Human Computer Interaction

HUMAN AND CONCEPTUAL MODEL

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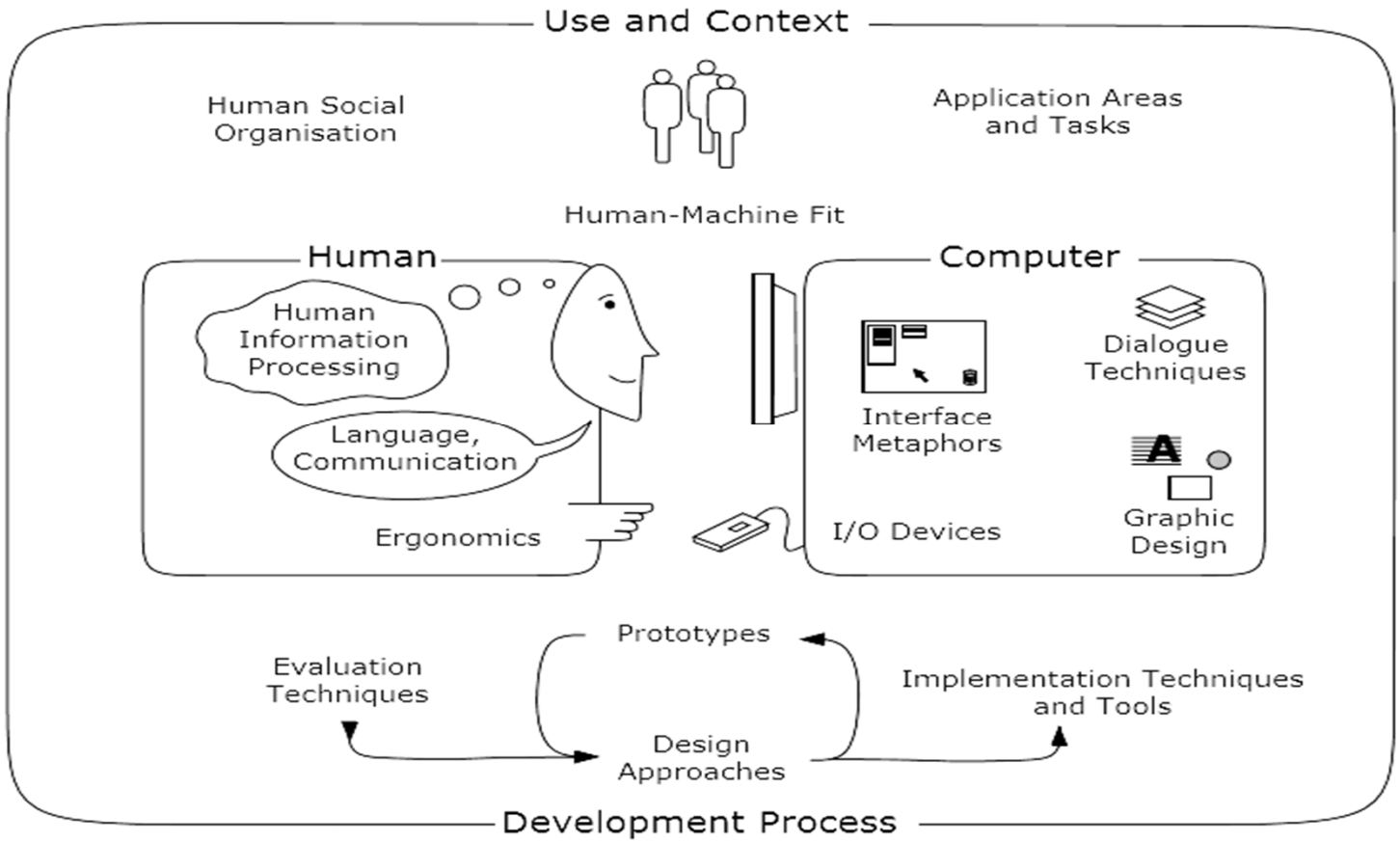
Content



The nature of Human-Computer Interaction. Adapted from the ACM SIGCHI Curricula for Human-Computer Interaction [Hewett et al., 2002]

Reference

- DonaldNorman, **The Design of Everyday Things, MITPress, 23 Dec 2013**
- Dix, Finlay…, **Human-Computer Interaction**, 3nd

Agenda

- Human
- Conceptual Models
- User Model
- Design Model

The Human

- Information i/o …
  - visual, auditory, haptic, movement
- Information stored in memory
  - sensory, short-term, long-term
- Information processed and applied
  - reasoning, problem solving, skill, error
- Emotion influences human capabilities
- Each person is different

Vision

Two stages in vision

- physical reception of stimulus
- processing and interpretation of stimulus

The Eye - physical reception

- Mechanism for receiving light and transforming it into electrical energy
- Light reflects from objects
- Images are focused upside-down on retina
- Retina contains rods for low light vision and cones for colour vision
- Ganglion cells (brain!) Detect pattern and movement

Interpreting the signal

- Size and depth
  - Visual angle indicates how much of view object occupies
    (relates to size and distance from eye)
  - Visual acuity is ability to perceive detail (limited)
  - Familiar objects perceived as constant size
    (in spite of changes in visual angle when far away)
  - Cues like overlapping help perception of size and depth

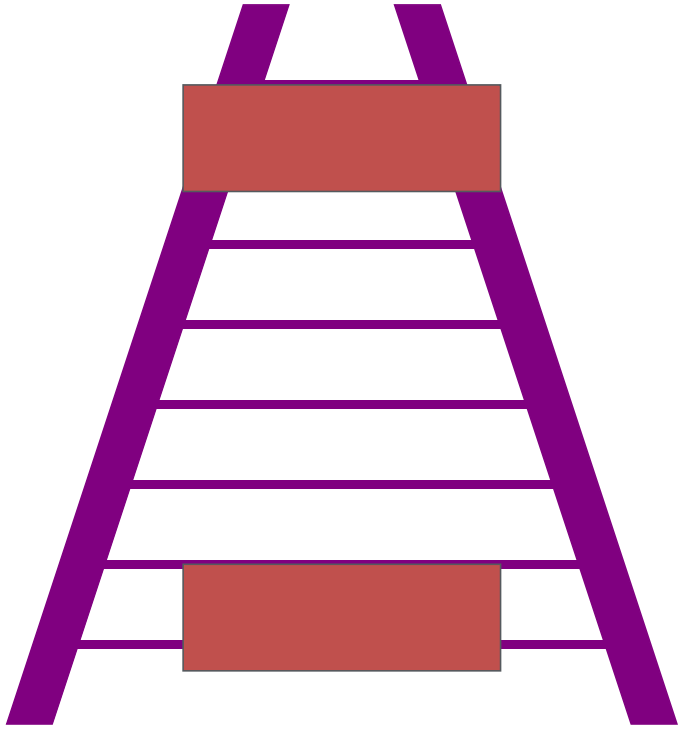
Interpreting the signal (cont.)

- Brightness
  - subjective reaction to levels of light
  - affected by luminance of object
  - measured by just noticeable difference
  - visual acuity increases with luminance as does flicker
- Colour
  - made up of hue, intensity, saturation
  - cones sensitive to colour wavelengths
  - blue acuity is lowest
  - 8% males and 1% females colour blind

Interpreting the signal (cont)

- The visual system compensates for:
  - movement
  - changes in luminance.
- Context is used to resolve ambiguity
- Optical illusions sometimes occur due to over compensation

Optical Illusions



the Ponzo illusion

Reading

- Several stages:
  - visual pattern perceived
  - decoded using internal representation of language
  - interpreted using knowledge of syntax, semantics, pragmatics
- Reading involves saccades and fixations
- Perception occurs during fixations
- Word shape is important to recognition
- Negative contrast improves reading from computer screen

Hearing

- Provides information about environment:
  distances, directions, objects etc.
- Physical apparatus:
  - outer ear – protects inner and amplifies sound
  - middle ear – transmits sound waves as vibrations to inner ear
  - inner ear – chemical transmitters are released and cause impulses in auditory nerve
- Sound
  - pitch – sound frequency
  - loudness – amplitude
  - timbre – type or quality

Hearing (cont)

- Humans can hear frequencies from 20Hz to 15kHz
  - less accurate distinguishing high frequencies than low.

- Auditory system filters sounds
  - can attend to sounds over background noise.
  - for example, the cocktail party phenomenon.

Touch

- Provides important feedback about environment.
- May be key sense for someone who is visually impaired.
- Stimulus received via receptors in the skin:
  - thermoreceptors – heat and cold
  - nociceptors – pain
  - mechanoreceptors – pressure
    (some instant, some continuous)
- Some areas more sensitive than others e.g. fingers.
- Kinethesis
  - awareness of body position
  - affects comfort and performance.

Movement

- Time taken to respond to stimulus:
  reaction time + movement time
- Movement time dependent on age, fitness etc.
- Reaction time - dependent on stimulus type:
  - visual ~ 200ms
  - auditory ~ 150 ms
  - pain ~ 700ms
- Increasing reaction time decreases accuracy in the unskilled operator but not in the skilled operator.

Movement (cont)

- Fitts' Law describes the time taken to hit a screen target:

$$Mt = a + b \log_2(D/S + 1)$$

where: a and b are empirically determined constants
Mt is movement time
D is Distance
S is Size of target

$\Rightarrow$ targets as large as possible
distances as small as possible

Memory

There are three types of memory function:

Sensory memories

Short-term memory or working memory → Attention

Long-term memory → Rehearsal

Selection of stimuli governed by level of arousal.

Sensory memory

- Buffers for stimuli received through senses
  - iconic memory: visual stimuli
  - echoic memory: aural stimuli
  - haptic memory: tactile stimuli
- Examples
  - “sparkler” trail
  - stereo sound
- Continuously overwritten

Short-term memory (STM)

- Scratch-pad for temporary recall
  - rapid access ~ 70ms
  - rapid decay ~ 200ms
  - limited capacity - 7± 2 chunks

Examples

212348278493202

0121 414 2626

HEC ATR ANU PTH ETR EET

Long-term memory (LTM)

- Repository for all our knowledge
  - slow access ~ 1/10 second
  - slow decay, if any
  - huge or unlimited capacity

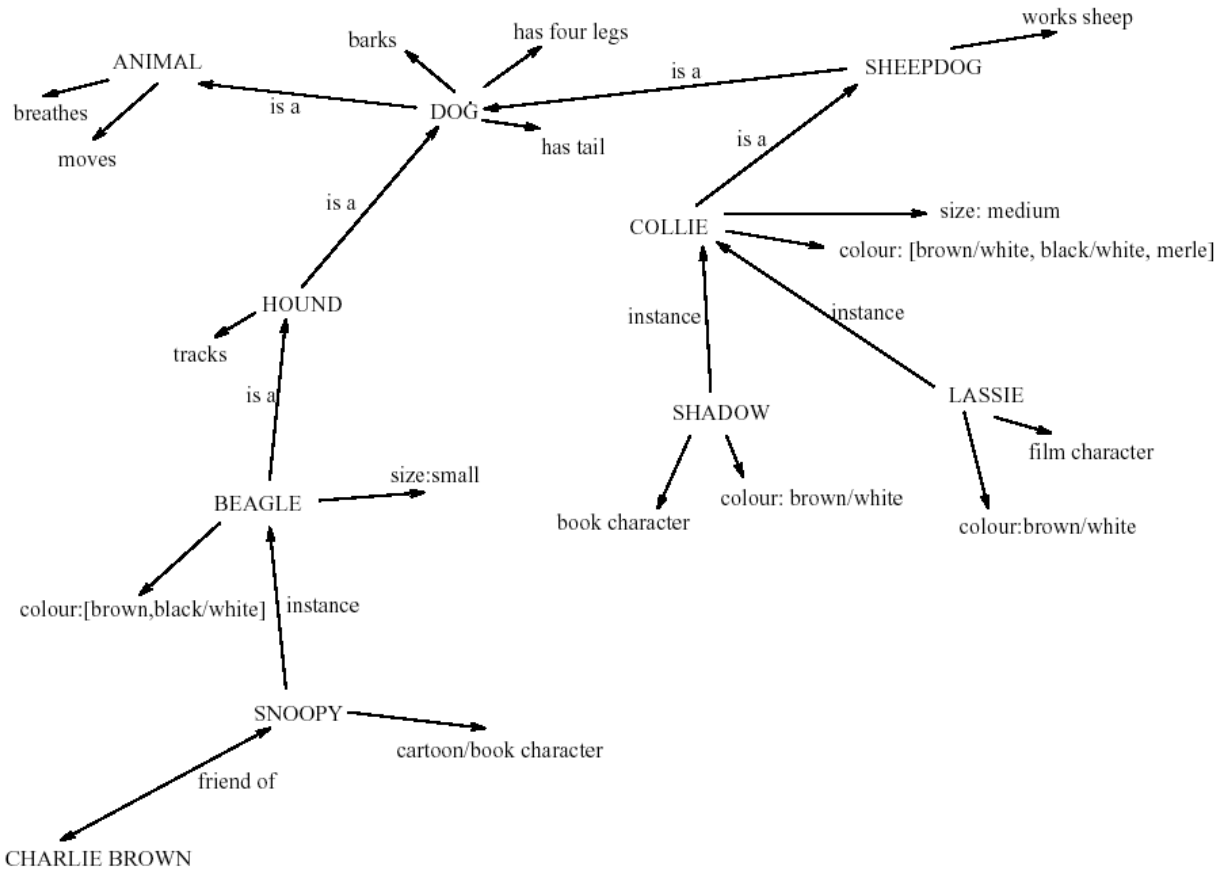
- Two types
  - episodic – serial memory of events
  - semantic – structured memory of facts, concepts, skills

  semantic LTM derived from episodic LTM

Long-term memory (cont.)

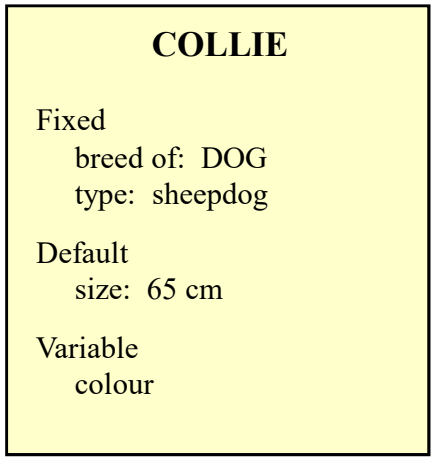
- Semantic memory structure
  - provides access to information
  - represents relationships between bits of information
  - supports inference
- Model: semantic network
  - inheritance – child nodes inherit properties of parent nodes
  - relationships between bits of information explicit
  - supports inference through inheritance

LTM - semantic network



Models of LTM - Frames

- Information organized in data structures
- Slots in structure instantiated with values for instance of data
- Type–subtype relationships



Models of LTM - Scripts

Model of stereotypical information required to interpret situation

Script has elements that can be instantiated with values for context

Script for a visit to the vet

Entry conditions: *dog ill*
vet open
owner has money

Result: *dog better*
owner poorer
vet richer

Props: *examination table*
medicine
instruments

Roles: *vet examines*
diagnoses
treats
owner brings dog in
pays
takes dog out

Scenes: *arriving at reception*
waiting in room
examination
paying

Tracks: *dog needs medicine*
dog needs operation

Models of LTM - Production rules

Representation of procedural knowledge.

Condition/action rules

if condition is matched

then use rule to determine action.

IF dog is wagging tail
THEN pat dog

IF dog is growling
THEN run away

LTM - Storage of information

- Rehearsal
  - Information moves from STM to LTM
- Total time hypothesis
  - Amount retained proportional to rehearsal time
- Distribution of practice effect
  - Optimized by spreading learning over time
- Structure, meaning and familiarity
  - Information easier to remember

LTM - Forgetting

- Decay
  - Information is lost gradually but very slowly
- Interference
  - New information replaces old: retroactive interference
  - Old may interfere with new: proactive inhibition
- So may not forget at all memory is selective …

… affected by emotion – can subconsciously `choose' to forget

LTM - retrieval

- Recall
  - Information reproduced from memory can be assisted by cues, e.G. Categories, imagery
- Recognition
  - Information gives knowledge that it has been seen before
  - Less complex than recall - information is cue

Thinking

- Reasoning
  - deduction, induction, abduction
- Problem solving

Problem solving

- Process of finding solution to unfamiliar task using knowledge.
- Several theories.
- Gestalt
  - problem solving both productive and reproductive
  - productive draws on insight and restructuring of problem
  - attractive but not enough evidence to explain `insight' etc.
  - move away from behaviourism and led towards information processing theories

Problem solving (cont.)

Problem space theory

- Problem space comprises problem states
- Problem solving involves generating states using legal operators
- Heuristics may be employed to select operators
  e.G. Means-ends analysis
- Operates within human information processing system
  e.G. STM limits etc.
- Largely applied to problem solving in well-defined areas
  e.G. Puzzles rather than knowledge intensive areas

Problem solving (cont.)

- Analogy
  - analogical mapping:
    - novel problems in new domain?
    - use knowledge of similar problem from similar domain
  - analogical mapping difficult if domains are semantically different

- Skill acquisition
  - skilled activity characterized by chunking
    - lot of information is chunked to optimize STM
  - conceptual rather than superficial grouping of problems
  - information is structured more effectively

Errors and mental models

Types of error

- Slips
  - right intention, but failed to do it right
  - Causes: poor physical skill, inattention etc.
  - Change to aspect of skilled behaviour can cause slip
- Mistakes
  - Wrong intention
  - Cause: incorrect understanding

    Humans create mental models to explain behaviour.

    If wrong (different from actual system) errors can occur

Emotion

- Various theories of how emotion works
  - James-Lange: emotion is our interpretation of a physiological response to a stimuli
  - Cannon: emotion is a psychological response to a stimuli
  - Schacter-Singer: emotion is the result of our evaluation of our physiological responses, in the light of the whole situation we are in
- Emotion clearly involves both cognitive and physical responses to stimuli

Emotion (cont.)

- The biological response to physical stimuli is called *affect*

- Affect influences how we respond to situations
  - positive $\rightarrow$ creative problem solving
  - negative $\rightarrow$ narrow thinking

"Negative affect can make it harder to do even easy tasks; positive affect can make it easier to do difficult tasks"

(Donald Norman)

Emotion (cont.)

- Implications for interface design
  - Stress will increase the difficulty of problem solving
  - Relaxed users will be more forgiving of shortcomings in design
  - Aesthetically pleasing and rewarding interfaces will increase positive affect

Individual differences

- Long term
  - sex, physical and intellectual abilities
- Short term
  - effect of stress or fatigue
- Changing
  - age

Ask yourself:
will design decision exclude section of user population?

Psychology and the Design of Interactive System

- Some direct applications
  - e.g. blue acuity is poor
    $\Rightarrow$ blue should not be used for important detail

- However, correct application generally requires understanding of context in psychology, and an understanding of particular experimental conditions

- A lot of knowledge has been distilled in
  - guidelines (chap 7)
  - cognitive models (chap 12)
  - experimental and analytic evaluation techniques (chap 9)

Knowledge in the Head and in the World

- Not all of the knowledge required for precise behaviour has to be in the head. It can be distributed:
  - partly in the head
  - partly in the world
  - and partly in the constraints of the world.

Placing Knowledge in the World

- Having knowledge in the world reduces the load on human memory:
- An example of the input format can be provided in the interface:
  - *Please enter the date (yyyy/mm/dd)*:
- Previously entered values can be used as defaults, so users do not have to remember items between screens.
- It is better if the designers of an interface place knowledge in the world.
- However, sometimes, users have to place knowledge in the world themselves to x a broken interface.
- Control-roomoperatorsatanuclearpowerplant xedbeer-taphandlestosimilar-lookingknobs,so as to better distinguish between them.
- Wherever possible, also allow expert users to internalise knowledge for faster and more e cient performance (say by learning to type a date in a particular format, rather than having to use the provided calendar widget).

To Err is Human

- People make errors routinely, you must design for error.
- Assume that any error, that can be made, will be made!
- Design explorable systems, where operations are easy to reverse.

Categories of Error

- Two fundamental categories of error:
  - **Slips** result from automatic behavior, when subconscious actions toward a correct goal go wrong.
  - **Mistakes** result from conscious deliberations, which formed an inappropriate goal.

Conceptual Models

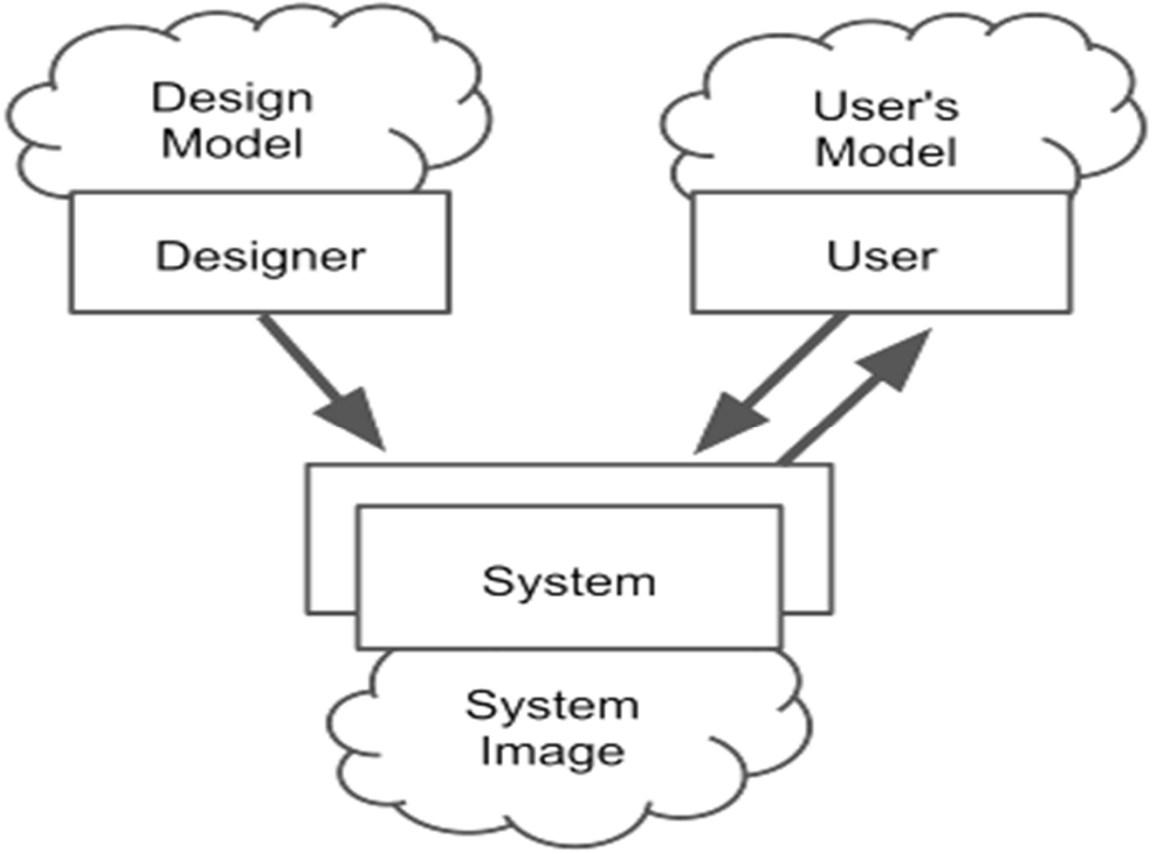
- A conceptual model is a mental model of how something works,which is formed inside a person'shead.
- A user's conceptual model built up and in uenced by numerous factors, including:
  - Familiarity with similar devices (transfer of previous experience)
  - A ordances
  - Mapping
  - Constraints
  - Causality
  - Instructions
  - Interacting with the device.
  - Conceptual models may be wrong, particularly if the above factors are misleading.

Projecting a Correct Conceptual Model

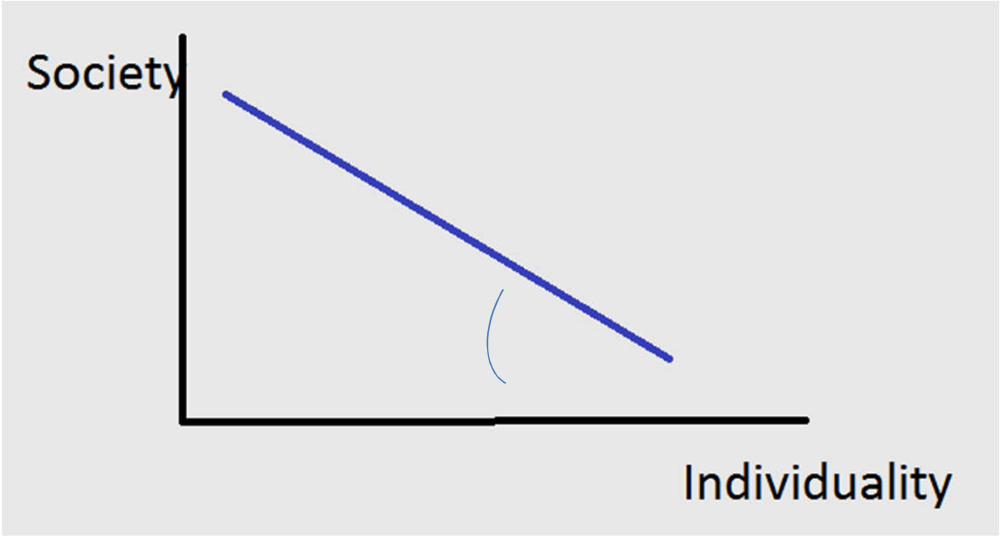
- Designers have their own conceptual model of a system, the design model.
- The system image is the actual implementation or embodiment of the design (including documentation, instructions, and labels).
- The user's model is built through interaction with the system.
- The designer expects the user's model to be the same as the design model, how ever all communication takes place through the system image.

→The system image should make the design model clear and consistent.

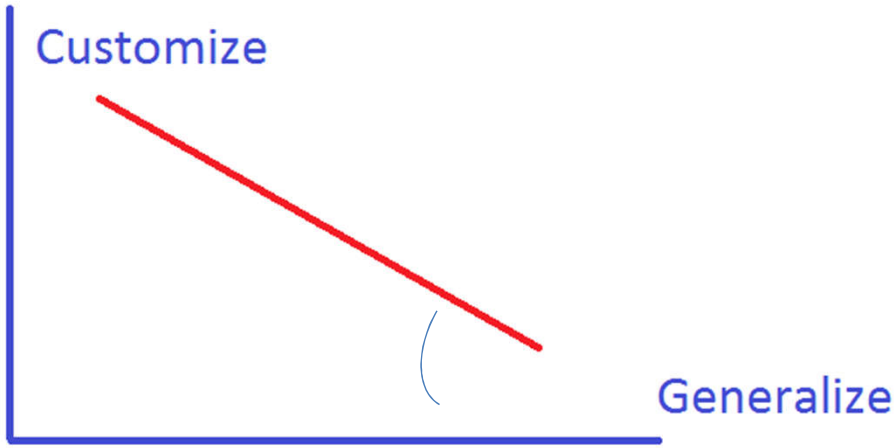
Correct Conceptual Model



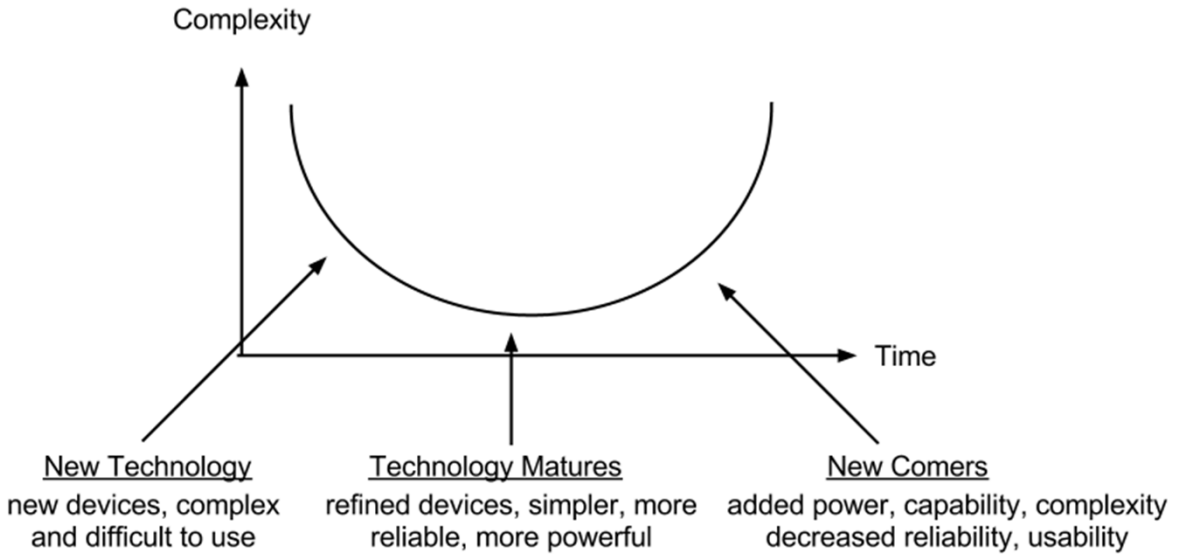
Design View



User View



Development of a Technology



A Digital Watch Projects
No Visible Conceptual Model

- **A ordances**: four buttons to push – but what do they do?
- **Mapping**: no clear relationship between buttons and possible actions.
- **Transfer of Prior Knowledge**: little similarity to analog watches.
- **Conceptual Model**: must be learnt from instructions.

A Digital Watch

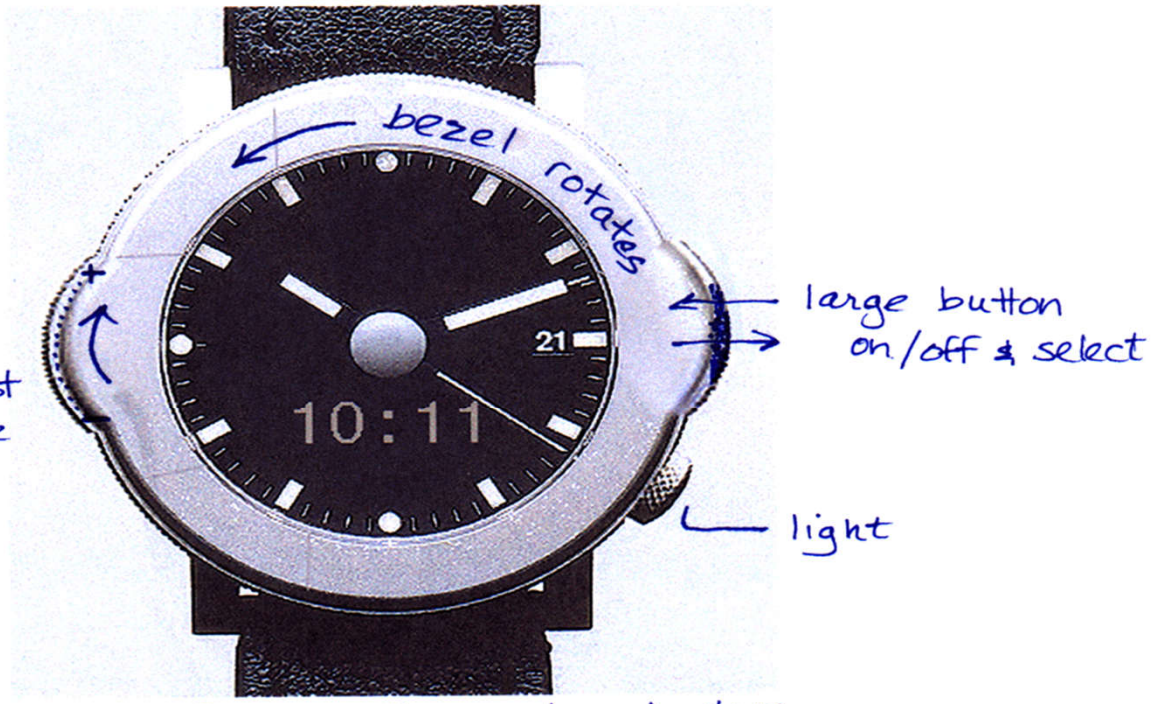


Fig 1: Time reading mode displays combined analog/digital view

User Model

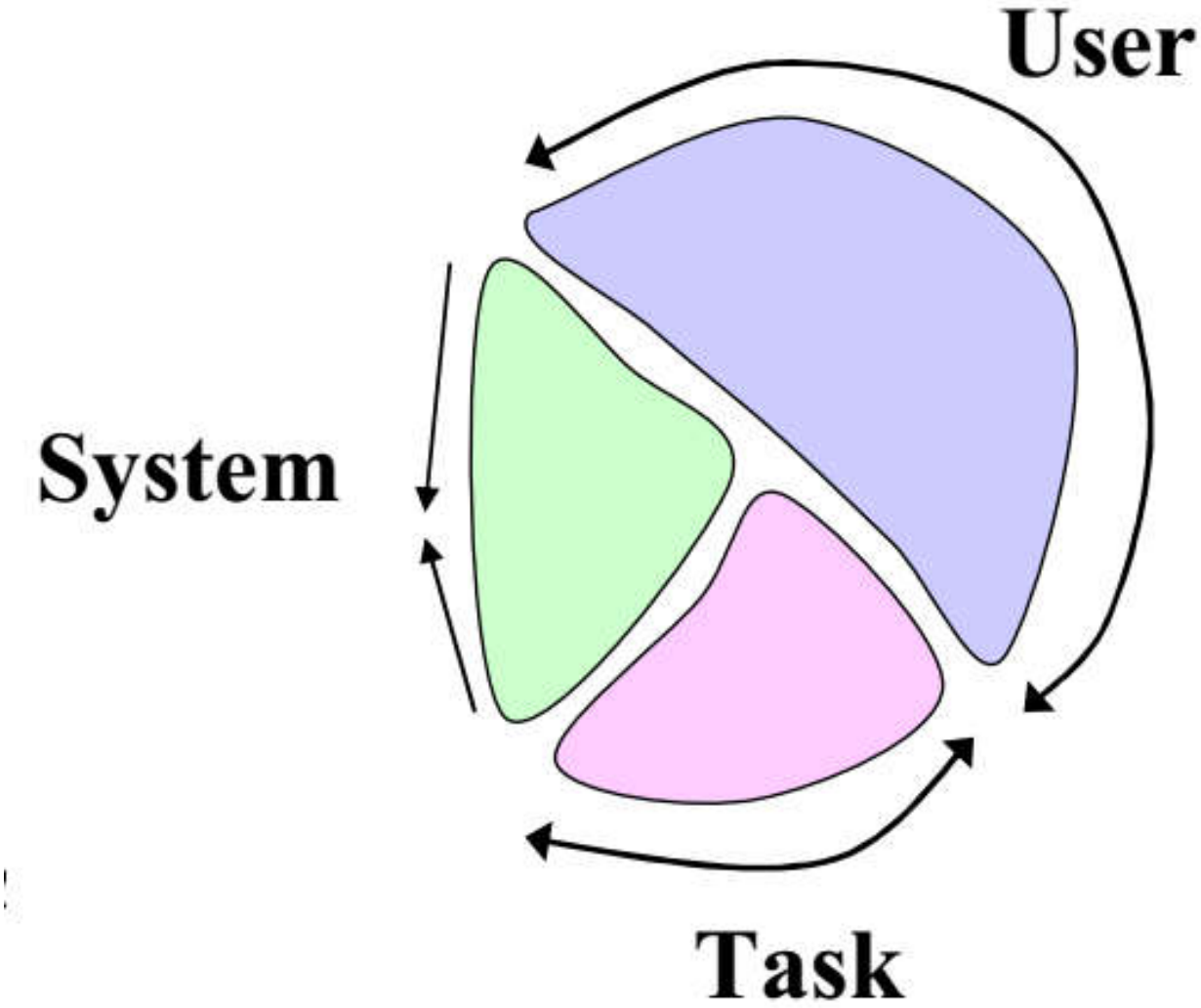
- Cognition
- Error
- Individual differences

Task Model

- Definition & frequency
- Strategies and operations

System Model (GUI + application)

- Ease of use - learning
- Customization
- Power - skilled performance
- Robustness - reliable, error handling, help


User
System
Task

User Model

- Cognition = perception + memory
- Software use is a cognitive / problem solving activity.
- Users solve learned problems (skill) and new problems (analogy, generalization).
- To solve problems users must perceive (recognize) them and understand them.
- Human perception is pattern oriented.
- We see the gestalt (and suffer illusions)

Human knowledge

- Human knowledge is procedural, episodic, and semantic.
  - Procedural - serial tasks
  - Episodic - individual life experiences
  - Semantic - knowledge, cultural

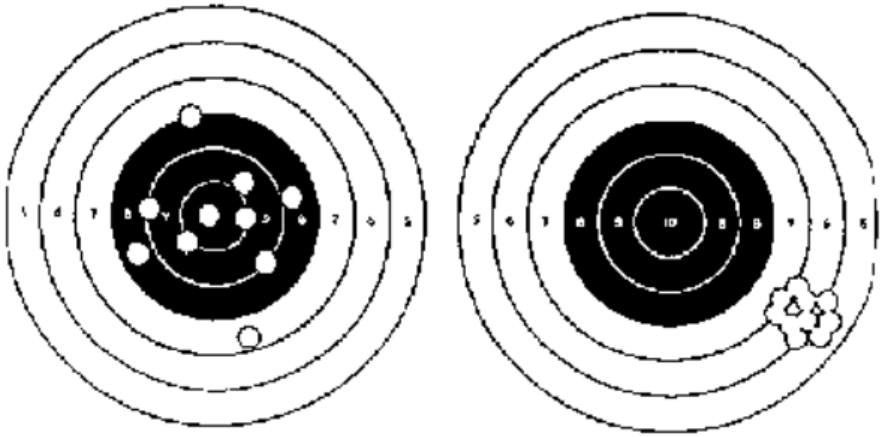
User's Syntactic Knowledge

- Task and environment specific knowledge.
- Syntactic knowledge facts are often discrete and disjoint from other syntactic facts.
- Learning: arbitrary nature often requires rote learning, learn by doing.
- System dependency: syntactic rules vary with system. Same goal requires different operations.
- Interference: same operations can have different results across applications and systems.
- Reduce Syntactic Complexity: structured command sets, menus, direct manipulation environments

User's Semantic Knowledge

- Conceptual knowledge about the domain of a task and environment..
- Concepts are built upon each other they are interconnected and have some "semantic" structure -- relationship.
- Semantic knowledge is best taught by analogy, or example, to other knowledge and by practical experience.
- Pictorial representations are helpful.
- Negative examples (misses).
- Task experts maybe computer novices & computer experts maybe task novices.
- Concepts: stable memory, generalizable across computer systems and applications.
- Tasks: often decomposable into subtasks with analogy to other known tasks

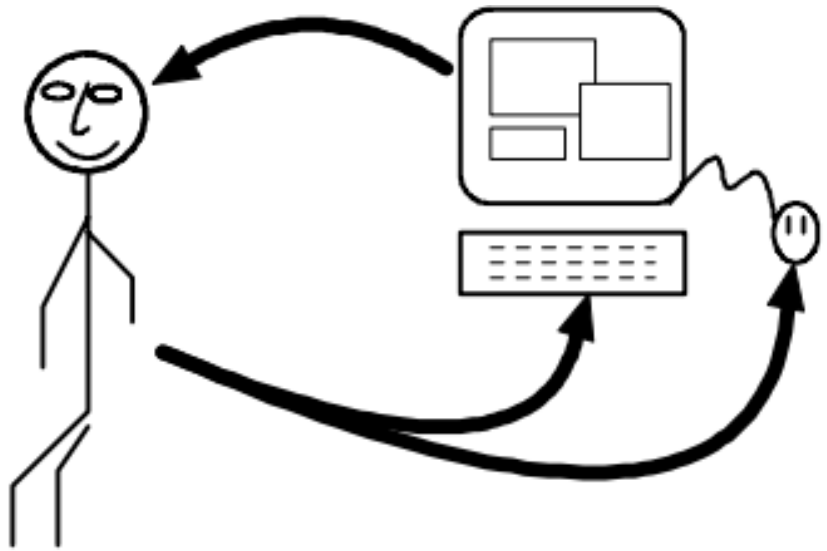
Human Error



Human Error

- **Error** a planned mental or physical activity that failed its intended outcome where the failure is not attributable to chance events.
- **Intention** a specification of desired action, a goal. Intentions generate plans (schemas, actions) to achieve goal.
- **Mistake** an error in intention (deficient judgement or inference).
- **Lapse** a failure in storage of the intention.
- **Slip** an error in execution of intention

User vs. **Software**



User vs. **Software**: **Strengths**

- World Knowledge
- Learner
- Pattern Matching
- Analogical
- Productive Thinking
- Vision & Sound

- Fast Accurate
- Reproductive "Thinking"
- Never Forgets
- Non Ambiguous Knowledge

User vs. **Software**: **Weakness**

- Limited Awareness
- Accurate
- Reproductive Thinking
- Forgets
- Individual Differences

- Limited World Knowledge
- Not Analogical
- Poor Learning
- Limited Input Senses

Design Model

- **Design** Models are a mixture of direct manipulation and menu based interface styles.
- Objects in task domain are visible: often icons
  - planning is a recognition (not recall) task
  - low syntactic & semantics memory icons semantics by analogy
  - spatial / visual tasks learned faster
  - visual memory retained longer
- User directly manipulates task object. Actions and results are visible, incremental and reversible (undo last step)

Design Model

- All action initiation done through a "button" {embedded button = menu, pull down or pop up menu items}.
  - no complex syntax for commands.
  - modeless or visible mode (greyed, disabled menu items)
  - minimizes slips
- Driving car analogy for direct manipulation

Weaknesses

- Repetitive tasks maybe hard to combine or parameterize, as in command line.
- Iconic interfaces may suffer description errors, visual interferences