mental models & (a start on) cognitive frameworks

mental models & cognitive frameworks
where else we’re covering it

by now (W06 pre-readings)
• intro to internal + external cognitive frameworks
  **updated learning goals on external for clarity
• mental models

upcoming workshop + assignments
• apply mental models, external representations in designing/evaluating prototypes
  (starting with project).
cognitive frameworks today

why and how cognition is relevant to HCI design

mental models: what they are, how we get and use them, and ways they can fail

exploratory learning: applying norman’s 7-stage model. (one way we generate and build MMs of new situations)

benefits/tradeoffs of external representations

learning goals

define mental models, describe their characteristics.
give examples of how a mental model can be acquired

explain what Norman’s 7-stage model is good for:
use gulfs/stages to analyze interactions with a system

be able to identify a mismatch in mental models
give examples of situations or interfaces where mismatch occurs

explain the difference between internal and external cognitive frameworks

➤ give examples of the types of factors or representations that could be important when analyzing distributed/external cognition

➤ give examples of external representations that help with memory load reduction, computational offloading and cognitive tracing
why look at cognition?

part of doing good design is understanding how people reason and react to interface experiences

cognitive frameworks: help us do this!
  – theoretical models that provide predictive and explanatory power for understanding user behaviour
  – based on theories of cognition

internal frameworks: about the mental process inside users head
  ⇒ mental models a (particularly useful) example

external frameworks: account for interactions with technologies, environment, context

mental models

"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."

-Norman (in Gentner & Stevens, 1983)

people use their mental models to:
  • reason about a system
    - how to interact with it; how it works
  • figure out what to do when things go wrong
mental models vs. conceptual design

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

coming: conceptual models and conceptual design
- this is what the designer does, to foster good mental model formation by the user.

www.conferencebike.com

Will it work? Why seven?
How does the drive train work? Which wheels steer? …

Our mental model of a bike isn’t as good as we think it is …
… but it’s good enough to recognize this as a bike!
recall our
design concepts:

the basics:
(elements of these in many of the others)
• affordance
• visibility
• feedback

→ all inform a user’ mental model

other concepts:
• mapping
• findability
• constraints (perceptible)
• transfer effects
• cultural associations
• individual differences

an object that helps you form a mental model:

**scissors**

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

mental model:
• physical object implies how the operating parts work

A reasonable mental model can be formed by just looking at and perhaps holding the object.
• Some things you don’t understand you do anyway: why big blade down?
• Model’s not perfect: what about “glide” style of cutting?
an object that hinders mental model formation: digital watch

affordances - mixed:
• four buttons are clearly for pushing and the screen shows a number – but unclear what the entire object affords
telling time? setting alarms, timers, viewing heartrate, other data?

visibility – lousy
• what will happen if you push each button? what mode is watch in?

constraints and mapping - unknown:
• no visible relation between buttons, possible actions and end result

transfer of training:
• little relation to analog watches. But, maybe from other digital devices.

Cultural idiom:
• some standardized core controls and functions but others variable

Mental model:
• must be taught, or learned by trial/error

Mental Model of a Telephone Call

This is a representation of a mental model. Where might it come from?

What happens between “circles” in this flow chart?

On your own: Compare it to Norman’s 7-stage, which is theoretical; is it the same thing?

Newman & Lamming
Fig 13.5
Norman’s seven-stage model

*a description of human goal-oriented action*

1. establish goals
2. form intention to act
3. decide on sequence of actions
4. execute the action sequence
5. perceive the state of the world
6. interpret perceived state
7. evaluate system wrt goals

**activity**

watch a video of a little boy attempting to figure out a puzzle
- he knows that ‘yellow’ lights it up; red doesn’t
- presented with an anomaly – how does it work?

will stop video at various points . . .

➔ on worksheet: describe his mental model formation using the gulf
full video
what babies think (excerpt)

http://tinyurl.com/ozx8zw5

portion from class starts at ~1 minute

dark purple box:

example (on your own)

Example task: you are an OSX user using Windows.

“Execution” steps might look like this:

1. Goal: I need to change my account’s password

2. Intention to act: There must be a control panel somewhere, but I don’t know where. I’ll have to poke around.

3. Decide on actions: I’ll start by clicking on the program-launch icon in lower left corner, then see if I can find something in there.

4. Execute: Okay, here goes… [click]

→ The world.
activity (on your own)

1. Figure out how to set an alarm clock on a cell phone that runs on a different system than yours (e.g., IOS ↔ Android).

2. Observe yourself as you do this → try to apply the 7-stage model.

what mental models tell the user

- establishing goals
  - what do I want to do with the system next?
  - intention to act
  - what can I do next?
  - what can I do next?
  - what if I do this?
  - sequence of actions
  - execution of the action sequence

- interpreting the perception
  - what did the system do that?
  - evaluation of interpretations
  - what did I do to make the system do that?
  - what did the system do that?
  - interpreting the perception
  - what am I seeing now?
  - perceiving the state of the world
  - what will I see as a result?

the world
Norman’s seven-stage model

*what is it good for?*

**internal framework:** best for *exploratory learning*
- but this is just one way to form a mental model of a system

less applicable to highly learned, semiautomatic behavior
- user has already developed strong expectation of what will happen/how it will happen
- gulfs in these cases tend to be very small
- unless something unexpected happens!

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**model mismatches**

*misconceptions* happen when user’s model differs in critical ways from how the system actually works.

- e.g., “more is more” belief about interactions.
  - high oven temperature makes oven heat faster
  - press ‘walk button’ repeatedly -> light changes faster

- e.g., folk theories and remedies for computing
  - reboot when computer “gets slow”
  - reboot computer to make projector work

We do these things because it feels like it makes a difference, but we don’t have a correct model of how they work!
mismatch: why does it happen?

Sometimes a **poor model is fostered**.
- e.g., Norman’s fridge: controls imply fridge/freezer controlled separately

![Diagram of fridge controls]

mismatch: norman’s fridge?

user’s mental model would reasonably look like this . . .
mismatch: norman’s fridge?

but actually the system works like this. . .

two controls interact to control one cooling unit

some characteristics of mental models

• 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
acquiring mental models

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)

models are often “runnable”:
perturb system to figure out how it works

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 7-stage model (interpretation)

used for prediction
- to select an appropriate action
- also part of Norman’s model (intention)
running a mental model: ‘doing x will result in y’

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

Mental simulation helps you ‘get’ the problem – “if I pick it up, what will happen …?”

Jacques Carelman: Catalog of unfindable objects
how can exploratory mental model formation break down?

- **Intention failure:** Make plan based on bad information
- **Execution failure:** accidental scroll with oversensitive touchpad
- **Goal failure:** lack of feedback -> unaware of need to “fix” a problem

establishing goals

- intention to act
- sequence of actions
- execution of the action sequence

the world

- interpreting the perception
- perceiving the state of the world
- evaluation of interpretations

information processing

another way of thinking about internal cognition

- metaphor: human like an information processor

ordered processing stages (with input/output)

- within each, processes (e.g., comparing, matching) act on mental representations

useful for making predictions, identifying bottlenecks

human processor model

- combines information processing with perceptual senses for **input** and **output**
Model Human Processor (MHP)

Remember this? if you know how long each stage takes – can calculate how long a task should take to complete

Cognitive Processor

Long-term Memory (LTM)

Working Memory (WM)

Visual Image Store

Auditory Image Store

Haptic Image Store

Attention filters what gets through…

Perceptual Processors

Motor Processor (action)


limitations of internal frameworks

can never really know exactly what’s in a user’s head
  • will always be a simplification

do not account for external factors, e.g.,
  • environment
  • external representations
  • other people
  • etc. . .
external cognition:

the use of the external world to achieve cognition

external cognition frameworks

concerned with how representations and factors in environment help and hinder cognition

distributed cognition: cognitive processes make use of other individuals, artifacts, internal/external representations

external cognition: cognitive processes across external representations (e.g., books, maps, diagrams, etc.)

embodied interaction: concerned with how someone’s experience of the world and the meaning they create is shaped through physical and social interactions

* a bit squishy. we won’t go into it any deeper
benefits of external representations

externalizing information – notes, todo lists, alarm clocks – very helpful for remembering
  • basically: encode information in your environment
  • reduces internal memory load (either long or short term)

computational offloading: using tools and devices to carry out computations, other tasks
  - e.g., doing math problems on paper
  - allows you to see the change, come back to it later, share it with others, etc.

computational offloading example: using whiteboards for discussion with multiple people
computational offloading
example: interactive information visualization for browsing genetics data


modification
reflecting changes or intention by modifying external representations by:

annotation:
- ✔ ✔ checking
  - crossing things off lists
- circling something

cognitive tracing: manipulating objects into new orders and structures. e.g.,
- rearranging cards in a poker hand
- rearranging scrabble letter to think of words
annotation + cognitive tracing
example: revision highlighting and tracked changes in word 2011

expressive channels of user communication. Over multiple iterations we designed both human-actuated and mechanized prototypes that go beyond the mobile device’s existing form factor by augmenting it with life-like gestures. We present four prototypes that explore a combination of visual and haptic gestures including breathing, carving, crawling, ear-tracting and vibration. Through two evaluations of these prototypes, we find that users are receptive to the idea of a living phone metaphor and the use of physical gestures to enrich their communications. Further, we find that physically rendered gestures have the potential to express common notifications (e.g., incoming calls), as well as communicate tacit emotional content. Finally, we present several design guidelines for future work in the design space of gestural mobile devices.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces · Graphical user interfaces.

General terms: Design, Human Factors Experimentation.

Keywords: Biological metaphor, body language, human-robot interaction, mobile computing, affective computing, ambient display

Figure 1: An early prototype (top left) of a mobile device creating a tactile (i.e., pressure sensitive) gesture.

diode) displays and paper-like E-ink displays [13]. Mobile device prototypes of mobile devices of varying fidelity that utilize such technologies have also been developed, including include Nokia’s Kinetic Device [8] and the PaperPhone [45]. A bendable mobile device made of electronic paper. As a result of such rapid developments, fully functional flexible smartphones (manually flexed or actuated) are expected to be commercially available as soon as 2013 [6]. Actuated (device-originated) motion will be next, ranging from the controlled release of stored energy supplied by users’ torquing and vibratory ambulation controlled by a user-settable charge, to actuated tendons or polymer membranes that can contract or inflate/dissolve a surface on its own [REPT] [8].

cognitive tracing
example: arranging sticky notes into affinity diagrams
why external representations

we often do use external representations naturally

sometimes people don’t realize they need them
• e.g., actual checklists for doctors performing operations;
  - lots of resistance initially
  - research shows they improve patient care a lot!

can often be set up in very personal ways
→ looking at the external representations people use tells you a lot about them & how they work

downsides to external representations

when reminders are too frequent, don’t match what user needs reminding about . . .people may start to ignore them!

Example: electronic systems that remind pharmacists about drug interactions
  – interactions vary in severity;
  – system shows alerts for all interactions, even those they judge ‘unimportant’
  ➔ result is alert fatigue – pharmacists miss reminders and make mistakes!
mental models (& cognitive frameworks)

**summary**

why and how cognition is relevant to HCI design

**mental models:** what they are, how we get and use them, and ways they can fail

exploratory learning: applying norman’s 7-stage model. 
*(one way we generate and build MMs of new situations)*

benefits of external representations
Lecture 6b Worksheet

Applying Norman’s 7-stage model
(to be completed individually)

PART 1 - Complete the following questions after the 1st example (instructor will pause the video)
1. What is the little boy’s ‘goal’ in this scenario?

2. a) Describe the gulf of execution in this scenario. What intentions does the boy have? What visible and allowed actions are there?

   b) How does the boy complete each step to cross this gulf?

   **Gulf of execution**
   1. form intention to act:

   2. decide on sequence of actions:

   3. execute action sequence:
Complete the following questions after the 2nd example (instructor will pause the video)

3. a) Describe the **gulf of evaluation** in this scenario. What is the system’s state? What is the user’s understanding of the state?

b) How does the boy complete each step to cross this gulf?

   **Gulf of evaluation**
   1. perceive the state of the world
   2. interpret the perceived state
   3. evaluate system with respect to goals

c) Has the boy’s mental model changed? If so, what is the change? What was the change in response to?

**PART 2** - Complete the following questions after watching the entire video.

4. After the boy’s final attempt, do you think the boy’s mental model matched the system model?

5. What would you do next to determine how the control of the light actually worked?