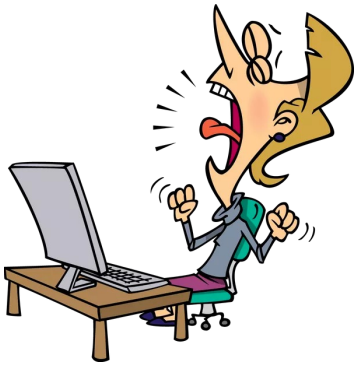
#3 Human-Computer Interaction



So far & this week

- So far:
  - HCI Definitions & framework
  - Design Thinking
  - Design Principles & Methodology
  - UCD vs SCD

- Today:
  - Modeling
    - Cognition
    - Activities
    - Prototypes

Modeling

What is a model?

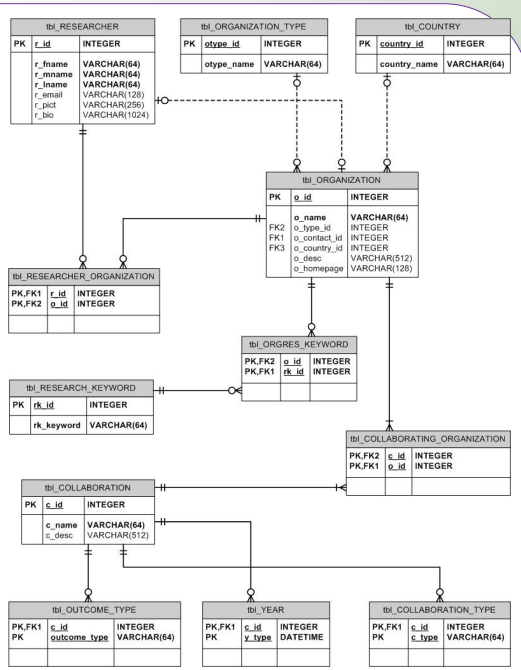
- A representation or approximation of a *system*

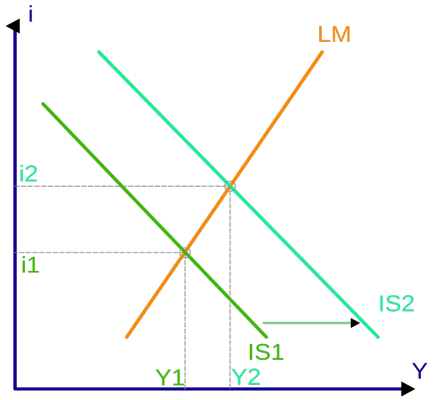
- Both the *system* and the *model* may be:
  - big or small; static or dynamic; simple or complex; ….

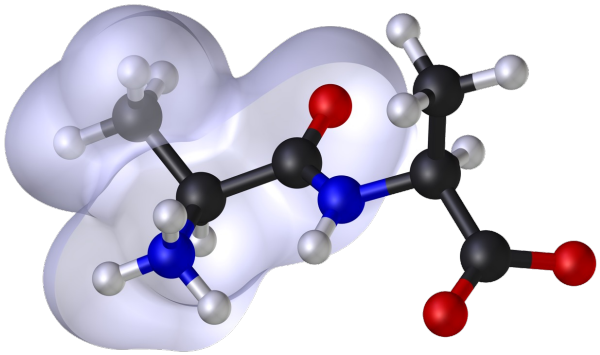
physical	non-physical
	
• architectural • car • sculpture • bridge • …	• cognition • statistical • mathematical • economic • …

What is a model?

https://www.youtube.com/watch?v=uWuNfhDvZz8







$$\mathcal{P} = \{\mathbb{P}(x;\mu,\sigma) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left\{-\frac{1}{2\sigma^2}(x-\mu)^2\right\} : \mu \in \mathbb{R}, \sigma > 0\}$$

Model fidelity

- Fidelity
  - A measure of the accuracy and precision of the correspondence between the *model* and the *modeled*
    - i.e., how *faithful* is the model to what it represents?

Modeling Cognition

What is cognition?

- “to know”, ‘to think’, “to conceptualize”, “to recognize”
- processes of the mind when we
  - read, think, reason, solve problems, remember, learn, communicate, …

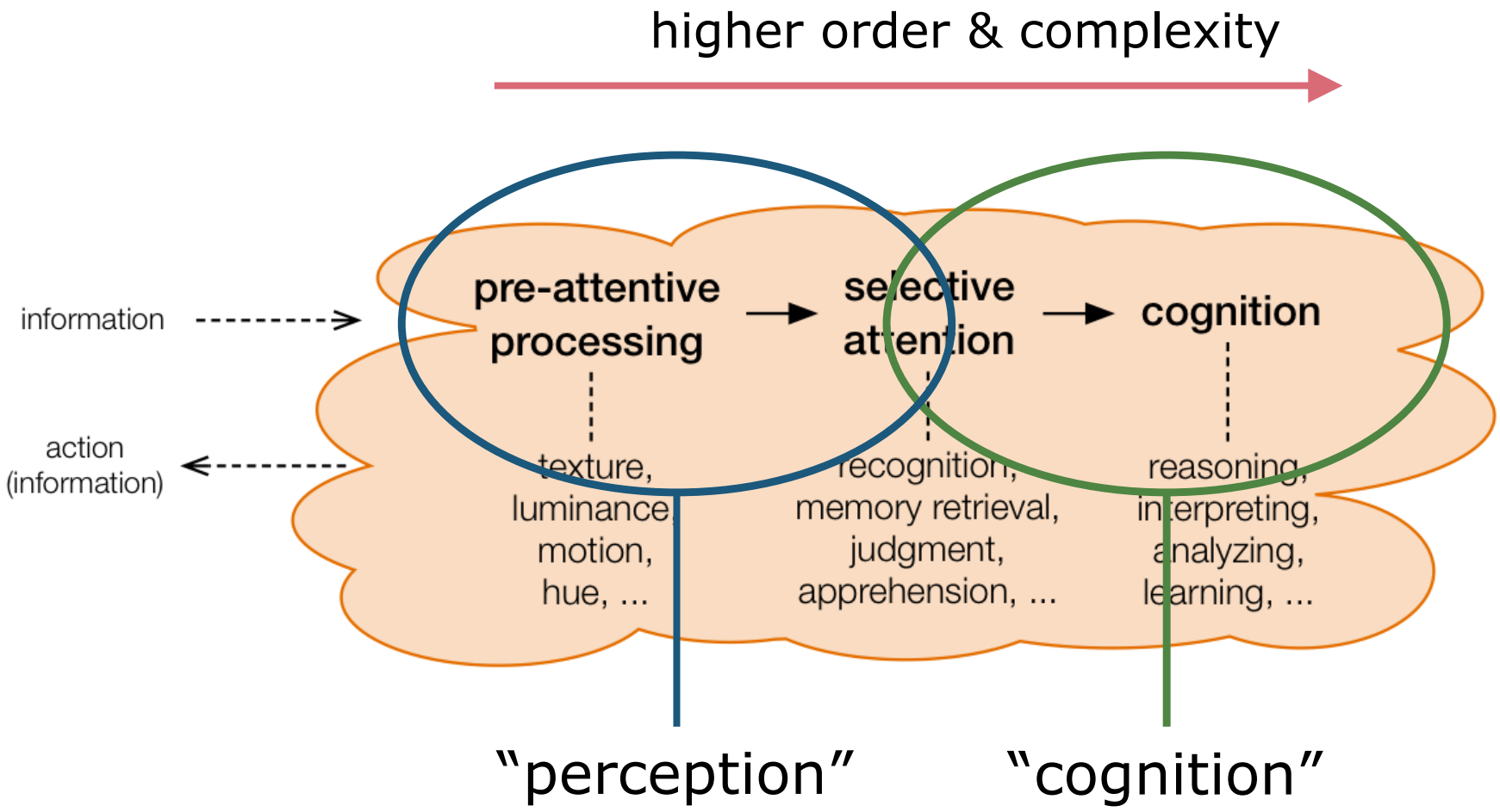
Cognition: Simple processes

- Perception
  - acquiring information from our environment from our senses
  - vision is our dominant sense
- Attention
  - selecting things to focus on from a range of possibilities
- Memory
  - storing and recalling information to help with all kinds of cognitive activities and processes

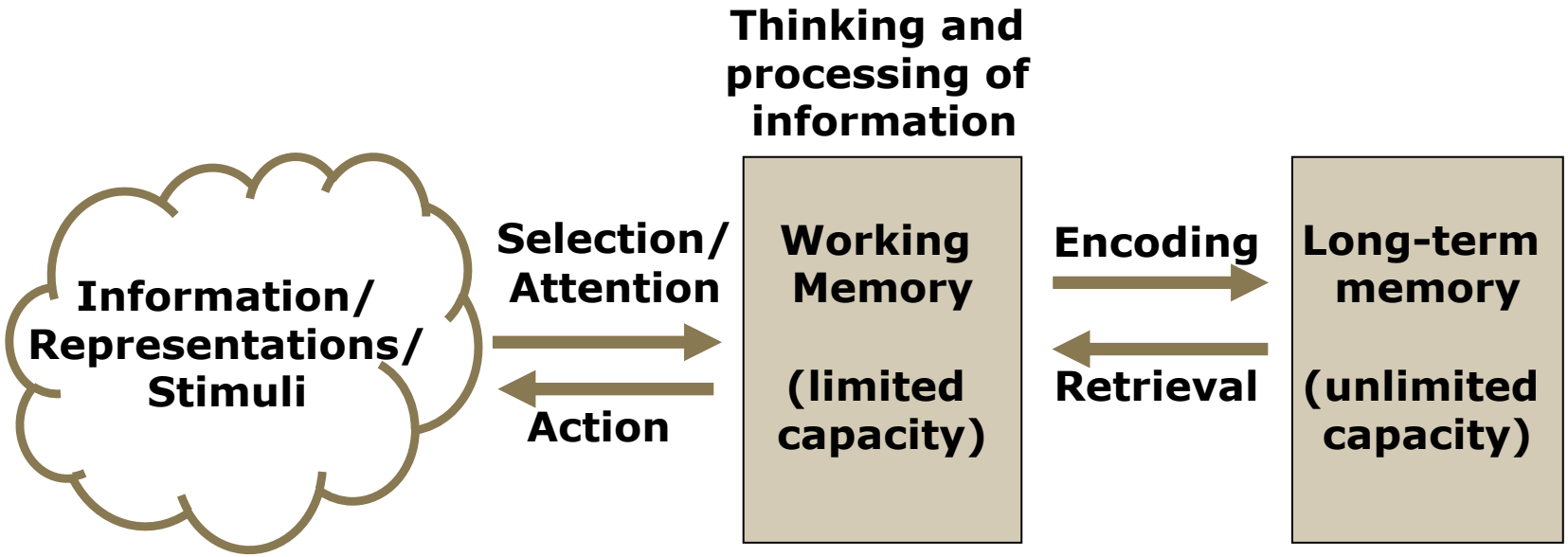
Cognition: Complex processes

- Reading, speaking, writing, listening
  - forms of language processing
- Learning
  - acquiring information and integrating it into existing mental representations
- Problem solving, planning, reasoning
  - moving with ideas from point A to point B

Cognition: Order and complexity



Simple model of cognition



Cognition ?

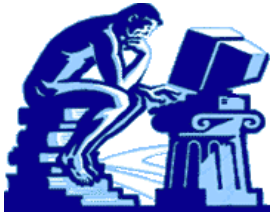
- Can you do the following multiplication in your head?
  - 3 * 5
- How about?
  - 387 * 64925
- How about playing a whole game of chess in the head—from the start to finish?

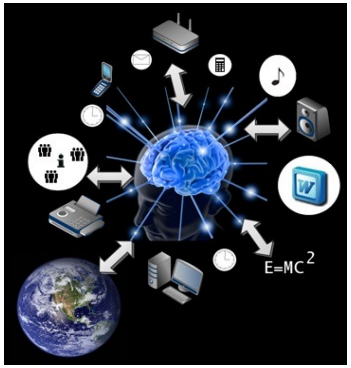
Thinking/cognition

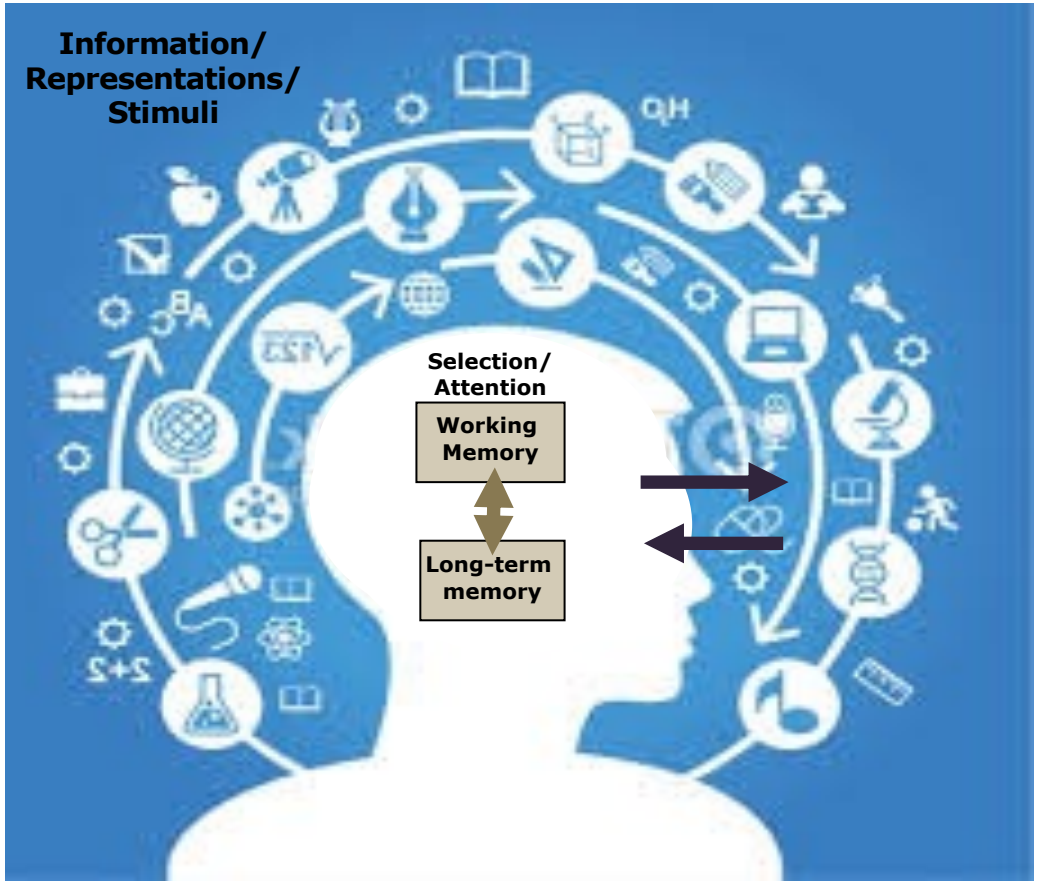
Mental tasks do not occur solely in the head. They are **distributed.** We think in **partnership** with external artifacts—both static and interactive ones. Cognition is artifact-dependent.

Theory of distributed cognition

- People think through, with, and by the aid of other people, tools, cultures, objects, representations, …. (in other words, other systems)
- What are the implications of this theory for HCI design? In particular, what does partnership imply for design?







Distributed cognition

- Cognition is an emergent property of interactions among internal and external systems
  - Think about cognition in terms of a system
- We think **with** things in our external environment
  - Where things are tools, artifacts, people, …
- For example:
  - Why do you use stickie notes?
  - What do you use Wikipedia for?
  - What do you use Google for?

Modes of cognition

experiential

- perceive and react to events automatically
- automatic and easy
- promotes shallowness of understanding
- little active mental effort required

reflective

- requires conscious contemplation
- requires mental effort
- promotes depth of understanding
- significant active mental effort required

not as dichotomous as they seem!

"Many existing sets of instrumentation and equipment fail by providing reflective tools for experiential situations or experiential tools for reflective situations."

-- Donald Norman, *Things that Make Us Smart*

Question

- What is the difference between productivity tools and educational tools?
- What about games?

Your projects

- Think about the point of your projects in the context of cognitive modes
  - Are you redesigning a game?
  - Is it for entertainment?
  - Is it for productivity?
  - Should there be a challenge for the user?
  - …

Coupling

- When we engage with any system, a coupling is created
- Are there different degrees of coupling?

Yes

- Weak to strong coupling
- e.g.,
  - Passive observation of a book
  - Interactive engagement with material

Coupling & UCD

- For human-centered artifacts, what degree of coupling do you need?
- How do you promote this type of coupling?

Cognitive offloading

- The extent to which different external systems affect (reduce or increase) the **amount of cognitive effort** required to carry out our activities
  - High
    - much of the effort is offloaded onto the external system
  - Low
    - much of the effort is required by the user to perform a given activity

Recall: Cognitive artifacts

"A cognitive artifact is an artificial device designed to maintain, display, or operate upon information in order to serve a representational function…"

- Donald Norman

Artifacts and distribution

- Tools and artifacts act as **partners** in cognition
  - They are not simply things to store information
  - They *enable* and *constrain* cognitive performance
  - Some tools *extend* & *enhance* human reasoning
  - Some tools *limit* human reasoning
  - Tools can *shape* human thinking and feeling

HCI artifacts can facilitate or hinder thinking and reasoning

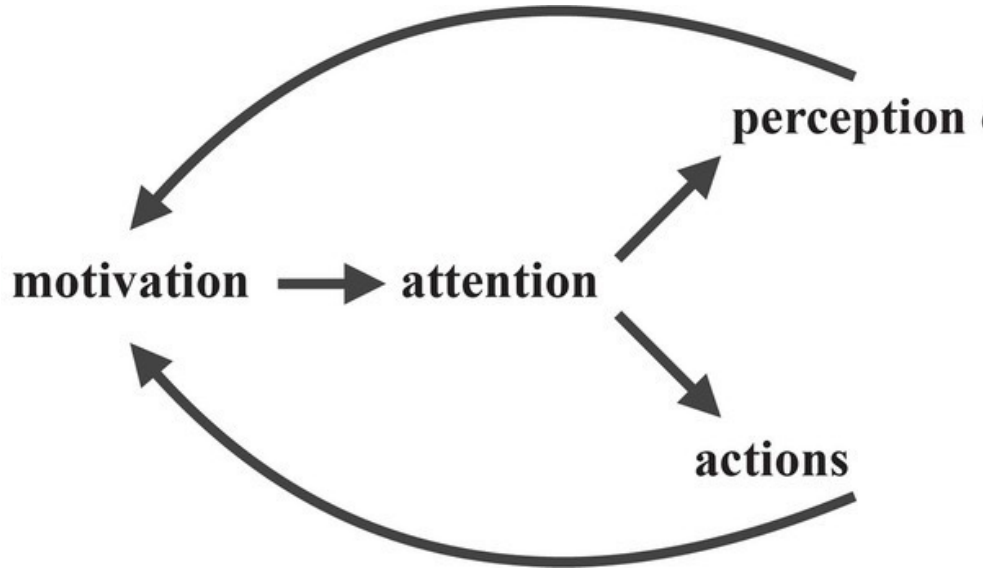
HCI artifacts

- As designers, do we know much about:
  - representations
  - human cognition
  - how people think through representations
  - how people act upon representations

- If we don't, we are just copying what we have seen that exits out there
  - How do we know our designs are good?
  - They may have negative effects on users
  - They may shape people's thinking

Modeling Cognition & Design Principles

Attention



Selective attention

https://www.youtube.com/watch?v=VoWqEwupZHc

Also see:
https://www.youtube.com/watch?v=vJG698U2Mvo

Selective attention

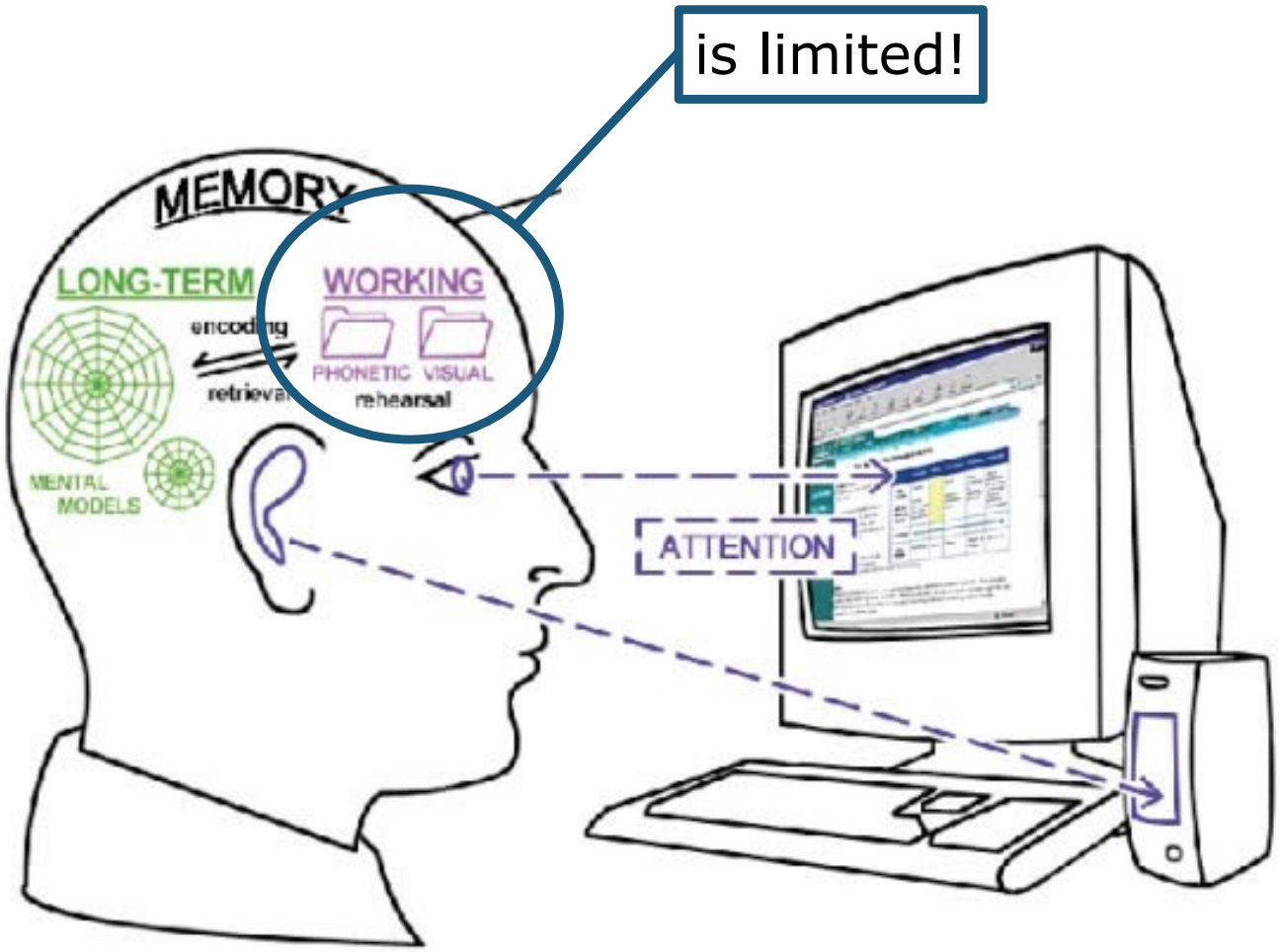
- Conscious attention is selective!
- Implication: user's often don't look around much
  - not just with things hidden in menus, but also things right on the screen!

Users often focus attention only on what is necessary for a current task—that is, what they need to do.

Selective attention: Design principle

- Designers need to think about the layout of objects **in the context** of the user's tasks

Memory


is limited!
MEMORY
LONG-TERM
WORKING
encoding
retrieval
PHONETIC
VISUAL
rehearsal
MENTAL MODELS
ATTENTION

Capacity of working memory

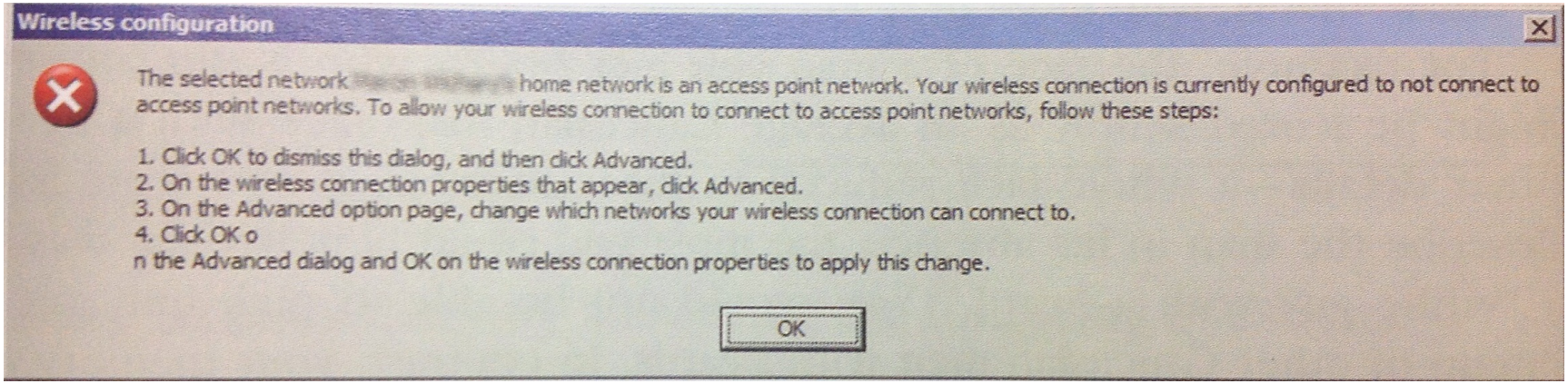
- Working memory is limited to a small number of "chunks"
- No precise number for all cases
  - ~7 for digits
  - ~6 for letters
  - ~5 for words
- Also depends on length of chunk, familiarity with chunk (e.g., does the person know the word?), and individual characteristics

why do you think this is important for design?

Working memory: Design principle

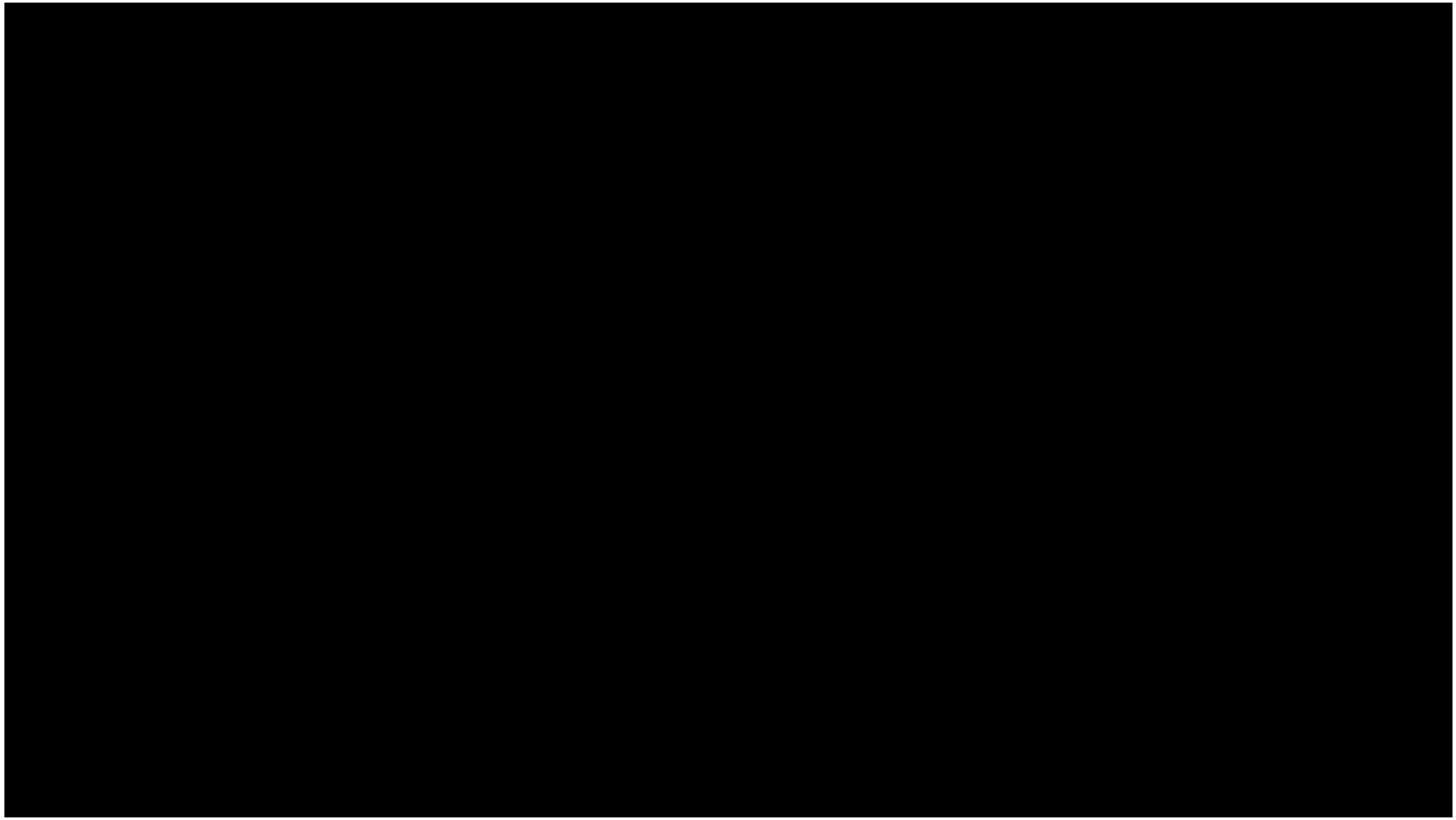
- System should help people remember essential information from one moment to the next
- Do not make the user keep important information in working memory
  - Especially if it is not directly related to their current goals/tasks!

Example of bad design



- Windows XP wireless configuration
- Gives users instructions, then tells them to close the window!

Change blindness



https://www.youtube.com/watch?v=bh_9XFzbWV8

Also see:

https://www.youtube.com/watch?v=FWSxSQsspiQ

Change blindness

- People do not notice differences in features other than those that their goals require them to pay attention to

Why do you think this is important for design?

  - User has to maintain the current state of his task, current state of the system, etc. in working memory
  - The user's working memory should not be overburdened!
  - There are all kinds of examples for design

Design lesson

- Human cognitive capabilities and limitations are manifested in the context of task performance

- Therefore, not only must designers be aware of working memory, change blindness, selective attention, perceptual issues, etc… but also have to know that:

Related design choices are task-dependent!

Cognitive engineering

- HCI design involves cognitive engineering
  - Knowing how to apply design principles
    - Application of cognitive science principles to design (of interactive computer systems)
- Proper coupling means creating systems that fit the cognitive system of users
- Therefore, we need to know about (at least) the important principles of cognitive science and how they translate to design principles

Design principles

We have seen some design principles.

There are many design principles that we will see later.

Mental Models

Mental models

Consider the image below

- What is it?
- What can you do with it?

Mental models

- Your answers constitute at least part of your mental model of a car
- HCI designers need a deep understanding of mental models
- Lesson for HCI design:
  - When users encounter a new product, they draw on their *existing mental models* to try to understand it

Mental models

https://www.youtube.com/watch?v=GzkkmFAsQSA

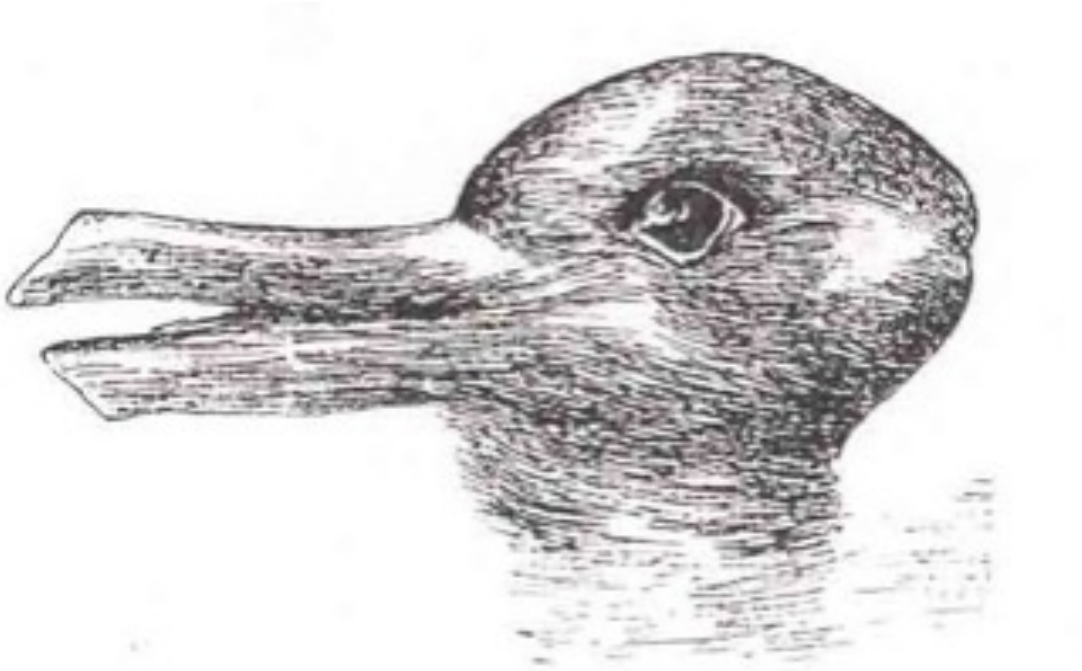
Also

https://www.youtube.com/watch?v=nAgXISssAws

"The models people have of themselves, of others, the environment, and the things with which they interact. People form mental models through experience, training and instruction. The mental model of a device is formed largely by interpreting its perceived actions and its visible structure."

-- Donald Norman, *Things that Make Us Smart*

What gets activated in your mind?



Familiarity and mental model activation

- Our familiarity with forms and behaviours in our environment determine which mental models are activated

- What if you had never seen a duck or rabbit before?

Perception is not just a product of external stimulus, but also of mental activity

Taking advantage of familiarity

- We can suggest the function and behaviour of virtual/digital/computational entities using familiar things—activate existing mental models

Familiarity and mental model activation

So, should all our designs be exact copies of objects in the real world?

If so, why have digital entities? After all, what represents objects better than the objects themselves?

Dynamism of mental models

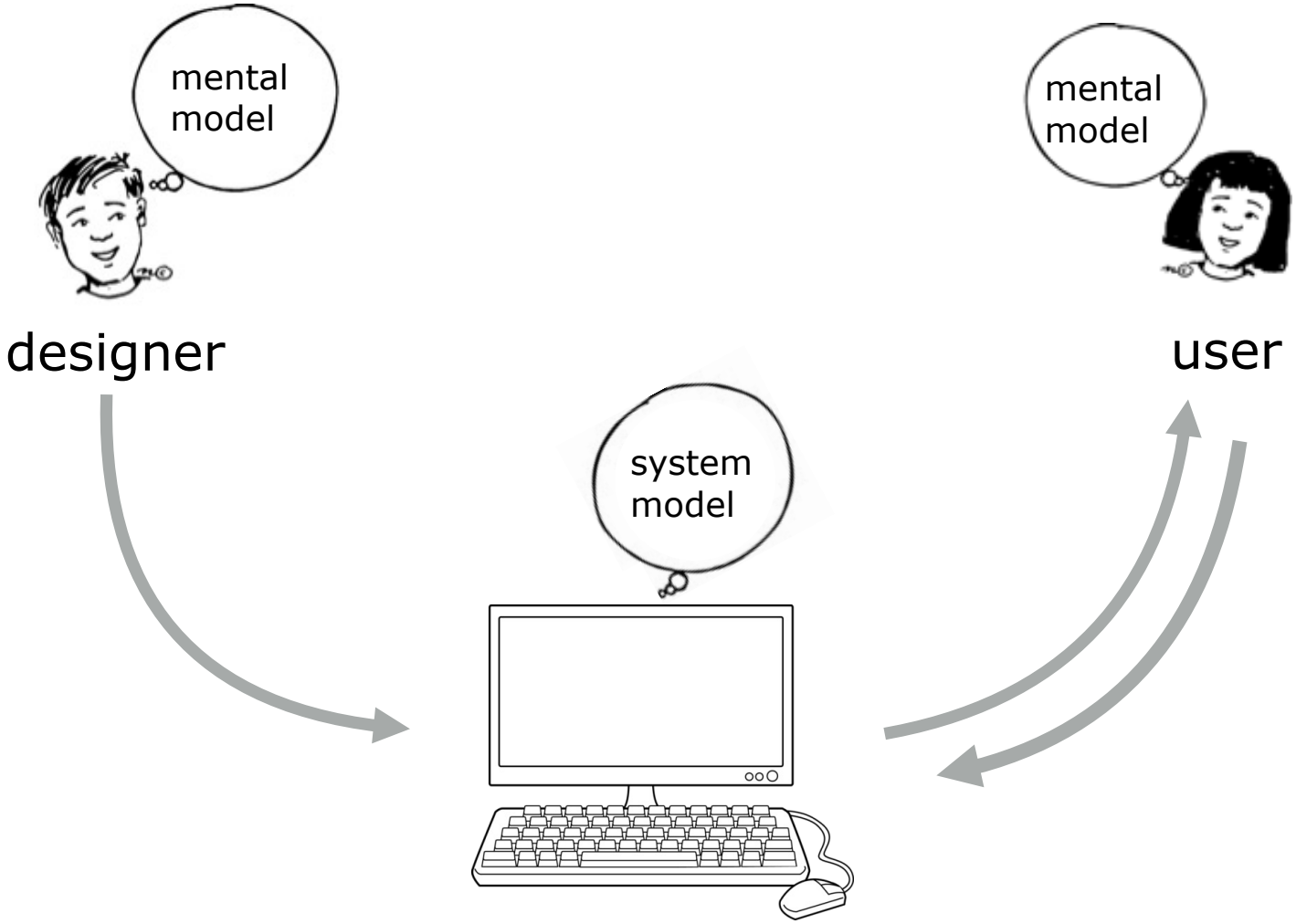
- People (and users) are learning from their experiences all the time
- Mental models are *dynamic*, *not static*
  - Thus, trying to model a user is like trying to hit a moving target
  - However, **given the right assistance**, users can learn to use unfamiliar tools
- How do you decide when to use convention and when to teach the user something new?

Summary

- Modeling: Cognition
- All in the context of distributed cognition
  - Distributed cognition is not one type of cognition … it is a lens through which cognition in general could be understood
- Cognition
  - limitations, capabilities
  - cognitive engineering
- Mental models

Modeling Activities

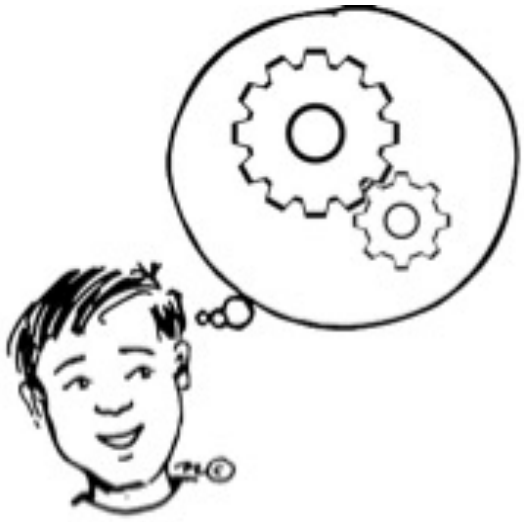
More models



System model

- System model: a kind of *hybrid* model
  - physically manifests (but abstractly represents) the system's "understanding" of the world, user, etc.
- To understand the gap between the *system model* and the *user's mental model*, we must consider the *designer's mental model* of
  - The user
  - The system

Designer's mental model



Which of these mental models is most appropriate for a designer?

Designer's mental model

How should the designer model the thought processes of the user?

ergonomics perspective
users want to be comfortable

affective psychological perspective
users are emotional

cognitive perspective
users are rational

Designer's mental model

- Designer
  - Designs are hypotheses about how users think
    - And what they need, what they like, how they feel, how they act, etc.
- Goal: Alignment and coupling
  - Successful designs arise from proper alignment of the user's mental model and the designer's mental model
  - This is what gives rise to the proper alignment of the system model and the user's mental model
  - UCD strategies are practical measures to try to achieve this alignment

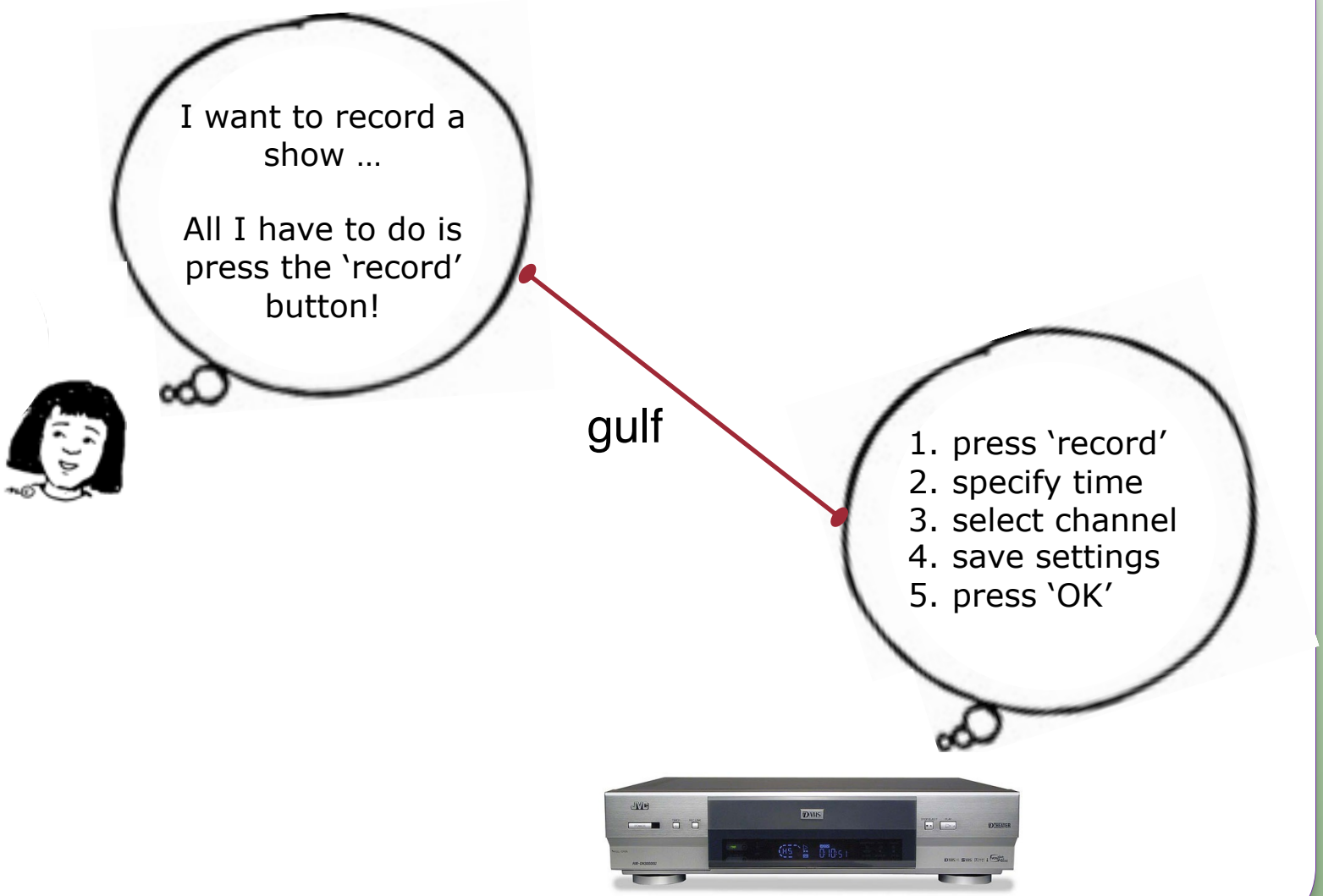
Conceptualizing model alignment

- The twin gulfs

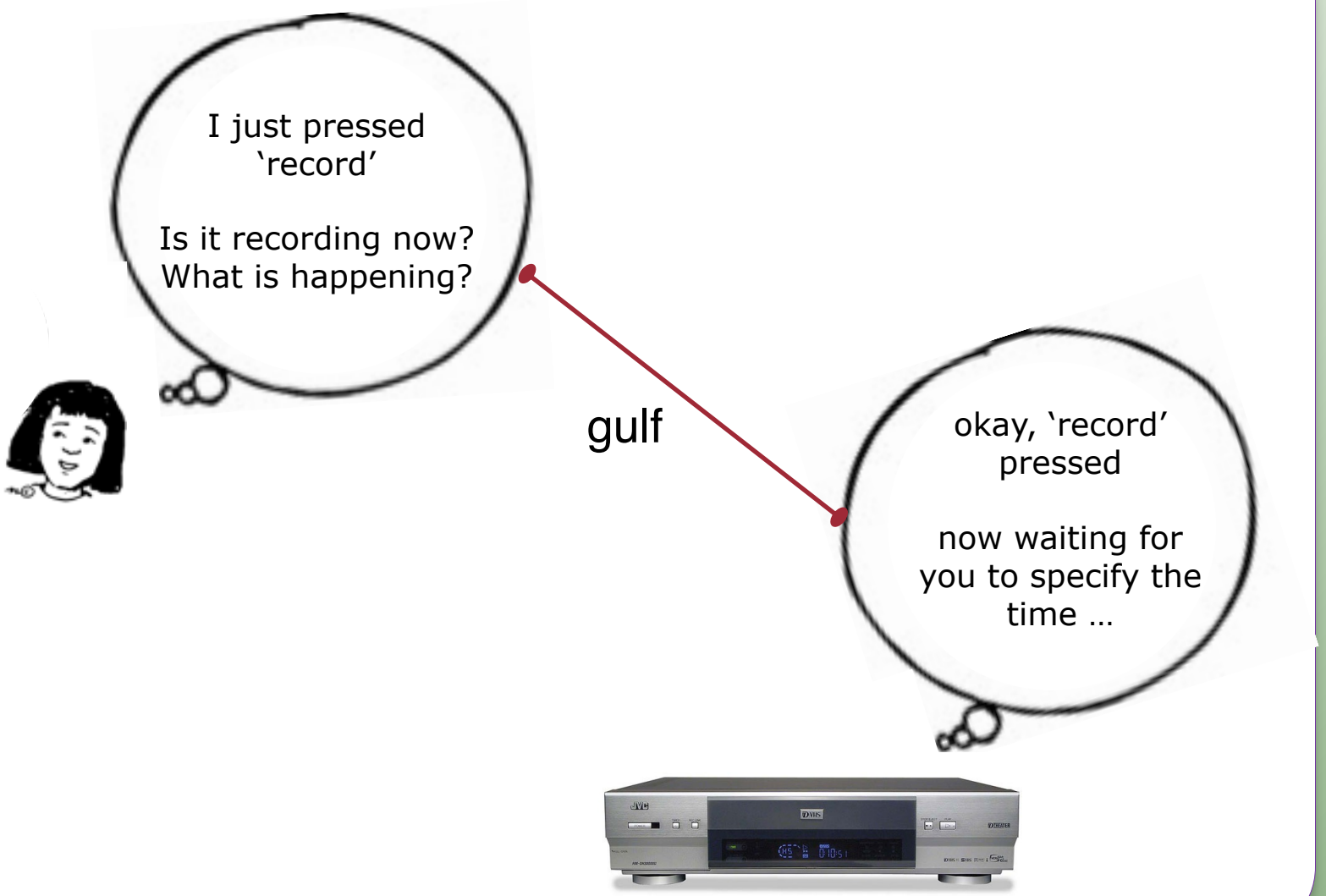
- Gulf of Execution
  - conceptual gap b/w what the system allows the user to do and what the user believes he/she can do
- Gulf of Evaluation
  - conceptual gap b/w the state of the system/what it intends to convey and what the user perceives

- Much of the HCI literature is concerned with alignment of user and system models and *how to bridge these two gulfs*

Gulf of execution



Gulf of evaluation



Design questions

- How easily can the user:
  - Determine the function of the device?
  - Tell what actions are possible?
  - Perform the action?
  - Tell what state the system is in?
  - Tell if the system is in desired state?
  - Determine mapping from system state to interpretation?

Cognition and activity

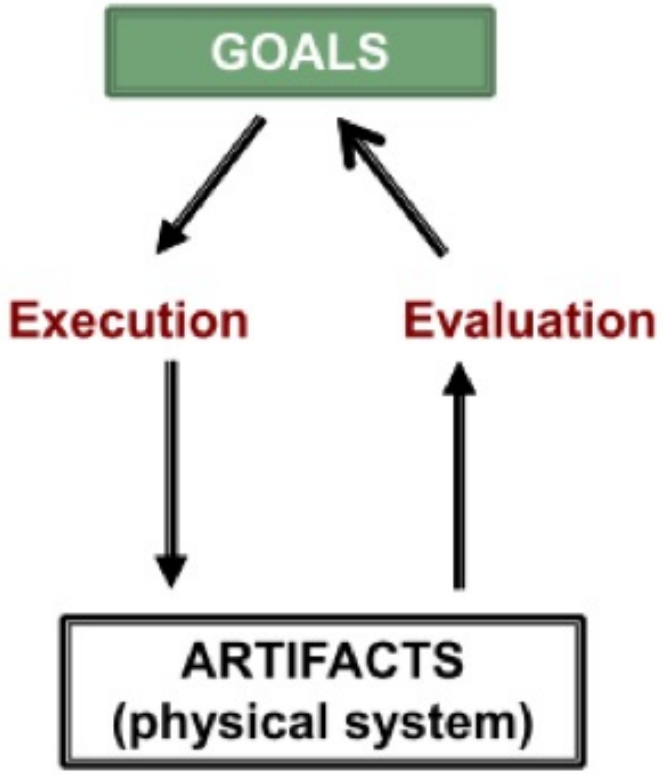
- What is a task?
- How do users perform tasks?
  - User has a goal, residing in the mind
  - Task is carried out with physical system
  - User must interpret (make sense of) system
  - Goals are expressed in terms relevant to the user
  - System's states and mechanisms are expressed relative to the system

Action cycle

- Actions are performed through a feedback mechanism involving:

- Execution
  - What a user wants to do to/with an artifact

- Evaluation
  - Interpreting what artifact did and comparing it to original goal



Bridging the gulfs

- To have usable and effective artifacts, the gulfs must be bridged
- Two extremes:
  - Designer can bridge the gulfs
  - User can bridge the gulfs

Bridging the gulfs

- Designer bridging gulfs
  - Construct input/output characteristics of artifact's interface to make better matches to psychological needs of user
  - Which design methodology is this?
- User bridging gulfs
  - Create plans, action sequences, and interpretations to move his/her intentions closer to the goals/requirements of the artifact
  - Which design methodology is this?

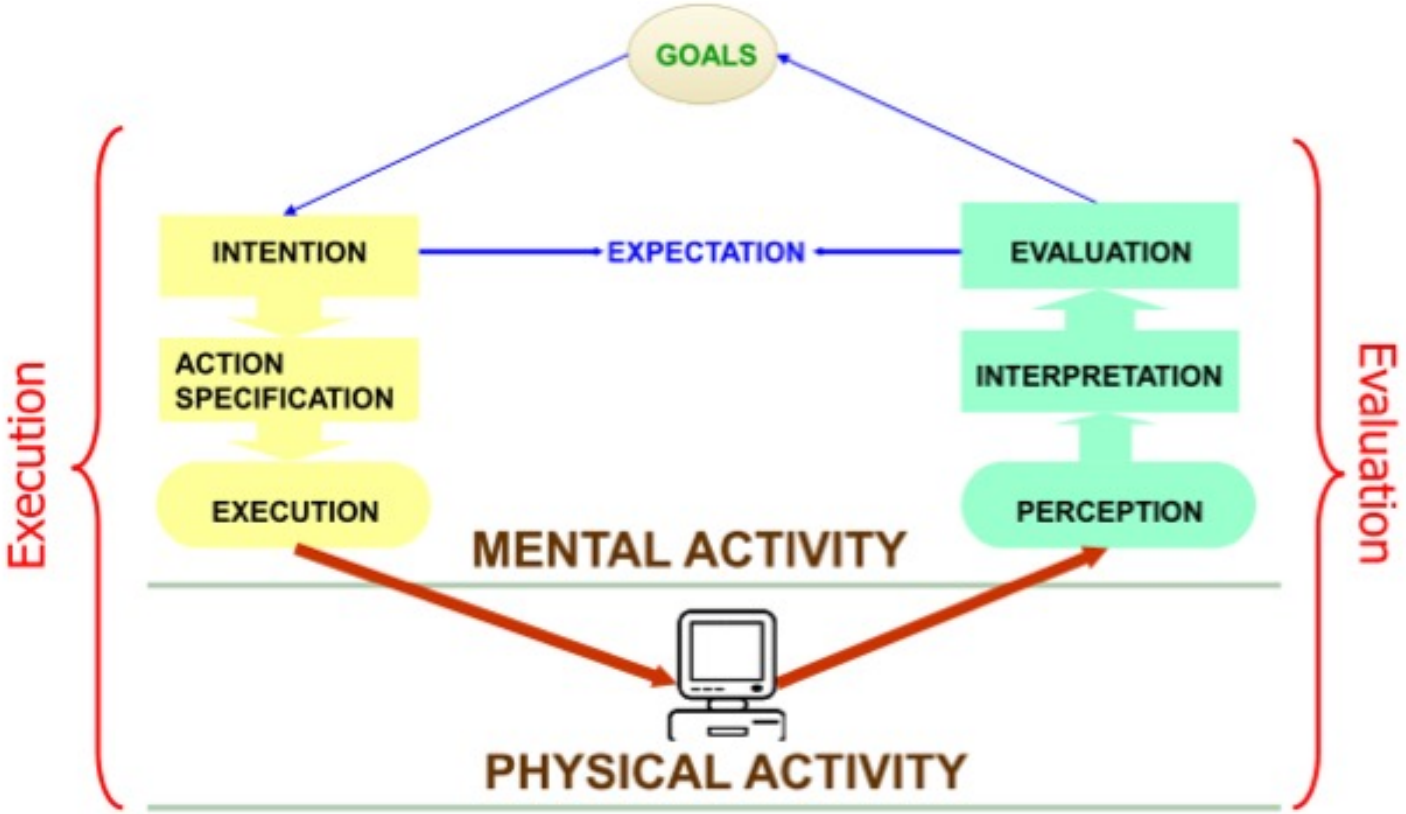
Stages of user activity

1. establishing a goal
2. forming intentions
3. specifying action sequence
4. executing action
5. perceiving artifact state
6. interpreting artifact state
7. evaluating artifact state with respect to initial goal and intentions

execution: 2, 3, 4

evaluation: 5, 6, 7

Stages of user activity



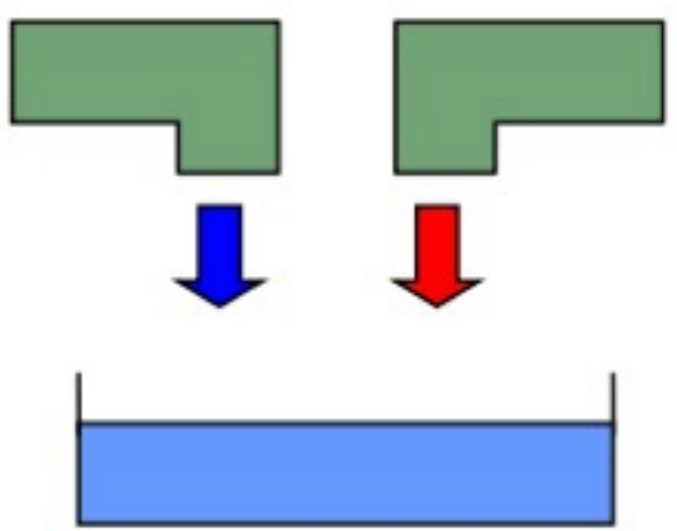
Here it is represented as cycle … added detail to the action cycle that we saw a few slides ago

Action cycle

https://www.youtube.com/watch?v=ahtOCfyRbRg

Stages of user activity: Example

1. Goal
   - wash dishes
2. Intention
   - fill sink with warm water
3. Action specification
   - turn on both taps
4. Execution
5. Perception
   - see water and sink filling
6. Interpretation
   - what is happening?
7. Evaluation
   - is temperature right?
   - adjust and iterate



Practical implications

- HCI artifacts can be characterized in terms of how well they support different stages of user activity
- For example:
  - Graphical user interface supports the interpretation stage better
  - Difficult to do this well in a command-line interface

Practical implications

- Most of the responsibility rests on the designer to provide a good model for users to understand
- Moving from psychological variables to physical variables is not easy
- User must translate goals conceived in psychological terms to artifact-suitable action

Practical implications

- Interface is understood through either proper design or training/experience
- Ideal situation:
  - No psychological effort needed to bridge gulfs
    - Simple situations
    - Expert users
- Non-ideal situation:
  - Active learning and problem solving to bridge gulfs
  - Aided by a good **conceptual model**

Interface as a two-sided coin

- What does the word “interface” mean?
- Two sides to an interface
  - Human side
    - Change interface through training and experience
  - System side
    - Change interface through proper design

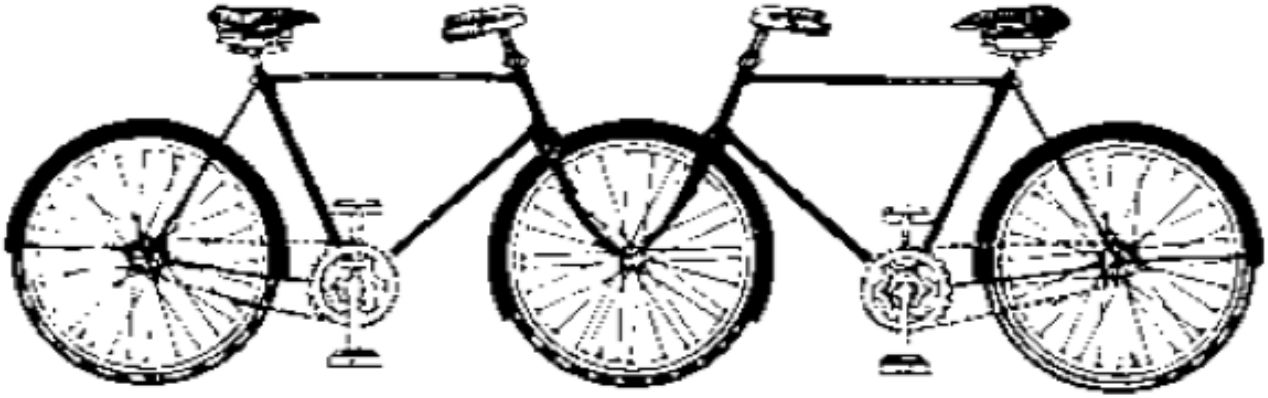
good usability and user experience are achieved often as a result of both

Conceptual Models

Conceptual models

- People form mental models of:
  - How objects work
  - Why events take place
  - What action causes what effect
  - ….
- Models allow people to *mentally simulate* the operation of a device
- Using the interface of a system, designers should provide appropriate conceptual models to help users form correct mental models

Conceptual model

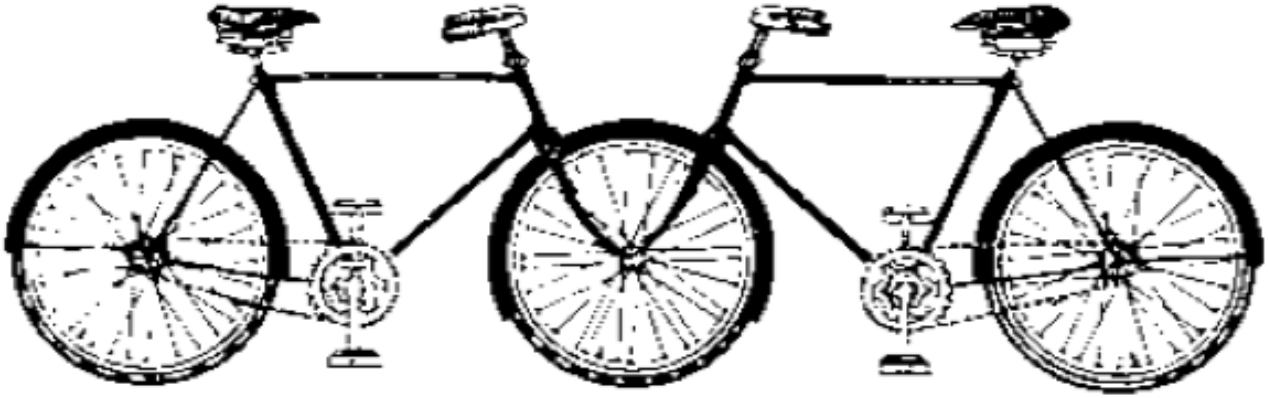


- *conveys* a model of how something conceptually works
- you mentally simulate its operation
- parts are visible and implications are clear

Conceptual model of a file system

http://www.youtube.com/watch?v=4yvFSuL5qII

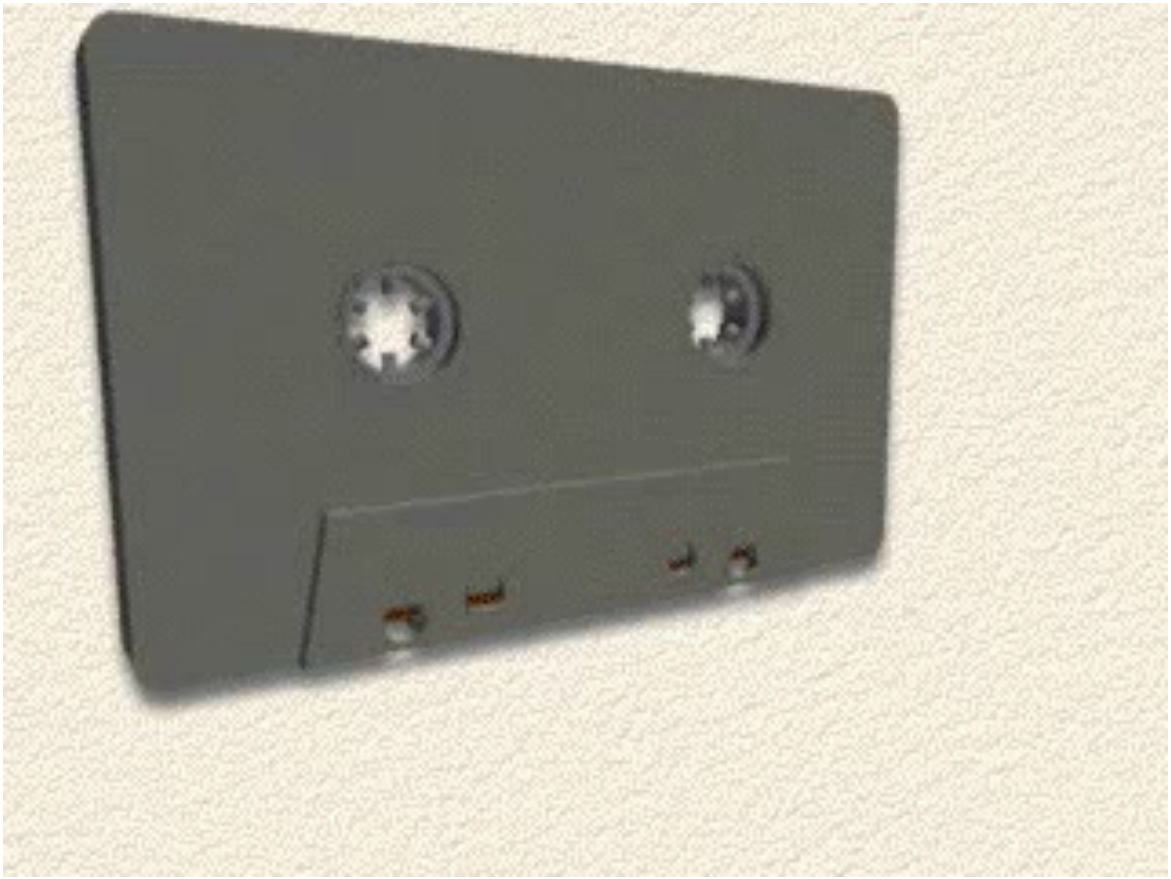
Conceptual models



Based on the previous video, what do you think is one major difference between conceptual models of computer systems and those of the bicycle above?

Computer systems usually have many of the parts and implications hidden from users!

Conceptual models



Even though this is not a computer system, this example illustrates very simply the idea of having hidden parts and their implications and the necessity of providing a conceptual model to the user through controls and icons.

http://www.youtube.com/watch?v=vQK02DFCRxc

Conceptual models

- Conceptual models are made from your design which embodies the following principles—to be studied later:
  - Gestalt rules
  - Affordances
  - Constraints
  - Mapping
  - Transfer
  - Consistency
  - Control
  - Feedback
  - Visibility
  - …

Modeling through Prototyping

Prototypes – Models of software applications

- In a concrete sense, HCI design depends on good *prototypes*
  - From Greek: *protos* (first) + *typos* (impression)
    - A model on which something is based or formed
- Software prototypes are *concrete models* of an incomplete design for testing design ideas
  - *High fidelity* – e.g., a real interactive application containing mock data
  - *Low fidelity* – e.g., a set of sketches of screenshots that are presented to a test user in sequence to mimic interaction

Prototyping methods

- Rapid or throw-away
  - Based on trial-and-error
- Evolutionary or organic
  - Based on biological phenomena
- Modular
  - Based on mechanistic phenomena

Prototyping methods: Rapid or throw-away

- Quick and dirty creation of designs that can be evaluated
- Allows for easy trial of ideas
- Emphasis on evaluating the prototype before discarding in favor of other prototypes

Prototyping methods: Evolutionary/organic

- Design is emergent
- Promotes bottom-up design
- Designer constantly learns from design
- Compromise between design and implementation
- Helps overcome gap b/w specification and implementation

Prototyping methods: Modular

- System built one section at a time
- Based on one overall master design
- Highly modular
- Pieces are bolted on to produce system gradually
- Promotes-top down design

Prototyping methods: Which to use

- We usually use the organic one, b/c it is most natural
- Taught to use the modular one
- Should use throw-away method more often

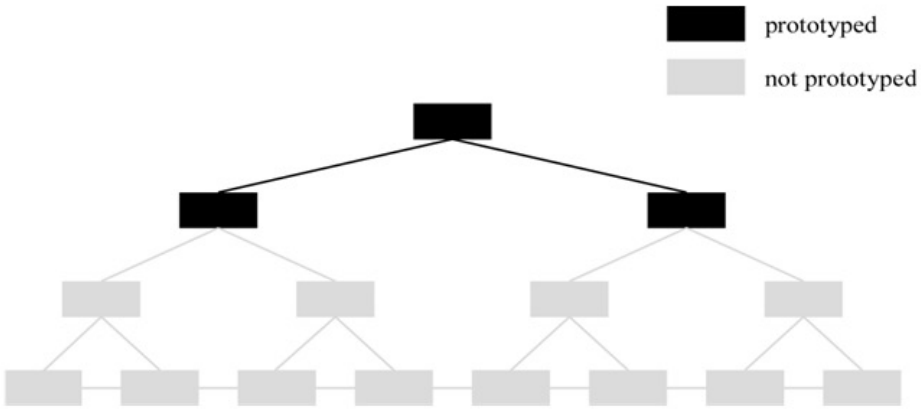
- Good to use all of them
  - Serve different purposes

Prototyping functionality

- Think about the application's functionality in an abstract way
  - Horizontal
  - Vertical
  - Scenario-based

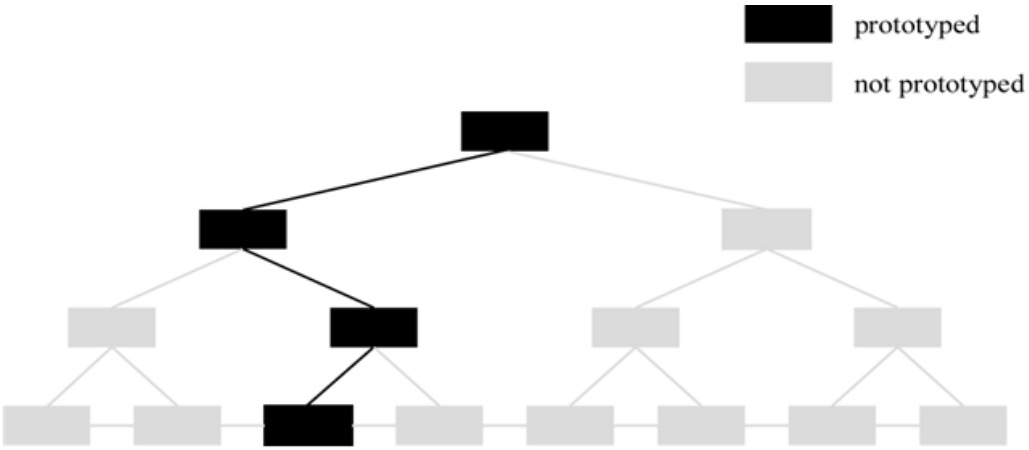
Prototyping functionality: Horizontal

- Shows surface/face layers of the system
- Broad and shallow
- Overview with limited underlying functionality
- Look and feel
- Simulation of the interface



Prototyping functionality: Vertical

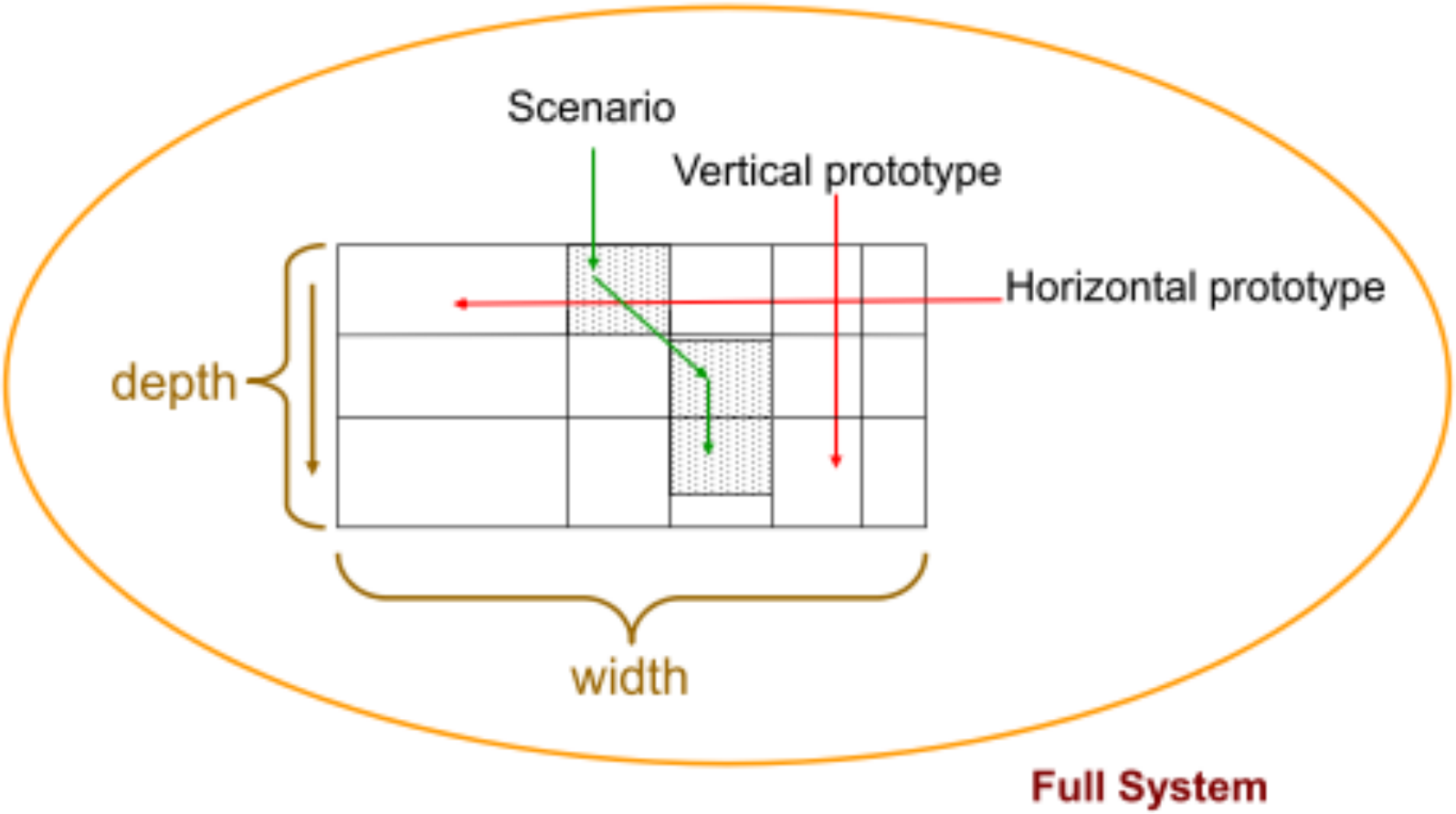
- In-depth functionality for a few selected features
- Reduction in number of features
- High- and low-level functionality for some restricted portion of the system



Prototyping functionality: Scenario-based

- Includes scripts of particular fixed use cases / features of the system
  - Prototype does not allow deviation from the scenario
- Mixes breadth and depth in a certain pre-specified area

Prototype functionality



Prototyping

- Prototyping methods vary, but in general *rapid prototyping* allows for frequent feedback and open dialogue between users and designers

- Watch these YouTube videos:
  - iPhone User Interface Design, Paper Prototype study
    - https://www.youtube.com/watch?v=V8LNDqMIapY
  - Example Usability Test with a Paper Prototype
    - https://www.youtube.com/watch?v=IYem-oBxX14
  - 10 Minute Mock Prototyping
    - https://www.youtube.com/watch?v=JjbeCkn0bJg
  - d.tools - Reflective Physical Prototyping
    - https://www.youtube.com/watch?v=AdsMZYTin9Q

Summary

- Modeling: Activity, Prototyping
- Action cycle & 7 stages of user activity
  - Twin gulfs, bridging these gulfs
- Conceptual models
- Prototyping