INTERACTION DESIGN

SHARP • ROGERS • PREECE

beyond human-computer interaction

5th Edition

Chapter 4

COGNITIVE ASPECTS

Overview

- What is cognition?

- Why it is important to understand in HCI

- Describe how cognition has been applied to interaction design

- Explain what are mental models and how to elicit them

- Cover relevant theories of cognition

What is cognition?

- Thinking, remembering, learning, daydreaming, decision-making, seeing, reading, talking, writing…

- Ways of classifying cognition at a higher level:
    - Experiential vs. reflective cognition (Norman, 1993)
    - Fast vs slow thinking (Kahneman, 2011)

Which involves fast vs slow thinking?

- 2 + 2 =

- 21 × 29 =

- What color eyes do you have?

- How many colors are there in the rainbow?

- How many months in the year have 31 days?

- What is the name of the first school you attended?

How can understanding cognition help?

- Provides knowledge about what users can and cannot be expected to do

- Identifies and explains the nature and causes of problems that users encounter

- Provides theories, modeling tools, guidance, and methods that can lead to the design of better interactive products

Cognitive processes

- Attention

- Perception

- Memory

- Learning

- Reading, speaking and listening

- Problem-solving, planning, reasoning and decision-making

Attention

- Selecting things on which to concentrate at a point in time from the mass of stimuli around us

- Allows us to focus on information that is relevant to what we are doing

- Involves audio and/or visual senses

- Focused 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

- Design recommendation

  - Information at the interface should be structured to capture users' attention, for example, use perceptual boundaries (windows), color, reverse video, sound, and flashing lights

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

Pennsylvania
Bedford Motel/Hotel: Crinaline Courts
  (814) 623-9511   S: $118 D: $120
Bedford Motel/Hotel: Holiday Inn
  (814) 623-9006 S: $129 D: $136
Bedford Motel/Hotel: Midway
  (814) 623-8107 S: $121 D: $126
Bedford Motel/Hotel: Penn Manor
  (814) 623-8177 S: $119 D: $125
Bedford Motel/Hotel: Quality Inn
  (814) 623-5189 S: $123 D: $128
Bedford Motel/Hotel: Terrace
  (814) 623-5111 S: $122 D: $124
Bradley Motel/Hotel: De Soto
  (814) 362-3567 S: $120 D: $124
Bradley Motel/Hotel: Holiday House
  (814) 362-4511 S: $122 D: $125
Bradley Motel/Hotel: Holiday Inn
  (814) 362-4501 S: $132 D: $140
Breezewood Motel/Hotel: Best Western Plaza
  (814) 735-4352 S: $120 D: $127
Breezewood Motel/Hotel: Motel 70
  (814) 735-4385 S: $116 D: $118

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

South Carolina

City	Motel/Hotel	Area code	Phone	Rates Single	Double
Charleston	Best Western	803	747-0961	$126	$130
Charleston	Days Inn	803	881-1000	$118	$124
Charleston	Holiday Inn N	803	744-1621	$136	$146
Charleston	Holiday Inn SW	803	556-7100	$133	$147
Charleston	Howard Johnsons	803	524-4148	$131	$136
Charleston	Ramada Inn	803	774-8281	$133	$140
Charleston	Sheraton Inn	803	744-2401	$134	$142
Columbia	Best Western	803	796-9400	$129	$134
Columbia	Carolina Inn	803	799-8200	$142	$148
Columbia	Days Inn	803	736-0000	$123	$127
Columbia	Holiday Inn NW	803	794-9440	$132	$139
Columbia	Howard Johnsons	803	772-7200	$125	$127
Columbia	Quality Inn	803	772-0270	$134	$141
Columbia	Ramada Inn	803	796-2700	$136	$144
Columbia	Vagabond Inn	803	796-6240	$127	$130

Activity

- 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, since both displays have the same density of information (31percent)?

- 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

Multitasking and attention

- Is it possible to perform multiple tasks without one or more of them being detrimentally affected?

- Multitasking can cause people to lose their train of thought, make errors, and need to start over

- Ophir et al. (2009) compared heavy vs light multitaskers
  - Heavy multitaskers were more prone to being distracted than those who infrequently multitask
  - Heavy multitaskers are easily distracted and find it difficult to filter irrelevant information

Multitasking experiment

- Lotteridge et al. (2015) conducted another study involving writing an essay under two conditions: relevant or irrelevant information

  - Heavy multitaskers were easily distracted but able to put this to good use if the distracting sources were relevant to the task in hand

  - Irrelevant information was found to impact task performance negatively

Multitasking at work

It is increasingly common for workers to multitask

- For example, hospital workers have to attend to multiple screens in an operating room that provide new kinds of real-time information
- This requires clinician's constant attention to check if any data is unusual or anomalous
- Need to develop new attention and scanning strategies

Is it OK to use a phone when driving?

No!

- Driving is very demanding
- Drivers are prone to being distracted
- There is a significant chance of causing accidents
- Drivers' reaction times are longer to external events when talking on the phone in a car (Caird et al., 2018)
- Drivers using their phones rely more on their expectations about what is likely to happen next as conducting a conversation takes up their attention
- Response time is slower to unexpected events (Briggs et al., 2018)
- Drivers often try to imagine what the other person's face is like–the person to whom they are speaking
  - Doing so competes with the processing resources needed to enable them to notice and react to what is in front of them

Are hands-free phones safer to use when driving?

- No, as same type of cognitive processing is happening when talking

- The same thing happens when talking with front seat passenger

    - But both can stop in mid-sentence if a hazard is spotted allowing the driver to switch immediately to the road

    - So, it's less dangerous talking to a front seat passenger than a remote person

    - A remote person on the end of a phone is not privy to what the driver is seeing and will carry on the conversation when there is a hazard

    - This makes it difficult for the driver to switch all their attention to the road

Design implications for attention

- Context: Make information salient when it needs to be attended to at a given stage of a task

- Use techniques to achieve this:
    - For example, color, ordering, spacing, underlining, sequencing, and animation

- Avoid cluttering visual interfaces with too much information

- Consider designing different ways to support effective switching and returning to an interface

Perception

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

Senses and Constructivism

• Senses (sight, hearing, smell, taste, touch) provide data about what is happening around us

• Designing good Web materials requires knowledge about how people perceive

• Our brains do not create <u>pixel-by-pixel images</u>

• Our minds create, or construct, models that summarize what comes from our senses

• These models are what we perceive

• When we see something, we don't remember all the details, only those that have meaning for us

• **<u>Context</u>** plays a major role in what people see in an image

Example what do you see
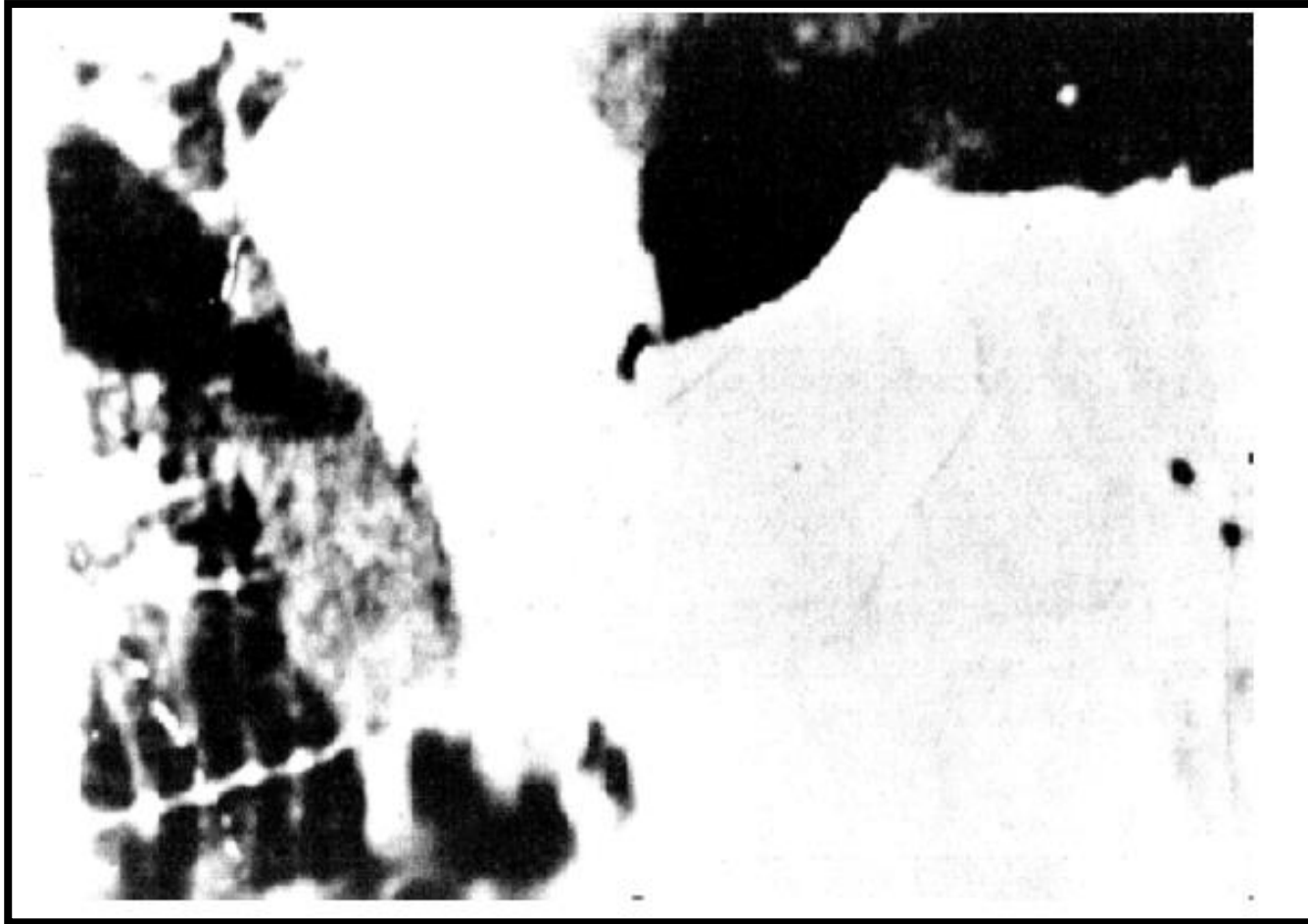
Hint: it's an animal facing you

Hint: This animal gives milk
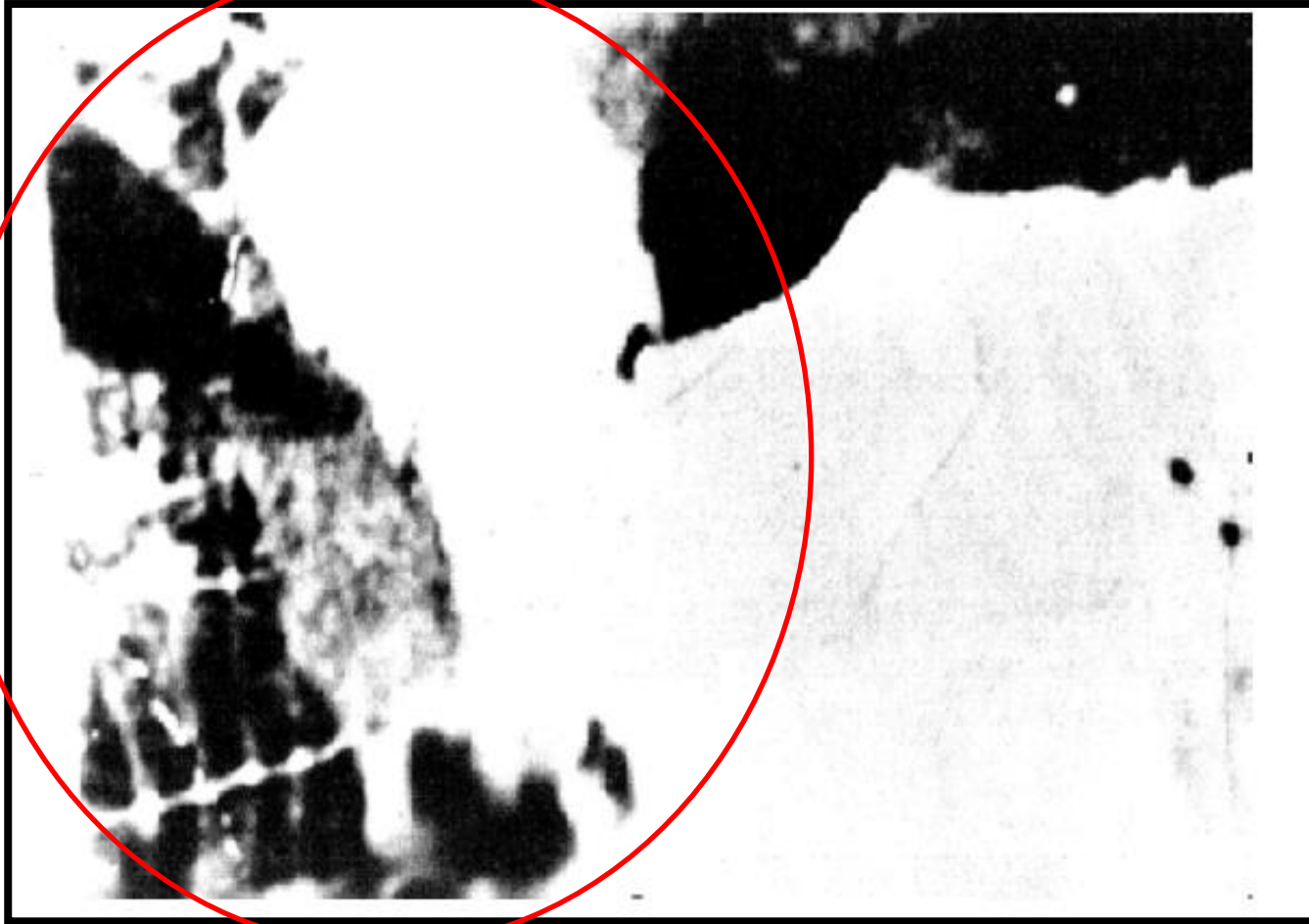
Gestalt psychology

<u>Gestalt psychology</u>

• "Gestalt" is German for "shape," but as the term is used in psychology it implies the idea of perception in context

• We don't see things in isolation, but as parts of a whole

Figure and ground

Images are partitioned into
- – Figure (foreground) and
- – Ground (background)

• Sometimes figure and ground are ambiguous

Figure and ground: Example 1

Figure and ground: Example 2

Five Principles of Gestalt
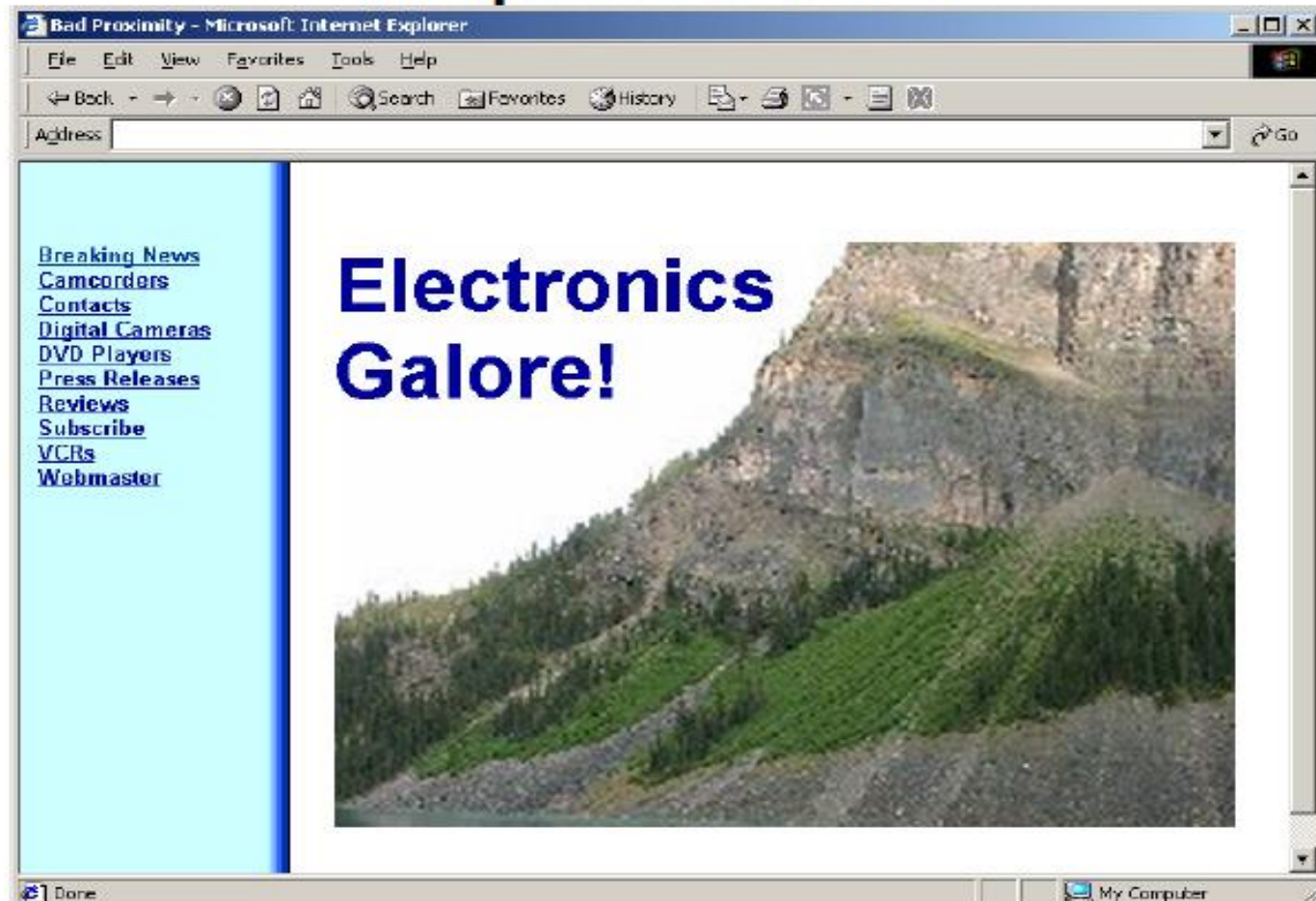
We organize things into meaningful units using

– Proximity: we group by distance or location

– Similarity: we group by type

– Symmetry: we group by meaning

– Continuity: we group by flow of lines (alignment)

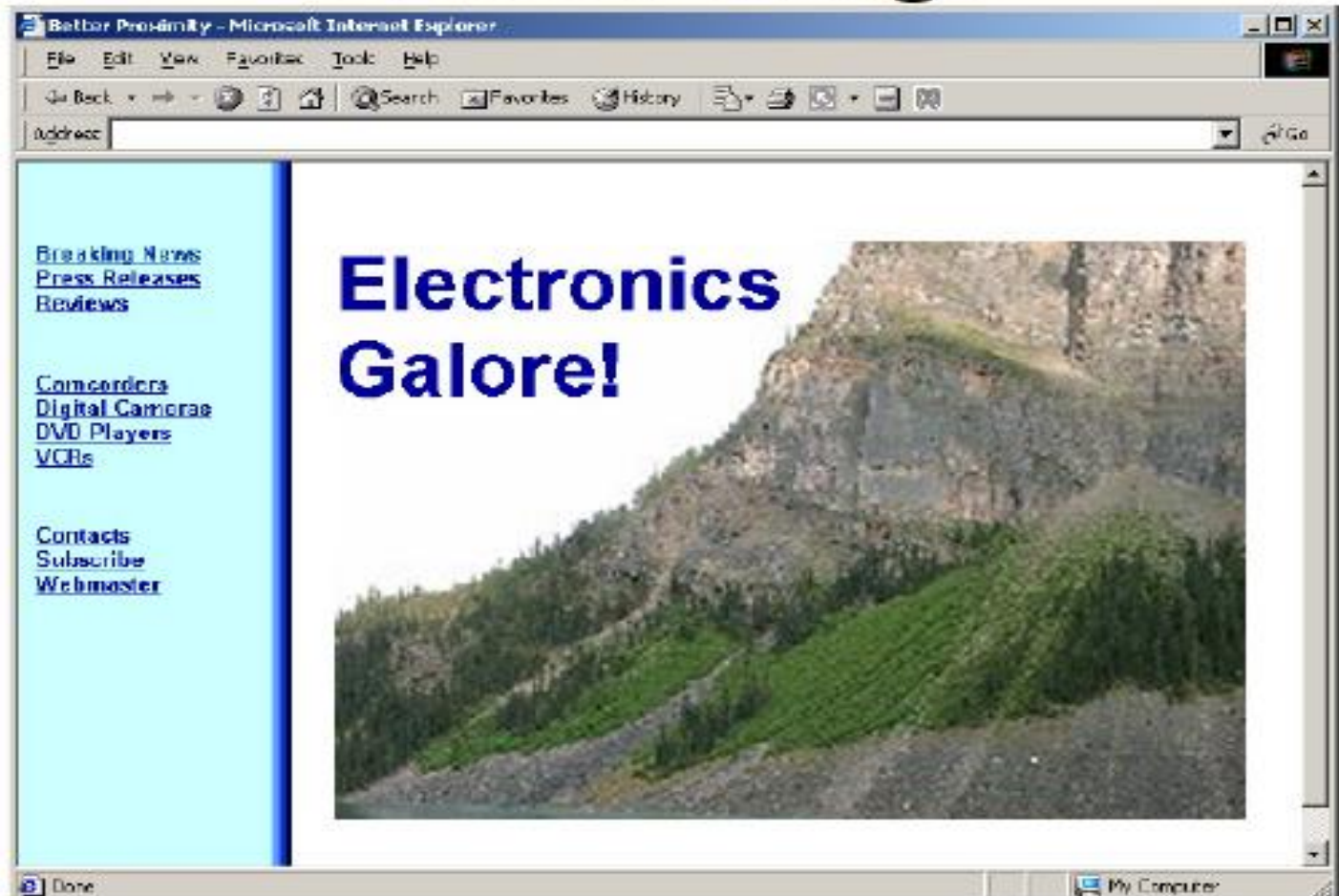– Closure: we perceive shapes that are not (completely) there
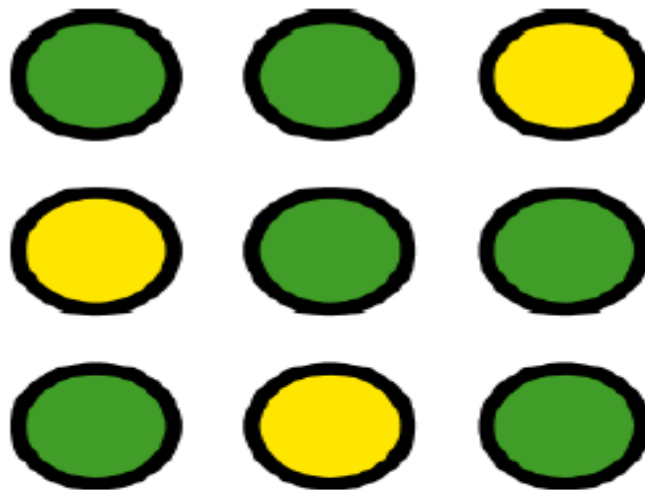
Proximity
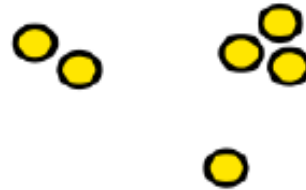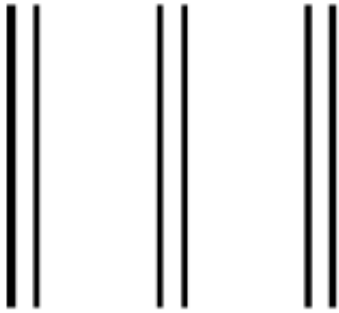
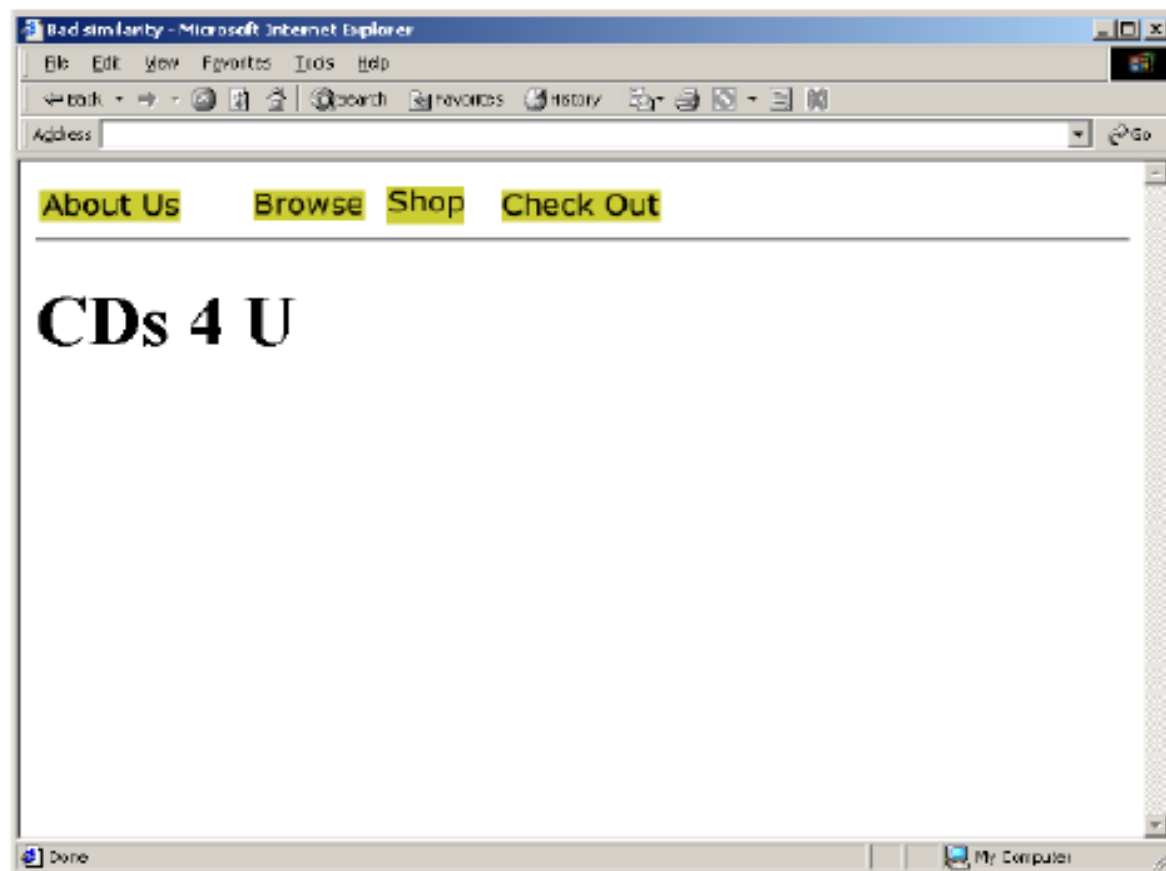# Example: a page that can be improved . .

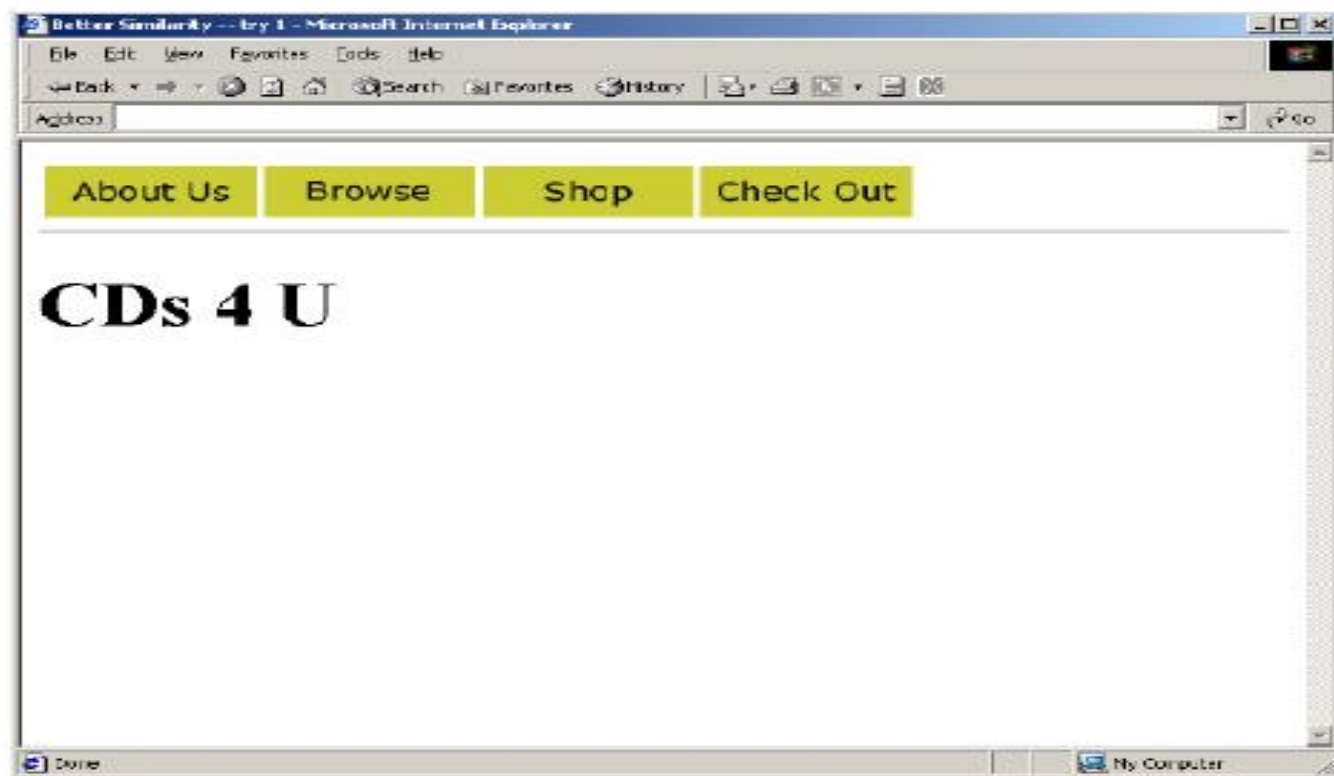# By using proximity to group related things

Similarity

Example: can you use similarity to improve this page?

Sure: make the buttons the same size:

Symmetry: we use our experience and expectations to make groups of things
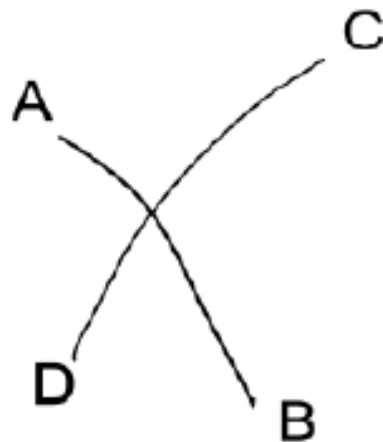
We see two triangles.

[ ][ ][ ]

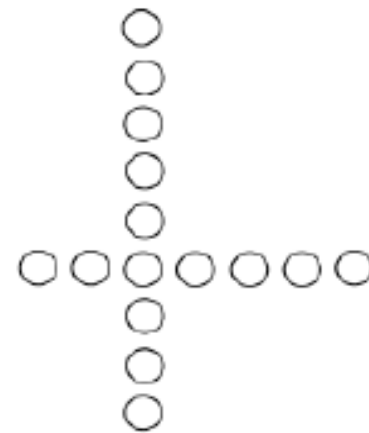We see three groups of paired square brackets.

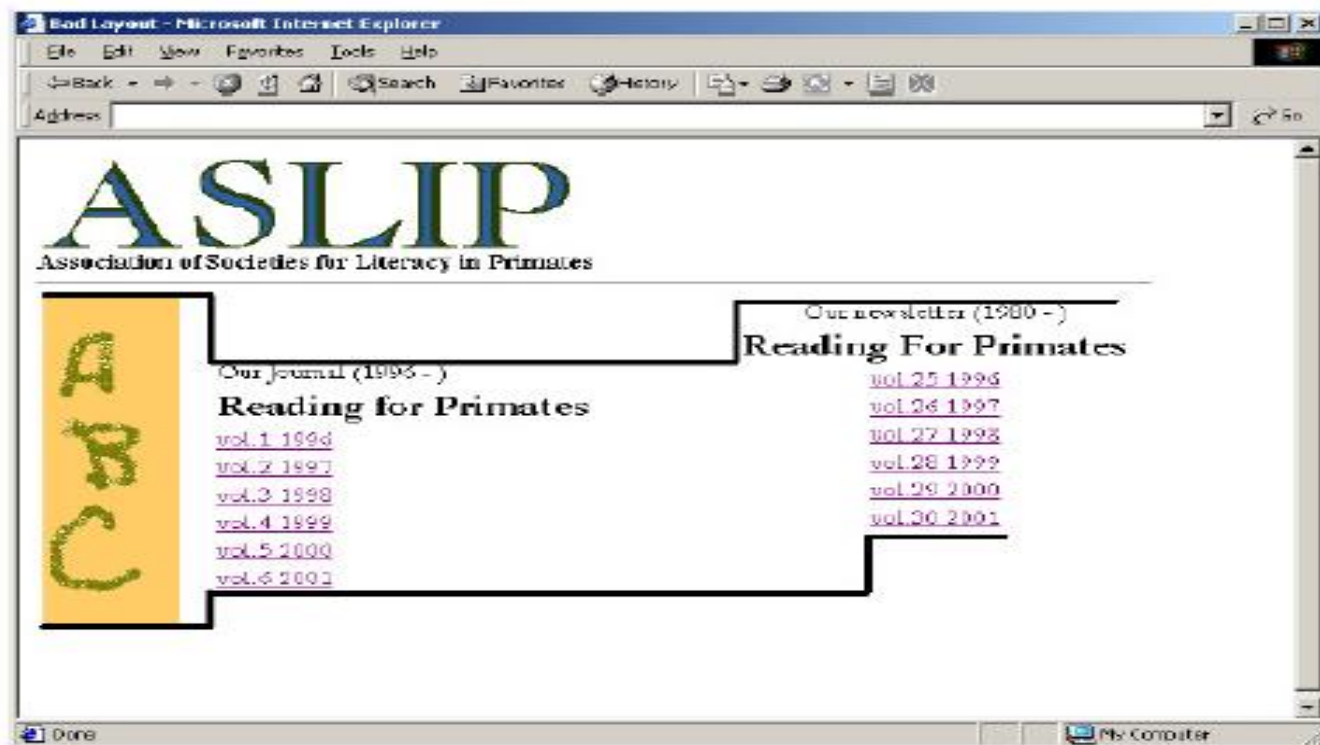# Continuity: flow, or alignment

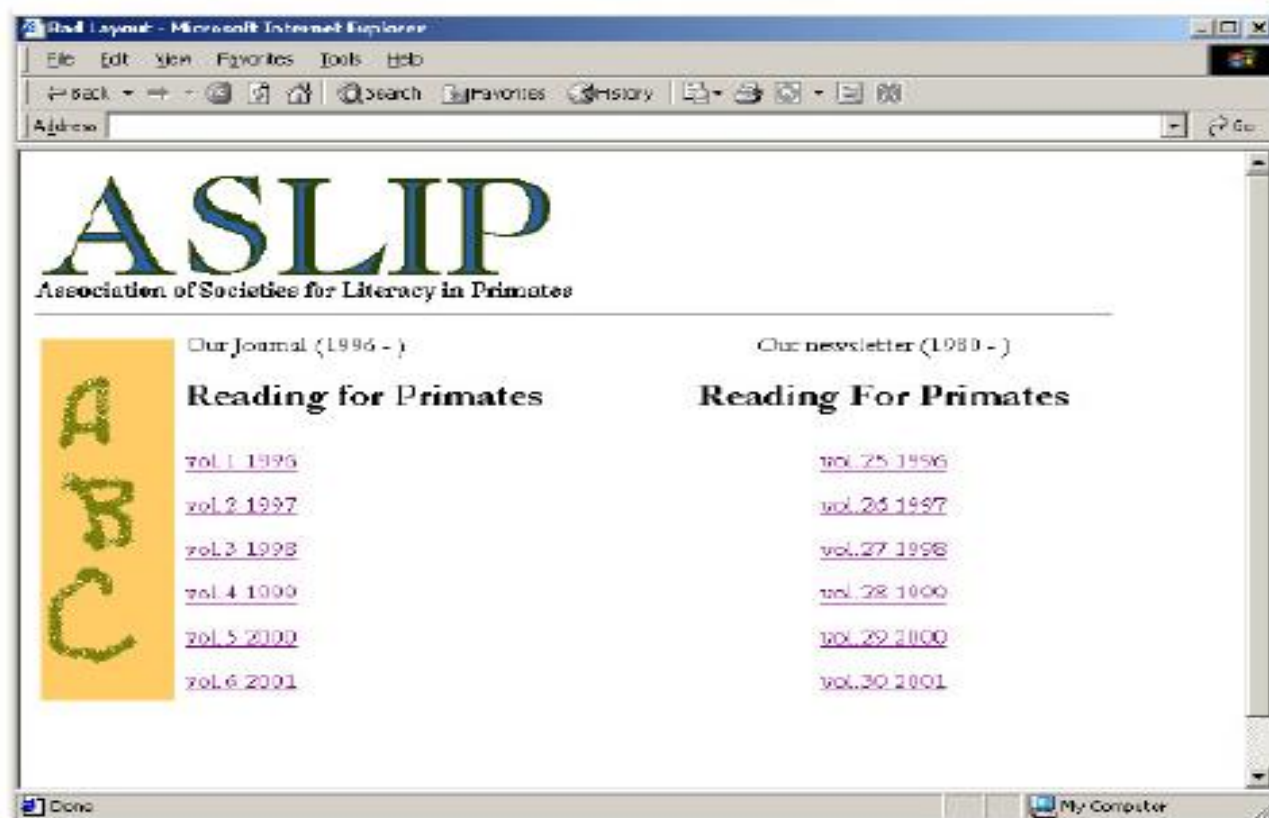We see curves AB and CD, not AC and DB, and not AD and BC

We see two rows of circles, not two L-shaped groups
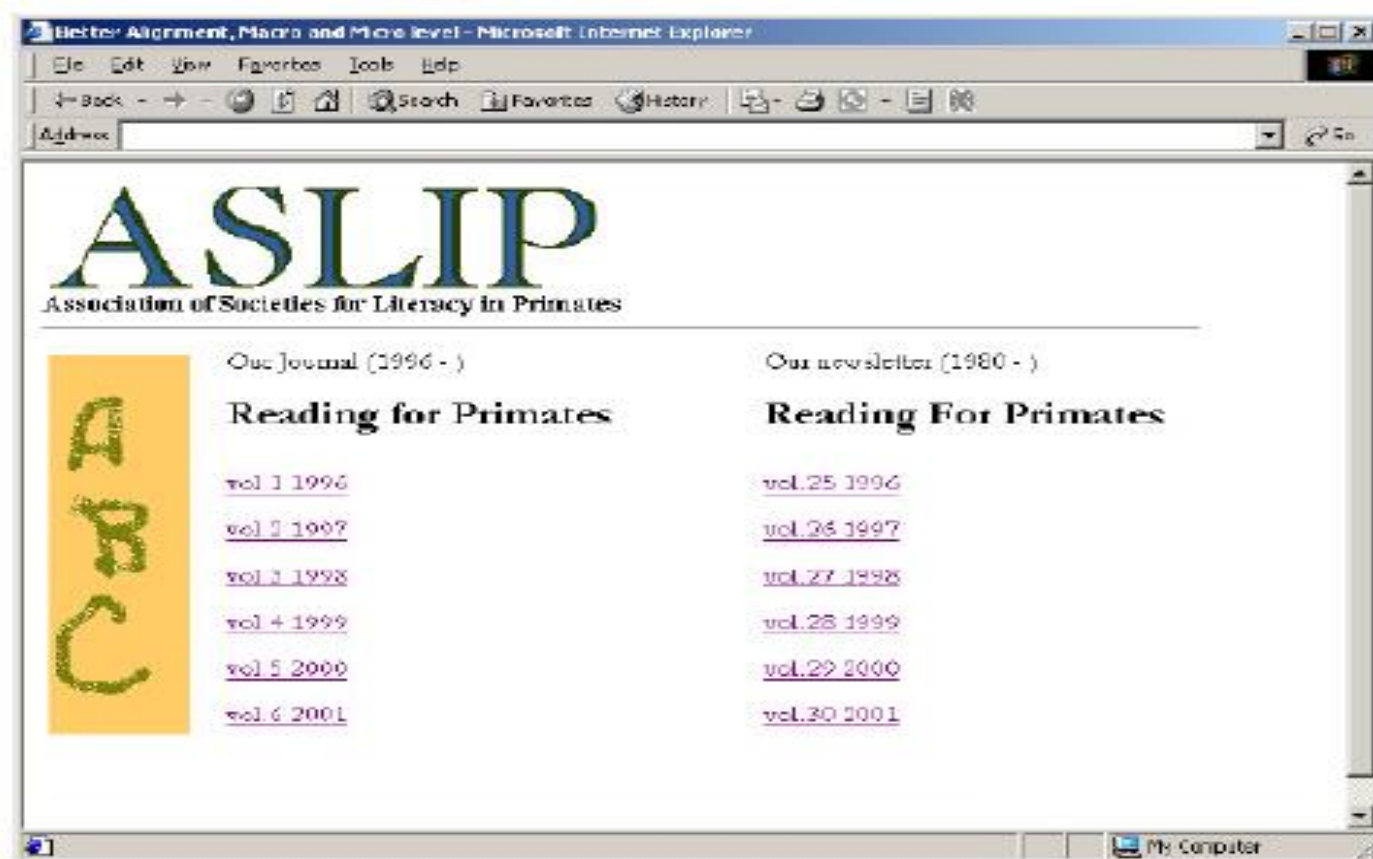
Can you use alignment (one form of continuity) to improve this page?

Sure: the lines on the previous slide show how to use horizontal alignment

But why stop? Left-align both columns to get vertical alignment also

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

Webmaster Russian Athletics Go Shockers Degree Options Newsletter	Curriculum Emergency (EMS) Statistics Award Documents Language Center Future Shockers	Student Life Accountancy McKnight Center Council of Women Commute Small Business	Dance Gerontology Marketing College Bylaws Why Wichita? Tickets
Geology Manufacturing Management UCATS Alumni News Saso	Intercollegiate Bowling Wichita Gateway Transfer Day Job Openings Live Radio	Thinker & Movers Alumni Foundations Corbin Center Jardine Hall Hugo Wall School	Career Services Doers & Shockers Core Values Grace Wilkie Hall Strategic Plan Medical Tech
Educational Map Physical Plant Graphic Design Non Credit Class Media Relations Advertising	Beta Alpha Psi Liberal Arts Counseling Biological Science Duerksen Fine Art EMT Program	Staff Aerospace Choral Dept. Alberg Hall French Spanish	Softball, Men's McKinley Hall Email Dental Hygiene Tenure Personnel Policies
English Graduate Complex Music Education Advising Center Medical School Levitt Arena	Religion Art Composition Physics Entrepreneurship Koch Arena Roster	Parents Wrestling Philosophy Wichita Lyceum Fairmount Center Women's Museum	Instrumental Nursing Opera Sports History Athletic Dept. Health Plan

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 process
  - Makes it hard to find information

- Do you agree?

Activity: Which is the easiest to read and why?

What is the time?

What is the time?

What is the time?

What is the time?

What is the time?

Design implications

- Icons should enable users to *distinguish* their meaning readily
- Bordering and spacing are effective visual ways of grouping information
- Sounds should be audible and distinguishable
- Research proper color contrast techniques when designing an interface:
  - Yellow on black or blue is fine
  - Yellow on green or white is a no-no
- Haptic feedback should be used judiciously

Cognitive processes

- Attention

- Perception

- Memory

- Learning

- Reading, speaking and listening

- Problem-solving, planning, reasoning and decision-making

Memory

- Involves recalling various kinds of knowledge that allow people to act appropriately
    - For example, recognizing someone's face or remembering someone's name
- First encode and then retrieve knowledge
- We don't remember everything−it involves filtering and processing what is attended to
- Context is important as to how we remember (that is, where, when, how, and so on)
- We recognize things much better than being able to recall things
- We remember less about objects that we have photographed than when we observe them with the naked eye (Henkel, 2014)

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
  - For example, 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 building, 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 books you read

- Which was easiest? Why?

- People are very good at remembering visual cues about things
  - For instance, the color of items, the location of objects and marks on an object

- They find it more difficult to learn and remember arbitrary material
  - For example, birthdays and phone numbers

Recognition versus recall

- **Command-based interfaces** require users to recall from memory a name from a possible set of 100s of names

- **Graphical interfaces** provide visually-based options (menus, icons) that users need only browse through until they recognize one

- Web browsers provide tabs and history lists of visited URLs that support recognition memory

The problem with the classic '7,+ or − 2'

- George Miller's (1956) theory of how much information people can remember

- People's immediate memory capacity is very limited to 7, + or − 2

- Has been applied in interaction design when considering how many options to display

- But is it a good use of a theory in HCI?

- Is it helpful?

When creating an interface, should the designer…

- 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?

- Not necessarily…

The reason is…

- People can scan lists of bullets, tabs, and menu items for the one they want

- They don't have to recall them from memory, having only briefly heard or seen them

- So you can have more than nine at the interface
  - For instance, history lists of websites visited

- Sometimes a small number of items is good
  - For example, smart watch displays

- Depends on task and available screen estate

Personal Information management

Is a growing problem for many users:

- They accumulate a vast numbers of documents, images, music files, video clips, emails, attachments, bookmarks, and so forth
- 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 you have 10,000s
- How might such a process be facilitated taking into account people's memory abilities?

Personal Information management

- Bergman and Whittaker, three interdependent processes model (2016) to help people manage their stuff:

    I.   How to decide what stuff to keep
    II. How to organize it when storing
    III. Which strategies to use to retrieve it later

- Most common approach is to use folders and naming

- Strong preference for scanning across and within folders when looking for something

- Search engines only helpful if you know the name of the file

- Smart search engines help with listing relevant files for partial name or when type in first letter

Memory aids

- SenseCam, developed by Microsoft Research Labs (now Autographer)
  - 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, especially those suffering from dementia

- Other aids include RemArc, which triggers long-term memory using old BBC materials

SenseCam

Design implications

- Reduce cognitive load by avoiding long and complicated procedures for carrying out tasks

- Design interfaces that encourage recognition rather than recall

- Provide users with various ways of labelling digital information to help them easily identify it again

  - For example, folders, categories, color, flagging, and time stamping

Learning

- Involves the accumulation of skills and knowledge involving memory
- Two main types:
    - Incidental learning (for example, recognizing people's faces, what you did today)
    - Intentional learning (for instance, studying for an exam, learning to cook)
    - Intentional learning is much harder!
    - Many technologies have been developed to help (for example, multimedia, animations, VR)

- People find it hard to learn by following instructions in a manual
- People prefer to learn by doing

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

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

- Voice user interfaces allow users to interact with them by asking questions
  - For example, Google Voice, Siri, and Alexa

- Speech-output systems use artificially-generated speech
  - For instance, written text-to-speech systems for the visually impaired

- Natural-language systems enable users to type in questions and give text-based responses
  - Such as, chatbots

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

Problem-solving, planning, reasoning, and decision-making

- All these processes involve *reflective* cognition
  - For example, 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
  - Such as maps, books, pen and paper
- May involve working through different scenarios and deciding which is best option

Design implications

- Provide information and help pages that are easy to access for people who wish to understand more about how to carry out an activity more effectively (for example, web searching)

- Use simple and memorable functions to support rapid decision-making and planning
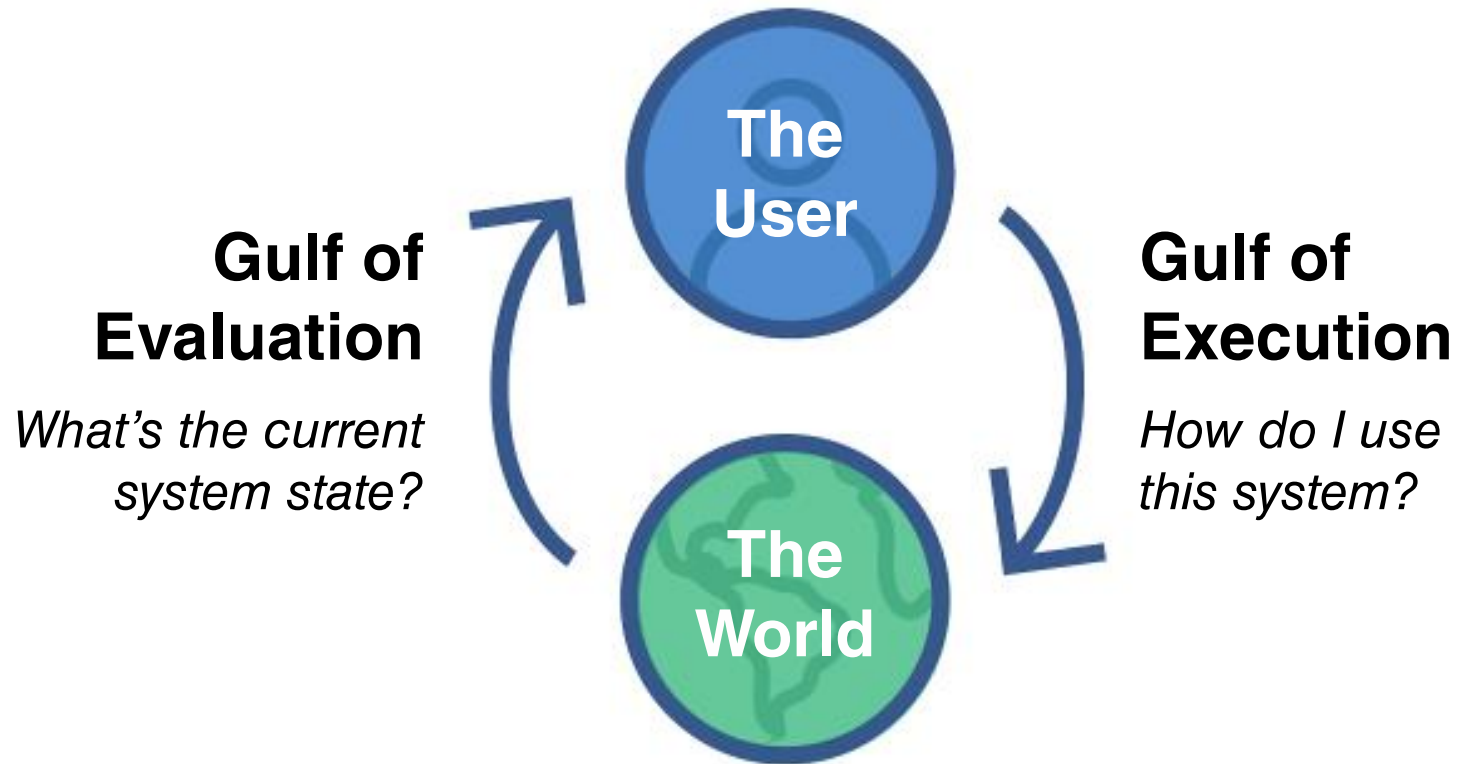
Cognitive frameworks

- These are used to explain and predict user behavior at the interface
    - Based on theories of behavior
    - Focus is on mental processes that take place
    - Also use of artifacts and representations
- Most well known are:
    - Mental models
    - Gulfs of execution and evaluation
    - Distributed cognition
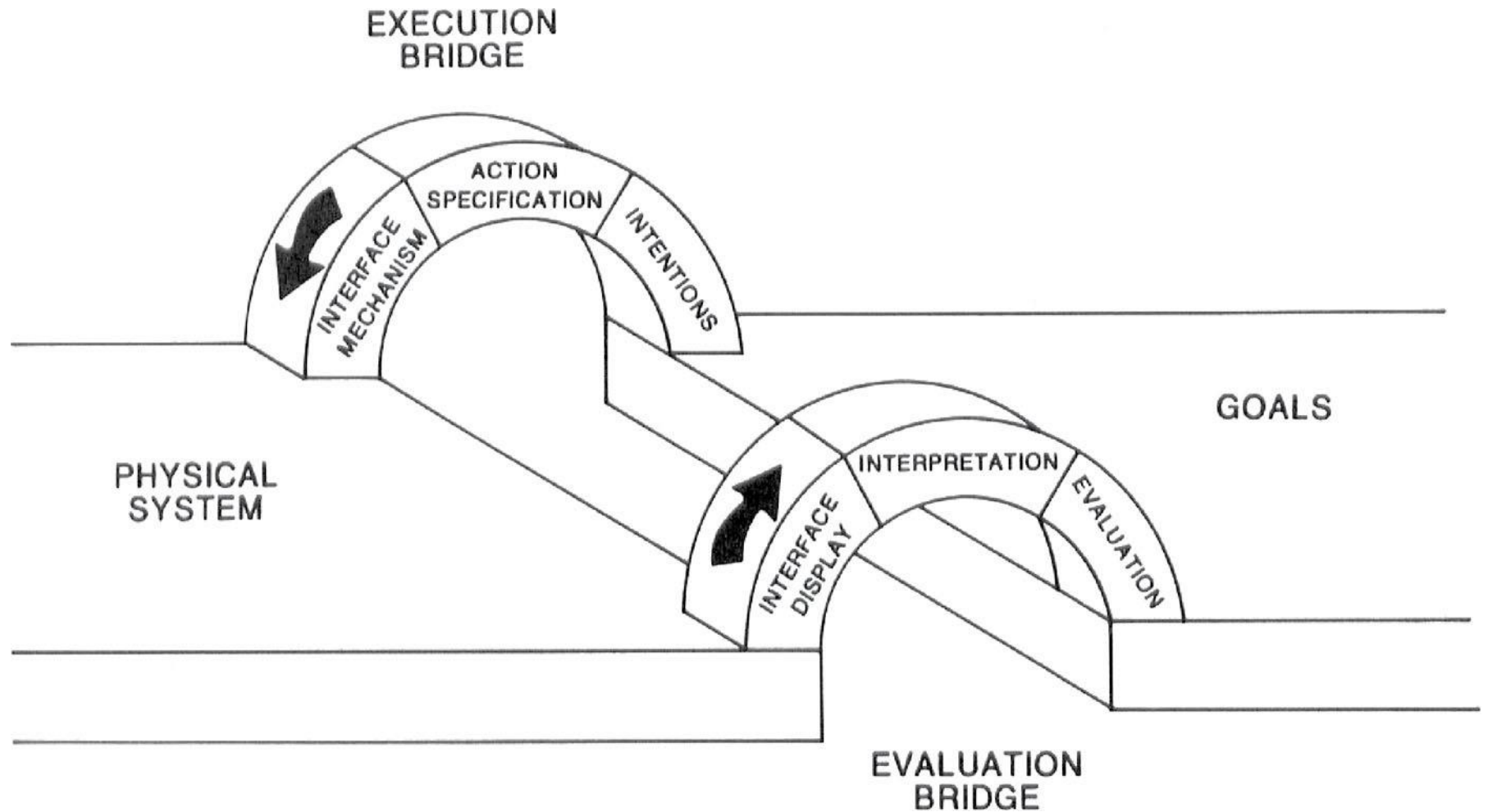   - External and embodied cognition

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

- Can reveal whether interface increases or decreases cognitive load and whether it is obvious what to do next (Norman, 1986; Hutchins et al, 1986)

Bridging the gulfs

Gulf of Evaluation

What's the current system state?

The User

The World

Gulf of Execution

How do I use this system?

Bridging the gulfs

EXECUTION BRIDGE

ACTION SPECIFICATION

INTENTIONS

INTERFACE MECHANISM

PHYSICAL SYSTEM

GOALS

INTERPRETATION

EVALUATION

INTERFACE DISPLAY

EVALUATION BRIDGE

Information processing

- Conceptualizes human performance in metaphorical terms of information processing stages
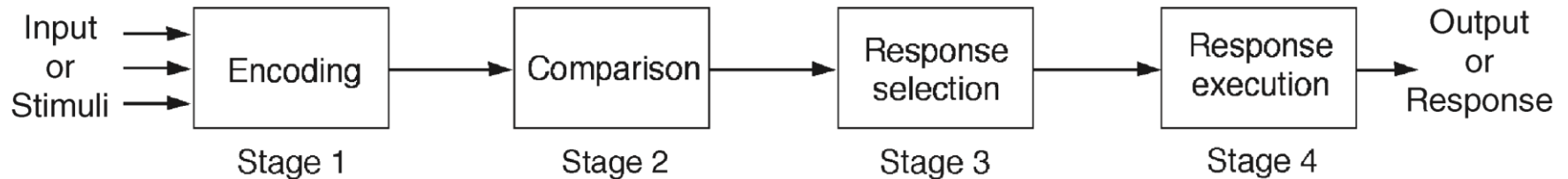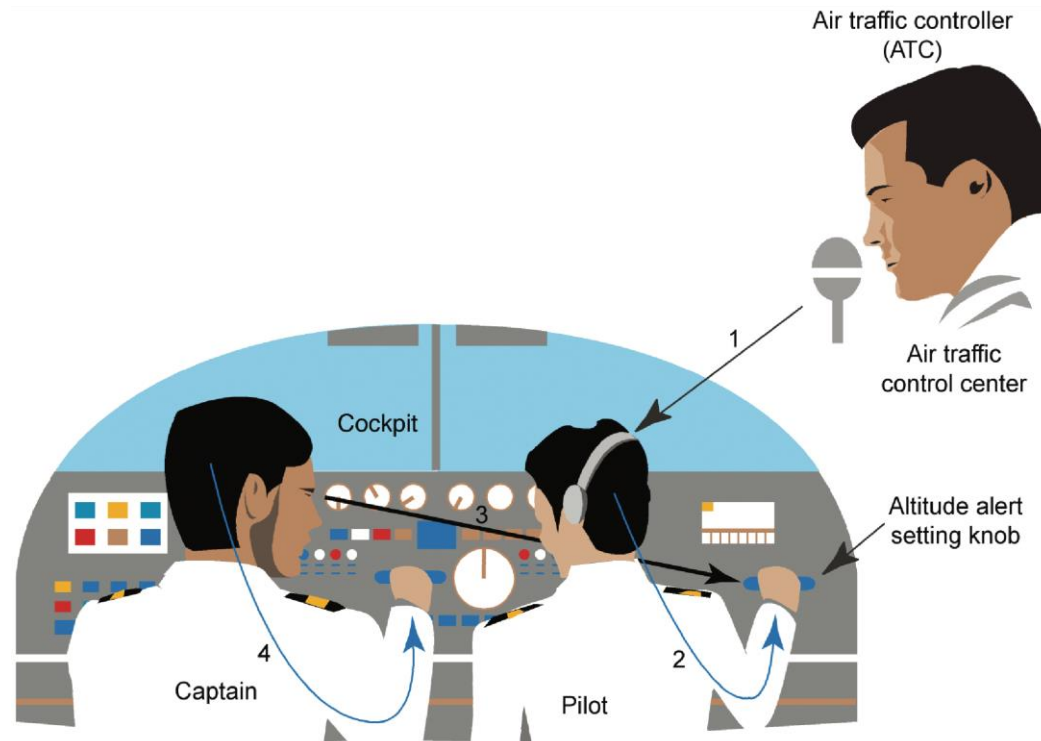
Limitations

- 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

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)

A cognitive system for ATC

Air traffic controller (ATC)

Air traffic control center

Cockpit

Altitude alert setting knob

Captain

Pilot

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 (for example, rules and procedures)

- The communication that takes place as the collaborative activity progresses

- How knowledge is shared and accessed

External cognition

- Concerned with explaining how we interact with external representations (such as maps, notes, and diagrams)

- What are the cognitive benefits and what processes involved

- How they extend cognition

- What technologies can we develop to help people carry out complex tasks (for example, learning, problem solving, and decision-making)?

Design implication

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

  - For example, information visualizations have been designed to allow people to make sense and rapid decisions about masses of data

Summary

- Cognition involves many 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