December 1st 2023

LECTURE 2
COGNITION, MEMORY, FOCUS MODELS & USER PSYCHOLOGY

1

Quintessence of Lecture 1

Underlying this lecture:

for development of interactive applications we focus on

User-Centred Design

key approach in development for Interaction

2

Aim – Approach for Interaction

Quote -Donald Norman -

"Talking to users is not a luxury, it's a necessity"

Model

- Operator accomplishes task with Computer

Aim

- To optimize the performance of human and computer together as a system.

Approach, User Centred

- Users should not have to adapt to the interface.

3

Key concepts in HCI and InfoVis

USABILITY

4

Poor "interface-interaction" Design

1. Increased mistakes in
   - system operation
   - data entry
2. Inaccessible functionality
3. User frustration
   - under-utilisation
   - low productivity
4. System failure because of user rejection

5

Software Quality: ISO 9126

Metrics and Evaluation

- Functionality
- Reliability
- Usability
- Efficiency
- Maintainability
- Portability
- PM Accessibility *(sometimes relevant, not ISO 9126)*

Important for system certification

6

Definition of Usability (Nielsen 2003)

- Usability is a quality attribute that assesses how easy user interfaces/interactions are to use.
- The word 'usability' also refers to methods for improving ease-of-use during the design process.
- Consequently, usability testing requires interaction with representative users/operators!

7

Usability Components

- Learnability
  - Ease of learning the system, i.e. the basic tasks
  - Skills retained over time (also Memorability)
- Throughput (also Efficiency)
  - Speed of task performance
  - Low user error rate
- Flexibility
  - Suitability for intended user expertise
  - Can system be customised?
- Attitude (also Satisfaction)
  - User subjective satisfaction with system

8

Usability & Goals

- Usability goals (criteria = objective)
  - effectiveness, efficiency, learnability, safety, etc.
- User experience goals (quality = subjective)
  - fun, motivating, aesthetically pleasing, supportive of creativity, rewarding, helpful, satisfying, etc.
- Sometimes there are conflicts
- "10 minute rule?", novice get essentials in 10 min
  - optimize what the user already knows…(Nelson 1980)
  - use the innate knowledge of the user (group) to learn the software (study workflow)
  - not for complex systems

9

User Activities - Capabilities

- Activities
  - Physical resources
    - Devices that support interaction
  - Cognitive resources
    - Support of cognitive functions
    - Memory
  - Affective resources, often related to UX Design
    - Pleasing
    - Intelligent use of color and graphics
- Activities are studied to understand "Human"

10

Key concepts in HCI and InfoVis

COGNETICS

11

Factors of Human Psychology

- Cognitive psychology
- Types of memory + characteristics
  - sensory, short term and long term
- The human processor
- Closure, Attitude, Anxiety
- Focusing Attention
- Structure, Cognition, Meaningfulness
- Emotion

12

Information Processing (1)

- Information is **Perceived**
  - How, What models help us understand
- Information is **Processed**
  - How, What models are useful
- Information is **Acted Upon**
  - How, what are the consequences for Interaction
  - HCI/InfoVis

13

Information to Human

- Information I/O, through Senses
  - visual, auditory, haptic (touch) movement, proprioception, smell & taste
- 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

14

Human Factors

- Cognitive Psychology
- Left brain / Right brain
- Model Human Processor
  - Sensory registers
  - Short term memory
  - Long term memory
- Implications of the model
- Other psychological observations
- Contribution to HCI/InfoVis

15

User Psychology Interactive Applications

- Helps identify target for design
- Helps explaining success or failure of designs
- Provides little prescriptive guidance for design
- Provides prediction of human performance

16

Key Publication

- The Psychology of Human Computer Interaction
  1983 Card et al.

'The domain of concern to us is how humans interact with computers. A scientific psychology should help us in arranging the interface so it is easy, efficient and error free – even enjoyable.'

- Cognitive psychology
- Psycho physics

17

Cognition

Cognition is a term used to describe the psychological processes involved in the acquisition, organisation and use of knowledge – emphasising the rational rather than the emotional characteristics.

Etymologically it is derived
from the Latin word *cognoscere*: to learn,
which in turn is based on *gnoscere*: to know.

Cognitive tasks could therefore simply be defined as those tasks that require or include cognition

18

Cognitive Psychology

- Cognitive psychology =
  study of how we gain knowledge of things
  - Experimental approach
  - cf. AI-study

In cognition we distinguish two modes:

- Experiential cognition: level of expertise required
  = automated pilot (effective-little effort)
- Reflective cognition: thinking, comparing and decision making
  = creative processes

19

Modes – Cognetics

- Conscious cognition (reflective)
  - Refers to the process you are actively involved in
  - usually one process.
- Unconscious cognition (experiential)
  - Refers to processes that you are not aware of at the time they occur
- Focus event
  - Might trigger unconscious cognition to become conscious

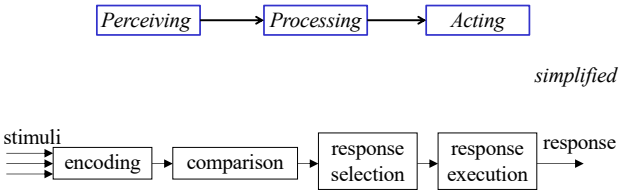
20

Modeling information

INFORMATION PROCESSING

21

Information Processing (2)



22

Differentiate Incoming Stimuli

- Sensing
  - mechanical aspect
  - stimulation of sensory receptor, nerves
- Perceiving
  - personal relationship with information
  - perceptions are unique to a person
  - what are we sensing!

23

Models for Computer Interaction

- Human Memory model
  - Distinguishes 3 types of memory
  - About how the memory is constructed
  - About how stimuli can be processed
- Model Human processor
  - Distinguishes 3 cooperating systems
  - About how stimuli are processed

24

How can we understand memory

MEMORY MODEL

25

Components Human Memory Model

Component	*Analogue*
• Sensory Memory – Short time, (0.1-0.5 s)	• Keyboard, Scanner, or Voice recognition system
• Short Term Memory – Limited info, (1-2 s)	• CPU
• Long Term Memory – Indefinitely	• ROM storage where software is stored

(Atkinson & Shiffrin)

26

Sensory Memory (Registers)

- Sensory Channels: temporary buffers
  - Iconic memory visual stimulus
  - Echoic memory acoustic stimulus
  - Haptic memory touch stimulus
  - Others … (proprioception, olfactory, gustatory)
- Information in unprocessed/un-coded state
  - Persistence 0.2 seconds (visual)
  - 2 seconds (audible)

27

Working Memory

- Central Executive Loop
  - Decision making
- Articular Loop
  - Auditory information
- Visio-spatial sketchpad
  - Visual information

28

Working (WM) - Short Term Memory (STM)

- Working Memory (WM) = aka Working storage; Temporary storage buffer
  - 20-30 seconds or more with rehearsal.
- Symbolically coded information
- Limited capacity
  - 7 plus or minus 2 chunks (Miller, 1956)
  - Modern vision: 3 to 4 items
- Number of chunks independent of bits/chunk
- Used for storage and decision-making
- Recency effect

29

Long Term Memory (LTM)

- Semantic memory: semantically based – structured
- Episodic memory : sequential events – personal
- Semantic + Episodic aka Declarative memory
- Virtually unlimited in size
  - ease of access related to:
    - frequency of access / refresh
    - time since last access
    - number and type of associative links
    - interference from other information activated by same associations
    - context (location, state of mind,…)
  - visual cues vs. abstract data

30

WM (*STM*) to LTM Link

- Rehearsal:
  - Repeatedly refreshing WM
  - Necessary to prevent decay (forgetting)
- Displacement
  - Shift out of WM registers
- Indirect
  - no conscious path; fast retrieval
- Asymmetric
  - fast read, slow write

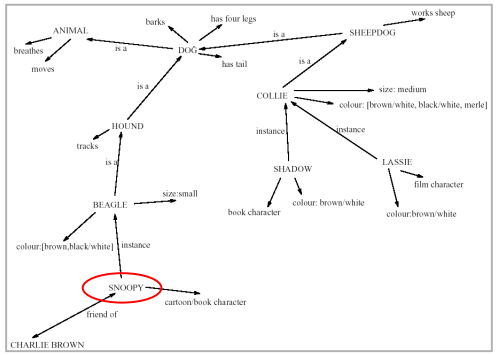
31

Semantic LTM

- Semantic LTM derived from Episodic LTM
- Semantic memory structure
  - provides access to information
  - represents relationships between bits of information
  - supports inference
- Model: semantic network
  - Semantic network represents the associations and relationships between single items in memory
  - inheritance – child nodes inherit properties of parent nodes
  - relationships between bits of information explicit
  - supports inference through inheritance

32

LTM - semantic network



33

The model human processor

PROCESSING STIMULI

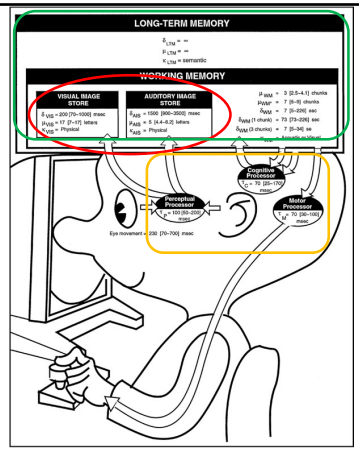
34

The Model Human Processor

- Model suppresses detail
  - ✓Allows simple predictions
- Model human as three interacting subsystems
  - ✓ Perceptual system
  - ✓ Cognitive system
  - ✓ Motor system

(*Card, Moran and Newell, 1983*)

35



36

Information Processing Cycle Times

	Average in *ms*	Range in *ms*
Perceptual system	100	50-200
Cognitive system	70	25-170
Motor system	70	30-100

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37

Relation of Processor with Interaction

- T_p time required for perception
- T_c time required for cognition
- T_m time required for motion response
- $T = n_p T_p + n_c T_c + n_m T_m$

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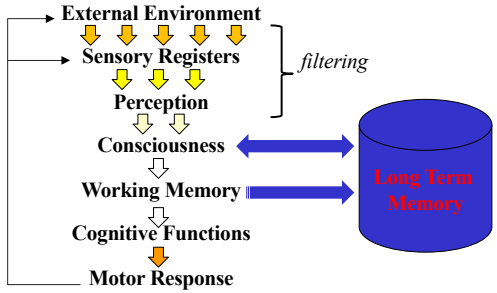
38

Human Information Processing



39

Implications from the Model

- Human processing capacity is relatively small
- Constant danger of overload: cognitive load!
- Implying designers must :
  - Use meaningful ~ familiar chunks wherever possible
  - Simplify decision-making
  - Minimise WM storage if problem solving ~ decision-making is required

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40

Memory's magic number

- Think before drawing conclusions based on this limitation
- Does it mean that:
  - only 7 items are allowed per menu?
  - only 7 buttons are permitted on a toolbar?
  - only 7 labels in a graph?
  - old theory; suffices to say limited
- Example?
  - 0031715275773
  - Think in chunks of information

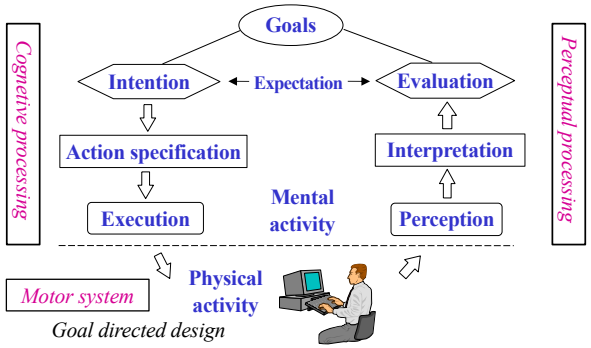
41

Memory limitation

- Memory is not for remembering the past (!)
- Its purpose is to guide *future* behavior
  - Prospective
  - Anticipate
  - Associations
- Things that are not really important are therefore not remembered
  - Filter
  - Help with cognitive aids

42

7 Stages of (Inter)Action (Norman, 1986)



43

Key concepts in HCI and InfoVis

PSYCHOLOGICAL STATE

44

Psychological Factors

- Closure
- User Attitude
- User Anxiety
- Control
- Observations
- **Attention**
- **Emotional state**

45

Closure

- User's desire to "close" a task: cq
  - Free working memory (WM load)
  - Start new tasks and processing
- User Interface/Interaction
  - Cognitive tasks should be "short"
  - e.g doing an online payment
  - e.g ATM, sequence of processing
  - e.g buying from a ticket-vendor machine
- PM: Closure as a term in HCI/InfoVis is not unambiguous.
  - Gestalt (Lecture 3)

46

User Attitude and Anxiety

- Negative attitude results in slower learning
- Anxiety (e.g. fear of failure)
  reduces WM capacity
  and causes slower learning
- Relation to negative affect
- Workplace politics
- Level of training
- Experiment with the system (idiot proof)

47

Control

- Inexperienced users/operators
  - willing to be led slowly by the computer
- Experienced users/observers
  - wish to take the initiative
  - operate the system rapidly
- As people gain experience,
  so their desire to control the computer increases
- … but who is in control (cf. interaction styles)

48

Psychological Observations

- Better at recognition (match) than recall (active search)
  - Major rationale for desktop metaphor, visual supports
  - Appeals to memory model
- Remember grouped things better
  - e.g. divider lines in menus, chunking, use of colour, glyphs
  - Relates to perception
- Learn by doing (episodes in memory)
  - Differ in how we learn
- Rely on previous experiences
  - Episodic memory (procedural memory)

49

Interaction and attention

ATTENTION

50

Focusing Attention

- Attention is the taking possession of mind, in clear and vivid form, of One out of what seems simultaneously possible objects or trains of thought;
- Required: withdrawal from some to deal effectively with others.
- Significance Interactive Applications:
  - Deal with distraction/concentration of users
  - Interface design/Visualization should take multi-tasking into account

51

Variations of Attention

- Orienting
- Expecting
- Searching
- Filtering

- Understand how and when a user/operator is focusing attention.
  - e.g. confirmation / confusion

52

It was cold and dark outside. The rain was making Sarah's clothes sticky and heavy, as she dragged herself along the path home. Suddenly, she stopped. A bright white light, cutting like a razor through the black sky, lit the corners of her eyes, and Sarah turned towards it. Awaiting the roaring of the clouds that would follow, she stared into the darkness. There it was. The faint rumbling in the distance reassured her that she was far enough for the thunderstorm to be safe, and she continued her walk. She scanned the horizon, where several lights could be discerned, shining through the windows of warm and dry houses, one of which was Sarah's home. Then she recognized her home, the third on the left, and soon enough she knocked the door. Her mother opened. "Where were you? We were all so worried!", her mother cries, as Sarah enters the room where her whole family was gathered. They all started talking to her, asking where she had been and what has happened, but the only thing that Sarah listened to were the comforting words of her mother, reassuring her that she was safely home now.

53

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Orienting

Expecting

Searching

Filtering

54

"Cocktail Party Phenomenon"

- Filtering non-relevant signals in a crowd
  - Allows to concentrate on conversation
  - This is focused attention
- Attention to interesting noise
  - Allows to overhear other conversation
  - This is divided attention
- Drawing attention to remarkable signals
  - Respond by the meaning of the signal (e.g. your name)
  - This is Meaningfulness of "item"

55

Locus of Attention

- Humans can only have a
  - Single locus of attention
  - Jeff Raskin – "the Human Interface"
- Humans can not be rewired to do otherwise
- Interfaces need to be designed taking that into account
- We can divide some attention
- Starting point GUI: von Neuman Machine

56

Interaction and Focus

FOCUS IN INTERACTION

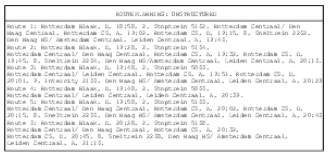
57

Focusing Attention in (G)UI

- Structuring the text
  - Balance amount of information presented to user
  - Grouped
  - Meaningful fashion
- Spatial temporal cues
- Color
- Cognitive aids
  - Flashing
  - Auditory
  - Blinking Cursor

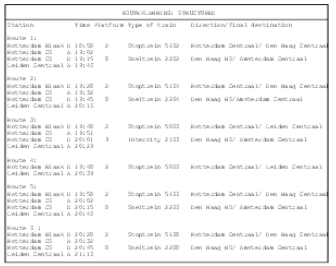
58

Structuring Information (1)



59

Structuring Information (2)



= *chunking*

60

Visual Flow (1)

• inefficient !

61

Visual Flow (2)

• 2 Foci

Orienting
Expecting
Searching
Filtering

62

Cognitive processing

- Automated cognitive processing
  - = experiential cognition
  - Fast
  - Minimal attention
  - Unavailable to consciousness
- Controlled cognitive processing
  - = reflective cognition
  - Slow
  - Dependent on attention
  - Requires conscious thought

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63

Meaningfulness

- More meaningful = deeper level of processing, likely to be remembered.
- Familiarity, Imagery, Context
- Make it Meaningful =
  - Chunking

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64

Meaningfulness Factors

- Factors that contribute to meaningfulness:
  - Familiarity, in everyday language …
    - Door/Read/Stop vs.
    - Compile/Scan/Deploy
  - Associated imagery, in the mind …: easy words
    - Ride/Sleep/Eat vs.
    - Begin/Increase/Evaluate
- Design: pick items that correspond to these rules, e.g. words in the UI/Vis/Legend

65

Other Factors

- Context (use of pictogram or icon)
  - Extent meaningfulness
- Culture
  - e.g. flow of reading
  - meaning of color
    - Red, Green, Blue
- Emotional state
- Analysis of the User

66

Influence of emotional state

EMOTION & INTERACTION

67

Emotion and Models

- Various theories of how emotion works
  - *James-Lange*: emotion is our interpretation of a physiological response to stimuli
  - *Cannon*: emotion is a psychological response to 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

68

Emotion: Affect

- The biological response to physical stimuli is called *Affect*
- ***Affect*** influences how we respond to situations
  - positive → creative problem solving
  - negative → narrow thinking
- Donald Norman:
  "Negative affect can make it harder to do even easy tasks; positive affect can make it easier to do difficult tasks"

69

Emotion and Interaction

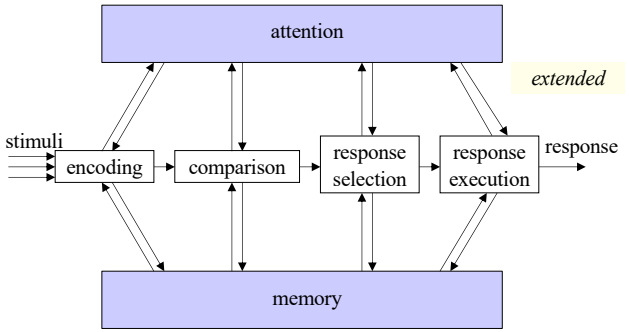
- Implications for interface/interaction design
  - stress will increase the difficulty of problem solving
    - quick understanding of an interface/interaction
  - relaxed users will be more forgiving of shortcomings in a design
    - able to cope with complex situations
    - very useful in the evaluation of a prototype
  - aesthetically pleasing and rewarding interfaces or information displays will increase positive affect

70

INFORMATION PROCESSING

71

Extended Information Processing (3)



72

Example Interaction

73

What did we see …

- Attention request
  - Orienting, Expecting, Searching and Filtering
- Poor feedback, no mapping
- User reasoning
- User uncertainty
- Negative affect

74

Review #2a

- Left brain - Right brain
- Memory Model
- Model Human Processor
- Closure
- User Attitude and Anxiety
- Control
- Various observations

75

Review #2b

- Focussing Attention, Variations
- “cocktail party phenomenon”
- Attention focus, Structuring layout
- Cognitive processing
- Meaningfulness & Cognitive aids
- Other factors (context, culture, user)
- Emotion and Affect

76