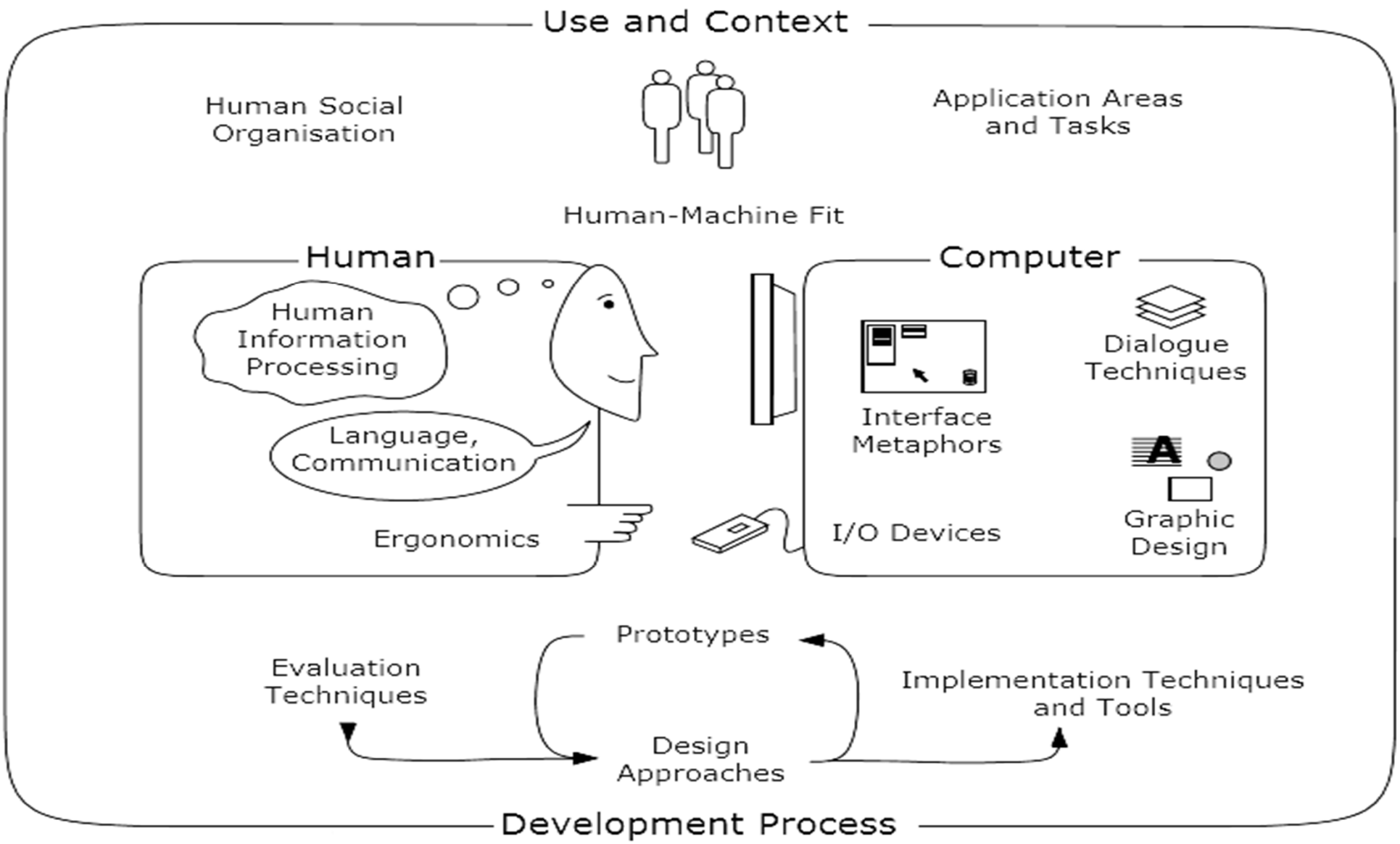
Human Computer Interaction

HUMAN AND CONCEPTUAL MODEL

By: Nguyễn Công Hoan

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

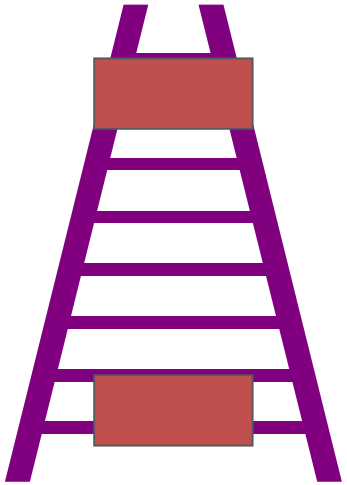
Interpreting the signal (cont)

- 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

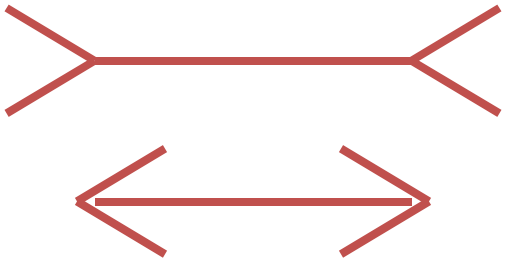
Interpreting the signal (cont)

- 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



the Muller Lyer 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

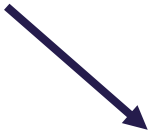
Memory

There are three types of memory function:

Sensory memories

Attention

Short-term memory or working memory



Rehearsal

Long-term memory

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

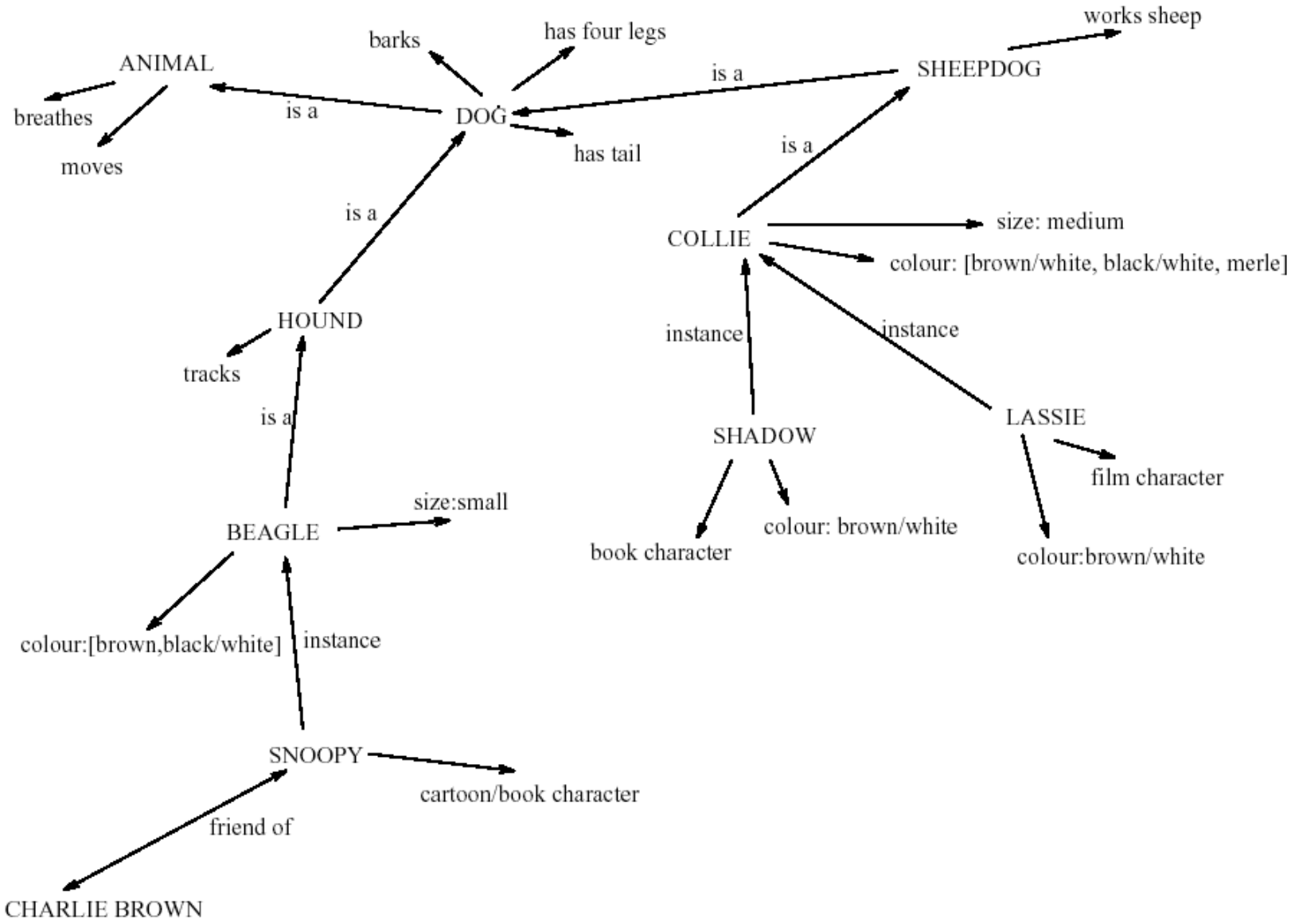
- Two types
  - episodic – serial memory of events
  - semantic – structured memory of facts,concepts, skills

  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

DOG

Fixed
legs: 4

Default
diet: carniverous
sound: bark

Variable
size:
colour

COLLIE

Fixed
breed of: DOG
type: sheepdog

Default
size: 65 cm

Variable
colour

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

Deductive Reasoning

- Deduction:
  - derive logically necessary conclusion from given premises.

    e.g. If it is Friday then she will go to work
    It is Friday
    Therefore she will go to work.

- Logical conclusion not necessarily true:

    e.g. If it is raining then the ground is dry
    It is raining
    Therefore the ground is dry

Deduction (cont.)

- When truth and logical validity clash …

  e.g. Some people are babies

  Some babies cry

  Inference - Some people cry

  Correct?

- People bring world knowledge to bear

Inductive Reasoning

- Induction:
  - generalize from cases seen to cases unseen

    e.g. all elephants we have seen have trunks
    therefore all elephants have trunks.

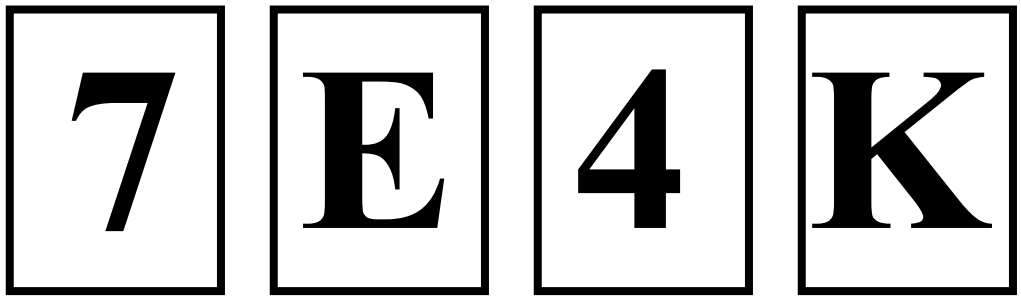
- Unreliable:
  - can only prove false not true

  … but useful!

- Humans not good at using negative evidence

  e.g. Wason's cards.

Wason's cards



If a card has a vowel on one side it has an even number on the other

Is this true?

How many cards do you need to turn over to find out?

…. and which cards?

Abductive reasoning

- reasoning from event to cause

  e.g. Sam drives fast when drunk.

  If I see Sam driving fast, assume drunk.

- Unreliable:
  - can lead to false explanations

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 behaviour, when subconscious actions toward a correct goal go wrong.
- **Mistakes** result from conscious deliberations, which formed an inappropriate goal.

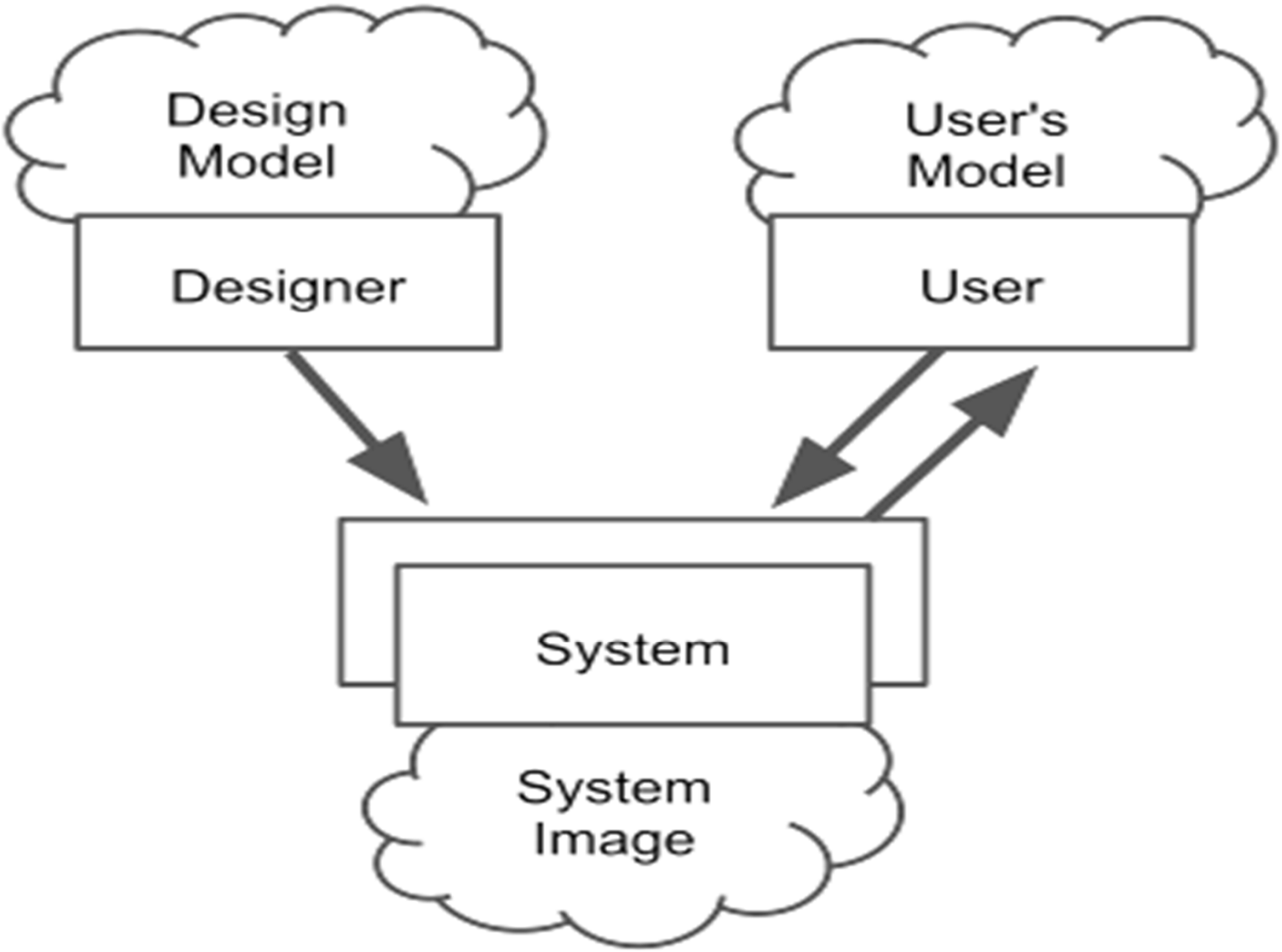
Conceptual Models

- 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

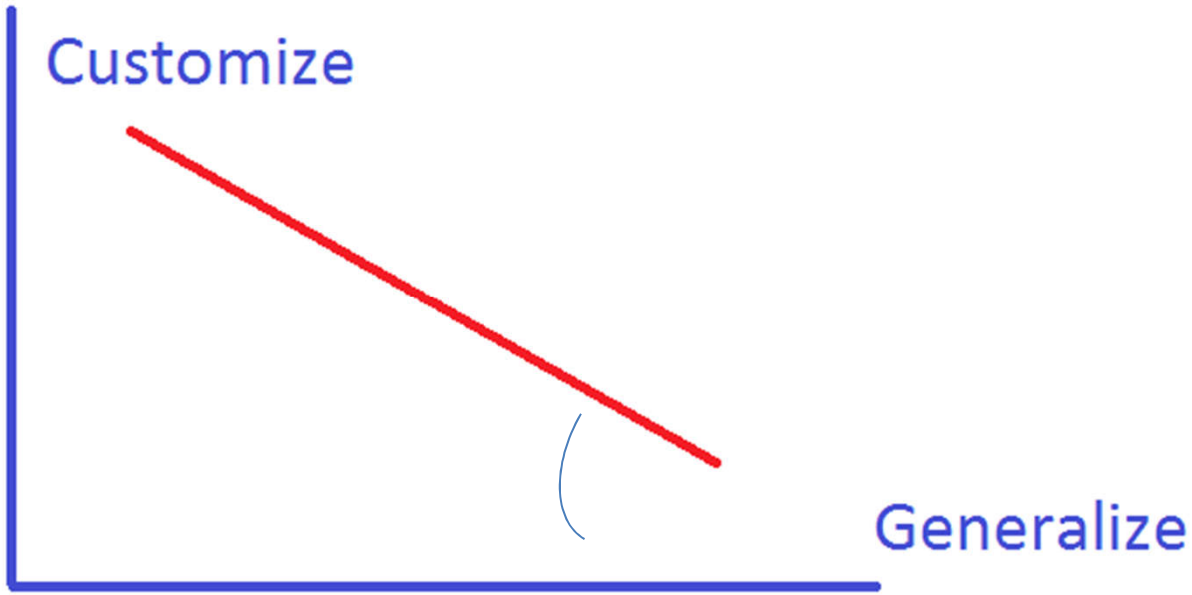
- Designers have their own conceptual model of a system, the design model.
- The system image is the actual implementation or embodiment of the design (including documentation, instructions, and labels).
- The user's model is built through interaction with the system.
- The designer expects the user's 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

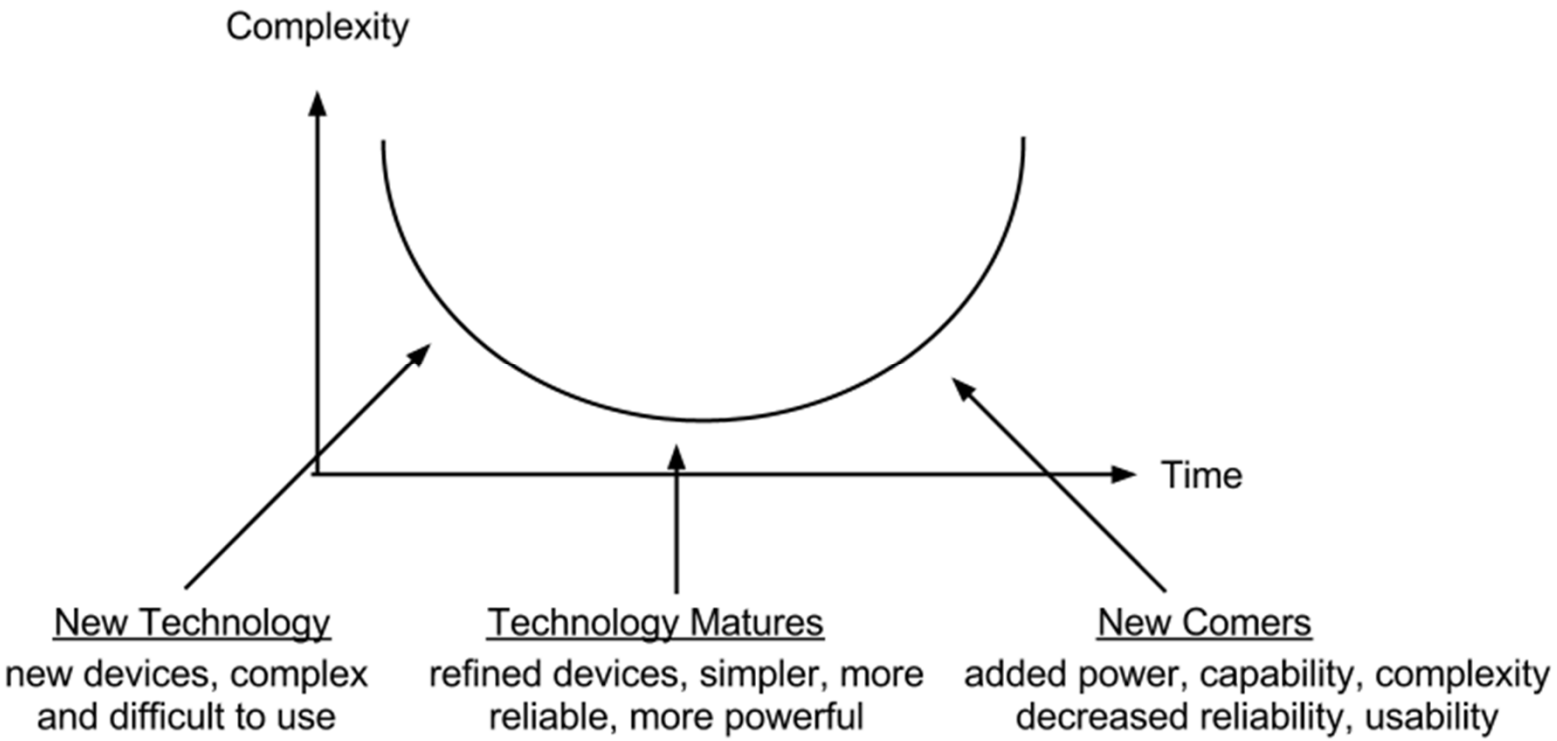


Design View

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

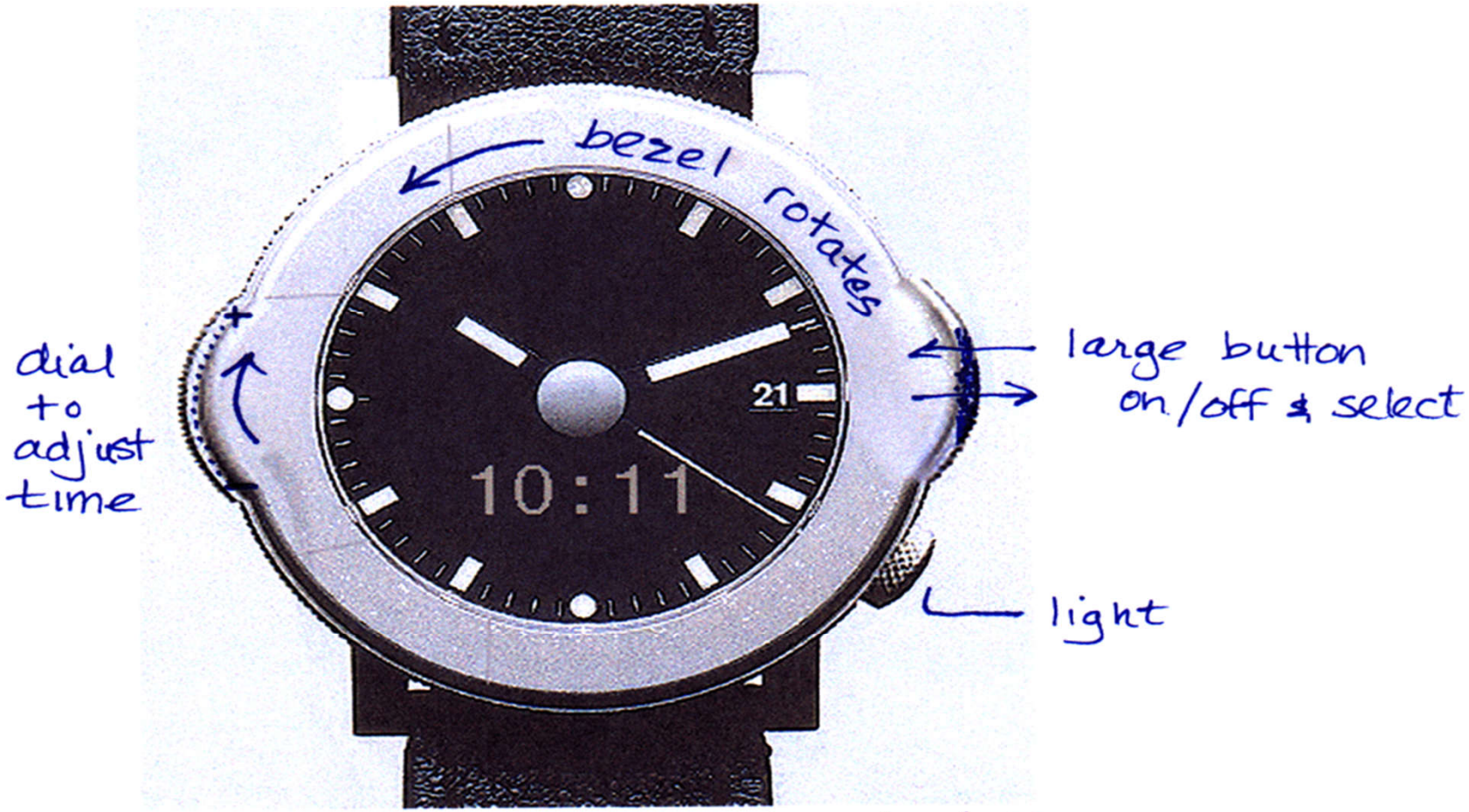


Fig 1: Time reading mode displays combined analog/digital view

User Model

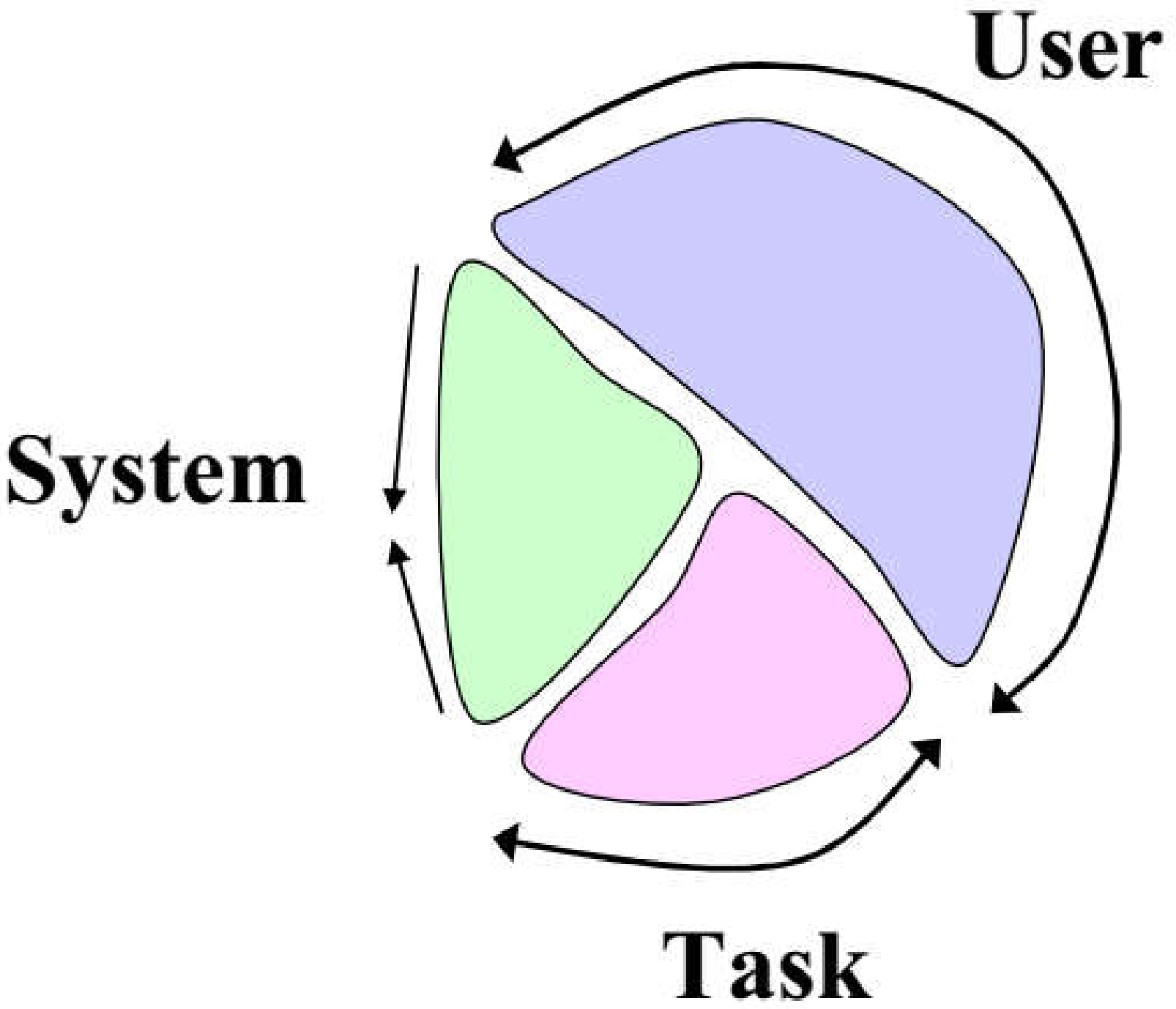
- Cognition
- Error
- Individual differences

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

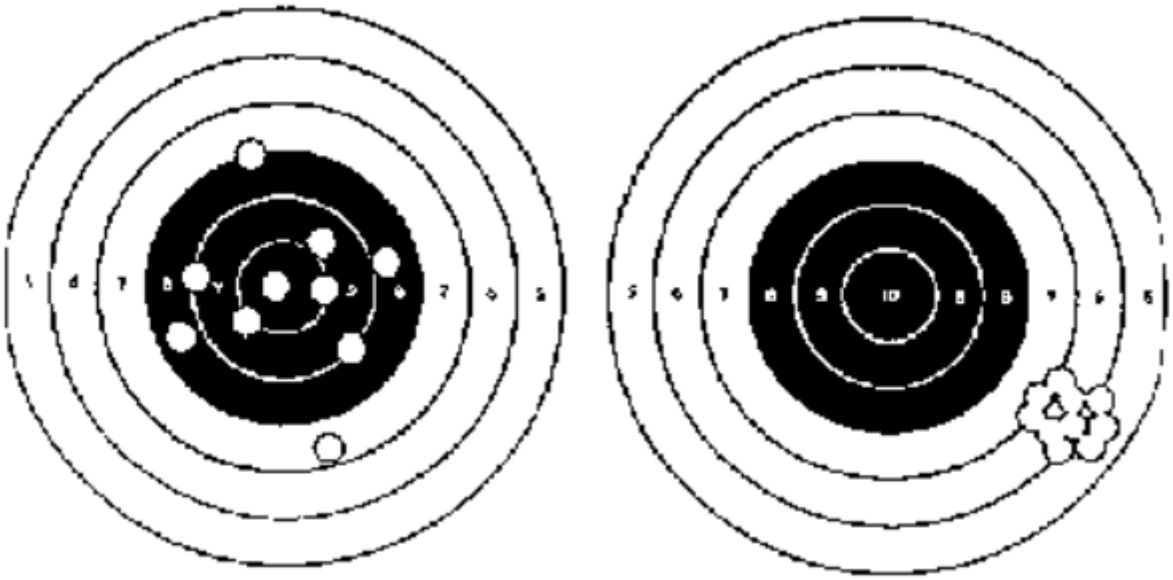
User's Syntactic Knowledge

- 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

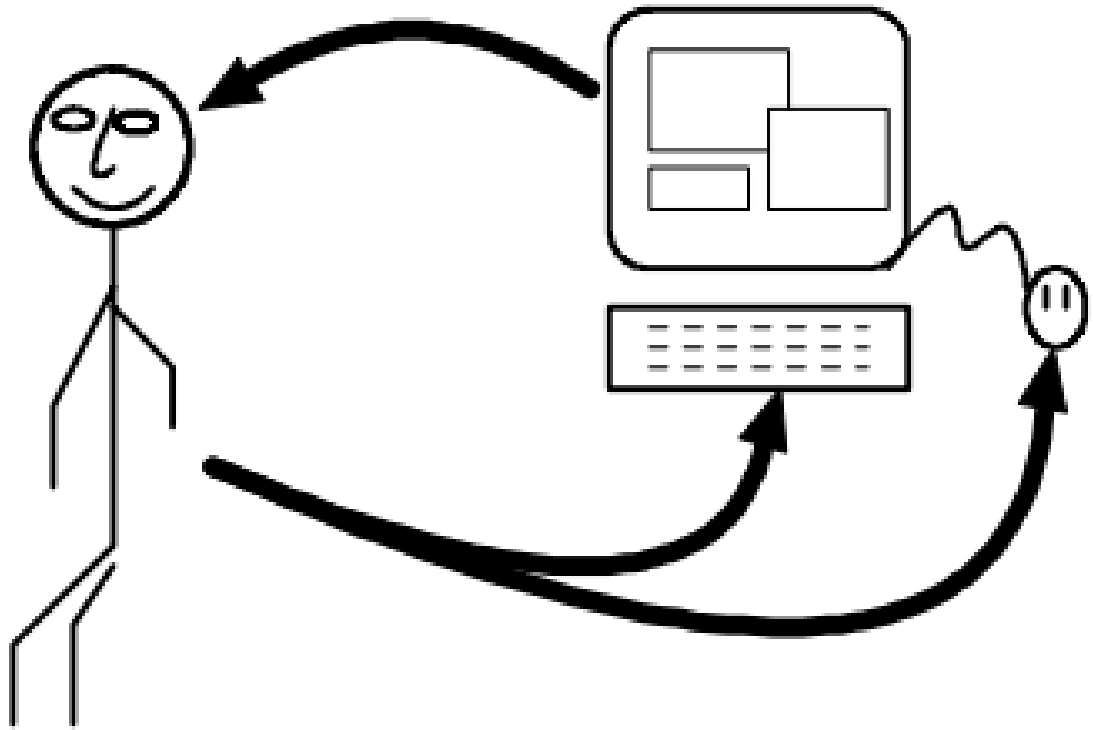
Human Error



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