ICS 463: Intro to Human Computer Interaction Design

3. Understanding Users: Cognition

Why Cognition in an ICS Course?

- Interacting with technology is cognitive
- Take into account cognitive processes involved and cognitive limitations of users
- Know what users can and cannot be expected to do
- Identify and explain the nature and causes of problems users encounter
- Supply theories, modelling tools, guidance and methods that can lead to the design of better interactive products

Classic Subdivision of Cognition

- Attention
- Perception
- Memory
- Learning
- Language (Reading, speaking and listening)
- Problem-solving (planning, reasoning and decision-making)
Information Processing Psychology

- Humans as information processors
  (one model ...)

  ![Diagram of Information Processing Stages]

  - Encoding
  - Comparison
  - Response Selection
  - Response Execution
  - Memory
  - Attention

Variants on Information Processing

- GOMS (Goals, Operations, Methods and Selection)
  - Quantitative predictions of performance
- Distributed Cognition
  - Cognition is distributed across individuals and artifacts
- Parallel Distributed Processing (Connectionist)
  - Brain metaphor

Perception
What's the big deal?

Constructivist Theories

Computations on representations to match models

Evidence:
- Size and shape constancy
- Influence of context and expectations

Ecological Theories

Affordances and flow over time coordinate action in the world

Examples:
- Optical flow
- Graspable, pushable objects
**Gestalt Principles**

We make sense of the visual world by grouping things together or seeing them as wholes...

- **Proximity**: objects close together
- **Similarity**: objects of same shape, color
- **Closure**: missing parts filled in
- **Continuity**: lines seen as continuous
- **Symmetry**: symmetric elements perceived as coherent figures

How would you apply this to design?

**Three-dimensional cues**

- **Size**: larger is closer
- **Interposition and Shadows**: obscured object is behind
- **Contrast**, clarity, brightness decrease at a distance
- **Texture**: finer at a distance
- **Motion Parallax**
- **Stereoscopic cues**

How would you apply this to design?

**Fidelity of Representation**

- **Arbitrary mappings**
  - "Red = danger"
- **Nonarbitrary mappings**
  - Size → size, width → width, etc.
- **Iconic (resemblance)**
  - File "folder"
- **Virtual reality**

When is fidelity important? What are the tradeoffs?
Processing Considerations

See Lohse article, Handbook of HCI 1997:

- **Parallel Detection**: color, value, angle, slope, length, texture
- **Serial Detection**: shape, area, curvature, orientation, connection, containment

How would we use this in design?

Uses of Color

- **Segmentation**: grouping related objects
- **Highlighting**:
  - Drawing attention to important item
  - Distinguishing figure from ground
- **Search** (by novices)
- No advantage for many tasks
- Avoid excessive use

Suitability to Task

- Different representations support different perceptual (and therefore cognitive) tasks
- Let's try an experiment ...
- See Lohse's chapter, Handbook of HCI 1997
Related Techniques

- **Not too much, not too little info**
  - too much info \(\rightarrow\) too much scanning
  - too little \(\rightarrow\) can’t remember info from other contexts
- **Structuring information to facilitate search**
  - Group related items
  - Structural alignment of uniform data
  - Prefix with unique keys
    - Example: Unix man pages should not start every option description with "This option .."

Attention

- "Taking possession of" some sensory information at the cost of others
- Necessary for handling "high bandwidth" input with limited "processor power"
- An active and selective process: extensive experimentation shows pre-attentive processing!
  - Example: The Cocktail Party Phenomenon
Related Techniques

• Spatial placement reflects priority and immediacy of need
  - Central

• Color highlights foreground info

• Visual and audio alerting to bring attention to periphery

Memory

Multi-Store Model of Memory

• Sensory: milliseconds
  - Iconic (visual)
  - Auditory

• Working (short term): seconds
  - “The magic number 7 plus or minus 2”

• Long Term: permanent(?)

• (WM vs. LTM boundary is probabilistic)
Design Implication of 7+-2?

- Present only 7 options on a menu
- Display only 7 icons on a tool bar
- Have no more than 7 bullets in a list
- Place only 7 items on a pull down menu
- Place only 7 tabs on the top of a website page ... etc.

But this is wrong! Why?

Factors affecting memory

- Recognition versus Recall
  - Recognition usually much easier (knowledge in world, not head) but requires presentation of selection set
- Modality
  - Multiple cues (visual, textual ...) good
  - Avoid cross-modal translations
- Context

Let's try a memory experiment ...

- The Password Game!
Learning is active

• Manuals for computer software are really bad . . .
• Would it matter if they were better?
• Most people learn by
  - Watching others
  - Trying it (data driven, hypothesis driven)
  - Guided performance
  - Transfer and analogy

Classic Theories of Learning

• You don’t really need to know …
  - Naive theories (tabula rasa)
  - Innate Knowledge (Plato)
  - Associationism
  - Kant’s Synthesis
• Associative / Behavioristic Theories
  - Classical conditioning
  - Operant conditioning
  - Partial reinforcement and extinction
  - Errorless learning (?)
  - Spaced practice
Cognitive Theories

- Tolman's rats had mental maps!
- Induction from examples
  - The role of negative examples
- Case-based and learning by analogy
- A Cognitive Theory (ACT)
  - Intended in part to explain skill acquisition
  - Declarative knowledge
  - Procedural knowledge through association and chunking
  - Autonomous stage

Automatic and Controlled Processing

<table>
<thead>
<tr>
<th>Controlled</th>
<th>Automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Attention required</td>
<td>- Not required</td>
</tr>
<tr>
<td>- Conscious control</td>
<td>- No control</td>
</tr>
<tr>
<td>- Can modify</td>
<td>- Hard to unlearn</td>
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<tr>
<td>- Only one controlled task at a time.</td>
<td>- Parallel tasking possible if no interference</td>
</tr>
<tr>
<td>- Multitasking difficult but possible with external prompts</td>
<td>- Can lose place if interrupted (don't know where to resume)</td>
</tr>
</tbody>
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Some Implications

- If multitasking is required, and especially if interruptions are possible, provide explicit information about state: external representations are part of the cognitive system
- Two sides of the automaticity coin:
  - Use uniform procedures (e.g., key chords) to leverage efficiency of automaticity
  - Reminders, confirmations: if routine, responses may become automated, useless!
  - "Type the third letter of this sentence backwards to confirm that you want to delete all files." (cf. Raskin)
### A Few More Learning Concepts

- **Transfer**
  - Near and Far Transfer
  - Thorndike’s Identical Elements
  - Negative Transfer

- **Depth of Processing and Integration**
  - Process by semantics, not surface form
  - Relate to existing knowledge
  - ⇒ Study strategies!

**Implications for design?**

### Errors and Learning

- We learn through errors (at some levels)
- Yet errors can divert us from learning
- **Mistakes:** based on misconceptions or faulty information
  - Requires semantic feedback
- **Slips:** unintentional mal-execution of an action
  - Signal and allow undo ... or just fix?

### Design Implications of Errors

- **Reduce conditions leading to errors**
  - Selection rather than generation
  - Signaling context (but see next item)
  - Eliminating inconsistencies and modes
  - Checking potentially erroneous actions

- **Yet design for errors anyway**
  - We make errors and learn through them
  - Immediate Feedback
  - Undo
Novices and Experts

- Studies of Chess, Physics, much more:
  - Experts chunk, so remember more
  - Novices see surface structure; experts see semantic or problem-solving related structure
- Design for transition from novice to expert
  - Give novices explicit, declarative methods of acting
  - Give experts efficient means of acting
  - Common example: icons & menus versus key chords

Social Theories of Learning

- Socio-Cognitive Conflict Theory
- Vygotsky: Zone of Proximal Development
- Legitimate Peripheral Participation
- Collaborative Learning works through ...
  - Explanation and justification (depth of processing)
  - Encountering alternatives (SCCT)
  - Acquisition of collaborative skills
  - Becoming a member of the community (LPP)

Mental Models
Theories of Knowledge Organization

- Episodic and Semantic
- Semantic networks
  - graphs of relations between concepts
  - associative activation
- Schemata
  - group related data and operations for objects
- Scripts
  - typical patterns of behavior indexed by situations
- Mental Models

Mental models

- Internal constructions of some aspect of the external world enabling predictions to be made
- Functional Models
  - what does it do, how do you use it
  - task oriented (task-action mapping)
- Structural Models
  - what are the parts, how connected
  - Inferring function from structure: harder but flexible
- "Runnable:" unconscious and conscious processes, where images and analogies are activated

Implications

People use mental models of systems to understand how to carry out tasks

- Design the mental model along with the actual system (simplified but accurate version of designer's model)
- Describe the model in the documentation
- Design ways to expose the model in the interface (transparency)
Transparency

- NOT to be understood as literal
- easy to understand
- intuitive to use
- useful feedback
- clear & easy to follow instructions
- appropriate online help
- context sensitive guidance of how to proceed when stuck

Distributed Cognition and External Representations

External cognition

- Concerned with explaining how we interact with external representations (e.g. maps, notes, diagrams)
- What are the cognitive benefits and what processes are involved
- How they extend our cognition
- What computer-based representations can we develop to help even more?
Representation Matters

Roles of Representations

- Offloading work (enabling performance)
  - External memory
  - Cognitive operations become perceptual or mechanical operations
- Making abstractions concrete
- Expressing and reflecting on one’s ideas
- Exploring implications of one’s models

Manipulation of Representations

- Annotation involves modifying existing representations through making marks
  - e.g. crossing off, ticking, underlining
- Cognitive tracing involves externally manipulating items into different orders or structures
  - e.g. playing scrabble, playing cards
What implications are there for design?
Distributed/Situated Cognition

- Cognition is distributed across individuals and artifacts
- "Cognition in the wild": Study cognitive activities as embodied and situated in a context
- Navigation Example

Analysis of SocioTechnical Systems

- How information is propagated through the technological, cognitive, social, and organizational system
- How information is transformed between different representational states of objects in the system, with consequences for action
- Situation awareness: implicit as well as explicit communication
- "Breakdowns" in coordination of activity are normal but should be readily repaired
- Shared context example

Roles of Shared Representations

Beyond individual (cognitive) roles ...
- Prompting participant's negotiations
- Resource for conversation through deixis
- Group awareness
Representations differ on ...

- **Expressiveness**: What can you "say" in the representation?
- **Salience**: What is easy to recover from the representation once you've constructed it?
- **Prompting**: What further (cognitive) activity does the representation suggest?

Design Implications

- Provide representations that reduce memory load and facilitate computational offloading
- Design each representation to reflect what should be focused on
- Assume that all mutable representations will be used as components of the medium of interaction
- Facilitate easy cross-representational references (e.g., references from chat or threaded discussion to argumentation or modeling representations)
- Encourage reflection on prior information (e.g., by visual reminders or reflection prompts)

Pau!

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