CPE/CSC 486: Human-Computer Interaction

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CAL POLY

Course Overview

- Introduction
- Cognitive Foundations
- Input-Output Devices
- Interaction Spaces
- Interaction Styles
- Interaction with Mobile Devices
- Speech-Based Interaction
- User Assistance
- Natural User Interfaces
- Case Studies
- Project Presentations

Chapter Overview
Cognitive Foundations

- Logistics
- Motivation
- Objectives
- Cognition
  - cognitive models
- Cognitive Processes
  - attention, memory, perception, learning, problem-solving, planning, reasoning, decision-making
- Mental Models
- Human Information Processing
- External Cognition
  - memory, computation
- Important Concepts and Terms
- Chapter Summary

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Motivation

- **interaction between humans and computers requires knowledge about capabilities and limitations**
  - humans in this chapter
  - computers in the next chapter
- **cognitive models examine information processing capabilities of humans**
  - critical for information transmission between humans and computers
- **through sensors and actuators, the human body interacts with the real world**
  - information transmission takes place through real-world information channels

Objectives

- to learn about cognitive models for the human mind
- to understand the cognitive capabilities and limitations of humans
- to be familiar with the most critical sensors and actuators used for information transmission
- to evaluate the suitability of transmission channels and methods
  - depends on context, tasks, environments

Logistics

- **Assignments**
  - A1 overview
- **Term Project**
  - teams and topics stable
- **Research Activity**
  - explore topics
  - discuss alternative delivery modes

Overview

- What is cognition?
- What are users good and bad at?
- Describe how cognition has been applied to interaction design
- Mental Models
- Internals classic theories of cognition
- More recent external theories of cognition

Why do we need to understand users?

- Interacting with technology is cognitive
- Need to take into account cognitive processes involved and cognitive limitations of users
- Provides knowledge about what users can and cannot be expected to do
- Identifies and explains the nature and causes of problems users encounter
- Supply theories, modelling tools, guidance and methods that can lead to the design of better interactive products

Cognitive processes

- Attention
- Perception and recognition
- Memory
- Learning
- Reading, speaking and listening
- Problem-solving, planning, reasoning and decision-making

Attention

- Selecting things to concentrate on at a point in time from the mass of stimuli around us
- Allows us to to focus on information that is relevant to what we are doing
- Involves audio and/or visual senses
- Focussed and divided attention enables us to be selective in terms of the mass of competing stimuli but limits our ability to keep track of all events
- Information at the interface should be structured to capture users' attention, e.g. use perceptual boundaries (windows), colour, reverse video, sound and flashing lights

Experiment

- **Identify an item in a listing on the screen**
  - two different arrangements
- **Setup**
  - task description is shown
  - timer starts when screen display is shown
  - timer stops when the participant has found the correct item
    - speak the correct answer
- **People**
  - participants
  - facilitator explains the task, assists the user
  - observer measures time

Activity: Find the price of a double room at the Holiday Inn in Bradley

- tell the observer the price once you've found it

Pennsylvania
Bedford Motel/Hotel: Crinaline Courts
(814) 623-9511 S: $18 D: $20
Bedford Motel/Hotel: Holiday Inn
(814) 623-9006 S: $29 D: $36
Bedford Motel/Hotel: Midway
(814) 623-8107 S: $21 D: $26
Bedford Motel/Hotel: Penn Manor
(814) 623-8177 S: $19 D: $25
Bedford Motel/Hotel: Quality Inn
(814) 623-5189 S: $23 D: $28
Bedford Motel/Hotel: Terrace
(814) 623-5111 S: $22 D: $24
Bradley Motel/Hotel: De Soto
(814) 362-3567 S: $20 D: $24
Bradley Motel/Hotel: Holiday House
(814) 362-4511 S: $22 D: $25
Bradley Motel/Hotel: Holiday Inn
(814) 362-4501 S: $32 D: $40
Breezewood Motel/Hotel: Best Western Plaza
(814) 735-4352 S: $20 D: $27
Breezewood Motel/Hotel: Motel 70
(814) 735-4385 S: $16 D: $18

Activity 2: Find the price for a double room at the Quality Inn in Columbia

South Carolina

City	Motel/Hotel	Area code	Phone	Rates Single	Rates Double
Charleston	Best Western	803	747-0961	$26	$30
Charleston	Days Inn	803	881-1000	$18	$24
Charleston	Holiday Inn N	803	744-1621	$36	$46
Charleston	Holiday Inn SW	803	556-7100	$33	$47
Charleston	Howard Johnsons	803	524-4148	$31	$36
Charleston	Ramada Inn	803	774-8281	$33	$40
Charleston	Sheraton Inn	803	744-2401	$34	$42
Columbia	Best Western	803	796-9400	$29	$34
Columbia	Carolina Inn	803	799-8200	$42	$48
Columbia	Days Inn	803	736-0000	$23	$27
Columbia	Holiday Inn NW	803	794-9440	$32	$39
Columbia	Howard Johnsons	803	772-7200	$25	$27
Columbia	Quality Inn	803	772-0270	$34	$41
Columbia	Ramada Inn	803	796-2700	$36	$44
Columbia	Vagabond Inn	803	796-6240	$27	$30

Evaluation Activities 1, 2

- Tullis (1987) found that the two screens produced quite different results
  - 1st screen - took an average of 5.5 seconds to search
  - 2nd screen - took 3.2 seconds to search
- Why?,
  - both displays have the same density of information (31%)
- Spacing
  - In the 1st screen the information is bunched up together, making it hard to search
  - In the 2nd screen the characters are grouped into vertical categories of information making it easier

Activity 3:

- **Dial the number of the hotel with the cheapest double room in Charleston**
  - signal completion after you've entered the phone number
  - no need to actually connect the call

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Evaluation Activity 3

- **more challenging than Activity 3**
  - calculations
  - short term memory
  - translation of visual input into action

Activity 4:

- **almost the same as Activity 3**
  - most expensive instead of cheapest
  - spoken text instead of visual display
- **Dial the number of the hotel with the most expensive single room in Bradley**
  - signal completion after you've entered the phone number
  - no need to actually connect the call

Activity: Find the price for a double room at the Quality Inn in Columbia

- Pennsylvania Bedford Motel/Hotel: Crinaline Courts (814) 623-9511 S:$18 D:$20 Bedford Motel/Hotel: Holiday Inn (814) 623-9006 S: $29 D: $36 Bedford Motel/ Hotel: Midway (814) 623-8107 5: $21 D: $26 Bedford Motel/Hotel: Penn Manor (814) 623-8177 5: $19 D: $25 Bedford Motel/Hotel: Quality Inn (814) 623-5189 S: $23 D: $28 Bedford Motel/Hotel: Terrace (814) 623-5111 S: $22 D: $24 Bradley Motel/Hotel: De Soto (814) 362-3567 5: $20 D: $24 Bradley Motel/Hotel: Holiday House (814) 362-4511 3: $22 D: $25 Bradley Motel/Hotel: Holiday Inn (814) 362-4501 S: $32 D: $40 Breezewood Motel/Hotel: Best Western Plaz. (814) 735-4352 S: $20 D: $27 Breezewood Motel/Hotel: Motel 70 (814) 735-4385 5: $16 D: $18

Evaluation Activity 3

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  - short term memory
  - translation of visual input into action

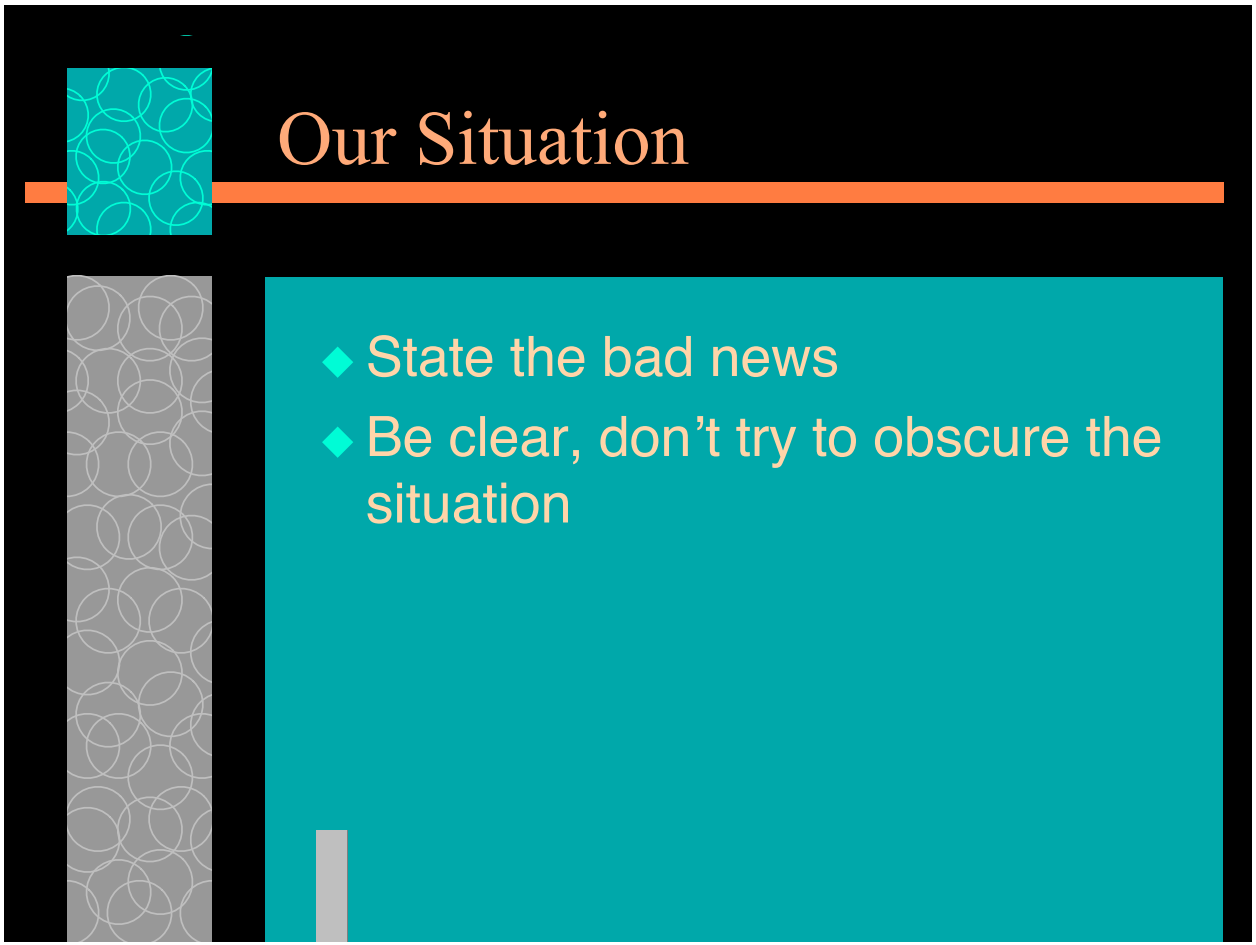
Multitasking and attention

- Is it possible to perform multiple tasks without one or more of them being detrimentally affected?
- Ophir et al (2009) compared heavy vs light multi-taskers
  - heavy were more prone to being distracted than those who infrequently multitask
  - heavy multi-taskers are easily distracted and find it difficult to filter irrelevant information

Design implications for attention

- Make information salient when it needs attending to
- Use techniques that make things stand out like color, ordering, spacing, underlining, sequencing and animation
- Avoid cluttering the interface with too much information
- Avoid using too much because the software allows it

An example of over-use of graphics



Perception

- How information is acquired from the world and transformed into experiences
- Obvious implication is to design representations that are readily perceivable, e.g.
  - Text should be legible
  - Icons should be easy to distinguish and read

Is color contrast good? Find italian

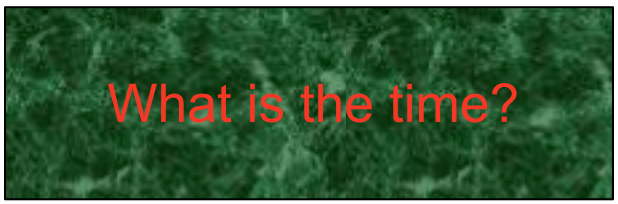
Black Hills Forest	Peters Landing	Jefferson Farms	Devlin Hall
Cheyenne River	Public Health	Psychophysics	Positions
Social Science	San Bernardino	Political Science	Hubard Hall
South San Jose	Moreno Valley	Game Schedule	Fernadino Beach
Badlands Park	Altamonte Springs	South Addision	Council Bluffs
Juvenile Justice	Peach Tree City	Cherry Hills Village	Classical Lit
Results and Stats	Highland Park	Creative Writing	Sociology
Thousand Oaks	Manchesney Park	Lake Havasu City	Greek
Promotions	Vallecito Mts.	Engineering Bldg	Wallace Hall
North Palermo	Rock Falls	Sports Studies	Concert Tickets
Credit Union	Freeport	Lakewood Village	Public Radio FM
Wilner Hall	Slaughter Beach	Rock Island	Children's Museum
Performing Arts	Rocky Mountains	Deerfield Beach	Writing Center
Italian	Latin	Arlington Hill	Theater Auditions
Coaches	Pleasant Hills	Preview Game	Delaware City
McKees Rocks	Observatory	Richland Hills	Scholarships
Glenwood Springs	Public Affairs	Experts Guide	Hendricksville
Urban Affairs	Heskett Center	Neff Hall	Knights Landing
McLeansboro	Brunswick	Grand Wash Cliffs	Modern Literature
Experimental Links	East Millinocket	Indian Well Valley	Studio Arts
Graduation	Women's Studies	Online Courses	Hughes Complex
Emory Lindquist	Vacant	Lindquist Hall	Cumberland Flats
Clinton Hall	News Theatre	Fisk Hall	Central Village
San Luis Obispo	Candlewood Isle	Los Padres Forest	Hoffman Estates

Are borders and white space better? Find french

Activity

- Weller (2004) found people took less time to locate items for information that was grouped
  - using a border (2nd screen) compared with using color contrast (1st screen)
- Some argue that too much white space on web pages is detrimental to search
  - Makes it hard to find information
- Do you agree?

Which is easiest to read and why?



What is the time?

What is the time?

What is the time?

What is the time?

Design implications

- Icons should enable users to readily *distinguish* their meaning
- Bordering and spacing are effective visual ways of grouping information
- Sounds should be audible and distinguishable
- Speech output should enable users to distinguish between the set of spoken words
- Text should be legible and distinguishable from the background
- Tactile feedback should allow users to recognize and distinguish different meanings

Memory

- Involves first encoding and then retrieving knowledge
- We don’t remember everything - involves filtering and processing what is attended to
- Context is important in affecting our memory (i.e. where, when)
- We recognize things much better than being able to recall things

Processing in memory

- Encoding is first stage of memory
  - determines which information is attended to in the environment and how it is interpreted
- The more attention paid to something…
- The more it is processed in terms of thinking about it and comparing it with other knowledge…
- The more likely it is to be remembered
  - e.g. when learning about HCI, it is much better to reflect upon it, carry out exercises, have discussions with others about it, and write notes than just passively read a book, listen to a lecture or watch a video about it

Context is important

- Context affects the extent to which information can be subsequently retrieved
- Sometimes it can be difficult for people to recall information that was encoded in a different context:
  - "You are on a train and someone comes up to you and says hello. You don't recognize him for a few moments but then realize it is one of your neighbors. You are only used to seeing your neighbor in the hallway of your apartment block and seeing him out of context makes him difficult to recognize initially"

Activity

- Try to remember the dates of your grandparents' birthday
- Try to remember the cover of the last two DVDs you bought or rented
- Which was easiest? Why?
- People are very good at remembering visual cues about things
  - e.g. the color of items, the location of objects and marks on an object
- They find it more difficult to learn and remember arbitrary material
  - e.g. birthdays and phone numbers

Recognition versus recall

- Command-based interfaces require users to recall from memory a name from a possible set of 100s
- GUIs provide visually-based options that users need only browse through until they recognize one
- Web browsers, MP3 players, etc., provide lists of visited URLs, song titles etc., that support recognition memory

The problem with the classic '7±2'

- George Miller's (1956) theory of how much information people can remember
- People's immediate memory capacity is very limited
- Many designers think this is useful finding for interaction design
- But…

What some designers get up to…

- Present only 7 options on a menu
- Display only 7 icons on a tool bar
- Have no more than 7 bullets in a list
- Place only 7 items on a pull down menu
- Place only 7 tabs on the top of a website page
  - But this is wrong? Why?

Why?

- Inappropriate application of the theory
- People can scan lists of bullets, tabs, menu items for the one they want
- They don't have to recall them from memory having only briefly heard or seen them
- Sometimes a small number of items is good
- But depends on task and available screen estate

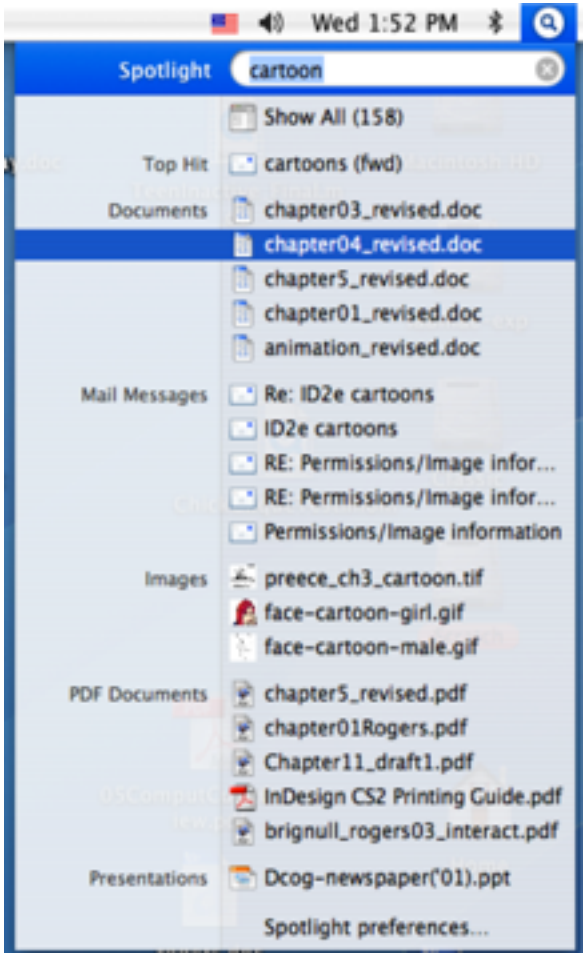
Personal information management

- Personal information management is a growing problem for many users
  - vast numbers of documents, images, music files, video clips, emails, attachments, bookmarks, etc.,
  - where and how to save them all, then remembering what they were called and where to find them again
  - naming most common means of encoding them
  - but can be difficult to remember, especially when have 1000s and 1000s
  - How might such a process be facilitated taking into account people's memory abilities?

Personal information management

- Memory involves 2 processes
  - recall-directed and recognition-based scanning
- File management systems should be designed to optimize both kinds of memory processes
  - e.g. Search box and history list
- Help users encode files in richer ways
  - Provide them with ways of saving files using colour, flagging, image, flexible text, time stamping, etc

Is Apple's Spotlight search tool any good?



Memory aids

- SenseCam developed by Microsoft Research Labs
- a wearable device that intermittently takes photos without any user intervention while worn
- digital images taken are stored and revisited using special software
- Has been found to improve people's memory, suffering from Alzheimers

SenseCam

Design implications

- Don’t overload users’ memories with complicated procedures for carrying out tasks
- Design interfaces that promote recognition rather than recall
- Provide users with various ways of encoding information to help them remember
  - e.g. categories, color, flagging, time stamping

Learning

- How to learn to use a computer-based application
- Using a computer-based application to understand a given topic
- People find it hard to learn by following instructions in a manual
    - prefer to learn by doing

Design implications

- Speech-based menus and instructions should be short
- Accentuate the intonation of artificially generated speech voices
  - they are harder to understand than human voices
- Provide opportunities for making text large on a screen

Reading, speaking, and listening

- The ease with which people can read, listen, or speak differs
  - Many prefer listening to reading
  - Reading can be quicker than speaking or listening
  - Listening requires less cognitive effort than reading or speaking
  - Dyslexics have difficulties understanding and recognizing written words

Applications

- Speech-recognition systems allow users to interact with them by using spoken commands
  - e.g. Google Voice Search app
- Speech-output systems use artificially generated speech
- e.g. written-text-to-speech systems for the blind
- Natural-language systems enable users to type in questions and give text-based responses
  - e.g. Ask search engine

Design implications

- Design interfaces that encourage exploration
- Design interfaces that constrain and guide learners
- Dynamically linking concepts and representations can facilitate the learning of complex material

Problem-solving, planning, reasoning and decision-making

- All involves reflective cognition
  - e.g. thinking about what to do, what the options are, and the consequences
- Often involves conscious processes, discussion with others (or oneself), and the use of artifacts
  - e.g. maps, books, pen and paper
- May involve working through different scenarios and deciding which is best option

Design implications

- Provide additional information/functions for users who wish to understand more about how to carry out an activity more effectively

- Use simple computational aids to support rapid decision-making and planning for users on the move

Mental models

- Users develop an understanding of a system through learning about and using it
- Knowledge is sometimes described as a mental model:
  - How to use the system (what to do next)
  - What to do with unfamiliar systems or unexpected situations (how the system works)
- People make inferences using mental models of how to carry out tasks

Mental models

- Craik (1943) described mental models as:
  - internal constructions of some aspect of the external world enabling predictions to be made
- Involves unconscious and conscious processes
  - images and analogies are activated
- Deep versus shallow models
  - e.g. how to drive a car and how it works

Everyday reasoning and mental models

(a) You arrive home on a cold winter's night to a cold house. How do you get the house to warm up as quickly as possible? Set the thermostat to be at its highest or to the desired temperature?

(b) You arrive home starving hungry. You look in the fridge and find all that is left is an uncooked pizza. You have an electric oven. Do you warm it up to 375 degrees first and then put it in (as specified by the instructions) or turn the oven up higher to try to warm it up quicker?

Heating up a room or oven that is thermostat-controlled

- Many people have erroneous mental models (Kempton, 1996)
- Why?
  - General valve theory, where 'more is more' principle is generalised to different settings (e.g. gas pedal, gas cooker, tap, radio volume)
  - Thermostats based on model of on-off switch model

Heating up a room or oven that is thermostat-controlled

- Same is often true for understanding how interactive devices and computers work:
  - poor, often incomplete, easily confusable, based on inappropriate analogies and superstition (Norman, 1983)
  - e.g. elevators and pedestrian crossings - lot of people hit the button at least twice
  - Why? Think it will make the lights change faster or ensure the elevator arrives!

Exercise: ATMs

- Write down how an ATM works
  - How much money are you allowed to take out?
  - What denominations?
  - If you went to another machine and tried the same what would happen?
  - What information is on the strip on your card? How is this used?
  - What happens if you enter the wrong number?
  - Why are there pauses between the steps of a transaction? What happens if you try to type during them?
  - Why does the card stay inside the machine?
  - Do you count the money? Why?

How did you fare?

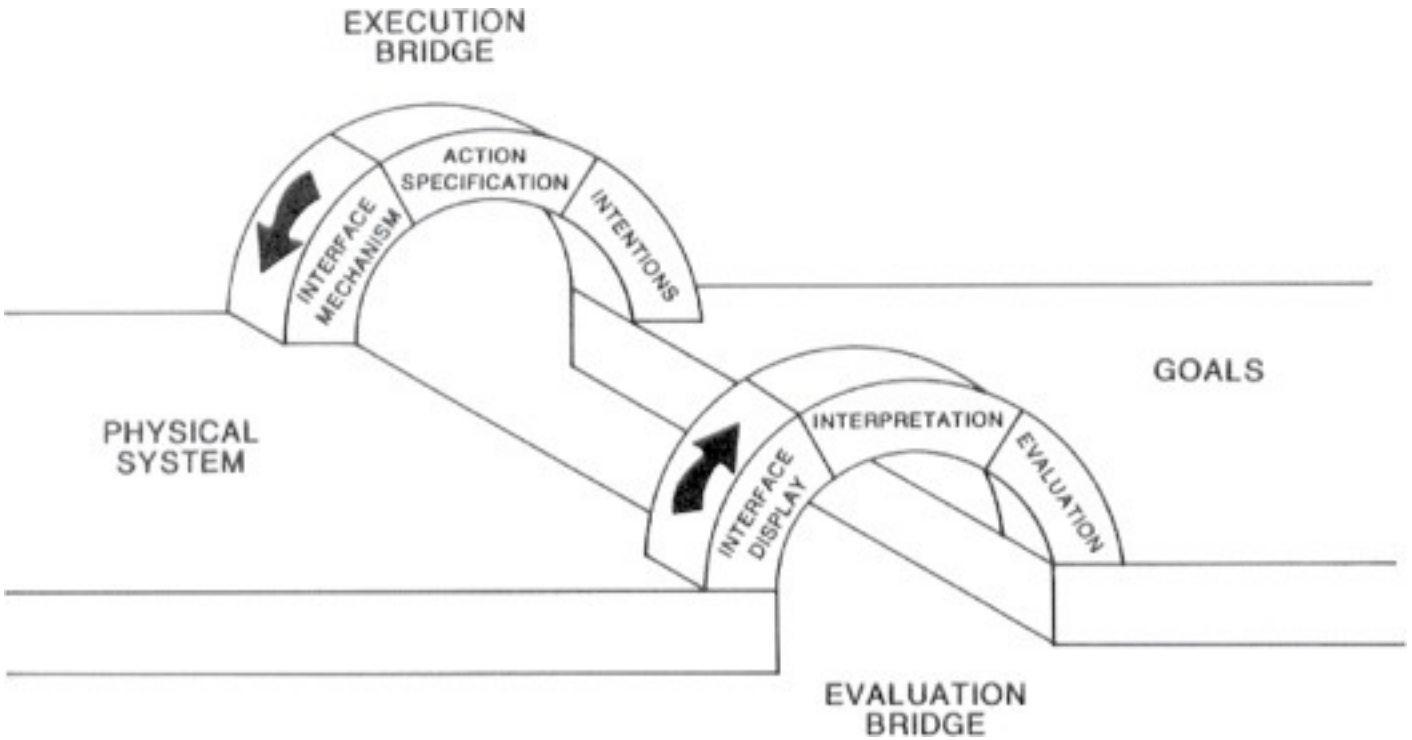
- Your mental model
  - How accurate?
  - How similar?
  - How shallow?
- Payne (1991) did a similar study and found that people frequently resort to analogies to explain how they work
- People's accounts greatly varied and were often ad hoc

Gulfs of execution and evaluation

- The 'gulfs' explicate the gaps that exist between the user and the interface
- The gulf of execution
  - the distance from the user to the physical system
- The gulf of evaluation
  - the distance from the physical system to the user
- Bridging the gulfs can reduce cognitive effort required to perform tasks

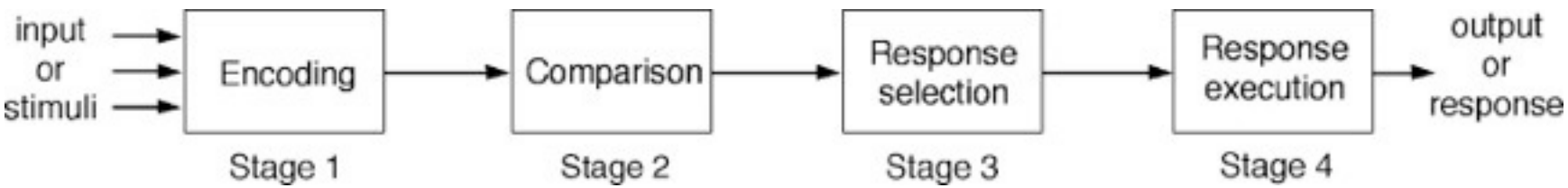
Norman, 1986; Hutchins *et al*, 1986

Bridging the gulfs



Information processing

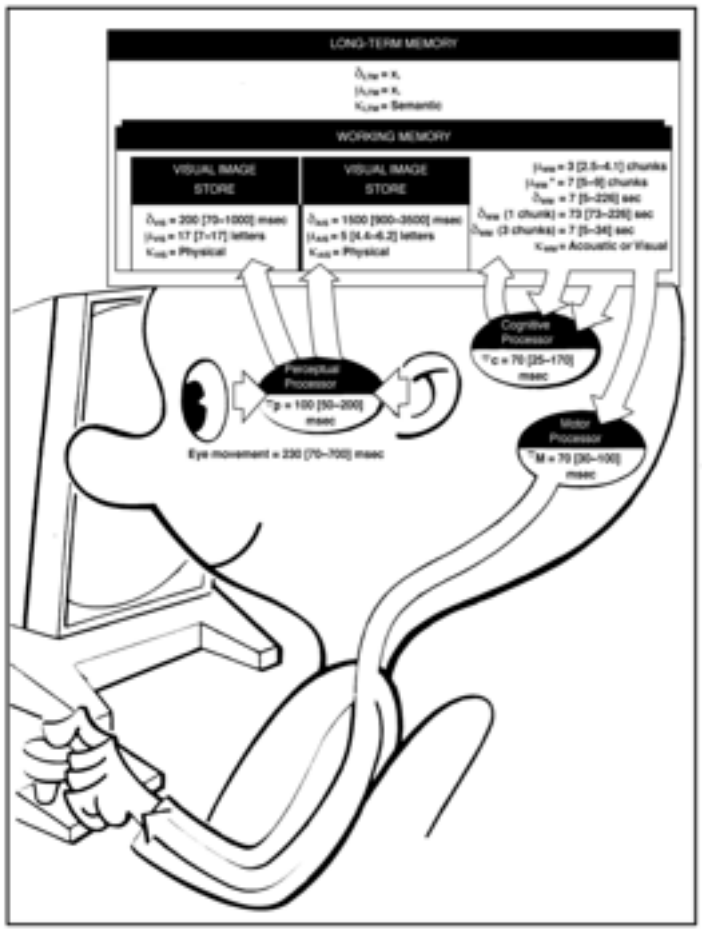
- Conceptualizes human performance in metaphorical terms of information processing stages



Model Human processor (Card et al, 1983)

- Models the information processes of a user interacting with a computer
- Predicts which cognitive processes are involved when a user interacts with a computer
- Enables calculations to be made of how long a user will take to carry out a task

The human processor model



Limitations

- based on modeling mental activities that happen exclusively inside the head
- do not adequately account for how people interact with computers and other devices in real world

Technology Influence

- **historically, human cognitive models have relied on the most recent technological developments**
  - now: computers
  - earlier:
    - electricity
    - clockworks
    - pneumatic and hydromatic methods
      - steam, water, air
      - pipes, valves

External cognition

- Concerned with explaining how we interact with external representations (e.g. maps, notes, diagrams)
- What are the cognitive benefits and what processes involved
- How they extend our cognition
- What computer-based representations can we develop to help even more?

Externalizing to reduce memory load

- Diaries, reminders, calendars, notes, shopping lists, to-do lists
  - written to remind us of what to do
- Post-its, piles, marked emails
  - where placed indicates priority of what to do
- External representations:
  - Remind us that we need to do something (e.g. to buy something for mother's day)
  - Remind us of what to do (e.g. buy a card)
  - Remind us when to do something (e.g. send a card by a certain date)

Computational offloading

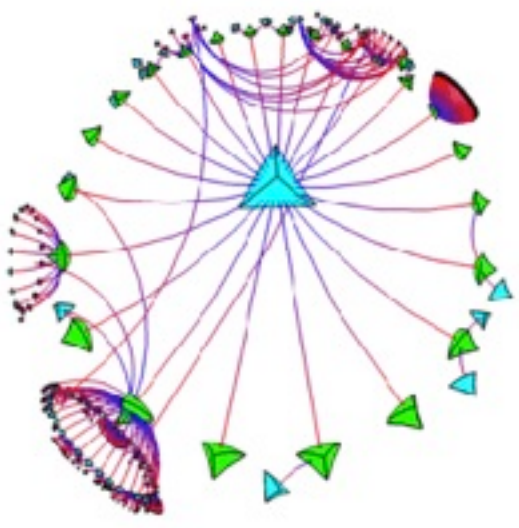
- When a tool is used in conjunction with an external representation to carry out a computation (e.g. pen and paper)
- Try doing the two sums below (a) in your head, (b) on a piece of paper and c) with a calculator.
  - 234 x 456 =??
  - CCXXXIIII x CCCCXXXXXVI = ???
- Which is easiest and why? Both are identical sums

Annotation and cognitive tracing

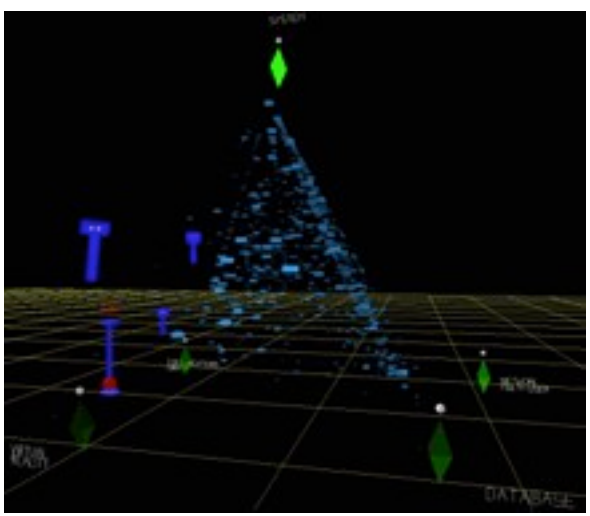
- Annotation involves modifying existing representations through making marks
  - e.g. crossing off, ticking, underlining
- Cognitive tracing involves externally manipulating items into different orders or structures
  - e.g. playing Scrabble, playing cards

Design implication

- Provide external representations at the interface that reduce memory load and facilitate computational offloading



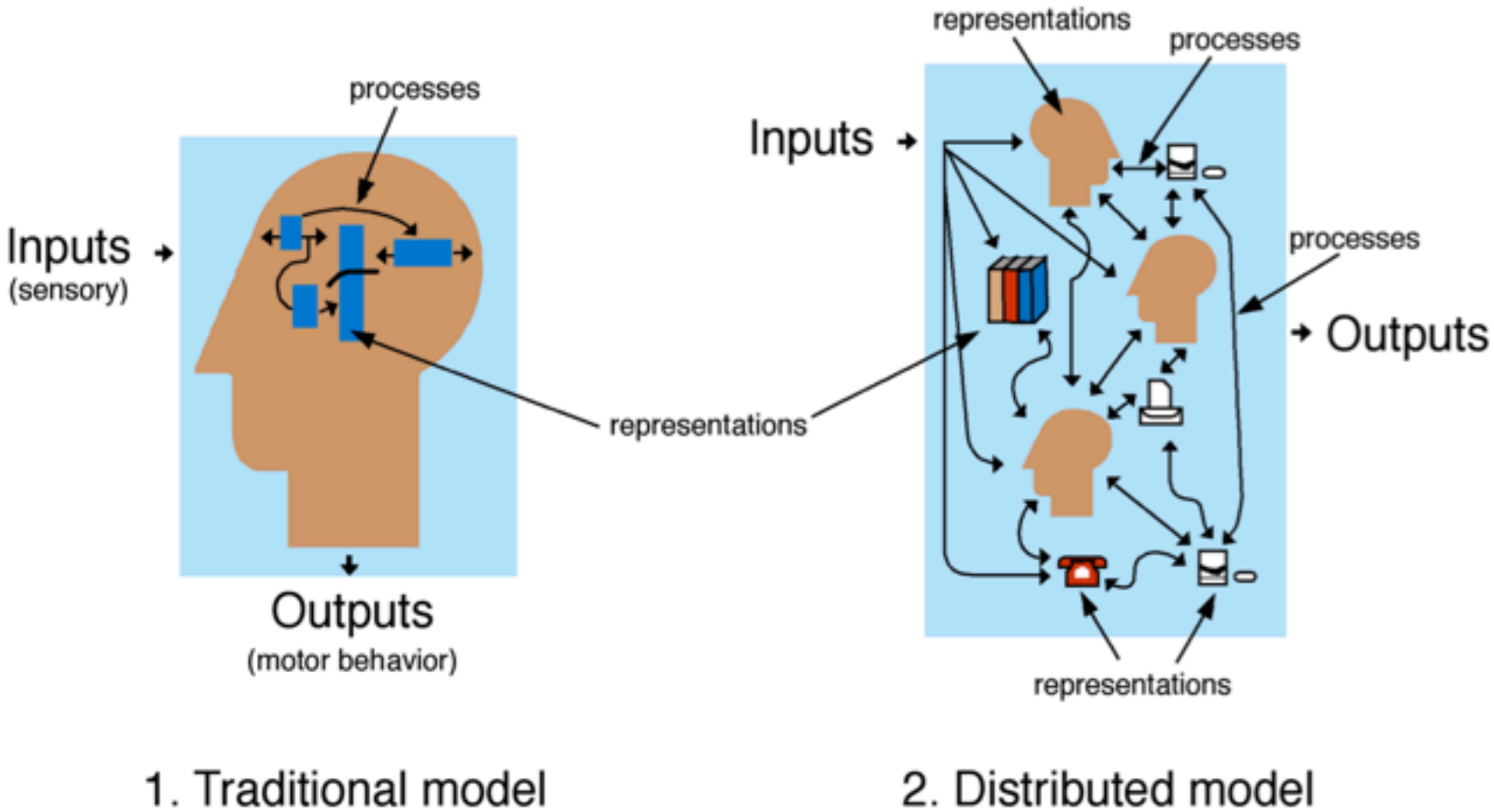
e.g. Information visualizations have been designed to allow people to make sense and rapid decisions about masses of data

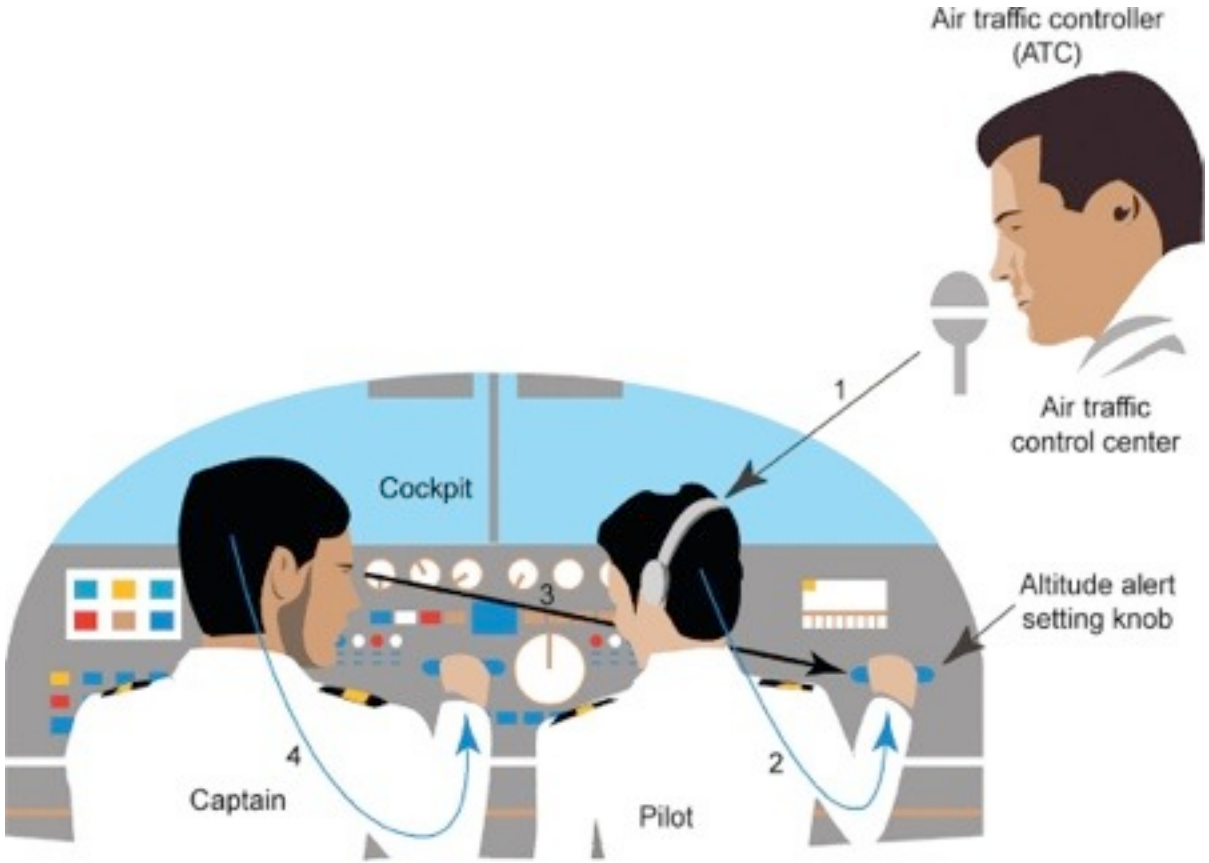


Distributed cognition

- Concerned with the nature of cognitive phenomena across individuals, artifacts, and internal and external representations (Hutchins, 1995)
- Describes these in terms of propagation across representational state
- Information is transformed through different media (computers, displays, paper, heads)

How it differs from information processing





Propagation of representational states:

1 ATC gives clearance to pilot to fly to higher altitude (verbal)

2 Pilot changes altitude meter (mental and physical)

3 Captain observes pilot (visual)

4 Captain flies to higher altitude (mental and physical)

What's involved

- The distributed problem-solving that takes place
- The role of verbal and non-verbal behavior
- The various coordinating mechanisms that are used (e.g. rules, procedures)
- The communication that takes place as the collaborative activity progresses
- How knowledge is shared and accessed

Important Concepts and Terms

- attention
- cognition
- decision-making
- external memory
- externalization
- human-machine interface
- information processing
- listening
- memory
- mental model
- perception
- planning
- problem-solving
- reading
- reasoning
- speaking

Summary

- Cognition involves several processes including attention, memory, perception and learning
- The way an interface is designed can greatly affect how well users can perceive, attend, learn and remember how to do their tasks
- Theoretical frameworks, such as mental models and external cognition, provide ways of understanding how and why people interact with products
- This can lead to thinking about how to design better products