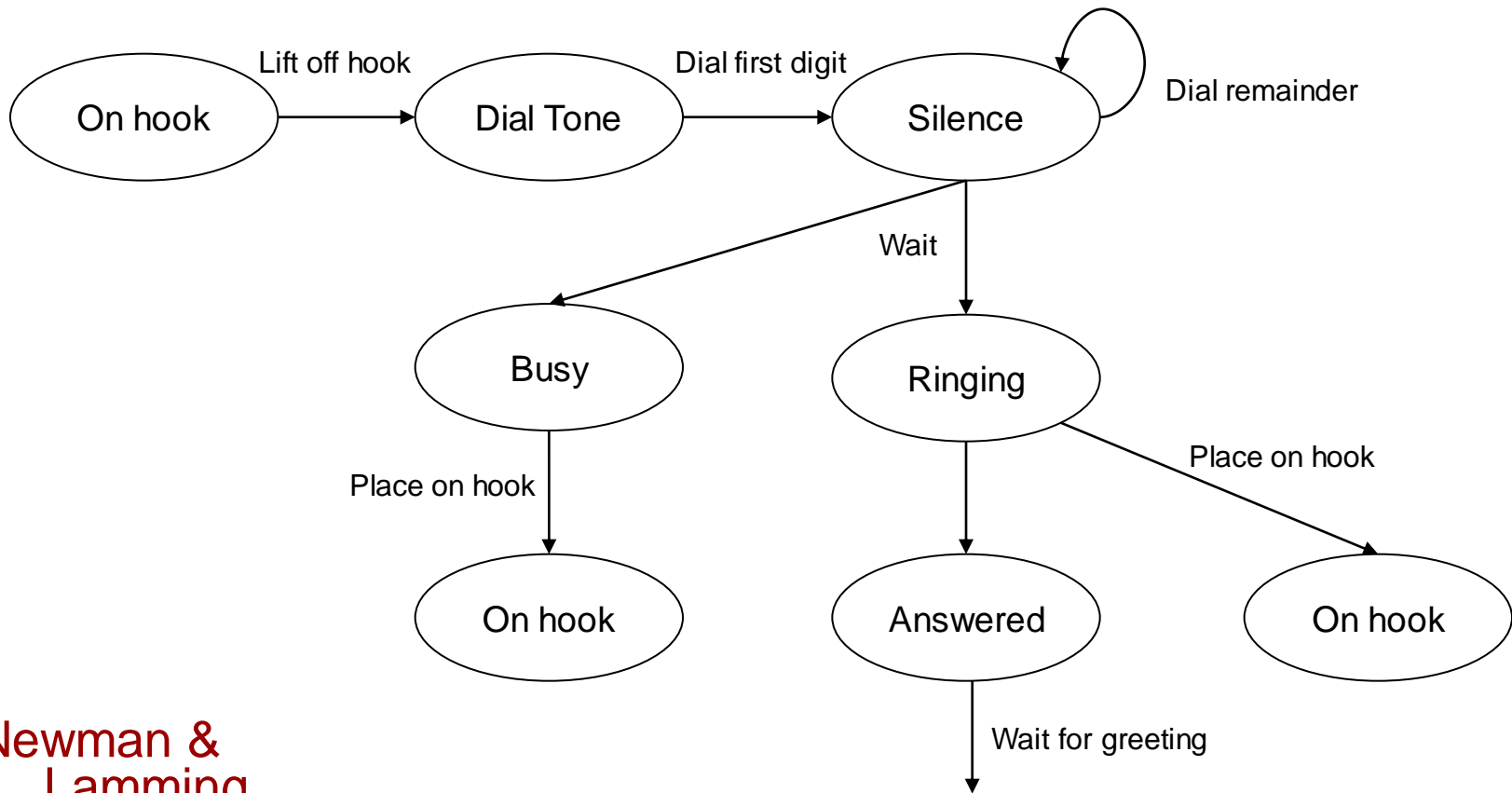
1. **Establish the goal** to be achieved
2. **Form the intention** for action to achieve goal
3. **Specify the action** sequence corresponding to the intention
4. **Execute** the action sequence
5. **Perceive** the system state resulting from the action sequence
6. **Interpret** the perceived system state
7. **Evaluate** the system state with respect to the goal and the intentions

What would be a good  $x$ ?

Did  $y$  happen?  
What does it mean?



# Mental model of a telephone call



Newman & Lamming  
Fig 13.5

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# Common forms of mental models: Many categorizations. Very high-level.

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- **Structural:** presents an image of *what the system is*
  - Descriptive (not prescriptive)
  - User may need additional knowledge to actually use it
  - Often more powerful / flexible, and often harder to use (esp. if don't have the necessary additional knowledge)
  - **Road map:** *it may show a particular type of information, but it isn't customized to your particular use of that info.*
- **Functional:** action-based; describes *how it is used*
  - Prescriptive; specific; often step-by-step
  - Does not assume global or system knowledge
  - Easier to use, but not very helpful for problem-solving or dealing with the unexpected
  - **Google directions:** *great when everything's there; need more when there's a roadblock.*

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# Structural models

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Presents an image of ***what the system is***

- **Most maps and schematics**
  - Provide a specific view of the system; “use as needed”
  - ***Different views:*** *street, bus, bike maps of same region are customized to drivers, bus riders and bikers. All are structural models.*
- **Object-action models**
  - Users think in terms of concrete or abstract objects
  - The system supports action on the objects
  - ***Unix:*** *files are objects, commands like mv acts on them*
- **Analogies/metaphors**
  - A new system (closely) resembles an old system
  - (usually) intent is to help *transfer* existing system knowledge
  - *desktop metaphor; spreadsheet.*

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# Functional models

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Presents an image of ***how the system is used***

- **Many kinds of user manuals**
  - step-by-step “how-tos”.
- **State transition model**
  - Changes in state need to be “visible”; step through them.
  - ***Telephone example, earlier slide; online shopping cart***
- **Functional “mapping” models**
  - Different from a “system map”!
  - Users learn a sequence of actions to accomplish tasks
  - The mappings need to be rote-learned; often arbitrary
  - ***Hand-held calculator maps “math” to key presses;***
  - ***keyboard shortcuts***

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# How users use mental models

## e.g. State transition model

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- Our view of using a telephone is as a series of **state changes**
  - e.g. represented as in telephone example (earlier)
- **MM predicts how long we wait at various points**
  - Unexpected delays or unfamiliar responses not understood
- **We try to fit what we hear into our model:**
  - international calls may encounter different delays
  - international calls may have extra steps
  - international calls may result in different signals
  - a separate device exerts control in fax calls

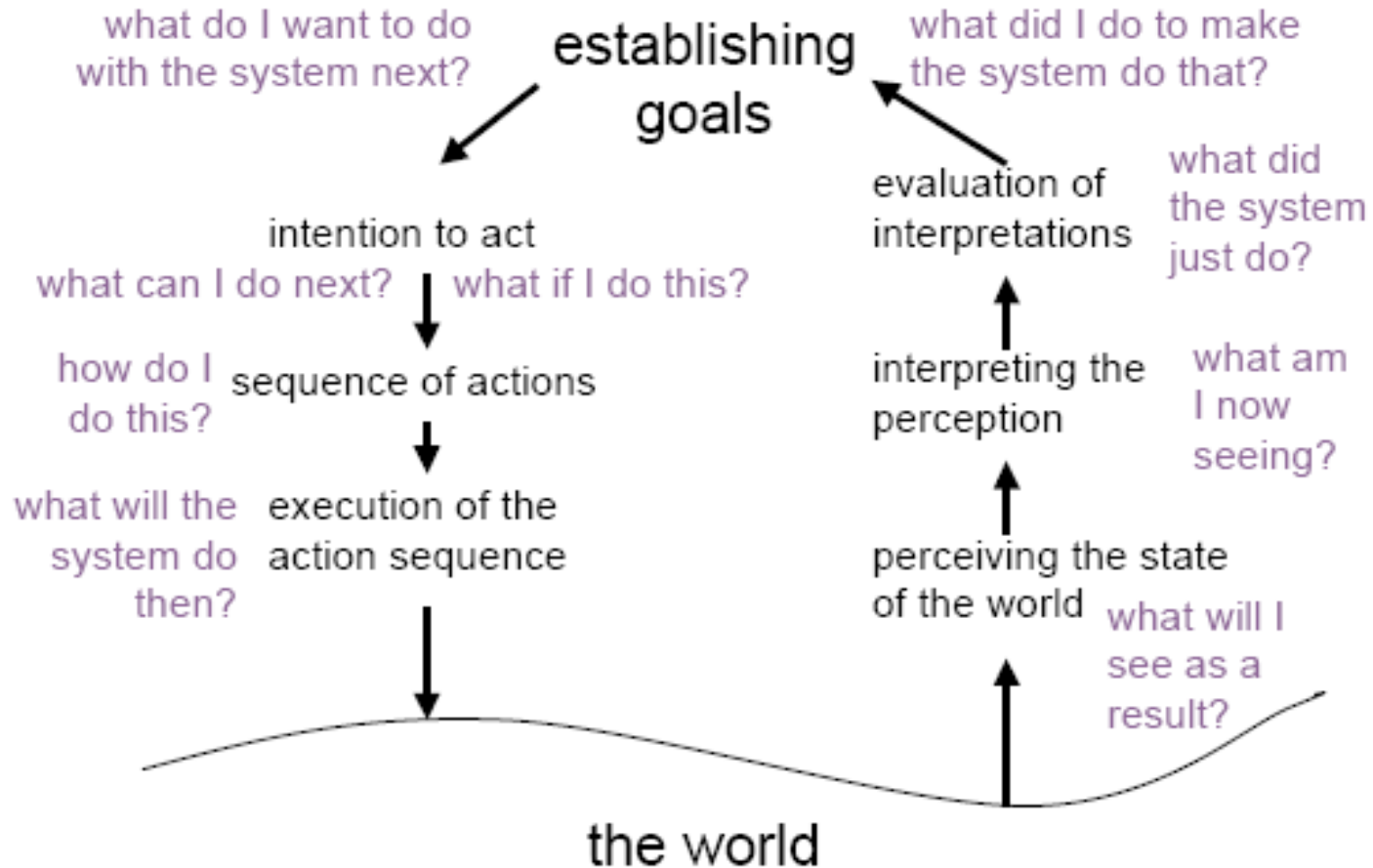
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# Topic: Mental models and user interaction

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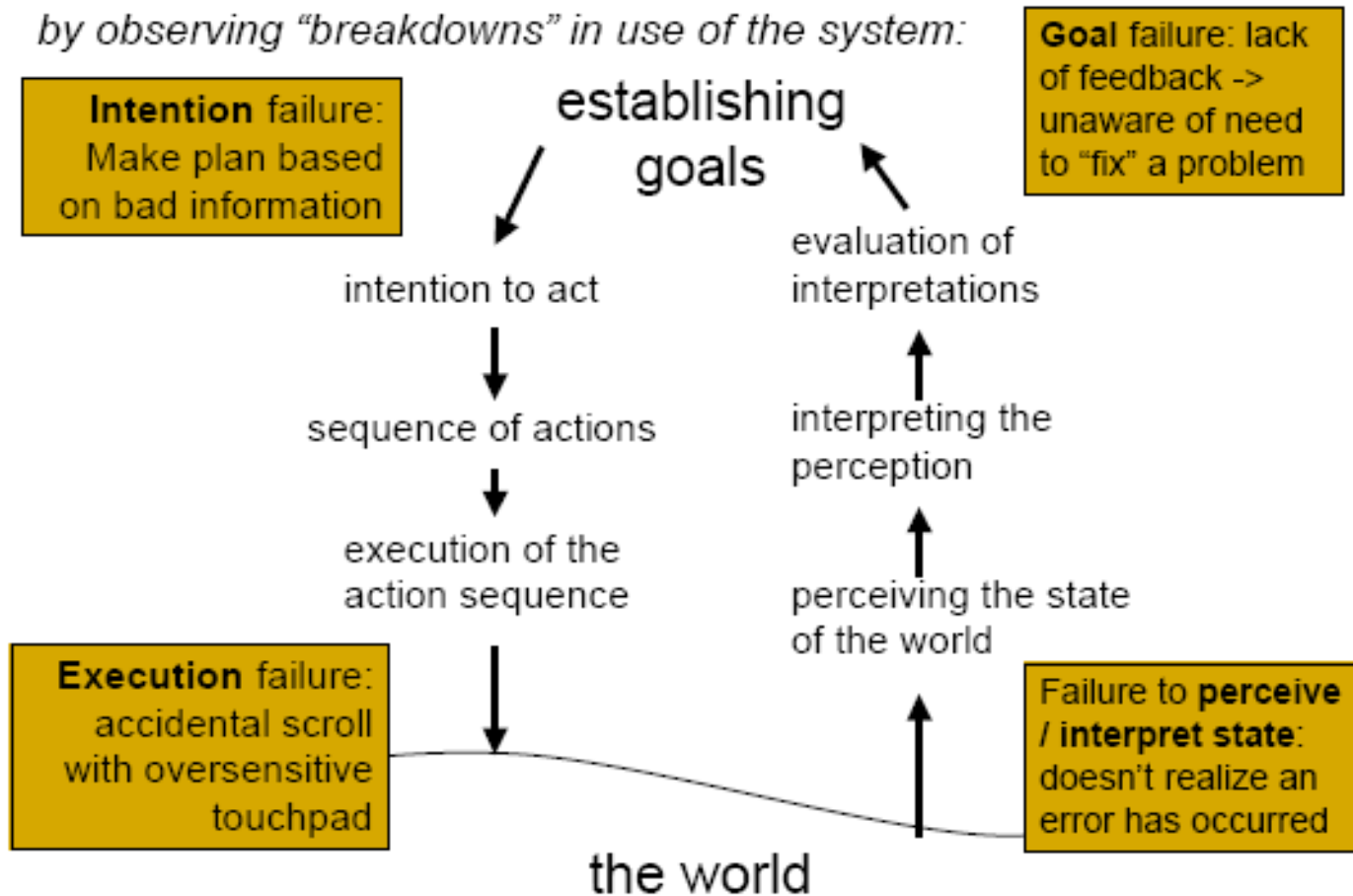
- Recap on previous lecture on mental models
- **Mental models and user interaction**

# What mental models tell the user



# How do designers identify a user's mental model?

by observing "breakdowns" in use of the system:





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# The system image

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- **We have control over what users see**
  - Responsible for turning the system model -> system image
  - Choose a system image to foster a good mental model
- **Some interfaces literally display the system model**
  - All objects and actions may be visible at all times
  - Automobile dashboard provides a system image of the car  
... sensor displays, physical controls
- **Currency (up-to-date-ness) is important**
  - The system image has to reflect the actual current state
- **Consistency is important**
  - Adaptive Microsoft drop-down menus violate consistency

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When a simple mental model might be better:

# Hiding system complexity

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- Many systems have messy low-level details
  - These may not be relevant to the user's activity
  - The full functionality of the system may not be required
- Example: MS Word has hundreds of commands
  - Many users need only a small subset of these commands
  - Users themselves can hide complexity by customization
  - IT administrators may provide macro capabilities
    - Macros bundle low-level commands into a single concept
  - Wizards allow a user to “do what's right”, skipping details
  - One approach: “**training wheels**”

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# Example

## of where it helps to hide system complexity

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- **Water faucet**
  - The [real] **system model** has independent hot & cold
  - The **system image** provides variable temperature
  - Some taps allow separate temperature control & volume control
  - Both “hot & cold” and “temperature & volume” are 2 DOF

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# Presenting the system image

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- **Explicit representation**
  - Provide a current and consistent map of everything
- **Implicit representation**
  - Provide cues about the system model
  - Progressively expose/reinforce the system model
  - Telephone voice mail example:
    - Good: *You have three new messages. Press 2 to hear your first new message.*
    - Bad: *Press 2 to hear new message.*

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# Conceptual models in design

## Guideline #1

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### Provide a good conceptual model

Allows user to predict the effects of their actions

- Problem:
  - Designer's conceptual model is communicated via **system image**.
    - Appearance, instructions, system behavior through interaction transfer, idioms and stereotypes.
  - If system image does not make model clear and consistent:
    - User will develop inconsistent conceptual model.
- “wrong” vs “simplified”?

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# Conceptual models in design

## Guideline #2

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- **Make things visible**

- Relations between user's intentions, required actions, and results are sensible and meaningful.
- Employ visible affordances, mappings, and constraints.
- Use visible cultural idioms.
- Remind person of what can be done and how to do it.

- **Narrow your gulfs!**

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# Good Practices for Conceptual Design

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- Choose an intended mental model **early in design**
- Link choice of **mental model to style of interaction**
- **Hide system features** that conflict with user's activity
- **Exploit system image** to foster intended mental model
- Ensure that **system image is current and consistent**
- Take into account users' **existing mental models**
- Allow for both **novice and expert** mental models
- Use **simple, concrete, familiar metaphors**
- Obey "**Law of Least Astonishment**" (Occam's Razor)

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# Mental models & paper prototypes: Revealing a mental model to the user

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- A storyboard or paper prototype is one way of illustrating / documenting an intended or observed mental model.
- Useful for design, communication, analysis.

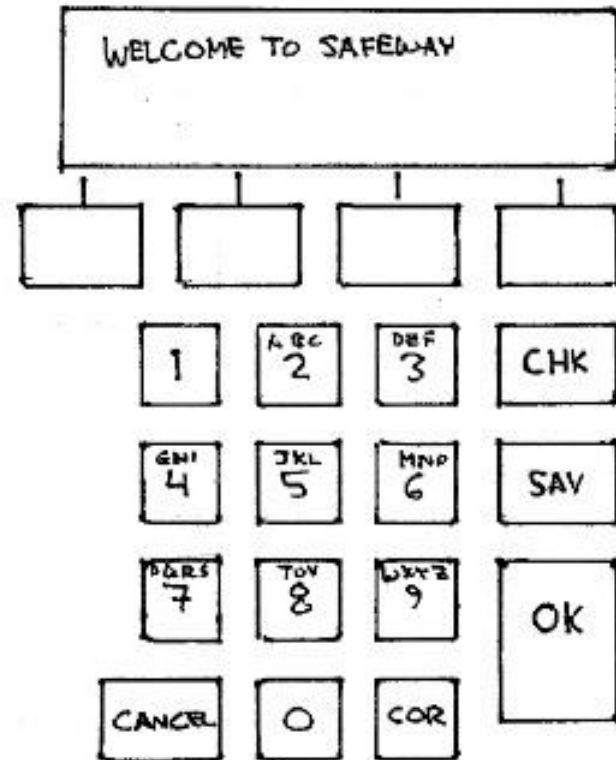
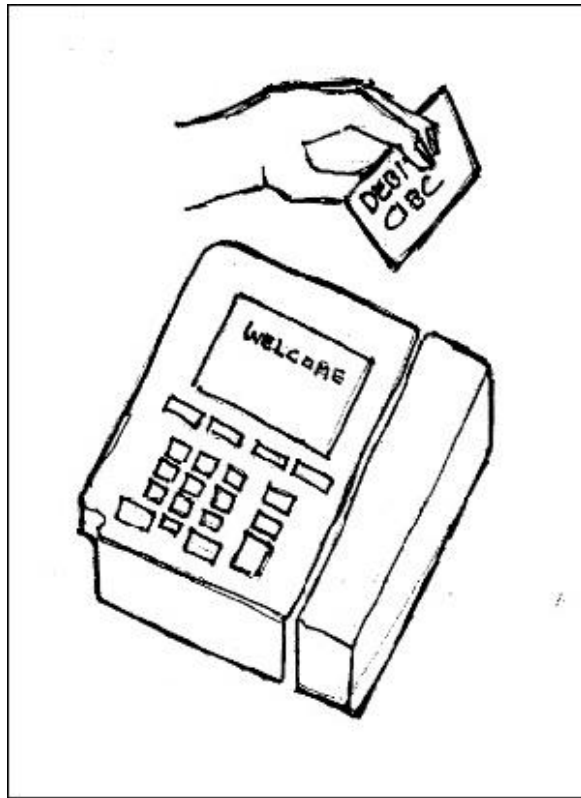
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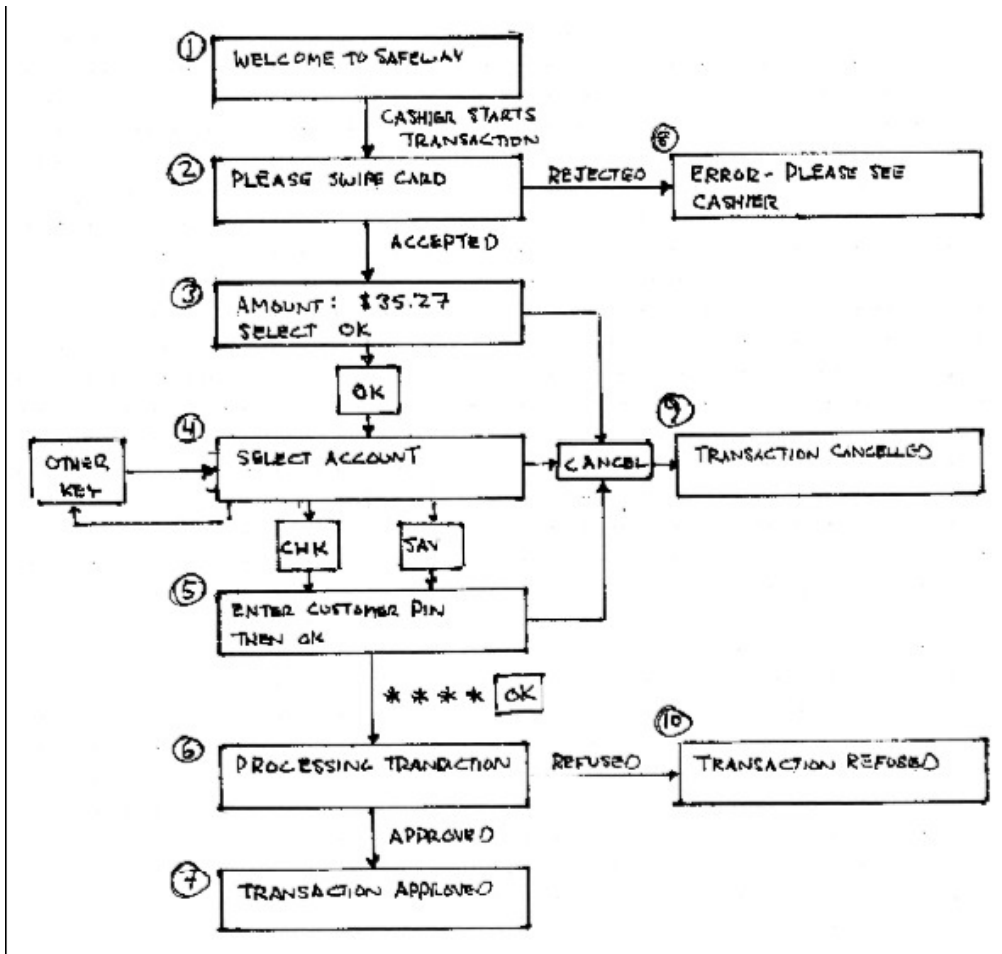
# Grocery ATM

(example of a paper prototype)

First, the task:



# One way to prototype the mental model



How will you prototype your project assignment?

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# Summary

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- Designer creates **conceptual models** and **system models**.
- User models (**mental models**) are developed by the user.
- Common mental model: **object-action model**.

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# Resources

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1. Kellogg S. Booth, Introduction to HCI Methods, University of British Columbia, Canada

<http://www.ugrad.cs.ubc.ca/~cs344/current-term/>