Announcements

Abstract Revisions - feedback released

Project Video Round 1 — due Fri May 13

   System: basic working prototype of the idea

   Study: pilot results from at least five people

   Team assessment is due with the video submission
Today
Conceptual Models
Cognitive amplification
Cognitive models in HCI
Embodied cognition
Distributed cognition
Cognitive limits
Braaaaaaaiiins
Conceptual Models
Refrigerator

Problem: freezer too cold, but fresh food just right
Refrigerator Controls

<table>
<thead>
<tr>
<th>Normal Settings</th>
<th>C and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colder Fresh Food</td>
<td>C and 5-6</td>
</tr>
<tr>
<td>Coldest Fresh Food</td>
<td>B and 7</td>
</tr>
<tr>
<td>Colder Freezer</td>
<td>D and 6-7</td>
</tr>
<tr>
<td>Warmer Fresh Food</td>
<td>C and 3-1</td>
</tr>
<tr>
<td>OFF (both)</td>
<td>0</td>
</tr>
</tbody>
</table>

What is your conceptual model?
Most Likely Conceptual Model

Independent Controls
Correct Conceptual Model

Possible solutions:
Make controls map to user’s model
Make controls reflect actual system
Conceptual Models

- Designer’s Model
- User’s Model
- System Image
Conceptual Models

Designer’s model may not match user’s model
Users get model from experience & usage
Users only work with system image, not with designer
Gulfs of Execution & Evaluation

Mental Model

Real World
Gulf of Evaluation

Real world:

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.67</td>
<td>0.79</td>
</tr>
<tr>
<td>0.32</td>
<td>0.63</td>
</tr>
<tr>
<td>0.39</td>
<td>0.72</td>
</tr>
<tr>
<td>0.27</td>
<td>0.85</td>
</tr>
<tr>
<td>0.71</td>
<td>0.43</td>
</tr>
<tr>
<td>0.63</td>
<td>0.09</td>
</tr>
<tr>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>0.20</td>
<td>0.54</td>
</tr>
<tr>
<td>0.51</td>
<td>0.38</td>
</tr>
<tr>
<td>0.11</td>
<td>0.33</td>
</tr>
<tr>
<td>0.46</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Mental model:

x, y correlated?

Evaluation
Gulf of Evaluation

Real world:

Mental model: $x,y$ correlated?
Real world:

\[ \rho = -.29 \]

Mental model: 

x, y correlated?
Gulf of Execution

Real world

Gulf

Mental model:
Draw a rectangle

Move 90 30
Rotate 35
Pen down
...

...
Gulf of Execution

Real world
1. Draw a rectangle
2. Rotate the shape

Mental model:
Draw a rectangle

Execution
Gulf of Execution

Real world  Execution  Gulf

Mental model: Draw a rectangle
Action Cycle

Goals

START HERE

Execution

Evaluation

The World
Action Cycle

- **Goals**
  - Evaluation of interpretations
  - Interpreting the perception
  - Perceiving the state of the world

- **Execution**
  - Intention to act
  - Sequence of actions
  - Execution of actions

- **The World**

START HERE
Semantic & Articulatory Distance

Semantic
Semantic distance reflects the relationship between the user’s intentions and the meaning of expressions in the interface languages.

Articulatory
Articulatory distance reflects the relationship between the physical form of an expression in the interaction language and its meaning.
Semantic & Articulatory Distance

**Semantic**
Is it possible to say what one wants to say?
Does the interaction match the user’s conceptual model?

**Articulatory**
Is form of expression similar to meaning of expression?
The Gulfs & Semantic Distance

**Gulf of Execution**
Match description level of interface language to level at which person thinks of the task (often interface is much lower) – (i.e. goal: draw star – draw star vs. draw pixels forming star)

**Gulf of Evaluation**
Match output to the user’s mental model to enable checking that goals have been met – (i.e. goal: get mean of set of numbers – present table of values vs. present mean)
The Gulfs & Articulatory Distance

**Gulf of Execution**
How similar is the interaction to the desired goal (i.e. move pointer with mouse, pointing with finger, lightpen, …)

**Gulf of Evaluation**
Depict output so that relationships between input action and output is obvious and easy to perceive (i.e. graphical chart vs. table of numbers)
Drawing Tools:
Which Gulf? Which Distance?

Turtle.Move(150)
Turtle.Turn(90)
Turtle.Move(150)
Turtle.MoveTo(50, 200)
Turtle.Angle = 45
Cognitive models in HCI
Cognitive amplification

Automation can help, but ultimately this power comes from better representation. By better understanding human cognition, we can design technology that makes us smarter.

“The powers of cognition come from abstraction and representation: the ability to represent perceptions, experiences, and thoughts in some medium other than that in which they have occurred, abstracted away from irrelevant details.” [Norman '94, Simon '81]
Example: Number scrabble

[Simon 1988]

Take turns picking numbers in 1,2,3,4,5,6,7,8,9 without replacement

Win if any **three** of your numbers add up to **15**.

It’s OK if you have extra numbers in your hand, as long as three of them add up to exactly 15.
Ready, set, go!

I will show the series of moves from players A and B so far. Raise your hand when you know what B's best next move should be.

A takes 4.
B takes 9.
A takes 2.
B takes 8.
A takes 5.

What should B do?
Re-encoding number scrabble

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>
Ready, set, go!

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>B</td>
</tr>
</tbody>
</table>
Building a better mouse(trap)

[Card and Moran 1988]

Doug Engelbart and Bill English felt that their mouse was an interim device, and wanted to make something better.

But none of their inventions were actually improving target acquisition speeds.

So, Stu Card and Tom Moran tested the mouse in the lab on a variety of pointing tasks.
Building a better mouse(trap)

[Card and Moran 1988]

Performance was very well modeled by Fitts’s Law. (Fitts’s Law is about human pointing, not mouses.)

Moreover, the mouse’s constant of proportionality (10.4 bits/sec) is approximately the same with the mouse as with the hand alone — so the mouse is near optimal, you actually can’t do better!

Here, modeling solved a problem that engineering couldn’t
Cognitive models

[Card and Moran 1988]

“... the scientific base of user technology, is necessary in order to understand why interaction techniques are (or are not) successful, to help us invent new techniques, and to pave the way for machines that aid humans in performing significant intellectual tasks.”
Model Human Processor [Card, Moran and Newell 1983]

An engineering model of a person to be used for understanding and design

We can use this model to estimate how efficient a user interface will be
GOMS [Card, Moran and Newell 1983]

Goals: what the user seeks to achieve

Operators: low-level operations

Methods: compositions of operations together

Selection rules: how to decide between multiple available methods

Given this specification, a system can trace a path that a user would take through a system to achieve their goal and report how long it would take
Example:

Goal: add a friend on Facebook

Operations: click on search bar; click on news feed post, click on...

Methods: make a search, post a status update, like a post
Keystroke Level Model: a specific model in the GOMS family. Designed to be quick and easy to use, no need to build a prototype.

Six operators: push a key, point to a target on the display, moving hands between keyboard/mouse/etc., drawing a line (seems extraneous), making a decision about the next step, waiting for system response

Provides a bunch of operators and methods

<table>
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<tbody>
<tr>
<td>Key</td>
<td>0.20</td>
</tr>
<tr>
<td>Point</td>
<td>1.1</td>
</tr>
<tr>
<td>Hands</td>
<td>0.4</td>
</tr>
<tr>
<td>Draw</td>
<td>(0.9n_D + 0.16 l_D)</td>
</tr>
<tr>
<td>Think</td>
<td>1.35</td>
</tr>
<tr>
<td>Wait</td>
<td>Depends</td>
</tr>
</tbody>
</table>
Example [via Wael Aboelsaadat]: minimize a window by clicking on the button, or using the keyboard shortcut?

Clicking on the button:
Point, click: $1.1\text{sec} + 0.1\text{sec} = 1.2\text{sec}$

(Yes, “click” had to be added to the model)

Keyboard shortcut:
Hands on keyboard, type:
$0.4\text{sec} + 0.2\text{sec} = 0.6\text{sec}$

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Where are they now?

Cognitive models have fallen out of favor, because they require effort to create and the low-level quantification is not always important.

But, for low-level optimizations and interface decisions, cognitive models can be quite useful. And at higher levels the quantification can serve as a rough guide.

These models remain very important to HCI as an example of how grounding our designs in psychological methods and results can lead to more effective approaches and insights.
Embodied cognition
Microsoft Productivity Vision [2015]
“...this vision, from an interaction perspective, is not visionary. It's a timid increment from the status quo, and the status quo, from an interaction perspective, is actually rather terrible.”

- Bret Victor
Compared to “pictures under glass”
A GUI’s mental model of a user

[Igoe and Sullivan 2004]
We think with our bodies

Tapping into proprioception, learned physical routines, and learning through physical interaction with the environment can both expand the vocabulary of interaction and more directly map onto our cognitive capacities [Klemmer, Hartmann, and Takayama 2006]
Epistemic action

[Kirsh and Maglio 1994]

Tetris as an example task to study cognition

Players see a piece, rotate it, and drop it into position

However, experts perform more rotations than strictly needed to position the piece. Why?

We perform actions in the world to uncover information that is hard for us to compute mentally
Distributed cognition
Distributed cognition

[Hutchins '95]

Theory: social and physical environments, not just people, can exhibit intelligence

Source: ethnography on the navigation bridge of Navy ships

Intelligent navigation is emergent — from people who coordinate via structured codes, and from their tools

Intelligent navigation does not reside within any single individual

Implication: when analyzing a system, look for cognition that arises between people or between people and artifacts
Limits to cognition
“In an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes.

What information consumes is rather obvious: it consumes the attention of its recipients.

Hence a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it.”

- Herb Simon, 1971
When we get worse

**Information overload**: as we get more and more information in our environments, we cease being able to make effective use of it — our decision making stops improving or even gets worse.

**Yerkes-Dodson Law**: as arousal (not volume of information) increases, performance increases, but only to a point.
Costs of multitasking

People have ~10 different working spheres per day, and spend 11.5 min per working sphere before switching [González and Mark CHI 2004]

When someone gets interrupted, they take 25 minutes on average before resuming [Mark, González, and Harris, CHI 2005]

People who self-report as high multitaskers are actually worse at multitasking [Ophir et al. PNAS 2009]

Proposed mechanism: worse at filtering out irrelevant stimuli
Cognition in HCI Research

HCI has roots in applied cognition

But today cognitive theories are not considered very much in HCI research

Great promise in connecting modern work in HCI with underlying cognitive theories