Human-Computer Interaction

Research Frameworks in HCI

Professor Bilge Mutlu

Today's Agenda

» Topic overview: *Research Frameworks*

» Discussion

» Project next steps

Topic overview: *Research Frameworks*

» What is HCI theory?

» Does HCI have foundational theories?

» What is theory anyway?

A quick hands-on activity (whole class)

We'll incrementally build a definition of "HCI theory"

» Define theory (without looking)

» Define theory (use your favorite search/AI)

» Apply ideas to HCI to construct a definition of "HCI theory"

Our definition of HCI theory

...theory is the answer to queries of why. Theory is about the connections among phenomena, a story about why acts, events, structure, and thoughts occur. Theory emphasizes the nature of causal relationships, identifying what comes first as well as the timing of such events.

— Sutton & Staw, 1995[1]

[1] Sutton, R. I., & Staw, B. M. (1995). *What theory is not.* Administrative Science Quarterly, 40(3), 371–384.

Strong *theory … delves into underlying processes so as to understand the systematic reasons for a particular occurrence or nonoccurrence.*

— Sutton & Staw, 1995[1]

[1] Sutton, R. I., & Staw, B. M. (1995). *What theory is not.* Administrative Science Quarterly, 40(3), 371–384.

A good theory explains, predicts, and delights.

— Weick, 1995[2]

[2] Weick, K. E. (1995). *What theory is not, theorizing is.* Administrative Science Quarterly, 40(3), 385–390.

Some Preliminaries

1. HCI research is a process by which we develop, test, and refine theory about how to design computer systems and social phenomena around them.

2. Theory should guide design, predict outcomes, and serve as an educational tool about the field —it should be informative, predictive, and prescriptive (Rogers, 2004; Carroll, 2009)[3],[4].

3. To clarify, theory is not *references*, *data*, *variables*, *diagrams*, or *hypotheses*. These are resources we use in *theorizing*.

4. Theory-building, or theorizing, is an *iterative*, *slow*, and *collective* process.

---

[3] Rogers, Y. (2004). *New theoretical approaches for human-computer interaction*. Annual Review of Information Science and Technology, 38(1), 87-143.

[4] Carroll, J. M. (2009). *Conceptualizing HCI theory*. In *Human-Computer Interaction: Development Process* (pp. 3-26). CRC Press.

A definition

HCI theory is the set of conceptual frameworks developed through iterative and collective research that explain and guide how humans interact with computing systems, serving to inform design, predict outcomes, and educate the field.

So, what are some HCI theories?

Distinctions

Analytical theories — Predictive/explanatory, often imported from psychology, sociology, anthropology.

Generative approaches — Design-led, reflective, produce new concepts/tools to guide design.

Analytical Theories

Definition: Analytical theories aim to explain and predict human–computer interaction by modeling cognitive, social, and environmental processes.[3] [4]

» Provide explanatory and predictive power

» Often imported from psychology, sociology, and anthropology

[3] Rogers, Y. (2004). *New theoretical approaches for human-computer interaction*. Annual Review of Information Science and Technology, 38(1), 87-143.

[4] Carroll, J. M. (2009). *Conceptualizing HCI theory*. In *Human-Computer Interaction: Development Process* (pp. 3-26). CRC Press.

Analytical Theories — Model Human Processor

Definition: A model that represents human cognition as an information-processing system made up of set of memories and processors and a set of principles and that can approximate processing times for a given user action.[5]

[5] Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction.* Lawrence Erlbaum Associates.

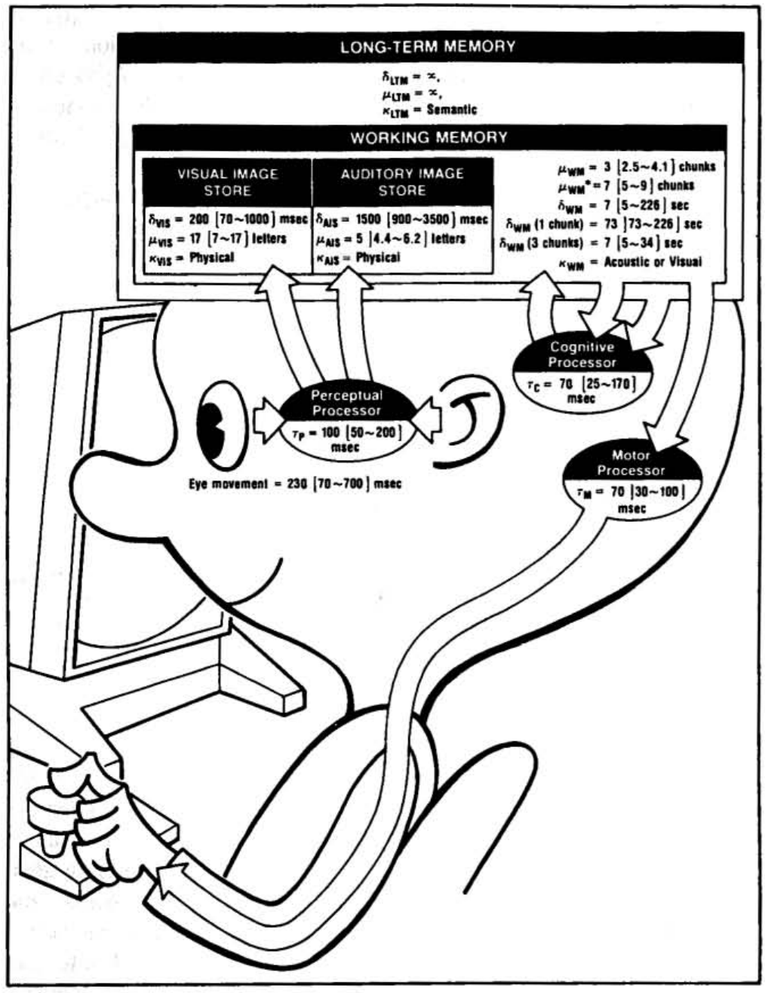


Figure 2.1. The Model Human Processor—memories and processors.

Sensory information flows into Working Memory through the Perceptual Processor. Working Memory consists of activated chunks in Long-Term Memory. The basic principle of operation of the Model Human Processor is the *Recognize-Act Cycle of the Cognitive Processor* (P0 in Figure 2.2). The Motor Processor is set in motion through activation of chunks in Working Memory.

P0. ***Recognize-Act Cycle of the Cognitive Processor.*** On each cycle of the Cognitive Processor, the contents of Working Memory initiate actions associatively linked to them in Long-Term Memory; these actions in turn modify the contents of Working Memory.

P1. ***Variable Perceptual Processor Rate Principle.*** The Perceptual Processor cycle time τ_P varies inversely with stimulus intensity.

P2. ***Encoding Specificity Principle.*** Specific encoding operations performed on what is perceived determine what is stored, and what is stored determines what retrieval cues are effective in providing access to what is stored.

P3. ***Discrimination Principle.*** The difficulty of memory retrieval is determined by the candidates that exist in the memory, relative to the retrieval clues.

P4. ***Variable Cognitive Processor Rate Principle.*** The Cognitive Processor cycle time τ_C is shorter when greater effort is induced by increased task demands or information loads; it also diminishes with practice.

P5. ***Fitts's Law.*** The time T_{pos} to move the hand to a target of size S which lies a distance D away is given by:

$$T_{pos} = I_M \log_2 (D/S + .5), \tag{2.3}$$

where I_M = 100 [70~120] msec/bit.

P6. ***Power Law of Practice.*** The time T_n to perform a task on the nth trial follows a power law:

$$T_n = T_1 n^{-\alpha}, \tag{2.4}$$

where α = .4 [.2~.6].

P7. ***Uncertainty Principle.*** Decision time T increases with uncertainty about the judgement or decision to be made:

$$T = I_C H,$$

where H is the information-theoretic entropy of the decision and I_C = 150 [0~157] msec/bit. For n equally probable alternatives (called Hick's Law),

$$H = \log_2 (n + 1). \tag{2.8}$$

For n alternatives with different probabilities, p_i, of occurence,

$$H = \Sigma_i p_i \log_2 (1/p_i + 1). \tag{2.9}$$

P8. ***Rationality Principle.*** A person acts so as to attain his goals through rational action, given the structure of the task and his inputs of information and bounded by limitations on his knowledge and processing ability:

Goals + Task + Operators + Inputs
+ Knowledge + Process-limits → Behavior

P9. ***Problem Space Principle.*** The rational activity in which people engage to solve a problem can be described in terms of (1) a set of states of knowledge, (2) operators for changing one state into another, (3) constraints on applying operators, and (4) control knowledge for deciding which operator to apply next.

Figure 2.2. The Model Human Processor—principles of operation.

Analytical Theories — GOMS

Definition: A family of predictive models of human performance that can be used to improve the efficiency of human-machine interaction by identifying and eliminating unnecessary user actions.

» Four variations: *KLM*, *CMN-GOMS*, *NGOMSL*, *CPM-GOMS*.[6]

» GOMS represents *goals*, *operators*, *methods*, and *selection rules*.

» KLM is constructed using four operators: keystroking, pointing, homing, drawing.

» New variations include TLM with new operators such as gesture, pinch, zoom, swipe, etc.

[6] John, B. E., & Kieras, D. E. (1994). The GOMS family of analysis techniques: Tools for design and evaluation. *Human-Computer Interaction*, 9(3), 293-335.

```
GOAL: EDIT-MANUSCRIPT
.  GOAL: EDIT-UNIT-TASK ...repeat until no more unit tasks
.  .  GOAL: ACQUIRE UNIT-TASK ...if task not remembered
.  .  .  GOAL: TURN-PAGE ...if at end of manuscript page
.  .  .  GOAL: GET-FROM-MANUSCRIPT
.  .  GOAL:EXECUTE-UNIT-TASK ...if a unit task was found
.  .  .  GOAL: MODIFY-TEXT
.  .  .  .  [select: GOAL:  MOVE-TEXT* ...if text is to be moved
.  .  .  .           GOAL:  DELETE-PHRASE ...if a phrase is to be deleted
.  .  .  .           GOAL:  INSERT-WORD] ...if a word is to be inserted
.  .  .  .    VERIFY-EDIT

*Expansion of MOVE-TEXT goal
GOAL: MOVE-TEXT
.  GOAL: CUT-TEXT
.  .  GOAL: HIGHLIGHT-TEXT
.  .  .  [select**:  GOAL: HIGHLIGHT-WORD
.  .  .                .  MOVE-CURSOR-TO-WORD
.  .  .                .  DOUBLE-CLICK-MOUSE-BUTTON
.  .  .                .  VERIFY-HIGHLIGHT
.  .  .                GOAL: HIGHLIGHT-ARBITRARY-TEXT
.  .  .                .  MOVE-CURSOR-TO-BEGINNING                1.10
.  .  .                .  CLICK-MOUSE-BUTTON                      0.20
.  .  .                .  MOVE-CURSOR-TO-END                      1.10
.  .  .                .  SHIFT-CLICK-MOUSE-BUTTON                0.48
.  .  .                .  VERIFY-HIGHLIGHT]                       1.35
.  .  GOAL: ISSUE-CUT-COMMAND
.  .  .  MOVE-CURSOR-TO-EDIT-MENU                                 1.10
.  .  .  PRESS-MOUSE-BUTTON                                       0.10
.  .  .  MOVE-MOUSE-TO-CUT-ITEM                                   1.10
.  .  .  VERIFY-HIGHLIGHT                                         1.35
.  .  .  RELEASE-MOUSE-BUTTON                                     0.10
.  GOAL: PASTE-TEXT
.  .  GOAL: POSITION-CURSOR-AT-INSERTION-POINT
.  .  .  MOVE-CURSOR-TO-INSERTION-POINT                           1.10
.  .  .  CLICK-MOUSE-BUTTON                                       0.20
.  .  .  VERIFY-POSITION                                          1.35
.  .  GOAL: ISSUE-PASTE-COMMAND
.  .  .  MOVE-CURSOR-TO-EDIT-MENU                                 1.10
.  .  .  PRESS-MOUSE-BUTTON                                       0.10
.  .  .  MOVE-MOUSE-TO-PASTE-ITEM                                 1.10
.  .  .  VERIFY-HIGHLIGHT                                         1.35
.  .  .  RELEASE-MOUSE-BUTTON                                     0.10
                                        TOTAL TIME PREDICTED (SEC) 14.38

 **Selection Rule for GOAL: HIGHLIGHT-TEXT:
  If the text to be highlighted is a single word, use the
  HIGHLIGHT-WORD method, else use the HIGHLIGHT-ARBITRARY-TEXT method.
```

Moving text with the *MENU-METHOD*

Description	Operator	Duration (sec)
Mentally prepare by Heuristic Rule 0	M	1.35
Move cursor to beginning of phrase	P	1.10
(no M by Heuristic Rule 1)		
Click mouse button	K	0.20
(no M by Heuristic Rule 0)		
Move cursor to end of phrase	P	1.10
(no M by Heuristic Rule 1)		
Shift-click mouse button		
(one average typing K)	K	0.28
(one mouse button click K)	K	0.20
Mentally prepare by Heuristic Rule 0	M	1.35
Move cursor to Edit menu	P	1.10
(no M by Heuristic Rule 1)		
Press mouse button	K	0.10
Move cursor to Cut menu item	P	1.10
(no M by Heuristic Rule 1)		
Release mouse button	K	0.10
Mentally prepare by Heuristic Rule 0	M	1.35
Move cursor to insertion point	P	1.10
Click mouse button	K	0.20
Mentally prepare by Heuristic Rule 0	M	1.35
Move cursor to Edit menu	P	1.10
(no M by Heuristic Rule 1)		
Press mouse button	K	0.10
Move cursor to Paste menu item	P	1.10
(no M by Heuristic Rule 1)		
Release mouse button	K	0.10
TOTAL PREDICTED TIME		14.38

[6] John, B. E., & Kieras, D. E. (1994). The GOMS family of analysis techniques: Tools for design and evaluation. *Human-Computer Interaction*, 9(3), 293-335.

Analytical Theories — Activity Theory[7]

Definition: Argues that human interaction with the world should be studied at the level of an activity.

» An activity is a hierarchical representation made up of *operations*, *tasks*, and *goals*.

» Activities are purposeful human interactions with objects mediated by physical and psychological *tools*.

» Frames human *activities* as the unit of analysis.

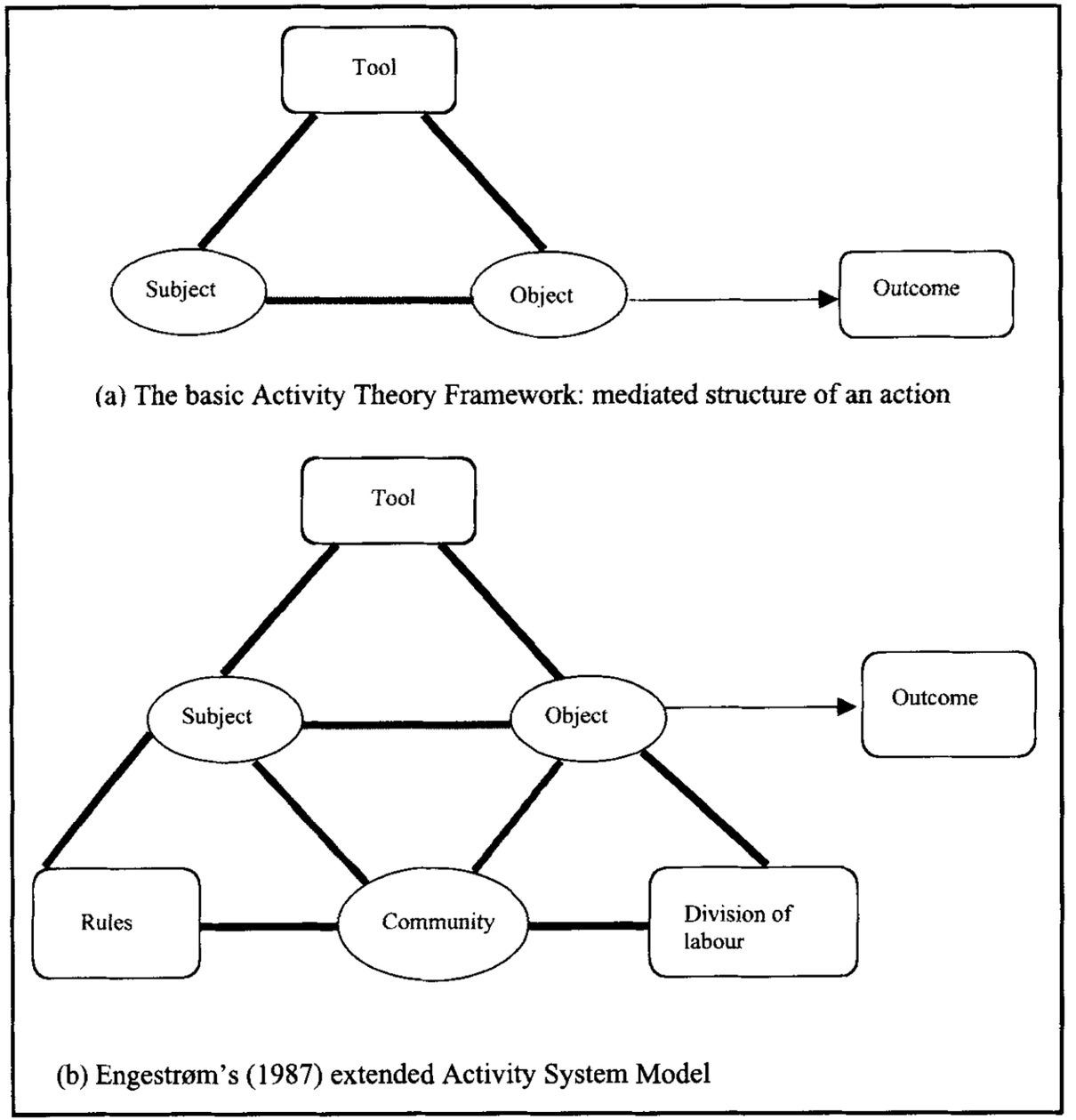


Figure 2.1 (a) The basic Activity Theory Framework and (b) Engestrøm's (1987) extended Activity System Model

[7]7: Kaptelinin, V., & Nardi, B. A. (2006). *Acting with technology: Activity theory and interaction design.* MIT Press.

Analytical Theories — Situated Action

Definition: A theory that posits that human actions are shaped by social and material circumstances, and thus they should be studied as an emergent property of the interactions among people or between people the environment.

Focused the attention of HCI researchers to *context*.

Analytical Theories — Distributed Cognition

Definition: In distributed cognition, the unit of analysis is extended beyond individual cognition to involve individuals and artifacts they use.

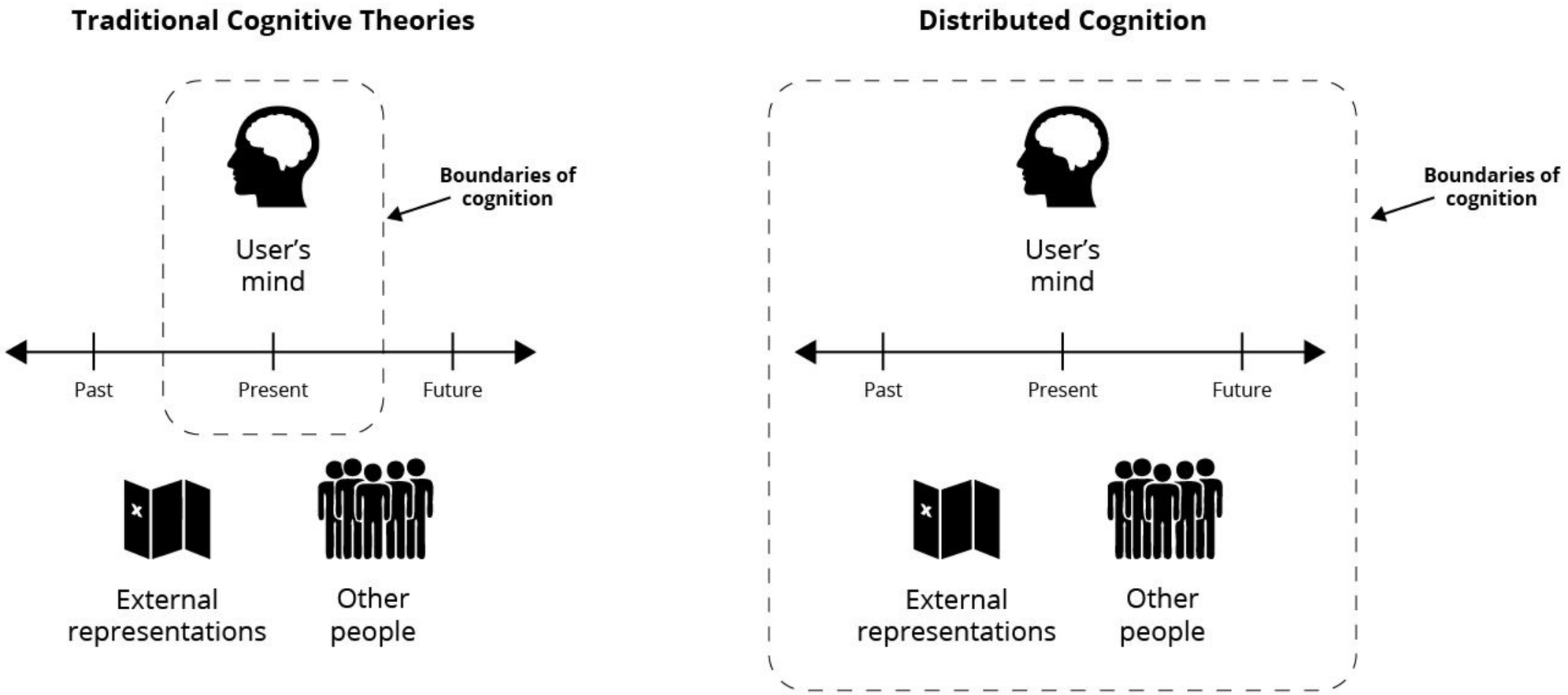
Cognitive processes are *distributed*:

» Across time

» Between individuals and groups

» Between internal and external representations in the system

8



[8] Image source: Matt Soave

Generative Approaches

Definition: Generative approaches aim to inspire and guide design, producing new concepts and frameworks rather than prediction.[3] [9]

» Provide ways of thinking, reflecting, and creating

» Often design-led; produce new forms of theory

[3] Rogers, Y. (2004). *New theoretical approaches for human-computer interaction*. Annual Review of Information Science and Technology, 38(1), 87-143.

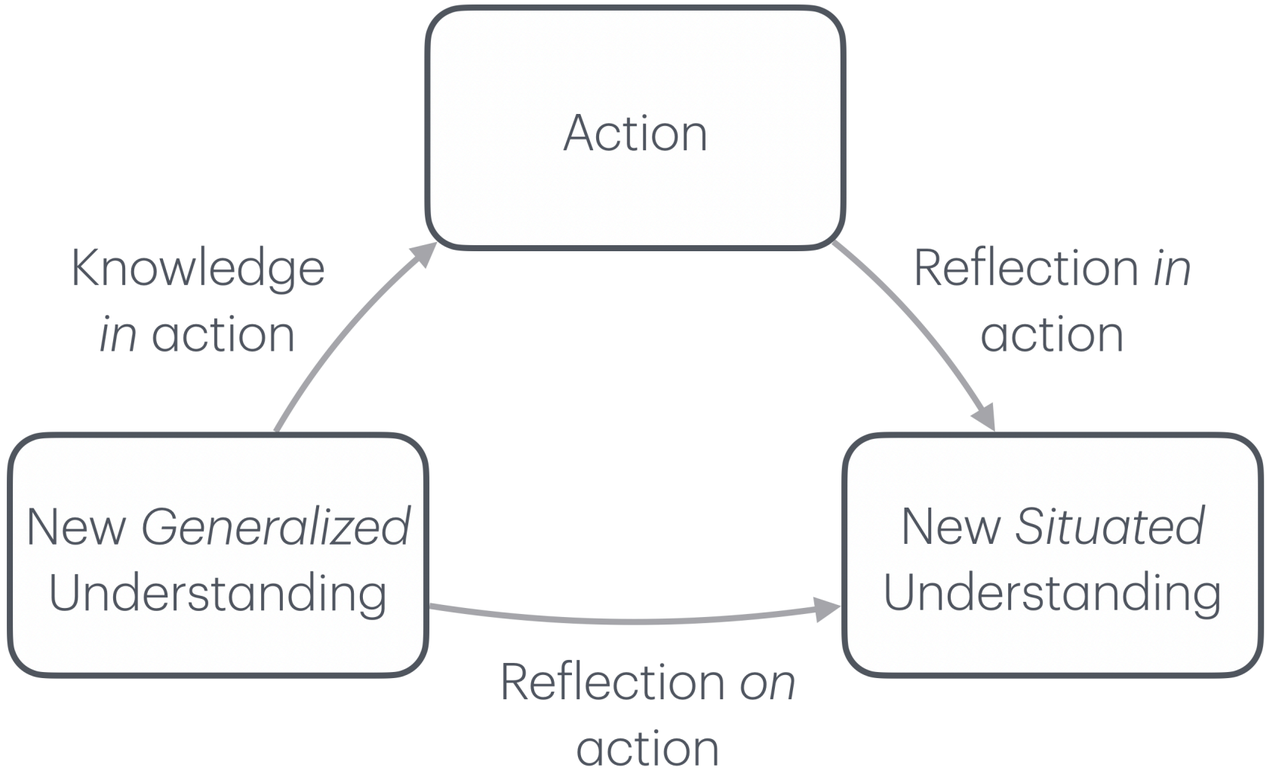
[9] Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Generative Approaches — Reflective Practice

Definition: Professionals generate insights by reflecting in action during practice.[9] [10]

» Emphasizes learning by doing and adapting

» Design as a reflective conversation with the situation



[9] Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

[10] Schön, D. A., & DeSanctis, G. (1986). The reflective practitioner: A critique of research on reflection in professional practice. *Human Relations*, 39(1), 7–24.

Generative Approaches — Design Rationale

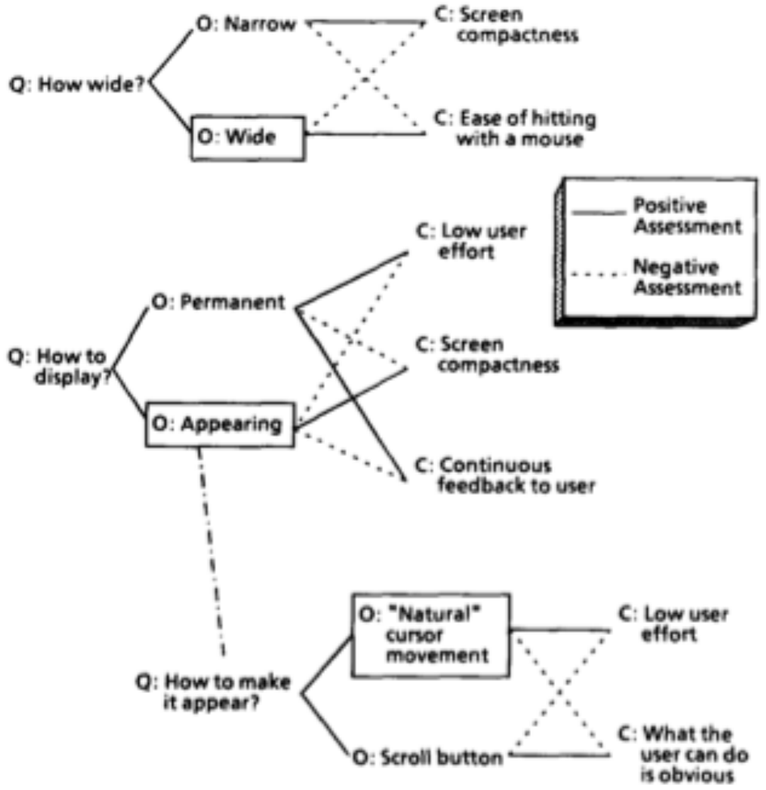
Definition: A framework for capturing, analyzing, and communicating design decisions.[11]

» Makes explicit the reasons behind design choices

» Supports collaborative design and future reuse of knowledge

» Example: Questions, Options, and Criteria (QOC frameworks)[12]

Figure 3. **A QOC representation of the design space for the XCL, elaborated from Figure 2 to include Criteria and Assessments. The boxed Options are the decisions made in the design of the XCL environment.**



[11] Carroll, J. M., & Rosson, M. B. (1992). Getting around the task-artifact cycle: How to make claims and design by scenario. *ACM Transactions on Information Systems (TOIS)*, 10(2), 181-212.

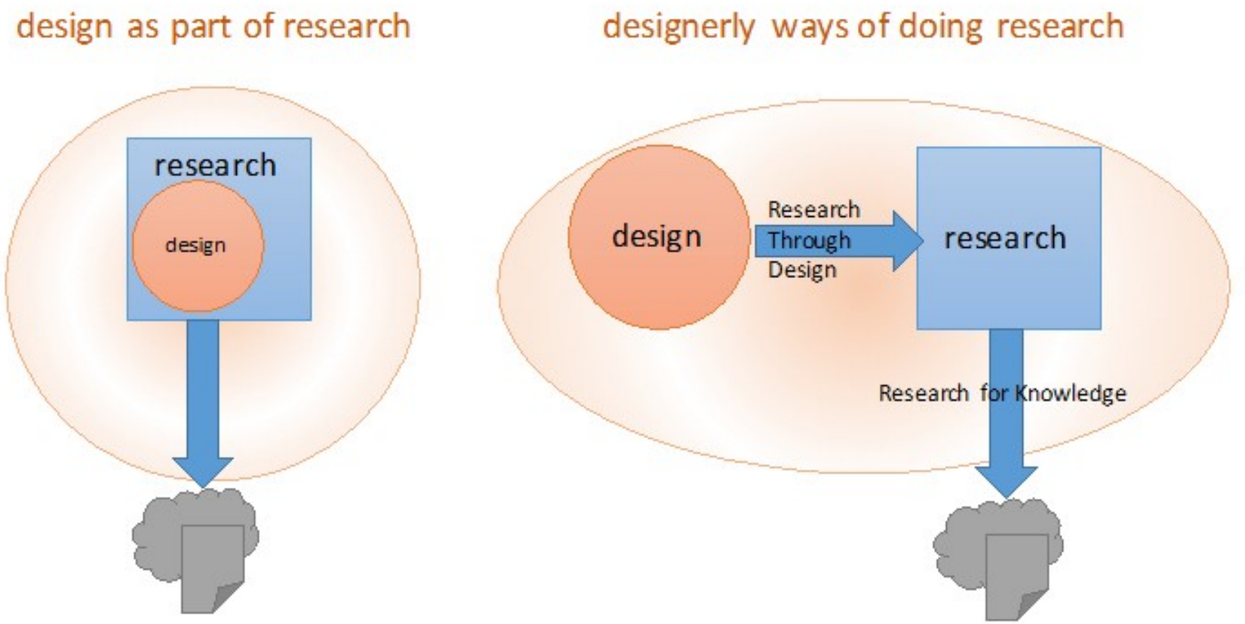
[12] MacLean, A., Young, R. M., Bellotti, V. M., & Moran, T. P. (1991). Questions, Options, and Criteria: Elements of Design Space Analysis. Human–Computer Interaction, 6(3-4), 201-250.

Generative Approaches — Research-through-Design (RtD)

Definition: Design practice as a method for theory-building, producing intermediate-level knowledge.[13] [14]

» Theories emerge from creating and evaluating artifacts

» Emphasizes generativity over prediction



[13] Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 493-502.

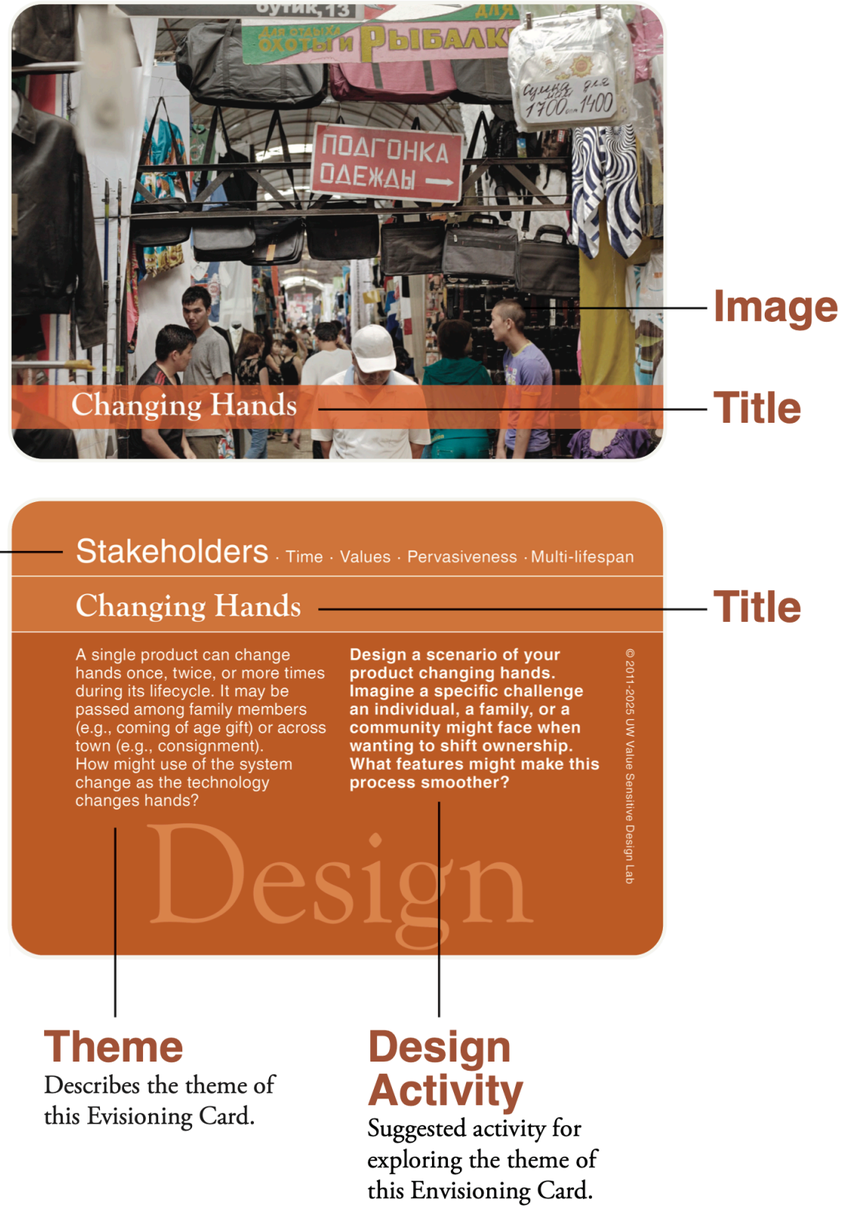
[14] Stappers & Giaccardi, 2014

Generative Approaches — Value Sensitive Design

Definition: A methodology for incorporating human values into technology design.[15] [16] [17]

» Brings ethics and values into design practice

» Generates conceptual, empirical, and technical contributions



[15] Friedman, B. (1996). Value-sensitive design. *Interactions*, 3(6), 16–23.

[16] Friedman, B., Kahn Jr, P. H., & Borning, A. (2006). Value sensitive design and information systems. In *Human-computer interaction and management information systems: Foundations* (pp. 348–372). M.E. Sharpe.

[17] Envisioning Cards

Discussion Format

- We'll let AI randomly pick 3-5 names
- In the selected order, students:
  - Present their provocation/critical artifact/policy or design recommendation (30 secs)
  - Lead class discussion (5-8 min)

What's Next?

- **Wednesday:**
  - **Methods** — Read *McGrath*[18] and *Edmondson & McManus*[19]
  - **Project** — Teams start working on project *deliverable 1*
    - Literature Survey, Research Question
    - Due Sep 26

[18] McGrath, J. E. (1995). Methodology matters: Doing research in the behavioral and social sciences. In *Readings in Human–Computer Interaction* (pp. 152-169). Morgan Kaufmann.

[19] Edmondson, A. C., & McManus, S. E. (2007). Methodological fit in management field research. *Academy of management review*, 32(4), 1246-1264.