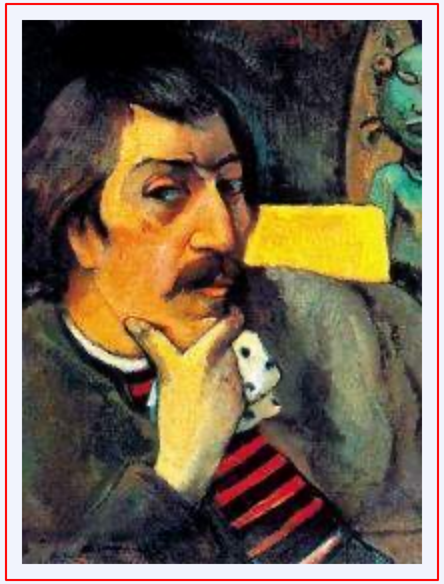

Welcome
Gestalts Principles

Theoretical Foundations in HCI
Gestalts Principles

Abbas Moallem, Ph.D.

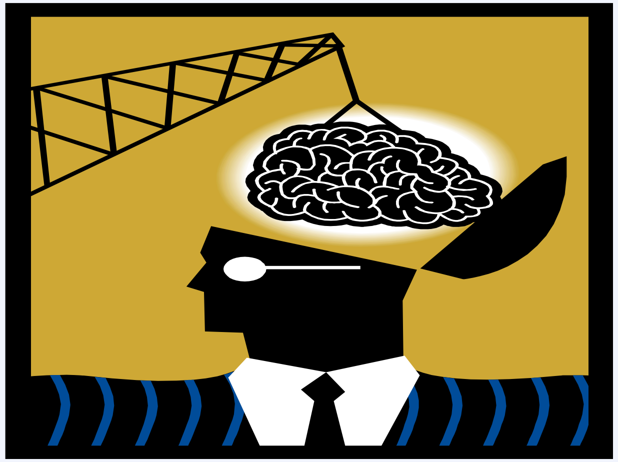
Overview

- Constructivist Theories
- Gestalt Laws of Perceptual Grouping



Mental Models

- **Users do not always think the way we expect them to**
  - **People interpret the world based on their knowledge and past experiences**
  - **The designer's job is to bridge the gap between users' mental models and the implementation model**



Mental Model

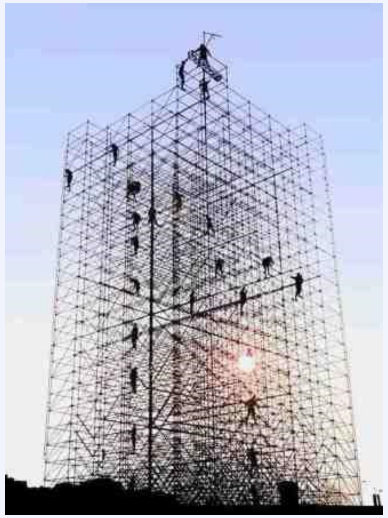
- Mismatch of Designers' Intention and the users' Mental Model at the Level of Task Delegation.
- Problem in Redesign of Task Semantic and Functionality.
- Issues Regarding Syntax Level of a Newly Designed Dialogue.
- Design Question at the Representational Level.

Constructivist Theories

- Perception involves the intervention of representations and memories.
- What we see is not a replica or copy of the world such as the image that a camera would produce.
- Instead, the visual system constructs a model of the world by transforming, enhancing, distorting and discarding information.

Constructivism

- An epistemology or a philosophical framework
- Theory of learning
  - Argues humans construct meaning from current knowledge structures.
  - These arguments about the nature of human learning guide constructivist learning theories and teaching methods of education.



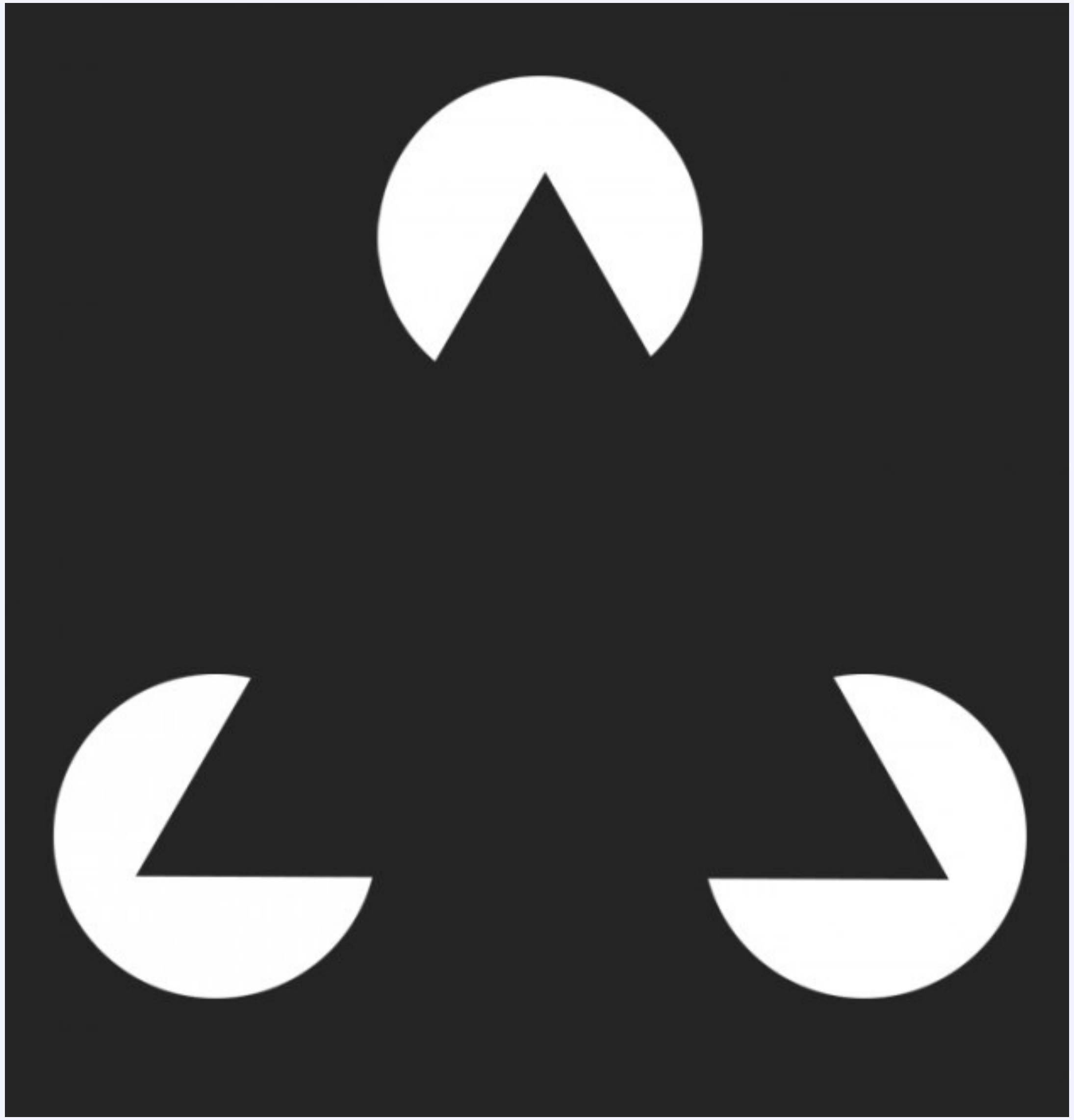
Effect of Construction

Provides us with a more constant view of the world than if we were merely to "see" the images that impinge on our retina.

Gestalt Principles

- The ability to interpret the meaning of scenes and objects based on innate laws of organization, or Gestalt principles, such as

What do you see when you look at this image?



The Gestalt Laws of Perceptual Grouping

Objects in a scene appear to group pre-attentively according to certain laws or principles, including:

- **Figure and Ground: Segment our visual world into Figure and Ground**
- **Proximity: Perceiving a whole as organized into subsets or groupings, which in turn are organized into parts**
- **Closure: Completing missing parts of a figure**
- **Similarity: Perceiving elements of same shape or color as belonging together**
- **Good Continuation: Objects that define smooth lines or curves**
- **Symmetry: Objects that form symmetrical patterns**

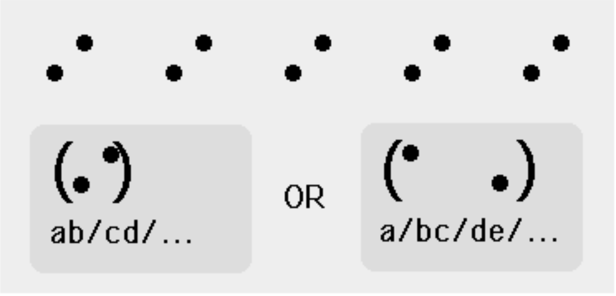
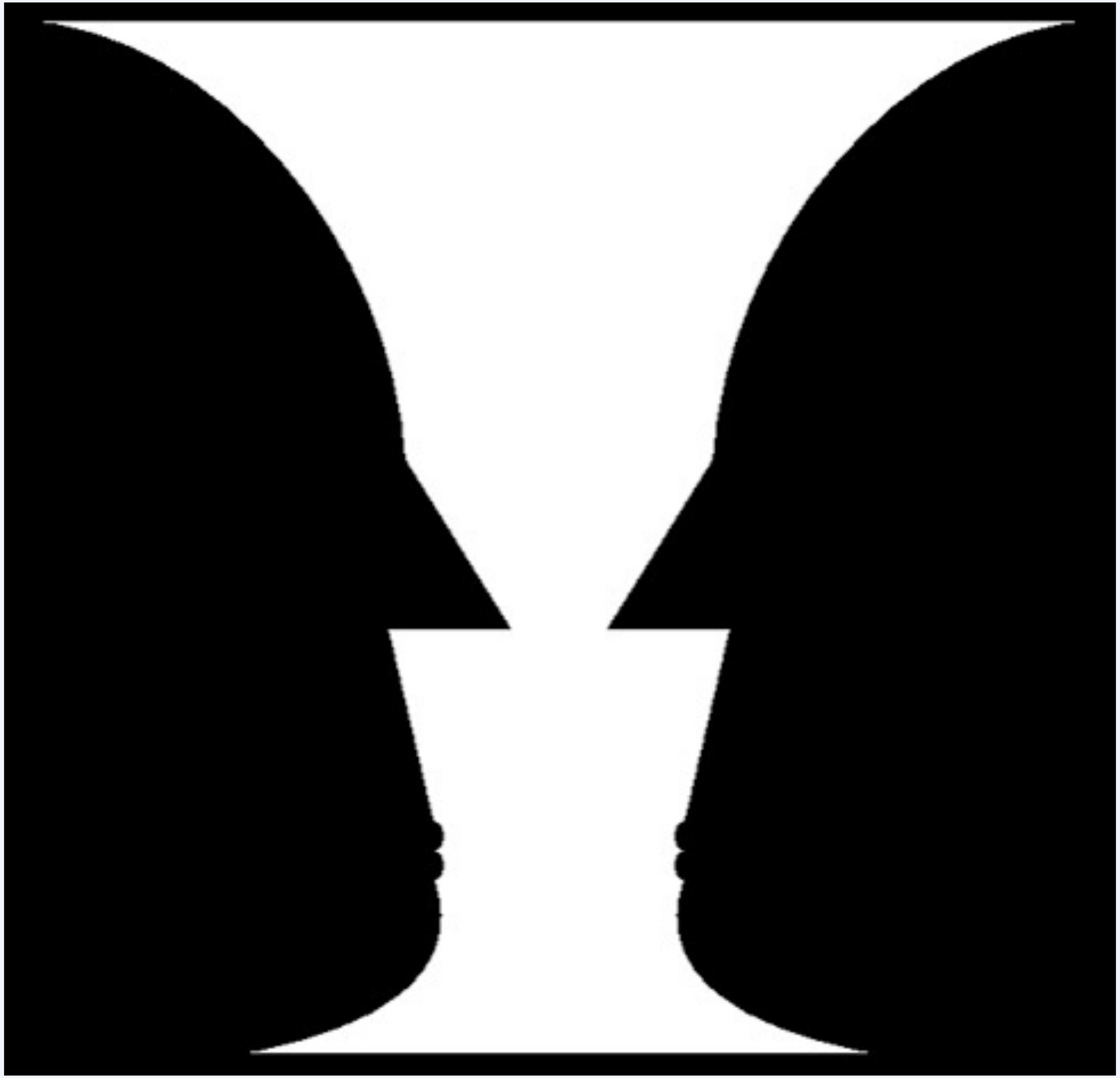


Figure-Ground Perception

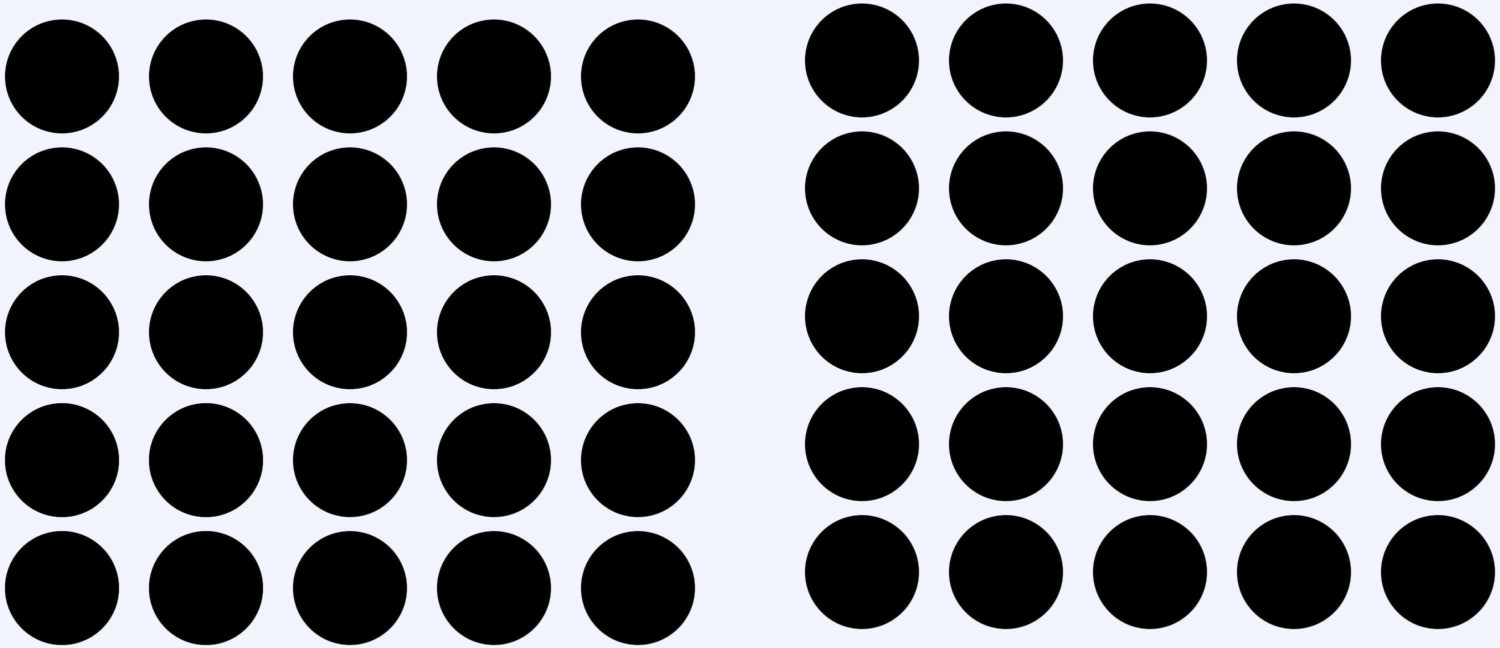


https://courses.lumenlearning.com/wsu-sandbox/chapter/gestalt-principles-of-perception/#Figure_05_06_FacesVase

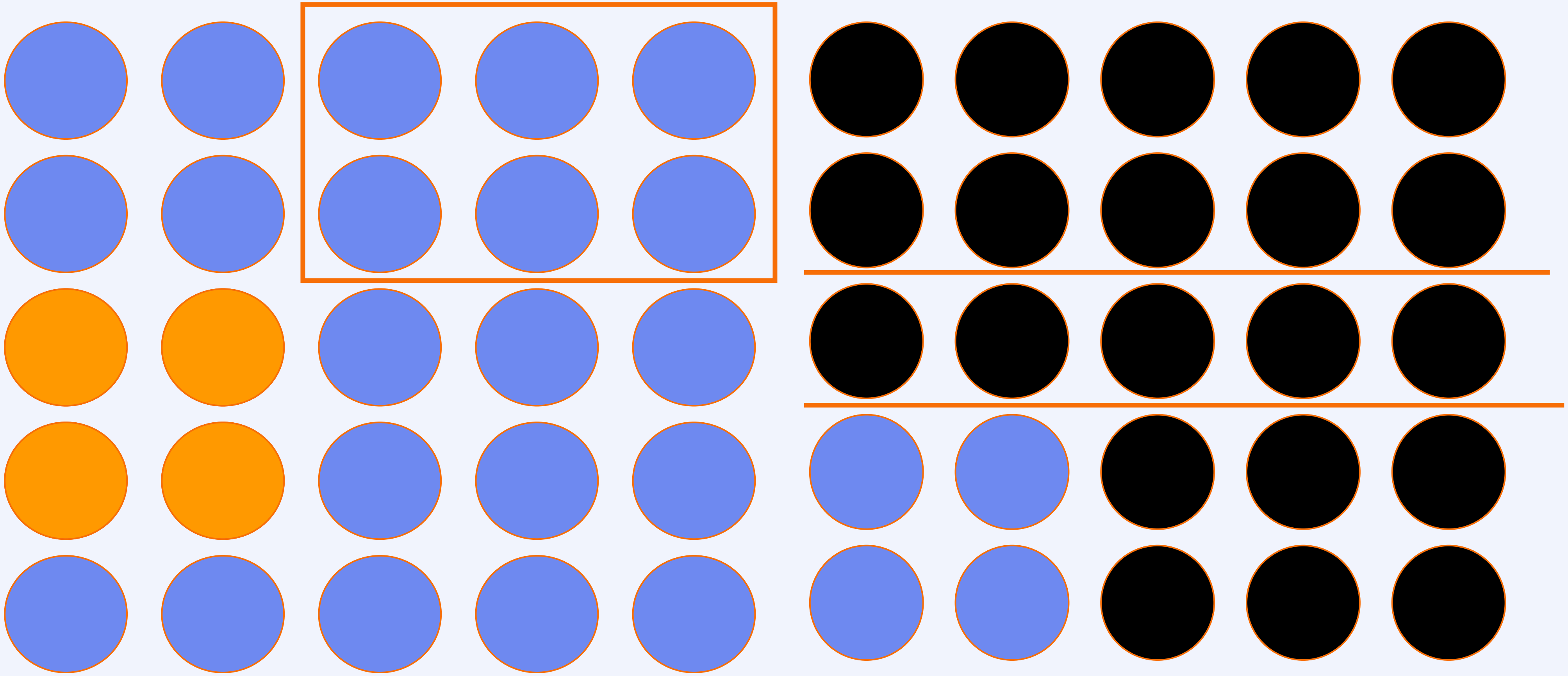
Figure-Ground Perception

Figure-Ground Perception

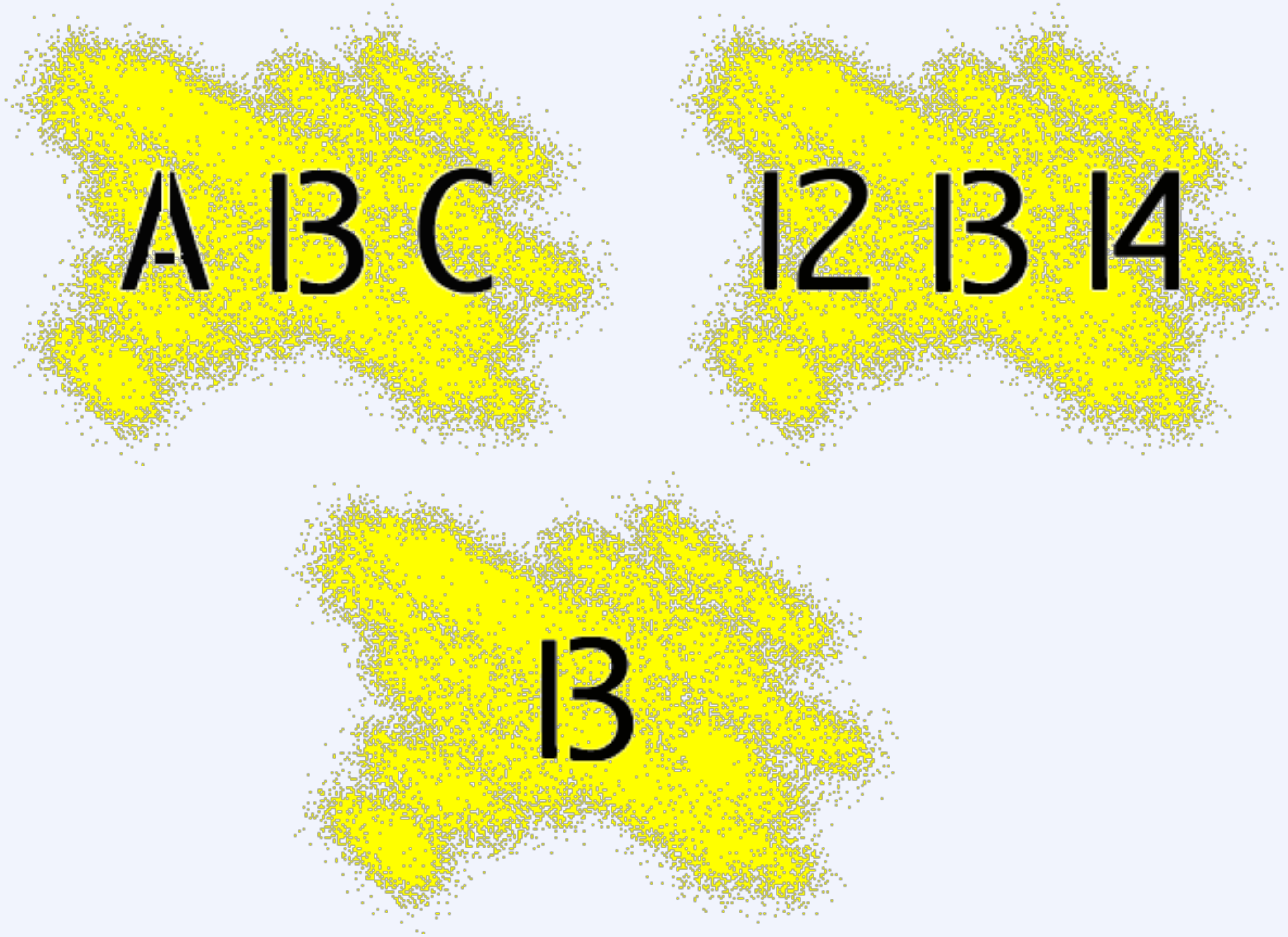
Gestalt Principles



Gestalt Principles



Example

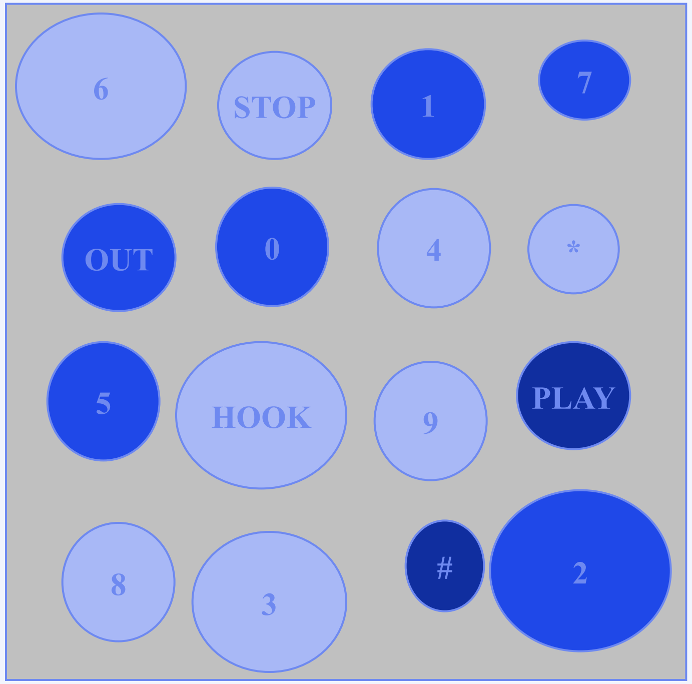


Exercise

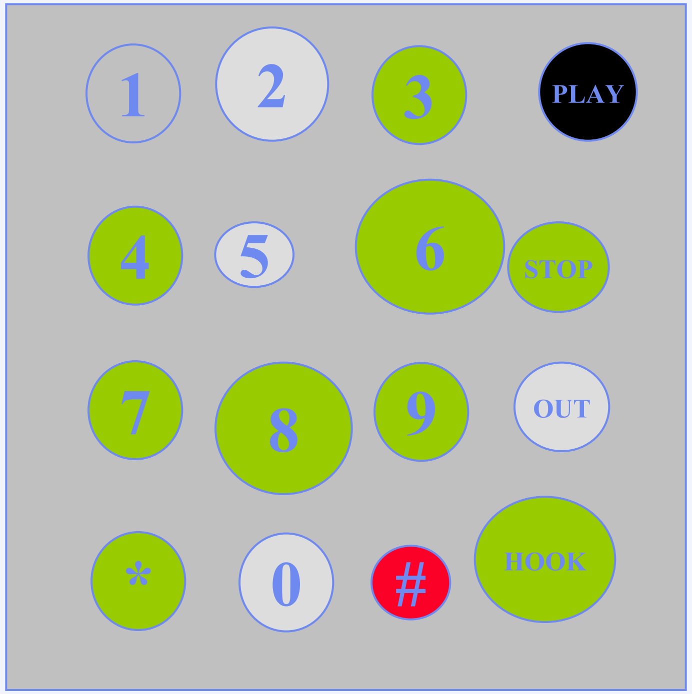
What do you notice about the middle letter of each word?

The effect of context on perception. The same stimulus is perceived as being an H in one word and A in the other

Grouping



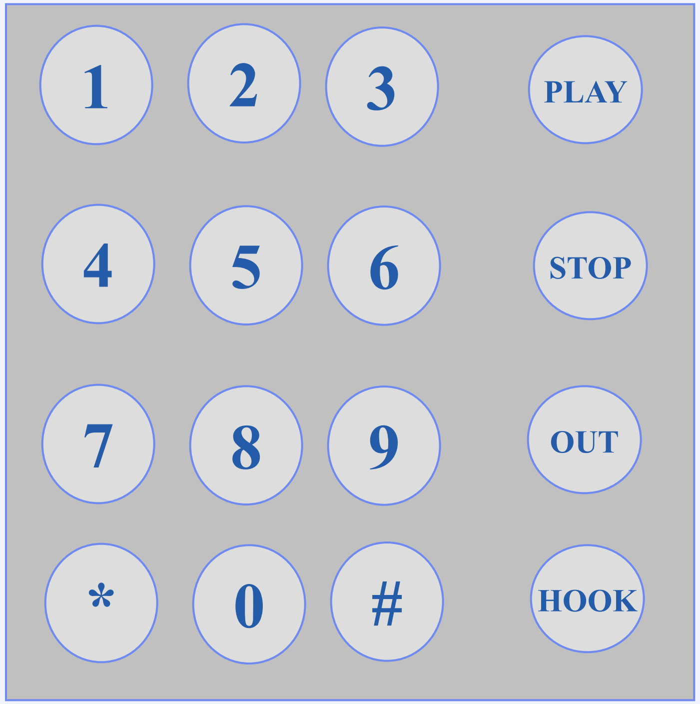
A



B

Adapted from Del Coates, 2003, Watches Tell More than Time

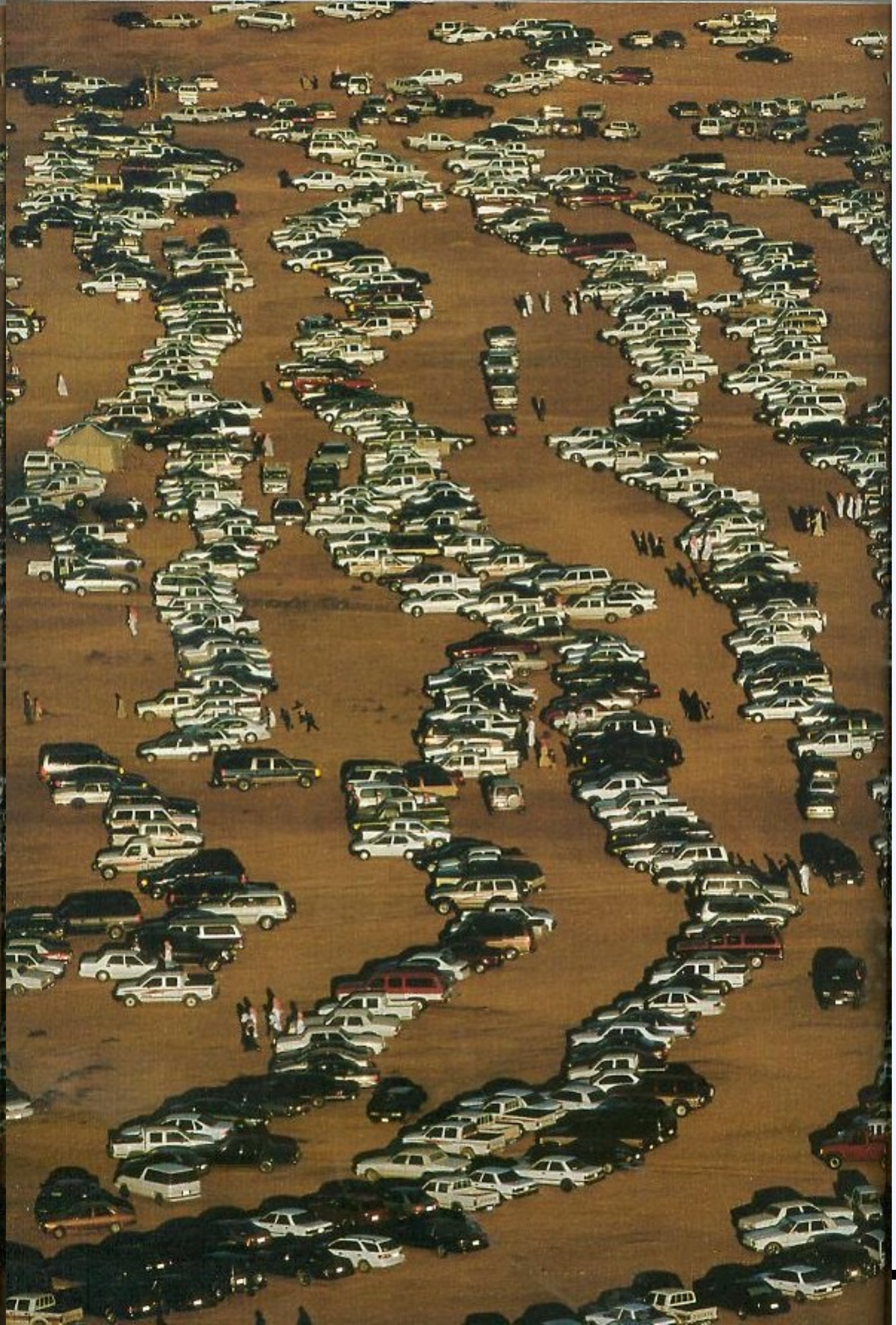
Grouping



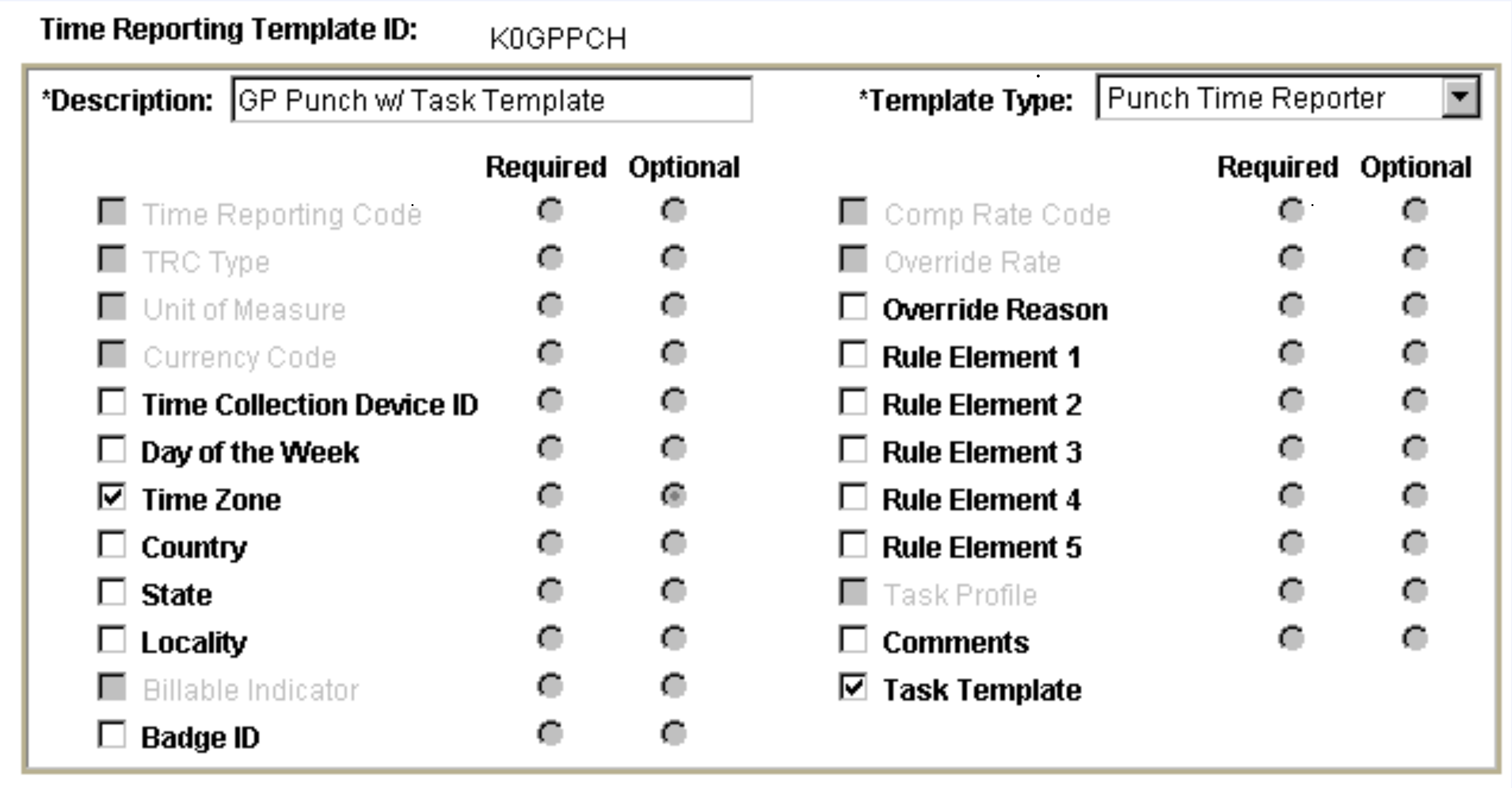
C

D

Adapted from Del Coates, 2003, Watches Tell More than Time

Example



Time Reporting Template ID: K0GPPCH

***Description:** GP Punch w/ Task Template

***Template Type:** Punch Time Reporter

	Required	Optional
☐ Time Reporting Code	○	○
☐ TRC Type	○	○
☐ Unit of Measure	○	○
☐ Currency Code	○	○
☐ Time Collection Device ID	○	○
☐ Day of the Week	○	○
☑ Time Zone	○	●
☐ Country	○	○
☐ State	○	○
☐ Locality	○	○
☐ Billable Indicator	○	○
☐ Badge ID	○	○

	Required	Optional
☐ Comp Rate Code	○	○
☐ Override Rate	○	○
☐ Override Reason	○	○
☐ Rule Element 1	○	○
☐ Rule Element 2	○	○
☐ Rule Element 3	○	○
☐ Rule Element 4	○	○
☐ Rule Element 5	○	○
☐ Task Profile	○	○
☐ Comments	○	○
☑ Task Template		

Example

Licenses and Certificates

Change License or Certificate

Simon Schumacher

*License or Certificate: Certificate Public Accountant

Issue Date: 12/01/1991 (example: 01/31/2000)

Expiration Date: 12/31/1994

Licence Number:

Issued By:

Country: USA

State: CA

☑ Renewal in Progress

☑ License Verified

Save

Return to Licenses and Certificates

* denotes required field

Example

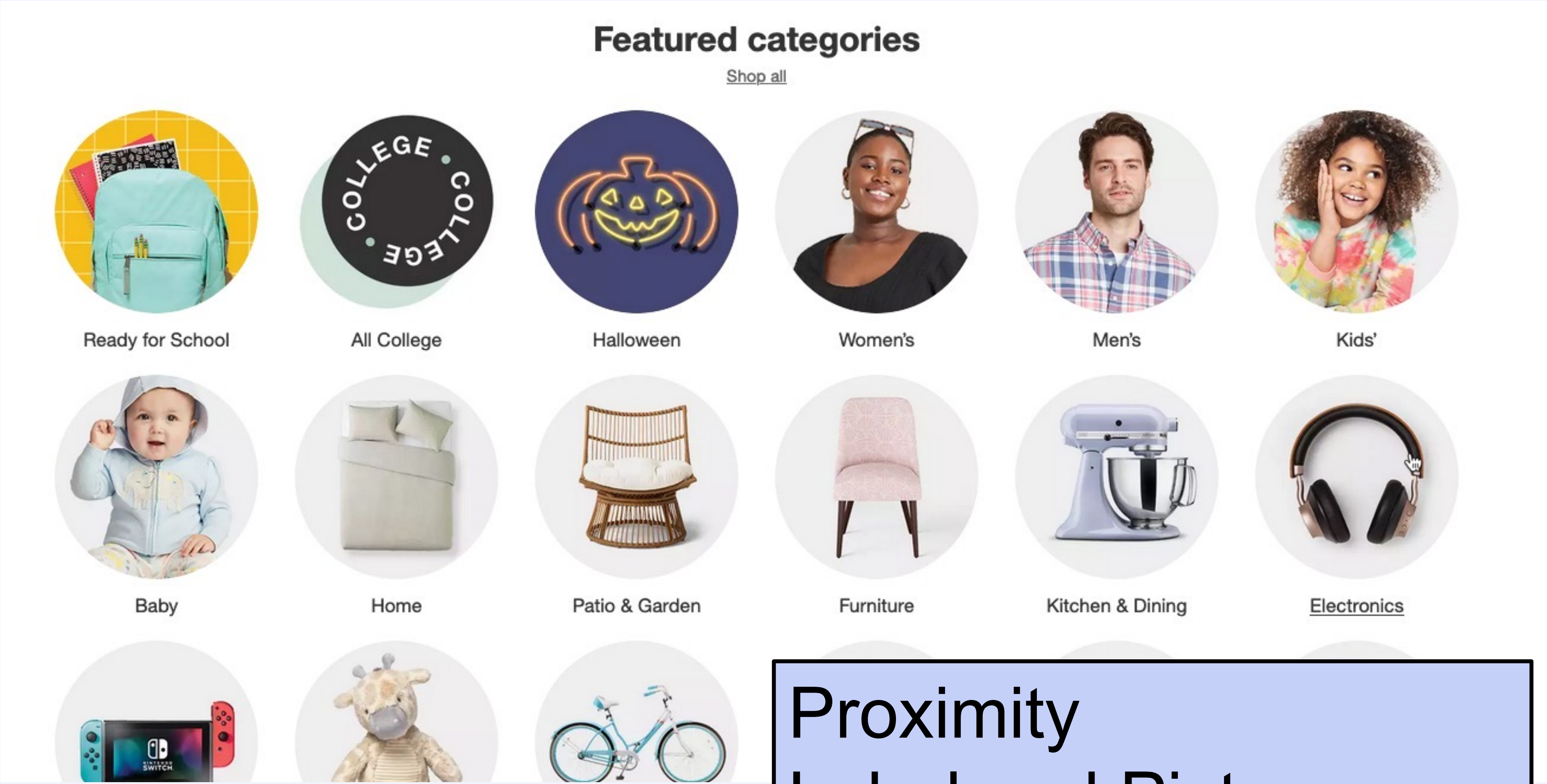
Pennsylvania
Bedford Motel/Hotel: Crinaline Courts
(814) 623-9511 S: $18 D: $20
Bedford Motel/Hotel: Holiday Inn
(814) 623-9006 S: $29 D: $36
Bedford Motel/Hotel: Midway
(814) 623-8107 S: $21 D: $26
Bedford Motel/Hotel: Penn Manor
(814) 623-8177 S: $19 D: $25
Bedford Motel/Hotel: Quality Inn
(814) 623-5189 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

Example

South Carolina

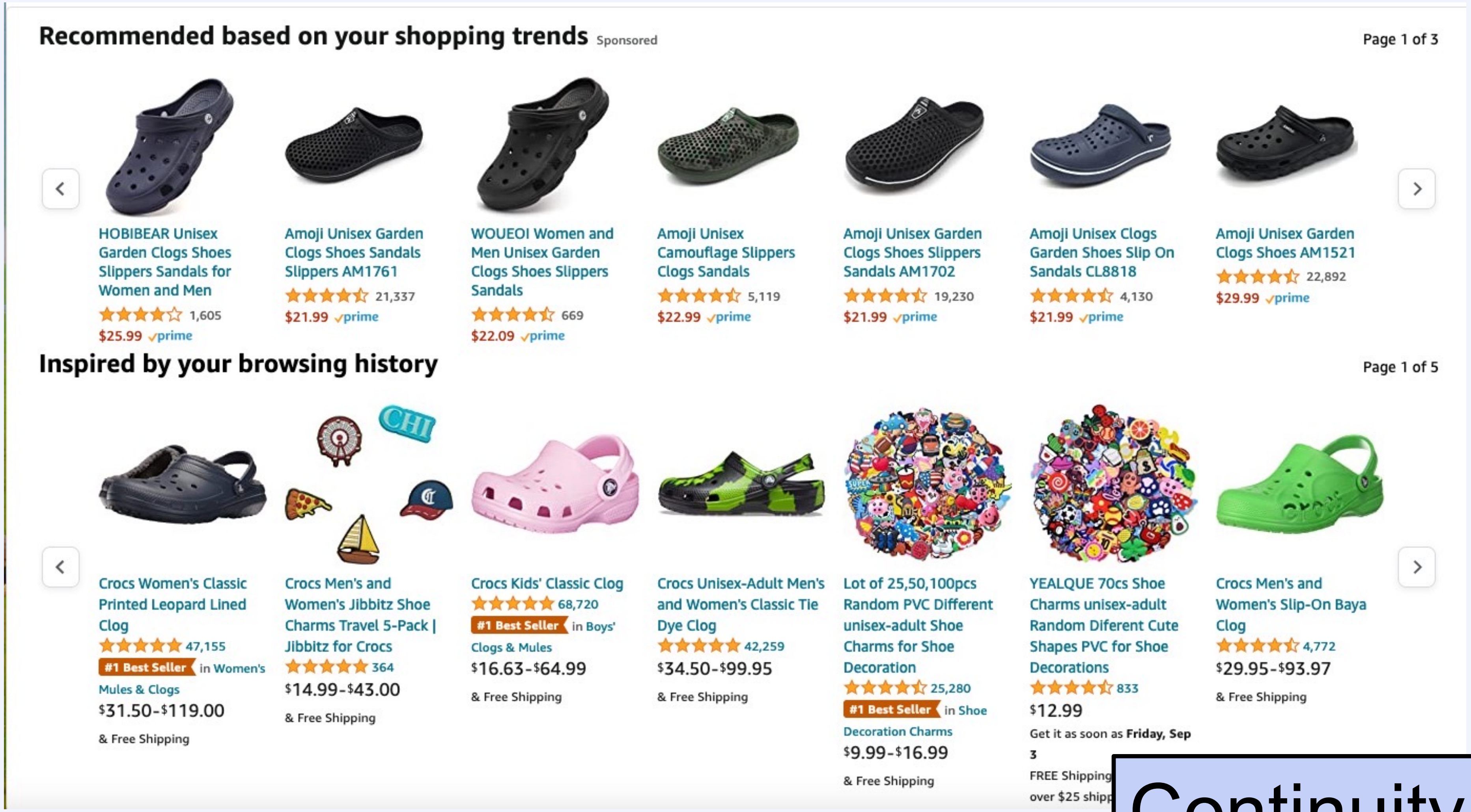
City	Motel/Hotel	Area code	Phone	Rates Single	Rates Double
Charleston	Best Western	803	747-0961	$26	$30
Charleston	Days Inn	803	881-1000	$18	$24
Charleston	Holiday Inn N	803	744-1621	$36	$46
Charleston	Holiday Inn SW	803	556-7100	$33	$47
Charleston	Howard Johnsons	803	524-4148	$31	$36
Charleston	Ramada 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

Which Law is applied to this screen?



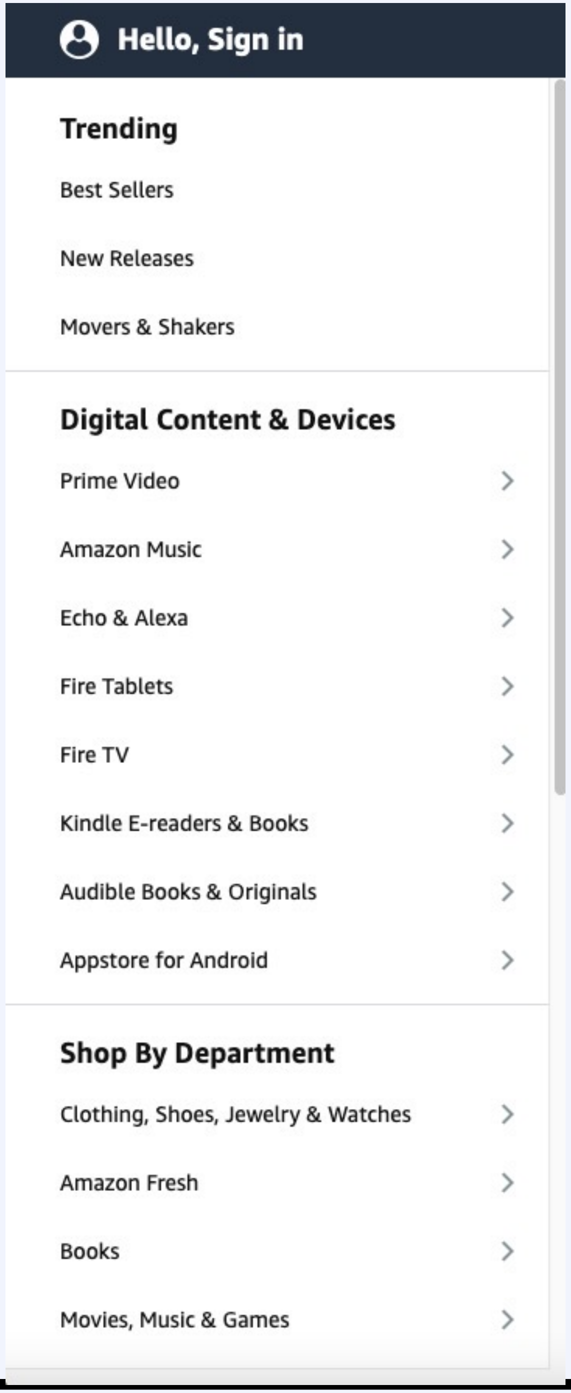
Proximity
Label and Picture

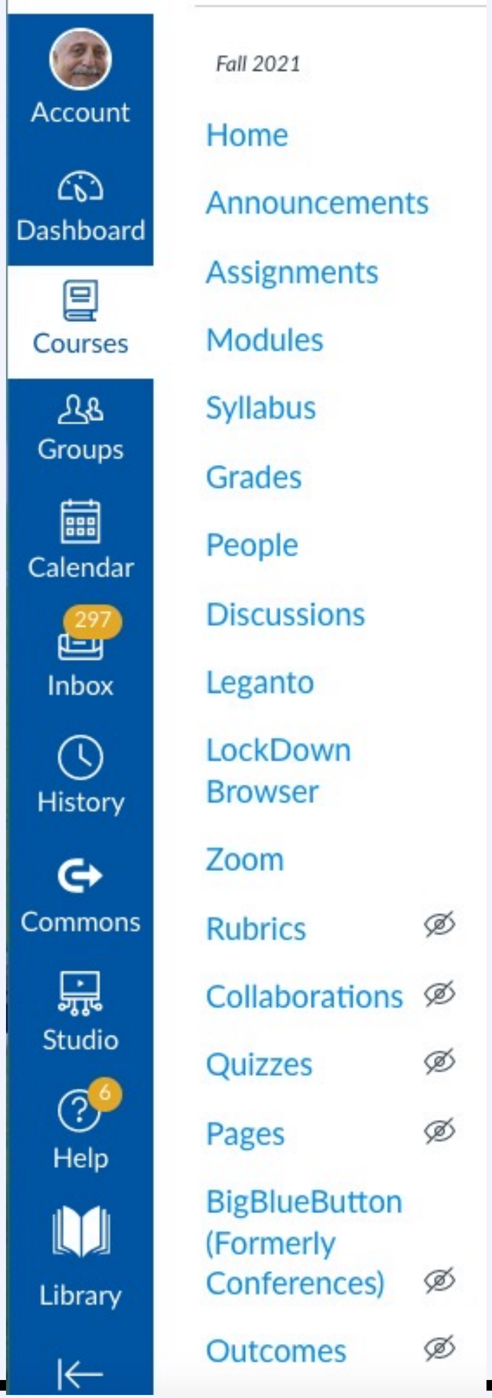
Which Law is applied to this screen?



Continuity

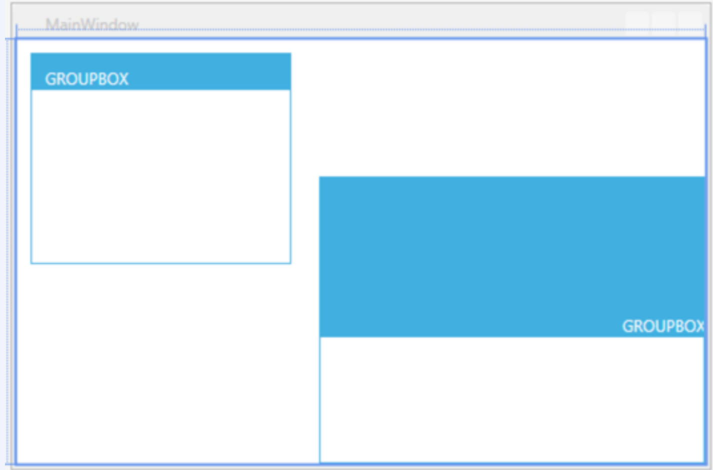
Grouping


Hello, Sign in
Trending
Best Sellers
New Releases
Movers & Shakers
Digital Content & Devices
Prime Video
Amazon Music
Echo & Alexa
Fire Tablets
Fire TV
Kindle E-readers & Books
Audible Books & Originals
Appstore for Android
Shop By Department
Clothing, Shoes, Jewelry & Watches
Amazon Fresh
Books
Movies, Music & Games

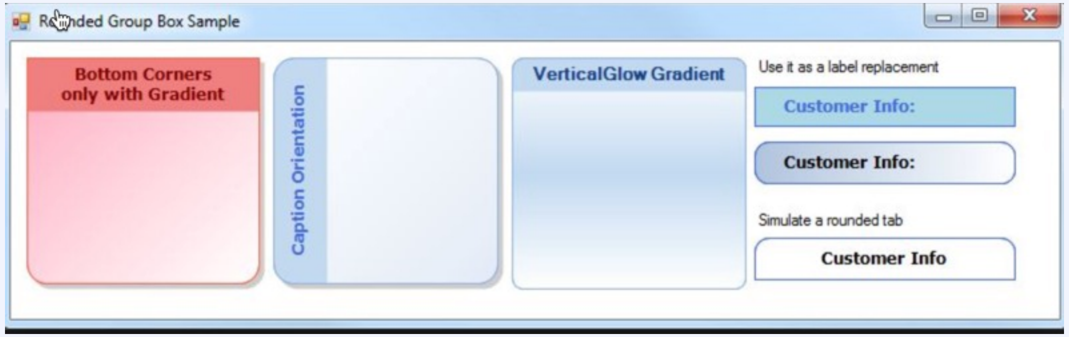

Account
Dashboard
Courses
Groups
Calendar
297
Inbox
History
Commons
Studio
6
Help
Library
Fall 2021
Home
Announcements
Assignments
Modules
Syllabus
Grades
People
Discussions
Leganto
LockDown Browser
Zoom
Rubrics
Collaborations
Quizzes
Pages
BigBlueButton (Formerly Conferences)
Outcomes

Questions

Summary



The Gestalt Laws of Perceptual Grouping can be used to design the layout of screens and its components




See You Next Week
Thank You For Your Participation

Welcome

- **Fundamental Principles In UI Design**

“I think; therefore I am.”

Rene Descartes

FUNDAMENTAL PRINCIPLES IN UI DESIGN

Overview

- Choice Reaction Time
- Automatic and Control Processing
- Mapping
- Affordances
- Direct Manipulation
- Constrains
- Attention
- Theory
- Models
- Framework
- Norman Model

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

MAPPING

Simon Effect

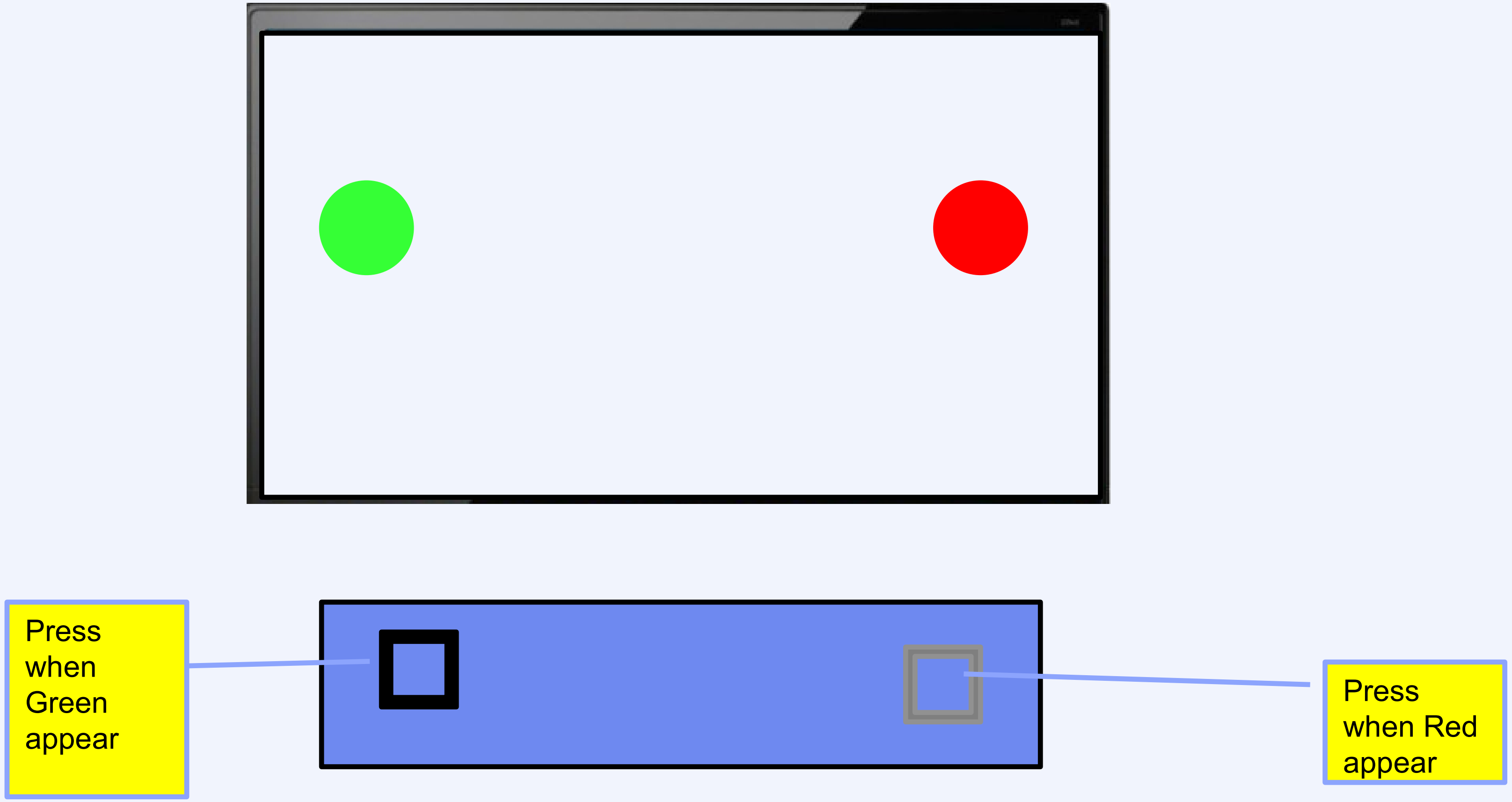
- A typical case of the Simon effect involves placing a participant in front of a computer monitor and a panel with two buttons on it, which he or she may press. The participant is told that the button on the right corresponds to red and to press the button on the right when they see something red appear on the screen. They are told that the button on the left corresponds to green and to press the button on the left button when they see something green appear on the screen. Participants are usually told to ignore the location of the stimulus and base their response on the task-relevant color.

Translation , Coding and Mapping

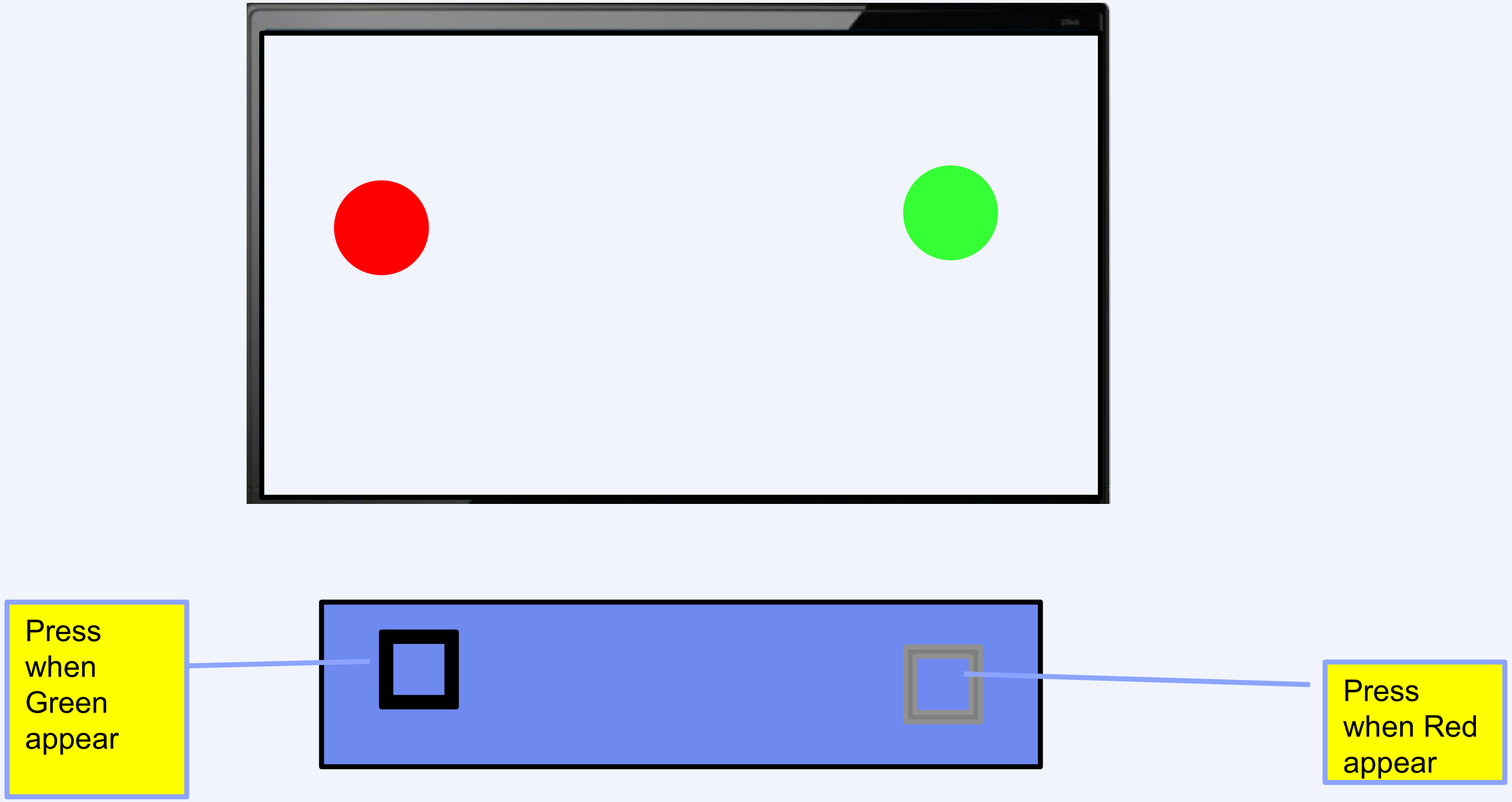
- Transcription is the seat of the human interface between perception of action.
- It has been repeatedly demonstrated that errors and choice reaction time to stimuli in a spatial array decrease when stimuli are mapped onto responses in spatially compatible manner.

- Fitts and Seeger (1953) referred to this finding as stimulus-response (S-R) compatibility and describe it to cognitive codes associated with spatial locations of elements in the stimulus and response arrays.

Simon Effect



Simon Effect



Simon Effect

- Reaction times are usually faster, and reactions are usually more accurate, when the stimulus occurs in the same relative location as the response, even if the stimulus location is irrelevant to the task.

Design Implication-Example

- Aircraft cockpits, for example, require a person to react quickly to a situation. Imagine that you are flying a plane and there is a problem with the left engine.

- In an aircraft with a good man-machine interface design (which most have), the indicator light for the left engine should be positioned physically to the left of the indicator light for the right engine.

-

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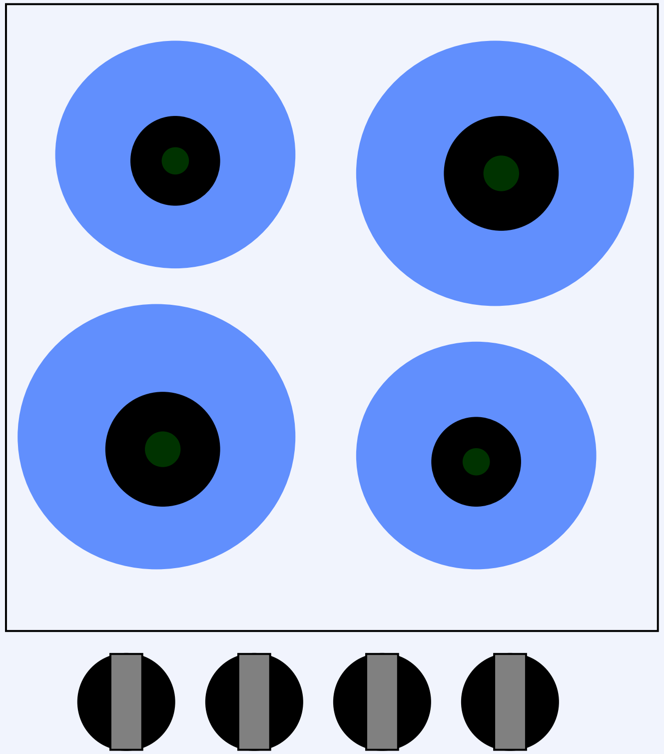
Mapping

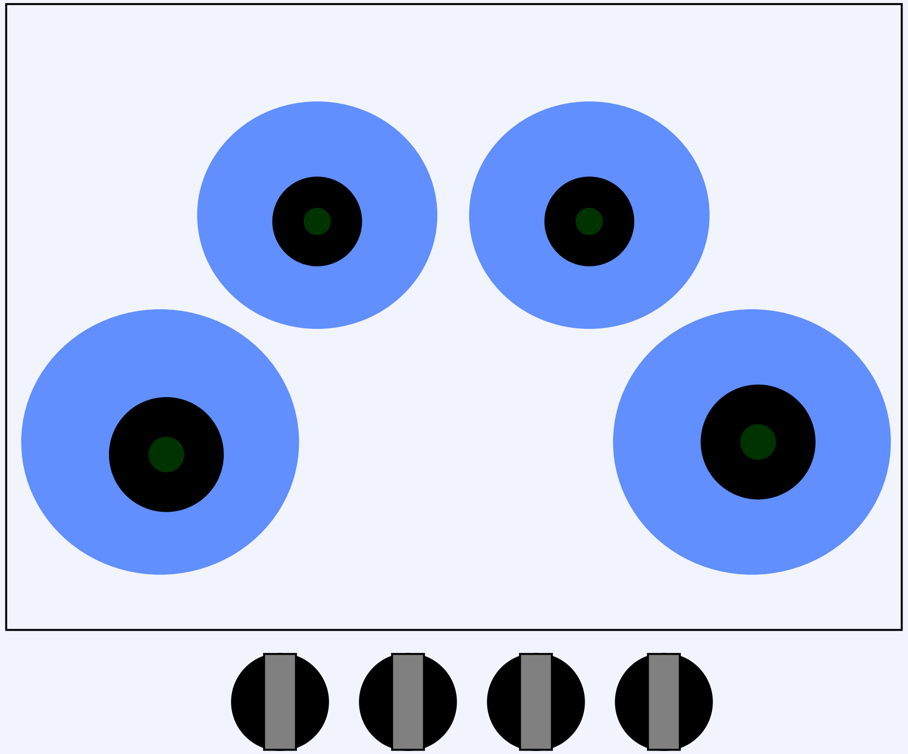
- The spatial and conceptual relation between parts of a system relate to their controls and their outcomes.
- Mapping are effective if they appear natural and intuitive to the users.
- Bad mapping occurs when the relation is inconsistent or incompatible.

Example: Mapping

Cooking rings and controls



Natural mapping for cooking rings and controls



Adapted from Norman, 1988

Mapping

Mapping

R

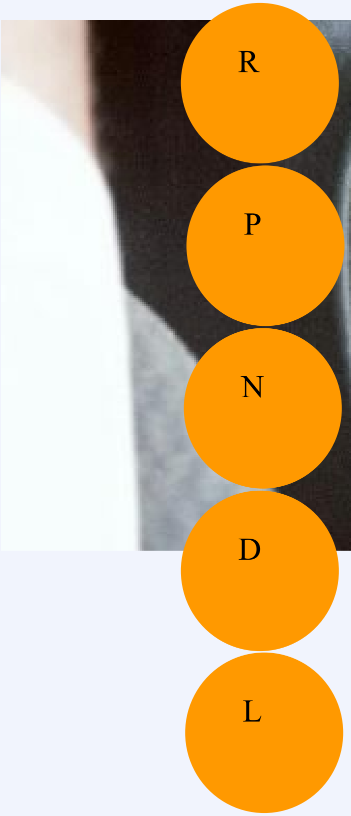
P

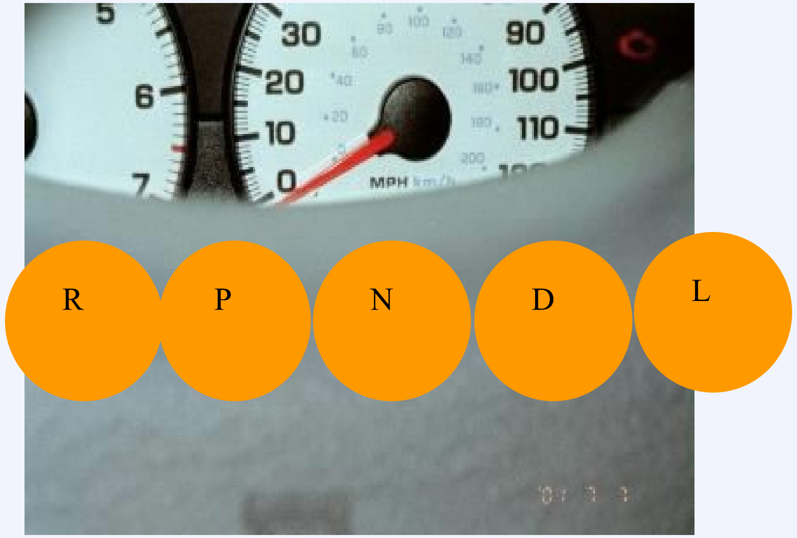
N

D

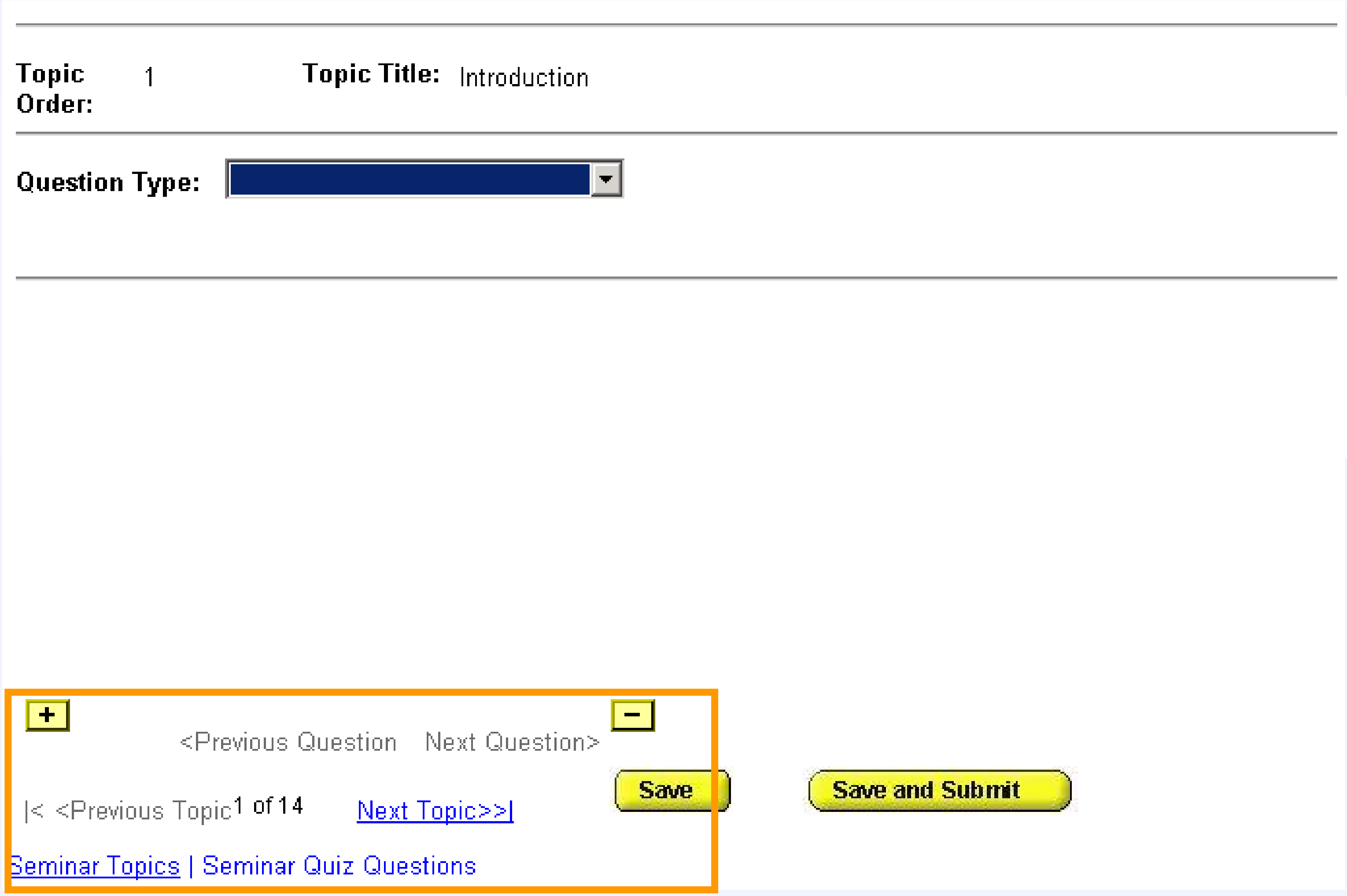
L

Mapping





Example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Topic Title: Introduction
Question Type:
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−
<Previous Question
Next Question>
|< <Previous Topic 1 of 14
Next Topic>>|
Save
Save and Submit
Seminar Topics | Seminar Quiz Questions

Example

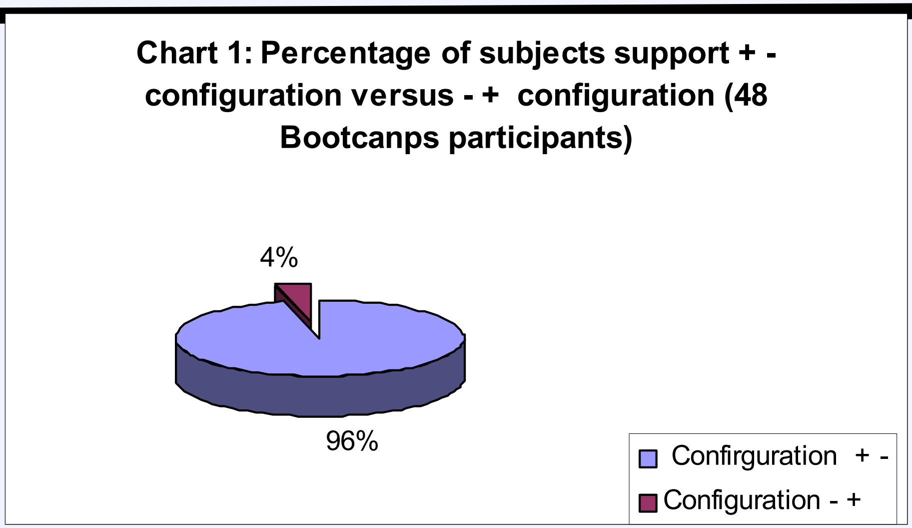


Chart 1: Percentage of subjects support + - configuration versus - + configuration (48 Bootcanps participants)
4%
96%
Confirguration + -
Configuration - +

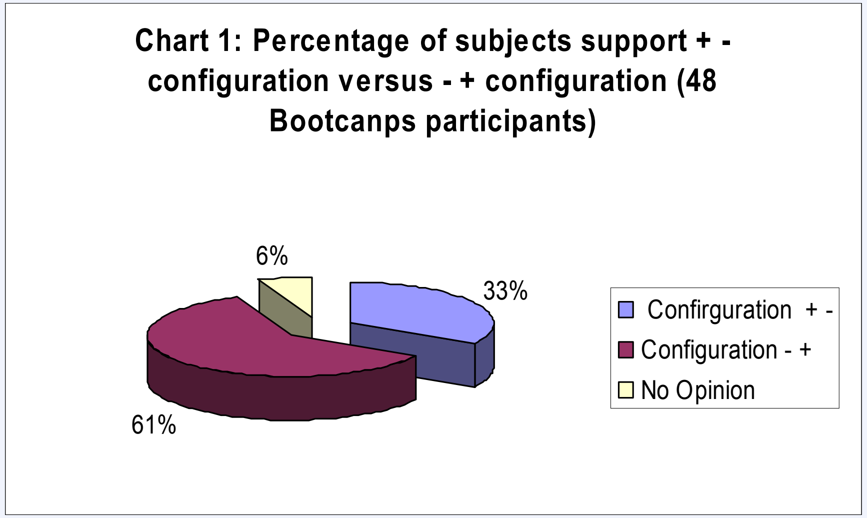
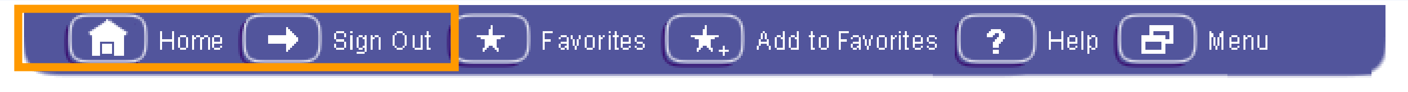


Chart 1: Percentage of subjects support + - configuration versus - + configuration (48 Bootcanps participants)
6%
33%
61%
Confirguration + -
Configuration - +
No Opinion

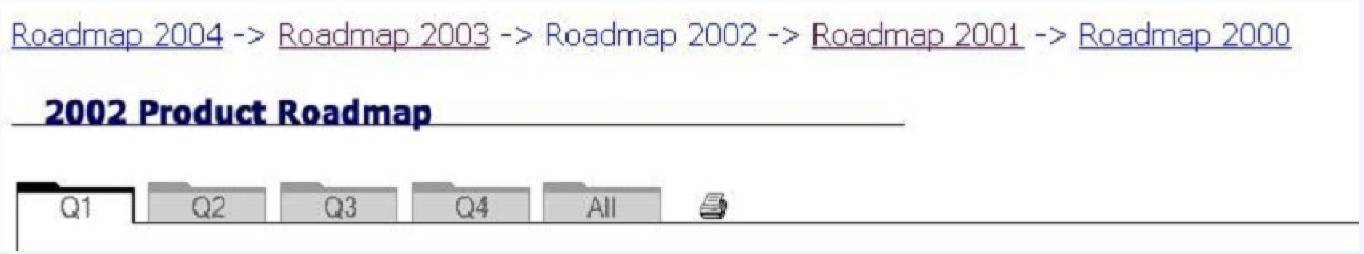
Example

Does this button bar follow the guidelines?



Separate potentially destructive buttons from frequently chosen selections

Example



Option 1	2004	2004	2003	2002	2001	2000
Option 2	2000	2001	2002	2003	2004	2004


See You Next Week
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Rene Descartes
Thank You For Your Participation

Welcome

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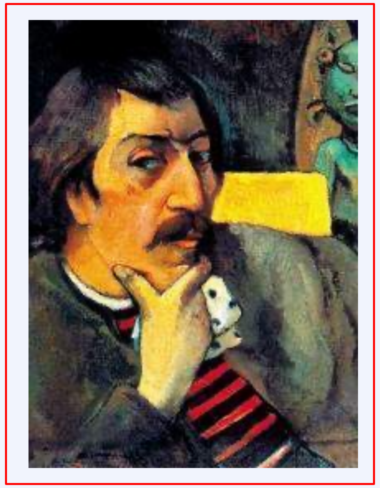
AFFORDANCES, CONSTRAINS & DIRECT MANIPULATION



Affordances Concepts

- Refers to properties of objects
- Determines what kind of operation and manipulation can be done to a particular object
- Example
  - Doors afford opening
  - Chair affords support
- When designing objects, what is important is “perceived affordance” (what a person thinks can be done with the object)

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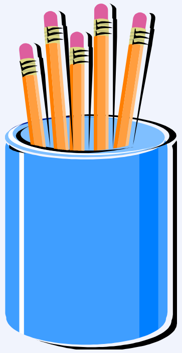
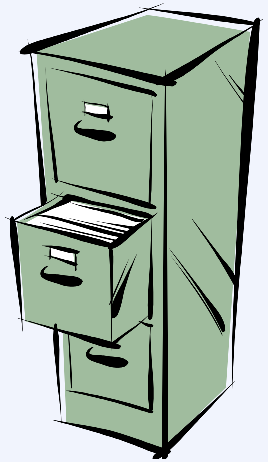
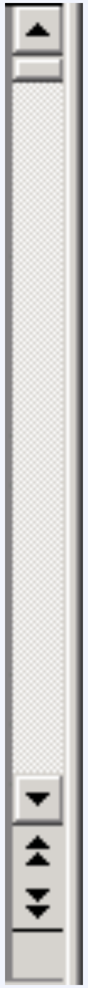
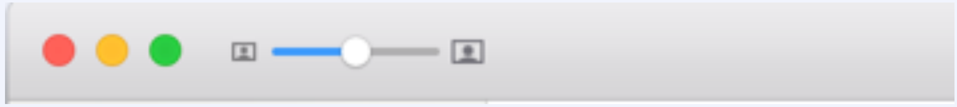
Affordances of the Objects

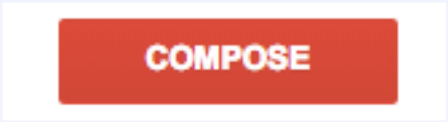




Manipulation & Affordances

Exercise: Affordances of the Objects







(a)

Manipulating

- Involves dragging, selecting, opening, closing and zooming actions on virtual objects
- Exploit's users' knowledge of how they move and manipulate in the physical world
- Can involve actions using physical controllers (e.g. Wii) or air gestures (e.g. Kinect) to control the movements of an on screen avatar
- Tagged physical objects (e.g. balls) that are manipulated in a physical world result in physical/digital events (e.g. animation)

Direct Manipulation

- Shneiderman (1983) coined the term DM, came from his fascination with computer games at the time
  - Continuous representation of objects and actions of interest
  - Physical actions and button pressing instead of issuing commands with complex syntax
  - Rapid reversible actions with immediate feedback on object of interest

Direct Manipulation

Direct manipulation systems have icons representing objects, which can be moved around the screen and manipulated by controlling a cursor with a mouse.

The systems have the following features:

- Visibility of the objects of interest
- Rapid, reversible, incremental actions
- Replacement of complex command language by direct manipulation of the object of interest

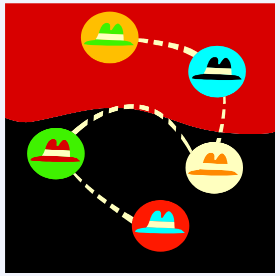
Advantages of Direct Manipulation Systems

- Novice can quickly learn the basic functionality.
- Experienced users can rapidly carry out a wide range of tasks.
- Knowledgeable intermittent users can retain operational concepts.
- Users can immediately see if their actions are helping them attain their goals.
- Users experience less anxiety because the system is understandable and actions can be easily reversed.
- Users gain confidence because they initiate an action, feel they are in control, and can predict system responses.

CONSTRAINS

Constraints

Constrains limit the number of possibilities of what can be done to an object, whereas affordance suggests the scope of an object in terms of what can do and how can interact with it.



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- **Knowledgeable intermittent users can retain operational concepts.**
- **Users can immediately see if their actions are helping them attain their goals.**
- **Users experience less anxiety because the system is understandable and actions can be easily reversed.**
- **Users gain confidence because they initiate an action, feel they are in control, and can predict system responses.**

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)

FOCUSING ATTENTION

Focusing Attention

- Our ability to attend to one event from masses of competing stimuli in the environment.
- The streams of information we choose to attend are relevant to the activities and intentions that we have at that time.

Attention

- Selecting things to concentrate on 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
- Information at the interface should be structured to capture users' attention, e.g. use perceptual boundaries (windows), colour, reverse video, sound and flashing lights

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

Is colour 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

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
- Search engines and form fill-ins that have simple and clean interfaces are easier to use

Focusing Attention at Interface

Structuring Information

- Present the proper amount of information on the screen (not too much, not too little).
- Group and order data in the meaningful part of the screen.
  - Perceptual laws of grouping
  - Spatial and temporal cues
  - Color
  - Alerting techniques such as flashing, auditory

Exercise: Focusing Attention

Is information in his “Library Ticket” grouped in an orderly fashion ?

```
Santa Clara County Library
Cupertino Public Library
05 DEC 00 05:46pm

Use our CATALOG at
www.santaclarcountylib.org/catalog/
or by direct-dial modem at 877-471-3349

Use TELECIRC at 800-471-0991

Renew titles
List titles checked out to you
Learn the total of fines owed
Review titles being held for you

Valid library card and
PIN (Personal Identification Number)
required

Library Catalog and Telecirc
are available
except 4am - 6am daily and
Friday evening 10pm - 3am

Patron:662222

New Loan: Accounting principles /
33305006699536            Due: 26 DEC 00 *
```

Group to focus attention

Example: Focusing Attention

By clicking,
more detail appears

27

Example: Focusing Attention

Use Color

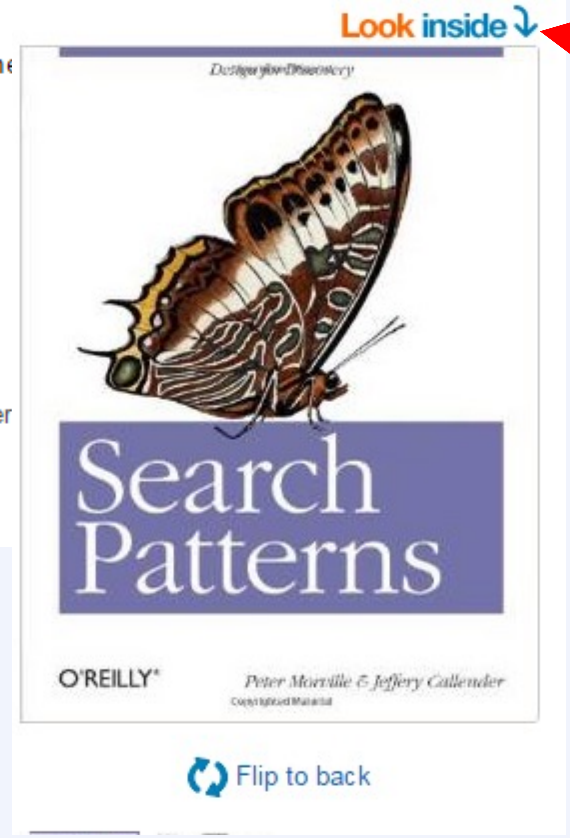
★★★½☆ ▾ 27 customer reviews

NEW Faculty Announcements

Extended Support Hours
The Online Campus is offering extended phone support hours during Spring Quarter. Call the Online Campus at **(510) 885-2100** during the following time for assistance:
Monday and Friday: 8:30 a.m. to 6 p.m., Tuesday, Wednesday, and Thursday: 8:30 a.m. **to 9:30 p.m.**

Semester Conversion
Semester Conversion is coming in Fall 2018. For updated information visit the Office of Semester Conversion website:
http://www20.csueastbay.edu/oaa/Semester/index.html

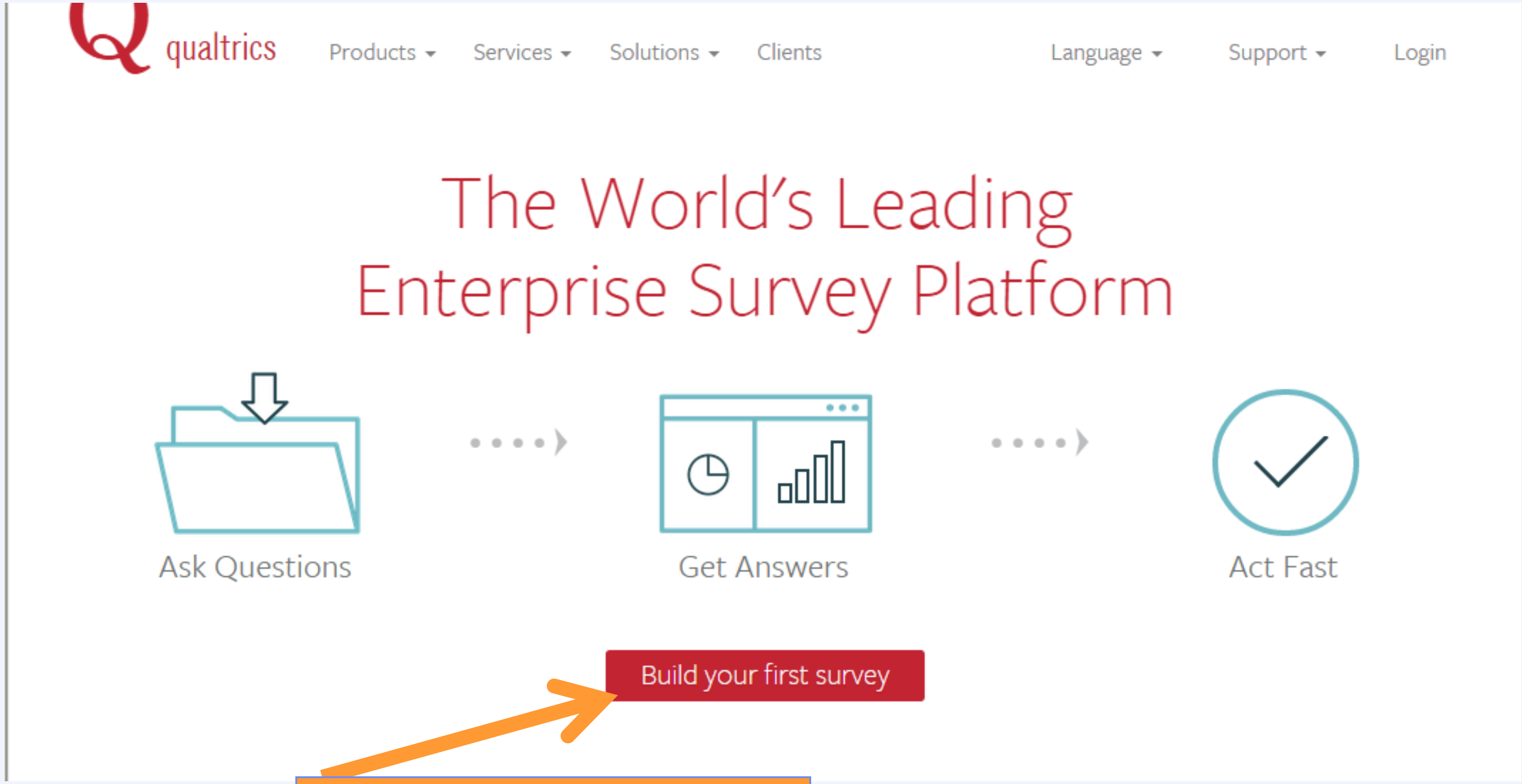
Spring Quarter Courses
Spring Quarter Courses (course ID 20152_XXXX_XX_X) are available to faculty. Courses are always available to instructors and course availability is always under instructor control. **If you wish to make your course available earlier**, it can be done from the Control Panel under Customization, Properties.
Other Hints And Tips Are Available At The Faculty Support Wiki
Instructions for Spring 2015 Course Copies and Introduction to New Course Shell



Use Color & Icon

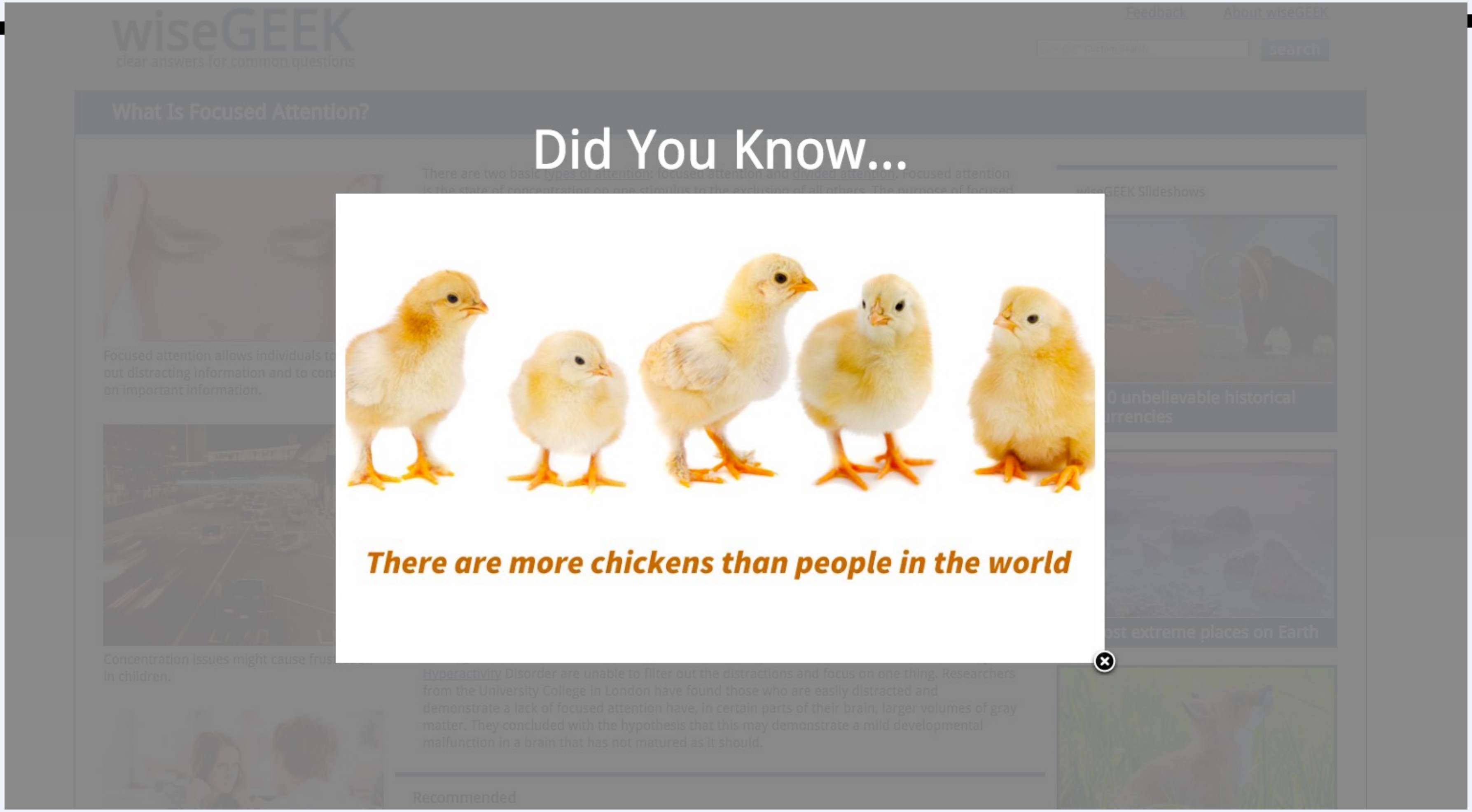
Example: Focusing Attention

Present the proper amount of information.



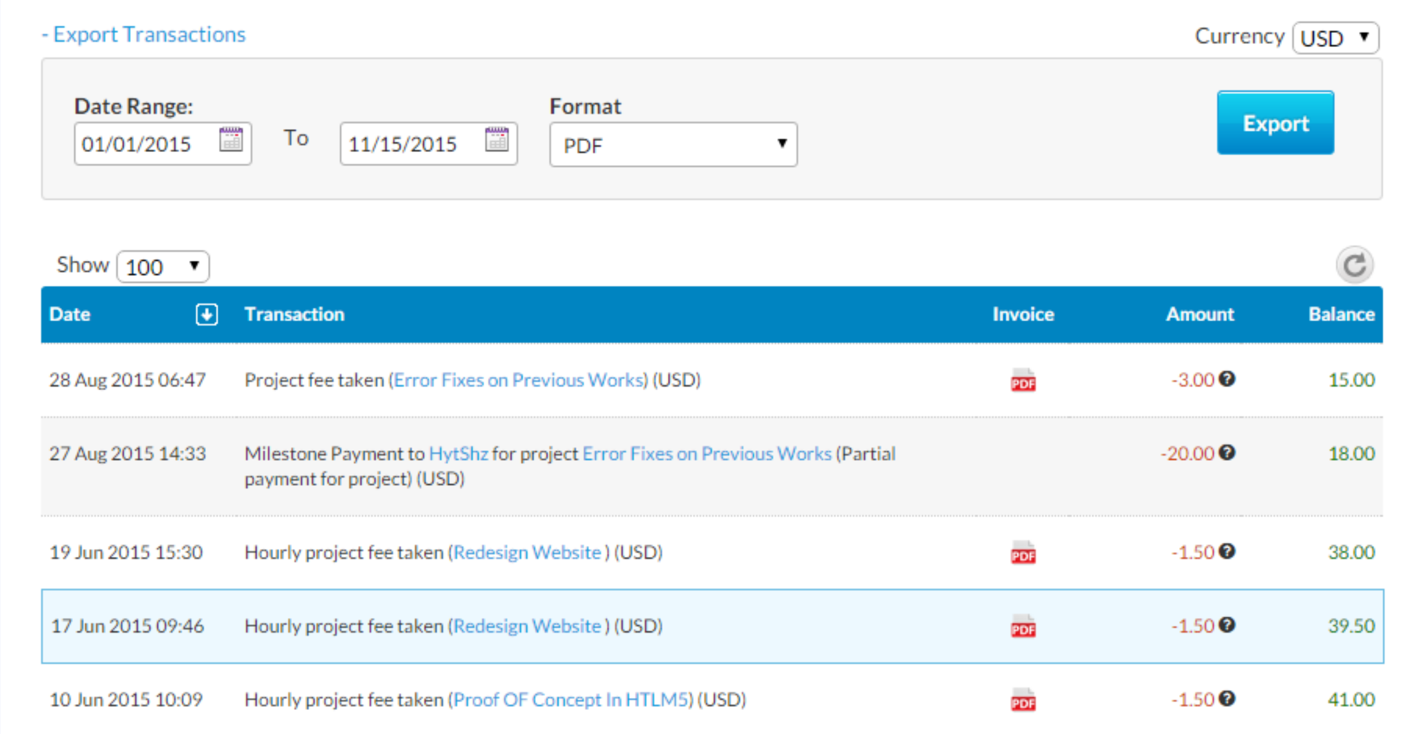
By clicking here,

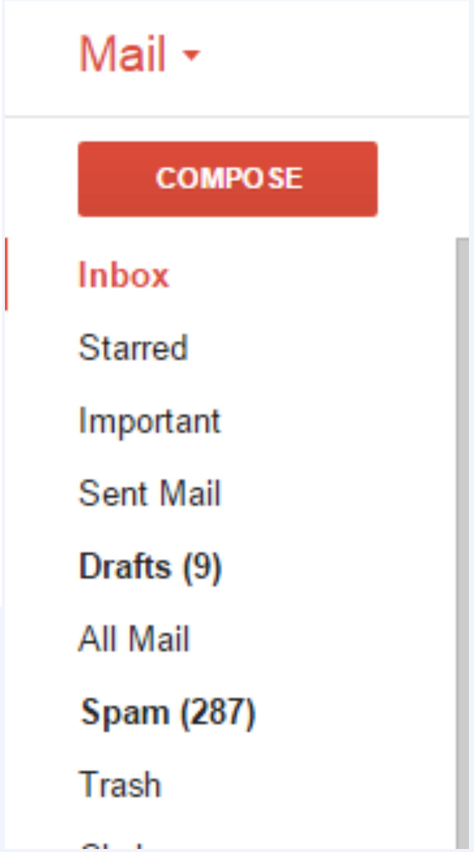
Example: Focusing Attention



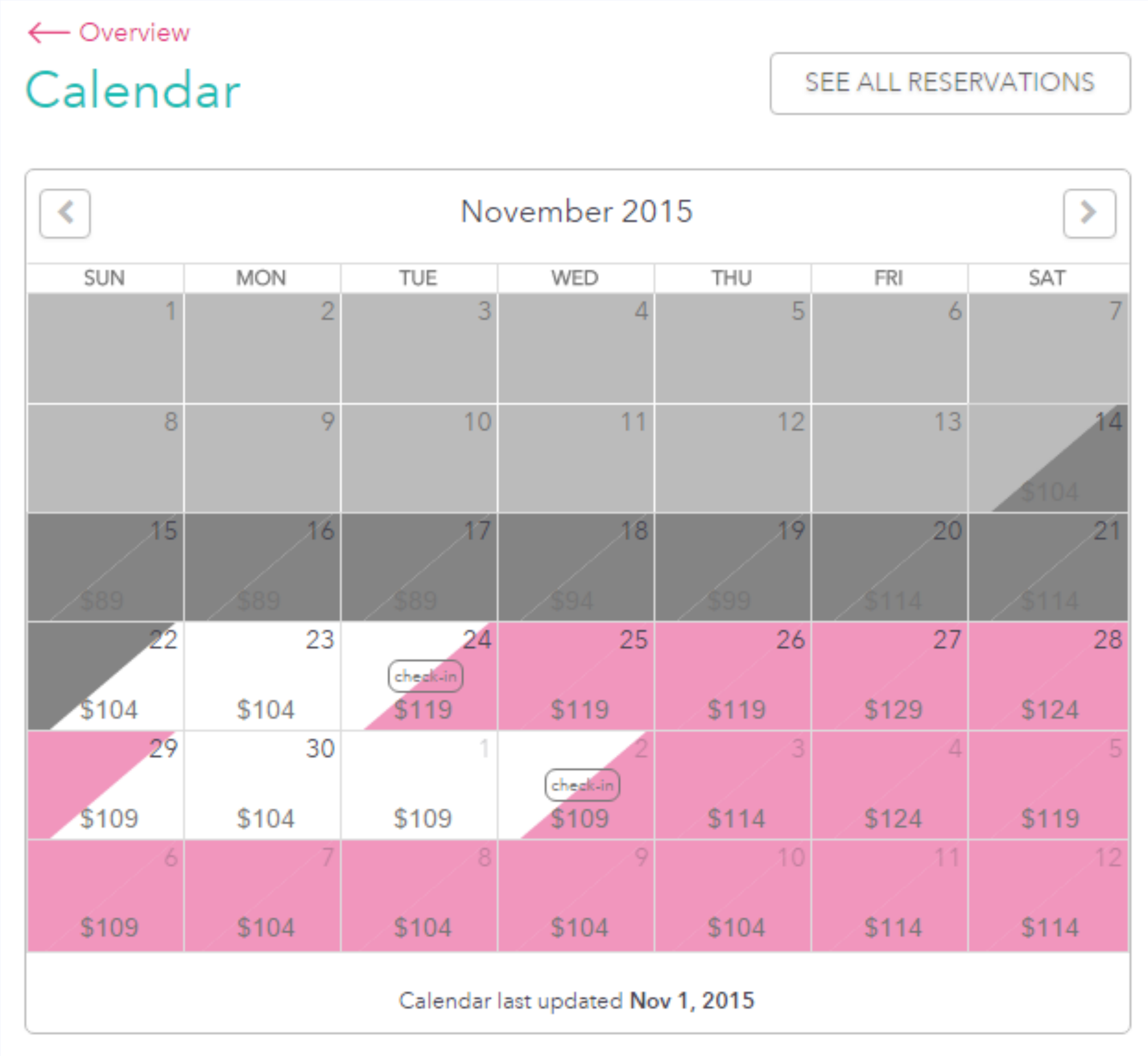
Modal Popup

Example: Focusing Attention



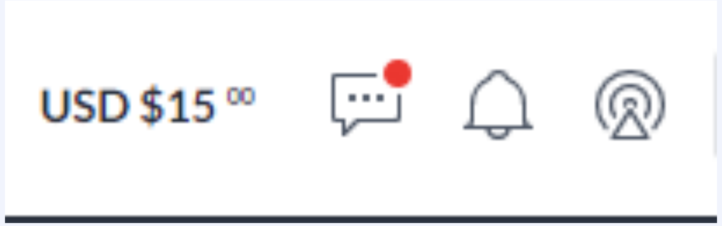


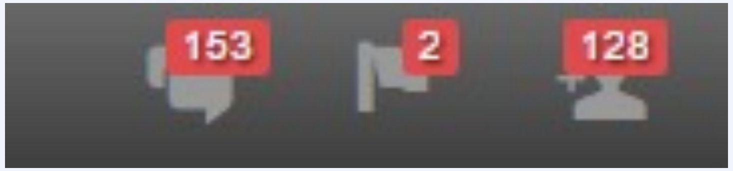
Example: Focusing Attention



Example: Focusing Attention

Alerting techniques such as flashing, auditory





What do You Think about this screen

eNETS

Wednesday, 23 November 2016

Consumer
eNETS

Privacy Policy

Security Guidelines

Customer Service

credit/debit card payment

If you are using a pop-up blocker, please add the following list as your allowed sites. Otherwise, the relevant transaction pages from the banks may not be displayed, or your transaction request may not be completed.

1. www.enets.sg

TRANSACTION INFORMATION

MasterCard. SecureCode. Verified by VISA

Merchant Name	GALALUZ PTE LTD
Merchant Reference Code	MMTVISA46E3BFA81FE94
NETS Reference Code	20161123033004983
Amount	USD 50.00

Important Notice: Please note down the transaction information in this section just in case you need to raise any query on this transaction.

CREDIT/DEBIT CARD INFORMATION

MasterCard VISA

Name on Card

Card Number

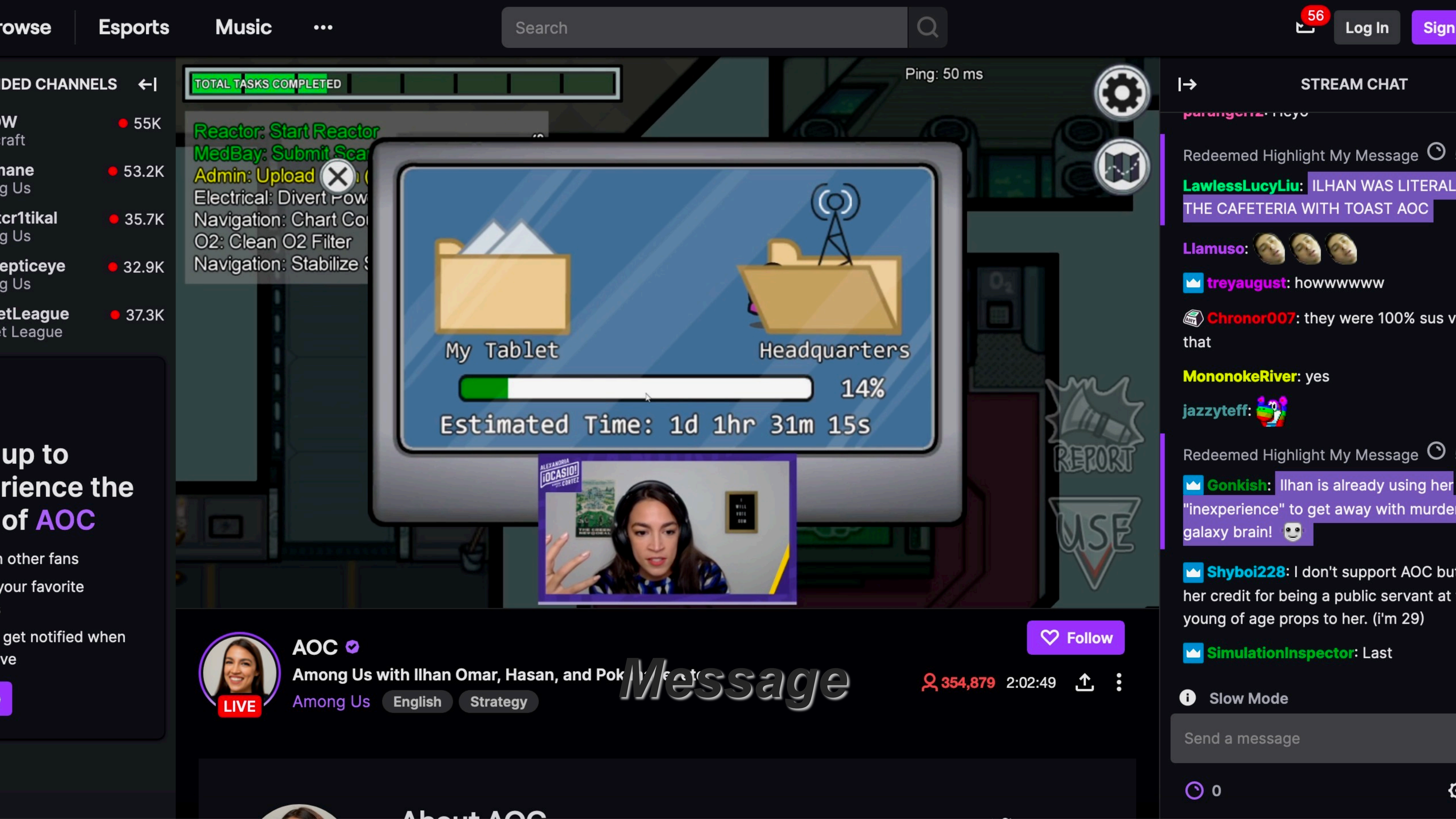
Please note that the Credit Card Number should be 13 or 16 digits.
Please input your card number without space or dash.

CVV / CVC2 [What is CVV/CVV2/CID]

Expiry Date Month (eg: 2016)

I have read, understood and accepted the following:
- The return & refund policy for the purchase of relevant products / services.
- The collection, use, disclosure and sharing of this

Fast, Secure & Hassle-free transactions



rowse
Esports
Music
Search
56
Log In
Sign
DED CHANNELS
W 55K
raft
hane 53.2K
g Us
cr1tikal 35.7K
g Us
epticeye 32.9K
g Us
etLeague 37.3K
t League
up to
rience the
of AOC
other fans
your favorite
get notified when
ve
TOTAL TASKS COMPLETED
Ping: 50 ms
Reactor: Start Reactor
MedBay: Submit Scan
Admin: Upload
Electrical: Divert Pow
Navigation: Chart Co
O2: Clean O2 Filter
Navigation: Stabilize
My Tablet
Headquarters
14%
Estimated Time: 1d 1hr 31m 15s
REPORT
USE
STREAM CHAT
Redeemed Highlight My Message
LawlessLucyLiu: ILHAN WAS LITERAL THE CAFETERIA WITH TOAST AOC
Llamuso:
treyaugust: howwwwww
Chronor007: they were 100% sus v that
MononokeRiver: yes
jazzyteff:
Redeemed Highlight My Message
Gonkish: Ilhan is already using her "inexperience" to get away with murde galaxy brain!
Shyboi228: I don't support AOC bu her credit for being a public servant at young of age props to her. (i'm 29)
SimulationInspector: Last
Slow Mode
Send a message
0
AOC
Among Us with Ilhan Omar, Hasan, and Pok
Message
Among Us
English
Strategy
LIVE
Follow
354,879
2:02:49
About AOC

Summary

- Focusing attention at interface is an effective way to help users to focus attention on specific part of user interfaces.
- Many techniques and visualization tools can help designers to bring users' attention to specific part of user interfaces.
- Multitasking divide user's attention. Consequently if it is important to focus full attention on UI elements the distraction and multitasking needs to be constrained.

See You Next Week

"I think; therefore I am."

Rene Descartes

Thank You For Your Participation

CHAPTER

Our Attention is Limited; Our Memory is Imperfect

7

Just as the human visual system has strengths and weaknesses, so do human attention and memory. This chapter describes some of those strengths and weaknesses as background for understanding how we can design interactive systems to support and augment attention and memory rather than burdening or confusing them. We will start with an overview of how memory works, and how it is related to attention.

SHORT- VERSUS LONG-TERM MEMORY

Psychologists historically have distinguished *short-term* memory from *long-term* memory. Short-term memory covers situations in which information is retained for intervals ranging from a fraction of a second to a few minutes. Long-term memory covers situations in which information is retained over longer periods (e.g., hours, days, years, even lifetimes).

It is tempting to think of short- and long-term memory as separate memory stores. Indeed, some theories of memory have considered them separate. After all, in a digital computer, the short-term memory stores (central processing unit [CPU] data registers) are separate from the long-term memory stores (random access memory [RAM], hard disk, flash memory, CD-ROM, etc.). More direct evidence comes from findings that damage to certain parts of the human brain results in short-term memory deficits but not long-term ones, or vice versa. Finally, the speed with which information or plans can disappear from our immediate awareness contrasts sharply with the seeming permanence of our memory of important events in our lives, faces of significant people, activities we have practiced, and information we have studied. These phenomena led many researchers to theorize that short-term memory is a separate store in the brain where information is held temporarily after entering through our perceptual senses (e.g., visual or auditory), or after being retrieved from long-term memory (see Fig. 7.1).

Designing with the Mind in Mind. http://dx.doi.org/10.1016/B978-0-12-407914-4.00007-5

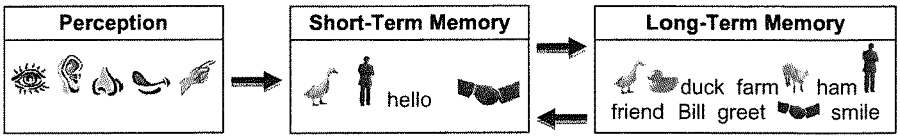


FIGURE 7.1

Traditional (antiquated) view of short-term versus long-term memory.

A MODERN VIEW OF MEMORY

Recent research on memory and brain function indicates that short- and long-term memory are functions of a single memory system—one that is more closely linked with perception than previously thought (Jonides et al., 2008).

Long-term memory

Perceptions enter through the visual, auditory, olfactory, gustatory, or tactile sensory systems and trigger responses starting in areas of the brain dedicated to each sense (e.g., visual cortex, auditory cortex), then spread into other areas of the brain that are *not* specific to any particular sensory modality. The sensory modality-specific areas of the brain detect only simple features of the data, such as a dark-light edge, diagonal line, high-pitched tone, sour taste, red color, or rightward motion. Downstream areas of the brain combine low-level features to detect higher-level features of the input, such as animal, the word "duck," Uncle Kevin, minor key, threat, or fairness.

As described in Chapter 1, the set of neurons activated by a perceived stimulus depends on both the features and context of the stimulus. The context is as important as the features of the stimulus in determining what neural patterns are activated. For example, a dog barking near you when you are walking in your neighborhood activates a different pattern of neural activity in your brain than the same sound heard when you are safely inside your car. The more similar two perceptual stimuli are—that is, the more features and contextual elements they share—the more overlap there is between the sets of neurons that fire in response to them.

The initial strength of a perception depends on how much it is amplified or dampened by other brain activity. All perceptions create some kind of trace, but some are so weak that they can be considered as not registered: the pattern was activated once but never again.

Memory formation consists of changes in the neurons involved in a neural activity pattern, which make the pattern easier to reactivate in the future.[1] Some such changes result from chemicals released near neural endings that boost or inhibit their sensitivity to stimulation. These changes last only until the chemicals dissipate

[1] There is evidence that the long-term neural changes associated with learning occur mainly during sleep, suggesting that separating learning sessions by periods of sleep may facilitate learning (Stafford and Webb, 2005).

or are neutralized by other chemicals. More permanent changes occur when neurons grow and branch, forming new connections with others.

Activating a memory consists of reactivating the same pattern of neural activity that occurred when the memory was formed. Somehow the brain distinguishes initial activations of neural patterns from *re*activations—perhaps by measuring the relative ease with which the pattern was reactivated. New perceptions very similar to the original ones reactivate the same patterns of neurons, resulting in *recognition* if the reactivated perception reaches awareness. In the absence of a similar perception, stimulation from activity in other parts of the brain can also reactivate a pattern of neural activity, which if it reaches awareness results in *recall*.

The more often a neural memory pattern is reactivated, the stronger it becomes—that is, the easier it is to reactivate—which in turn means that the perception it corresponds to is easier to recognize and recall. Neural memory patterns can also be strengthened or weakened by excitatory or inhibitory signals from other parts of the brain.

A particular memory is not located in any specific spot in the brain. The neural activity pattern comprising a memory involves a network of millions of neurons extending over a wide area. Activity patterns for different memories overlap, depending on which features they share. Removing, damaging, or inhibiting neurons in a particular part of the brain typically does not completely wipe out memories that involve those neurons, but rather just reduces the detail or accuracy of the memory by deleting features.[2] However, some areas in a neural activity pattern may be critical pathways, so that removing, damaging, or inhibiting them may prevent most of the pattern from activating, thereby effectively eliminating the corresponding memory.

For example, researchers have long known that the hippocampus, twin seahorse-shaped neural clusters near the base of the brain, plays an important role in storing long-term memories. The modern view is that the hippocampus is a controlling mechanism that directs neural rewiring so as to "burn" memories into the brain's wiring. The amygdala, two jellybean-shaped clusters on the frontal tips of the hippocampus, has a similar role, but it specializes in storing memories of emotionally intense, threatening situations (Eagleman, 2012).

Cognitive psychologists view human long-term memory as consisting of several distinct functions:

- ***Semantic*** long-term memory stores *facts and relationships.*
- ***Episodic*** long-term memory records *past events.*
- ***Procedural*** long-term memory remembers *action sequences.*

These distinctions, while important and interesting, are beyond the scope of this book.

[2]This is similar to the effect of cutting pieces out of a holographic image: it reduces the overall resolution of the image, rather than removing areas of it, as with an ordinary photograph.

Short-term memory

The processes just discussed are about long-term memory. What about short-term memory? What psychologists call short-term memory is actually a *combination* of phenomena involving perception, attention, and retrieval from long-term memory.

One component of short-term memory is perceptual. Each of our perceptual senses has its own very brief short-term "memory" that is the result of residual neural activity after a perceptual stimulus ceases, like a bell that rings briefly after it is struck. Until they fade away, these residual perceptions are available as possible input to our brain's attention and memory-storage mechanisms, which integrate input from our various perceptual systems, focus our awareness on some of that input, and store some of it in long-term memory. These sensory-specific residual perceptions together comprise a minor component of short-term memory. Here, we are only interested in them as potential inputs to working memory.

Also available as potential input to working memory are long-term memories reactivated through recognition or recall. As explained earlier, each long-term memory corresponds to a specific pattern of neural activity distributed across our brain. While activated, a memory pattern is a candidate for our attention and therefore potential input for working memory.

The human brain has multiple attention mechanisms, some voluntary and some involuntary. They focus our awareness on a very small subset of the perceptions and activated long-term memories while ignoring everything else. That tiny subset of all the available information from our perceptual systems and our long-term memories that we are aware of *right now* is the main component of our short-term memory, the part that cognitive scientists often call *working memory*. It integrates information from all of our sensory modalities and our long-term memory. Henceforth, we will restrict our discussion of short-term memory to working memory.

So what is working memory? First, here is what it is *not*: it is not a *store*—it is not a *place* in the brain where memories and perceptions *go* to be worked on. And it is nothing like accumulators or fast random-access memory in digital computers.

Instead, working memory is our combined focus of attention: everything that we are conscious of at a given time. More precisely, it is a few perceptions and long-term memories that are activated enough that we remain aware of them over a short period. Psychologists also view working memory as including an executive function—based mainly in the frontal cerebral cortex—that manipulates items we are attending to and, if needed, refreshes their activation so they remain in our awareness (Baddeley, 2012).

A useful—if oversimplified—analogy for memory is a huge, dark, musty warehouse. The warehouse is full of long-term memories, piled haphazardly (not stacked neatly), intermingled and tangled, and mostly covered with dust and cobwebs. Doors along the walls represent our perceptual senses: sight, hearing, smell, taste, touch. They open briefly to let perceptions in. As perceptions enter, they are briefly illuminated by light coming in from outside, but they quickly are pushed (by more entering perceptions) into the dark tangled piles of old memories.

In the ceiling of the warehouse are a small fixed number of searchlights, controlled by the attention mechanism's executive function (Baddeley, 2012). They swing around and focus on items in the memory piles, illuminating them for a while until they swing away to focus elsewhere. Sometimes one or two searchlights focus on new items after they enter through the doors. When a searchlight moves to focus on something new, whatever it had been focusing on is plunged into darkness.

The small fixed number of searchlights represents the limited capacity of working memory. What is illuminated by them (and briefly through the open doors) represents the contents of working memory: out of the vast warehouse's entire contents, the few items we are attending to at any moment. See Figure 7.2 for a visual.

The warehouse analogy is too simple and should not be taken too seriously. As Chapter 1 explained, our senses are *not* just passive doorways into our brains, through which our environment "pushes" perceptions. Rather, our brain actively and continually *seeks out* important events and features in our environment and "pulls" perceptions in as needed (Ware, 2008). Furthermore, the brain is buzzing with activity most of the time and its internal activity is only modulated—not determined—by sensory input (Eagleman, 2012). Also, as described earlier, memories are embodied as networks of neurons distributed around the brain, not as objects in a specific location. Finally, activating a memory in the brain can activate related ones; our warehouse-with-searchlights analogy doesn't represent that.

Nonetheless, the analogy—especially the part about the searchlights—illustrates that working memory is a *combination* of several *foci of attention*—the currently

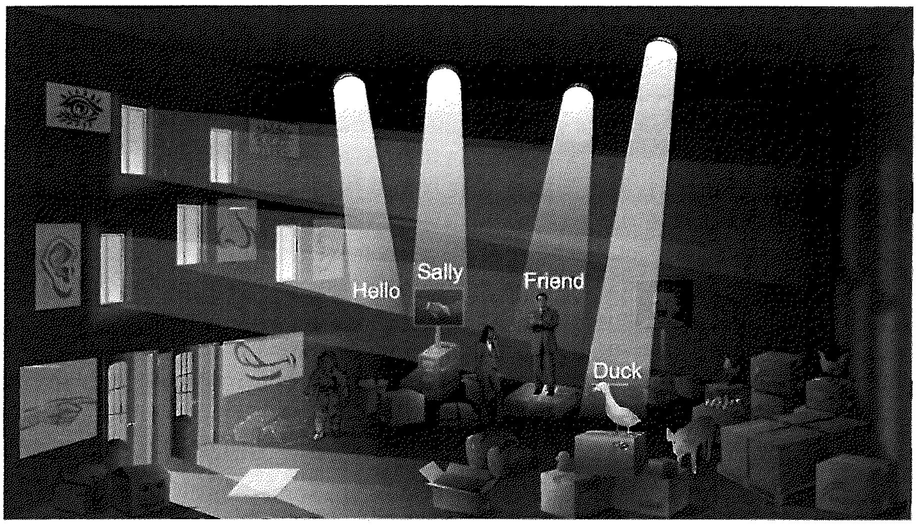


FIGURE 7.2

Modern view of memory: a dark warehouse full of stuff (long-term memory), with searchlights focused on a few items (short-term memory).

activated neural patterns of which we are aware—and that the capacity of working memory is extremely limited, and the content at any given moment is very volatile.

What about the earlier finding that damage to some parts of the brain causes short-term memory deficits, while other types of brain damage cause long-term memory deficits? The current interpretation is that some types of damage decrease or eliminate the brain's ability to focus attention on specific objects and events, while other types of damage harm the brain's ability to store or retrieve long-term memories.

CHARACTERISTICS OF ATTENTION AND WORKING MEMORY

As noted, working memory is equal to the focus of our attention. Whatever is in that focus is what we are conscious of at any moment. But what determines what we attend to and how much we can attend to at any given time?

Attention is highly focused and selective

Most of what is going on around you at this moment you are unaware of. Your perceptual system and brain sample very selectively from your surroundings, because they don't have the capacity to process everything.

Right now you are conscious of the last few words and ideas you've read, but probably not the color of the wall in front of you. But now that I've shifted your attention, you *are* conscious of the wall's color, and may have forgotten some of the ideas you read on the previous page.

Chapter 1 described how our perception is filtered and biased by our goals. For example, if you are looking for your friend in a crowded shopping mall, your visual system "primes" itself to notice people who look like your friend (including how he or she is dressed), and barely notice everything else. Simultaneously, your auditory system primes itself to notice voices that sound like your friend's voice, and even footsteps that sound like those of your friend. Human-shaped blobs in your peripheral vision and sounds localized by your auditory system that match your friend snap your eyes and head toward them. While you look, anyone looking or sounding similar to your friend attracts your attention, and you won't notice other people or events that would normally have interested you.

Besides focusing on objects and events related to our current goals, our attention is drawn to:

- ***Movement, especially movement near or toward us.*** For example, something jumps at you while you walk on a street, or something swings toward your head in a haunted house ride at an amusement park, or a car in an adjacent lane suddenly swerves toward your lane (see the discussion of the *flinch reflex* in Chapter 14).
- ***Threats.*** Anything that signals or portends danger to us or people in our care.

- ***Faces of other people.*** We are primed from birth to notice faces more than other objects in our environment.
- ***Sex and food.*** Even if we are happily married and well fed, these things attract our attention. Even the mere words probably quickly got your attention.

These things, along with our current goals, draw our attention involuntarily. We don't become aware of something in our environment and then orient ourselves toward it. It's the other way around: our perceptual system detects something attention-worthy and orients us toward it preconsciously, and only afterwards do we become aware of it.[3]

Capacity of attention (a.k.a. working memory)

The primary characteristics of working memory are its low capacity and volatility. But what is the capacity? In terms of the warehouse analogy presented earlier, what is *the small fixed number* of searchlights?

Many college-educated people have read about "the magical number seven, plus or minus two," proposed by cognitive psychologist George Miller in 1956 as the limit on the number of simultaneous unrelated items in human working memory (Miller, 1956).

Miller's characterization of the working memory limit naturally raises several questions:

- ***What are the items in working memory?*** They are current perceptions and retrieved memories. They are goals, numbers, words, names, sounds, images, odors—anything one can be aware of. In the brain, they are patterns of neural activity.
- ***Why must items be unrelated?*** Because if two items are related, they correspond to one big neural activity pattern—one set of features—and hence one item, not two.
- ***Why the fudge-factor of plus or minus two?*** Because researchers cannot measure with perfect accuracy how much people can keep track of, and because of differences between individuals in working memory capacity.

Later research in the 1960s and 1970s found Miller's estimate to be too high. In the experiments Miller considered, some of the items presented to people to remember could be "chunked" (i.e., considered related), making it appear that people's working memory was holding more items than it actually was. Furthermore, all the subjects in Miller's experiments were college students. Working memory capacity varies in the general population. When the experiments were revised to disallow unintended chunking and include noncollege students as subjects, the average capacity of working memory was shown to be more like four plus or minus one—that is, three to five items (Broadbent, 1975; Mastin, 2010). Thus, in our warehouse analogy, there would be only four searchlights.

[3] Exactly how long afterwards is discussed in Chapter 14.

More recent research has cast doubt on the idea that the capacity of working memory should be measured in whole items or "chunks." It turns out that in early working memory experiments, people were asked to briefly remember items (e.g., words or images) that were quite different from each other—that is, they had very few features in common. In such a situation, people don't have to remember every feature of an item to recall it a few seconds later; remembering some of its features is enough. So people appeared to recall items as a whole, and therefore working memory capacity seemed measurable in whole items.

Recent experiments have given people items to remember that are similar—that is, they share many features. In that situation, to recall an item and not confuse it with other items, people must remember more of its features. In these experiments, researchers found that people remember more details (i.e., features) of some items than of others, and the items they remember in greater detail are the ones they paid more attention to (Bays and Husain, 2008). This suggests that the unit of attention—and therefore the capacity of working memory—is best measured in item features rather than whole items or "chunks" (Cowan et al., 2004). This jibes with the modern view of the brain as a feature-recognition device, but it is controversial among memory researchers, some of whom argue that the basic capacity of human working memory is three to five whole items, but that is reduced if people attend to a large number of details (i.e., features) of the items (Alvarez and Cavanagh, 2004).

Bottom line: The true capacity of human working memory is still a research topic.

The second important characteristic of working memory is how volatile it is. Cognitive psychologists used to say that new items arriving in working memory often bump old ones out, but that way of describing the volatility is based on the view of working memory as a temporary storage place for information. The modern view of working memory as the current focus of attention makes it even clearer: focusing attention on new information turns it away from some of what it was focusing on. That is why the searchlight analogy is useful.

However we describe it, information can easily be lost from working memory. If items in working memory don't get combined or rehearsed, they are at risk of having the focus shifted away from them. This volatility applies to goals as well as to the details of objects. Losing items from working memory corresponds to forgetting or losing track of something you were doing. We have all had such experiences, for example:

- Going to another room for something, but once there we can't remember why we came.
- Taking a phone call, and afterward not remembering what we were doing before the call.
- Something yanks our attention away from a conversation, and then we can't remember what we were talking about.
- In the middle of adding a long list of numbers, something distracts us, so we have to start over.

WORKING MEMORY TEST

To test your working memory, get a pen or pencil and two blank sheets of paper and follow these instructions:

1. Place one blank sheet of paper after this page in the book and use it to cover the next page.
2. Flip to the next page for three seconds, pull the paper cover down and read the **black numbers** at the top, and flip back to this page. Don't peek at other numbers on that page unless you want to ruin the test.
3. Say your phone number backward, out loud.
4. Now write down the black numbers from memory. … Did you get all of them?
5. Flip back to the next page for three seconds, read the **red numbers** (under the black ones), and flip back.
6. Write down the numbers from memory. These would be easier to recall than the first ones if you noticed that they are the first seven digits of π (3.141592), because then they would be only one number, not seven.
7. Flip back to the next page for 3 seconds, read the **green numbers**, and flip back.
8. Write down the numbers from memory. If you noticed that they are odd numbers from 1 to 13, they would be easier to recall, because they would be three chunks ("odd, 1, 13" or "odd, seven from 1"), not seven.
9. Flip back to the next page for three seconds, read the **orange words**, and flip back.
10. Write down the words from memory. … Could you recall them all?
11. Flip back to the next page for three seconds, read the **blue words**, and flip back.
12. Write down the words from memory. … It was certainly a lot easier to recall them all because they form a sentence, so they could be memorized as one sentence rather than seven words.

3 8 4 7 5 3 9

3 1 4 1 5 9 2

1 3 5 7 9 11 13

town river corn string car shovel

what is the meaning of life

IMPLICATIONS OF WORKING MEMORY CHARACTERISTICS FOR USER-INTERFACE DESIGN

The capacity and volatility of working memory have many implications for the design of interactive computer systems. The basic implication is that user interfaces should help people remember essential information from one moment to the next. Don't require people to remember system status or what they have done, because their attention is focused on their primary goal and progress toward it. Specific examples follow.

Modes

The limited capacity and volatility of working memory is one reason why user-interface design guidelines often say to either avoid designs that have *modes* or provide adequate mode feedback. In a moded user interface, some user actions have different effects depending on what mode the system is in. For example:

- In a car, pressing the accelerator pedal can move the car either forwards, backwards, or not at all, depending on whether the transmission is in drive, reverse, or neutral.The transmission sets a mode in the car's user interface.
- In many digital cameras, pressing the shutter button can either snap a photo or start a video recording, depending on which mode is selected.

- In a drawing program, clicking and dragging normally selects one or more graphic objects on the drawing, but when the software is in "draw rectangle" mode, clicking and dragging adds a rectangle to the drawing and stretches it to the desired size.

Moded user interfaces have advantages; that is why many interactive systems have them. Modes allow a device to have more functions than controls: the same control provides different functions in different modes. Modes allow an interactive system to assign different meanings to the same gestures to reduce the number of gestures users must learn.

However, one well-known *dis*advantage of modes is that people often make *mode errors*: they forget what mode the system is in and do the wrong thing by mistake (Johnson, 1990). This is especially true in systems that give poor feedback about what the current mode is. Because of the problem of mode errors, many user-interface design guidelines say to either avoid modes or provide strong feedback about which mode the system is in. Human working memory is too unreliable for designers to assume that users can, without clear, continuous feedback, keep track of what mode the system is in, even when the users are the ones changing the system from one mode to another.

Search results

When people use a search function on a computer to find information, they enter the search terms, start the search, and then review the results. Evaluating the results often requires knowing what the search terms were. If working memory were less limited, people would always remember, when browsing the results, what they had entered as search terms just a few seconds earlier. But as we have seen, working memory is very limited. When the results appear, a person's attention naturally turns away from what he or she entered and toward the results. Therefore, it should be no surprise that people viewing search results often do not remember the search terms they just typed.

Unfortunately, some designers of online search functions don't understand that. Search results sometimes don't show the search terms that generated the results. For example, in 2006, the search results page at Slate.com provided search fields so users could search again, but didn't show what a user had searched for (see Fig. 7.3A). A recent version of the site shows the user's search terms (see Fig. 7.3B), reducing the burden on users' working memory.

Calls to action

A well-known "netiquette" guideline for writing email messages, especially messages that require responses or ask the recipients to do something, is to restrict each message to one topic. If a message contains multiple topics or requests, its recipients may focus on one of them (usually the first one), get engrossed in responding to that, and forget to respond to the rest of the email. The guideline to put different topics or requests into separate emails is a direct result of the limited capacity of human attention.

(A)

(B)

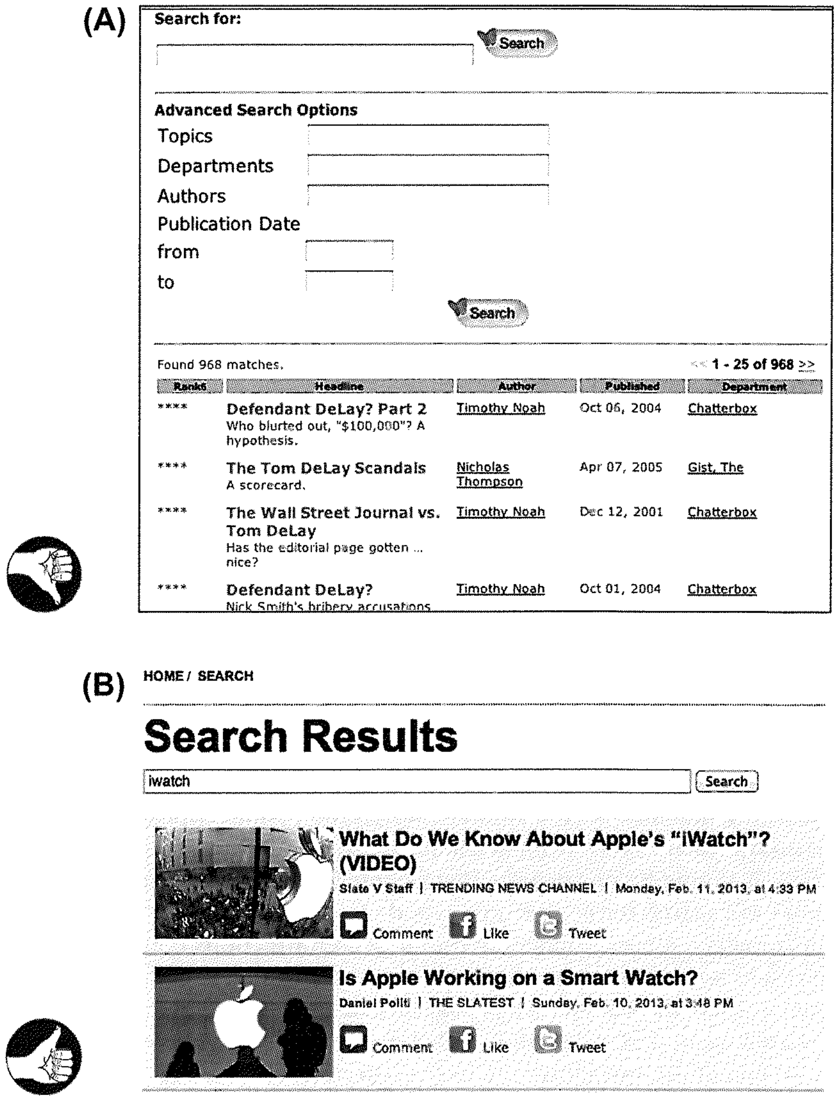


FIGURE 7.3

Slate.com search results: (A) in 2007, users' search terms were not shown, but (B) in 2013, search terms are shown.

Web designers are familiar with a similar guideline: Avoid putting competing calls to action on a page. Each page should have only *one* dominant call to action—or one for each possible user goal—to not overwhelm users' attention capacity and cause them go down paths that don't achieve their (or the site owner's) goals.

A related guideline: Once users have specified their goal, don't distract them from accomplishing it by displaying extraneous links and calls to action. Instead, guide them to the goal by using a design pattern called the *process funnel* (van Duyne et al., 2002; see also Johnson, 2007).

Instructions

If you asked a friend for a recipe or for directions to her home, and she gave you a long sequence of steps, you probably would not try to remember it all. You would know that you could not reliably keep all of the instructions in your working memory, so you would write them down or ask your friend to send them to you by email. Later, while following the instructions, you would put them where you could refer to them until you reached the goal.

Similarly, interactive systems that display instructions for multistep operations should allow people to refer to the instructions while executing them until completing all the steps. Most interactive systems do this (see Fig. 7.4), but some do not (see Fig. 7.5).

Navigation depth

Using a software product, digital device, phone menu system, or Web site often involves navigating to the user's desired information or goal. It is well established that navigation hierarchies that are broad and shallow are easier for most people—especially those who are nontechnical—to find their way around in than narrow, deep hierarchies (Cooper, 1999). This applies to hierarchies of application windows and dialog boxes, as well as to menu hierarchies (Johnson, 2007).

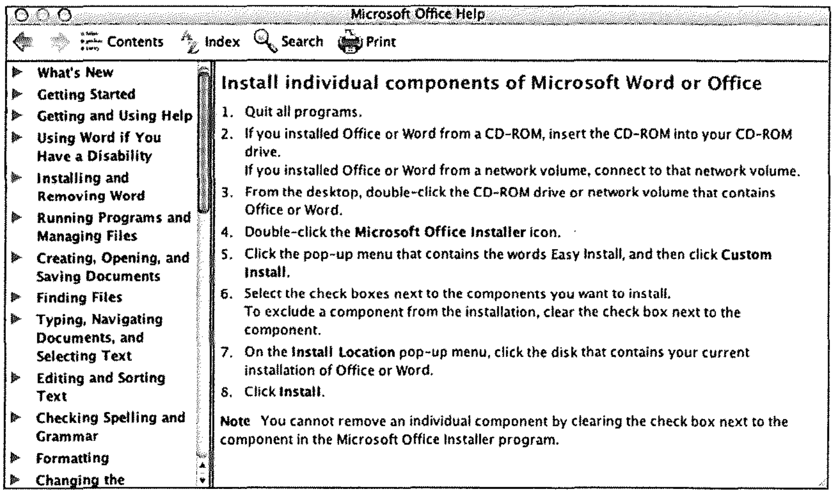


FIGURE 7.4

Instructions in Windows Help files remain displayed while users follow them.

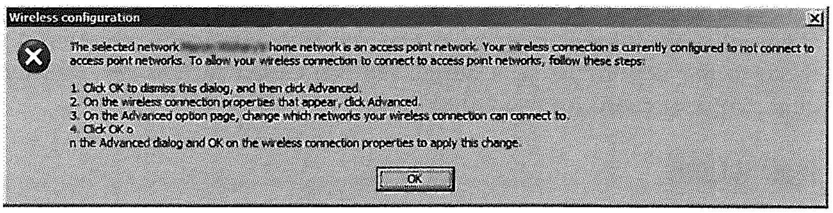


FIGURE 7.5

Instructions for Windows XP wireless setup start by telling users to close the instructions.

A related guideline: In hierarchies deeper than two levels, provide navigation "breadcrumb" paths to constantly remind users where they are (Nielsen, 1999; van Duyne et al., 2002).

These guidelines, like the others mentioned earlier, are based on the limited capacity of human working memory. Requiring a user to drill down through eight levels of dialog boxes, web pages, menus, or tables—especially with no visible reminders of their location—will probably exceed the user's working memory capacity, thereby causing him or her to forget where he or she came from or what his or her overall goals were.

CHARACTERISTICS OF LONG-TERM MEMORY

Long-term memory differs from working memory in many respects. Unlike working memory, it actually *is* a memory store.

However, specific memories are not stored in any one neuron or location in the brain. As described earlier, memories, like perceptions, consist of patterns of activation of large sets of neurons. Related memories correspond to overlapping patterns of activated neurons. This means that every memory is stored in a distributed fashion, spread among many parts of the brain. In this way, long-term memory in the brain is similar to holographic light images.

Long-term memory evolved to serve our ancestors and us very well in getting around in our world. However, it has many weaknesses: it is error-prone, impressionist, free-associative, idiosyncratic, retroactively alterable, and easily biased by a variety of factors at the time of recording or retrieval. Let's examine some of these weaknesses.

Error-prone

Nearly everything we've ever experienced is stored in our long-term memory. Unlike working memory, the capacity of human long-term memory seems almost unlimited. Adult human brains each contain about 86 billion neurons (Herculano-Houzel, 2009). As described earlier, individual neurons do not store memories; memories are encoded by networks of neurons acting together. Even if only some of the brain's neurons are involved in memory, the large number of neurons allows for a great many different combinations of them, each capable of representing a different memory. Still, no one has yet measured or even estimated the maximum information capacity of the human brain.[4] Whatever the capacity is, it's a lot.

However, what is in long-term memory is not an accurate, high-resolution recording of our experiences. In terms familiar to computer engineers, one could characterize long-term memory as using heavy compression methods that drop a great deal of information. Images, concepts, events, sensations, actions—all are reduced to combinations of abstract features. Different memories are stored at different levels of detail—that is, with more or fewer features.

For example, the face of a man you met briefly who is not important to you might be stored simply as an average Caucasian male face with a beard, with no other details—a whole face reduced to three features. If you were asked later to describe the man in his absence, the most you could honestly say was that he was a "white guy with a beard." You would not be able to pick him out of a police lineup of other Caucasian men with beards. In contrast, your memory of your best friend's face includes many more features, allowing you to give a more detailed description and pick your friend out of any police lineup. Nonetheless, it is still a set of features, not anything like a bitmap image.

As another example, I have a vivid childhood memory of being run over by a plow and badly cut, but my father says it happened to my brother. One of us is wrong.

In the realm of human-computer interaction, a Microsoft Word user may remember that there is a command to insert a page number, but may not remember which *menu* the command is in. That specific feature may not have been recorded when the user learned how to insert page numbers. Alternatively, perhaps the menu-location feature *was* recorded, but just does not reactivate with the rest of the memory pattern when the user tries to recall how to insert a page number.

Weighted by emotions

Chapter 1 described a dog that remembered seeing a cat in his front yard every time he returned home in the family car. The dog was excited when he first saw the cat, so his memory of it was strong and vivid.

A comparable human example would be an adult could easily have strong memories of her first day at nursery school, but probably not of her tenth. On the first day, she was probably upset about being left at the school by her parents, whereas by the tenth day, being left there was nothing unusual.

Retroactively alterable

Suppose that while you are on an ocean cruise with your family, you see a whale-shark. Years later, when you and your family are discussing the trip, you might remember

[4]The closest researchers have come is Landauer's (1986) use of the average human learning rate to calculate the amount of information a person can learn in a lifetime: 10^9 bits, or a few hundred megabytes.

A LONG-TERM MEMORY TEST

Test your long-term memory by answering the following questions:

1. Was there a roll of tape in the toolbox in Chapter 1?
2. What was your *previous* phone number?
3. Which of these words were *not* in the list presented in the working memory test earlier in this chapter: city, stream, corn, auto, twine, spade?
4. What was your first-grade teacher's name? Second grade? Third grade? ...
5. What Web site was presented earlier that does not show search terms when it displays search results?

Regarding question 3: When words are memorized, often what is retained is the *concept*, rather than the exact word that was presented. For example, one could hear the word "town" and later recall it as "city."

seeing a whale, and one of your relatives might recall seeing a shark. For both of you, some details in long-term memory were dropped because they did not fit a common concept.

A true example comes from 1983, when the late President Ronald Reagan was speaking with Jewish leaders during his first term as president. He spoke about being in Europe during World War II and helping to liberate Jews from the Nazi concentration camps. The trouble was, he was never in Europe during World War II. When he was an actor, he was in a *movie* about World War II, made entirely in Hollywood. That important detail was missing from his memory.

IMPLICATIONS OF LONG-TERM MEMORY CHARACTERISTICS FOR USER-INTERFACE DESIGN

The main thing that the characteristics of long-term memory imply is that people need tools to augment it. Since prehistoric times, people have invented technologies to help them remember things over long periods: notched sticks, knotted ropes, mnemonics, verbal stories and histories retold around campfires, writing, scrolls, books, number systems, shopping lists, checklists, phone directories, datebooks, accounting ledgers, oven timers, computers, portable digital assistants (PDAs), online shared calendars, etc.

Given that humankind has a need for technologies that *augment* memory, it seems clear that software designers should try to provide software that fulfills that need. At the very least, designers should avoid developing systems that *burden* long-term memory. Yet that is exactly what many interactive systems do.

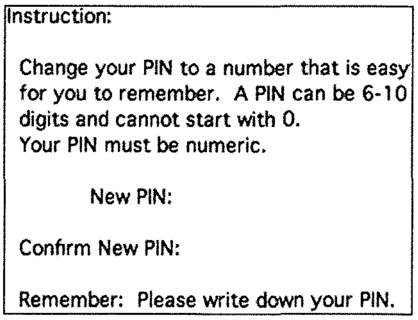
Authentication is one functional area in which many software systems place burdensome demands on users' long-term memory. For example, a web application developed a few years ago told users to change their personal identification number (PIN) "to a number that is easy to remember," but then imposed restrictions that made it impossible to do so (see Fig. 7.6). Whoever wrote those instructions seems to have realized that the PIN requirements were unreasonable, because the instructions end by advising users to write down their PIN! Nevermind that writing a PIN down creates a security risk and adds yet *another* memory task: users must remember where they hid their written-down PIN.

A contrasting example of burdening people's long-term memory for the sake of security comes from Intuit.com. To purchase software, visitors must register. The site requires users to select a security question from a menu (see Fig. 7.7). What if you can't answer *any* of the questions? What if you don't recall your first pet's name, your high school mascot, or any of the answers to the other questions?

But that isn't where the memory burden ends. Some questions could have several possible answers. Many people had several elementary schools, childhood friends, or heroes. To register, they must choose a question and then *remember* which answer they gave to Intuit.com. How? Probably by writing it down somewhere. Then, when Intuit.com asks them the security question, they have to *remember* where they put the answer. Why burden people's memory, when it would be easy to let users make up a security question for which they can easily recall the one possible answer?

Such unreasonable demands on people's long-term memory counteract the security and productivity that computer-based applications supposedly provide (Schrage, 2005), as users:

- Place sticky notes on or near computers or "hide" them in desk drawers.
- Contact customer support to recover passwords they cannot recall.


Instruction:

Change your PIN to a number that is easy for you to remember. A PIN can be 6-10 digits and cannot start with 0.
Your PIN must be numeric.

New PIN:

Confirm New PIN:

Remember: Please write down your PIN.

FIGURE 7.6

Instructions tell users to create an easy-to-remember PIN, but the restrictions make that impossible.

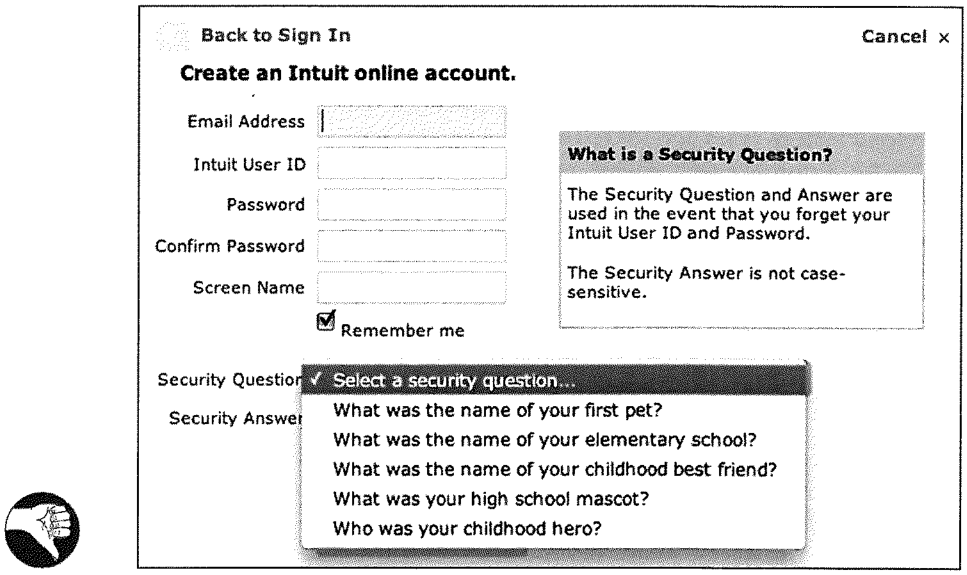


FIGURE 7.7

Intuit.com's registration burdens long-term memory: users may have no unique, memorable answer for any of the questions.

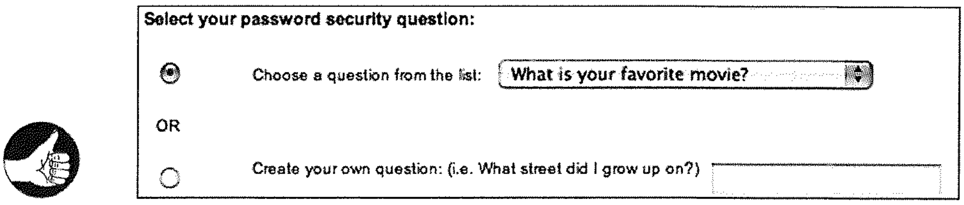


FIGURE 7.8

NetworkSolutions.com lets users create a security question if none on the menu works for them.

- Use passwords that are easy for others to guess.
- Set up systems with no login requirements at all, or with one shared login and password.

The registration form at NetworkSolutions.com represents a small step toward more usable security. Like Intuit.com, it offers a choice of security questions, but it also allows users to create their own security question—one for which they can more easily remember the answer (see Fig. 7.8).

Another implication of long-term memory characteristics for interactive systems is that learning and long-term retention are enhanced by user-interface consistency.

The more consistent the operation of different functions, or the more consistent the actions on different types of objects, the less users have to learn. User interfaces that have many exceptions and little consistency from one function or object to another require users to store in their long-term memory many features about each function or object and its correct usage context. The need to encode more features makes such user interfaces harder to learn. It also makes it more likely that a user's memory will drop essential features during storage or retrieval, increasing the chances that the user will fail to remember, misremember, or make other memory errors.

Even though some have criticized the concept of consistency as ill-defined and easy to apply badly (Grudin, 1989), the fact is that consistency in a user interface greatly reduces the burden on users' long-term memory. Mark Twain once wrote: "If you tell the truth, you never have to remember anything." One could also say, "If everything worked the same way, you would not have to remember much." We will return to the issue of user-interface consistency in Chapter 11.

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CHAPTER

Limits on Attention Shape Our Thought and Action

8

When people interact purposefully with the world around them, including computer systems, some aspects of their behavior follow predictable patterns, some of which result from the limited capacity of attention and short-term memory. When interactive systems are designed to recognize and support those patterns, they fit better with the way people operate. Some user-interface design rules, then, are based directly on the patterns and thus indirectly on the limits of short-term memory and attention. This chapter describes seven important patterns.

WE FOCUS ON OUR GOALS AND PAY LITTLE ATTENTION TO OUR TOOLS

As Chapter 7 explained, our attention has very limited capacity. When people are doing a task—trying to accomplish a goal—most of their attention is focused on the goals and data related to that task. Normally, people devote very little attention to the tools they are using to perform a task, whether they are using computer applications, online services, or interactive appliances. Instead, people think about their tools only superficially, and then only when necessary.

We are, of course, *capable* of attending to our tools. However, attention (i.e., short-term memory) is limited in capacity. When people refocus their attention on their tools, it is pulled away from the details of the task. This shift increases the chances of users losing track of what they were doing or exactly where they were in doing it.

For example, if your lawn mower stops running while you are mowing your lawn, you will immediately stop and focus on the mower. Restarting the mower becomes your primary task, with the mower itself as the focus. You pay scant attention to any tools you use to restart the mower, just as you paid scant attention to the mower when your primary focus was the lawn. After you restart the mower and

Designing with the Mind in Mind. http://dx.doi.org/10.1016/B978-0-12-407914-4.00008-7

resume mowing the lawn, you probably wouldn't remember where you were in mowing the lawn, except that the lawn itself shows you.

Other tasks—for example, reading a document, measuring a table, counting goldfish in a fish tank—might not provide such a clear reminder of your interrupted task and your position in it. You might have to start over from the beginning. You might even forget what you were doing altogether and go off to do something else.

That is why most software design guidelines state that software applications and most Web sites should not call attention to themselves; they should fade into the background and allow users to focus on their own goals. That design guideline is even the title of a popular web design book: *Don't Make Me Think* (Krug, 2005). That is, if your software or Web site makes me think about *it*, rather than what I am trying to do, you've lost me.

WE NOTICE THINGS MORE WHEN THEY ARE RELATED TO OUR GOALS

Chapter 1 described how our immediate goals filter and bias our perception. Chapter 7 discussed the connections between attention and memory. This chapter provides examples showing that perceptual filtering and biasing, attention, and memory are all closely related.

Our environment is full of perceptual details and events. Obviously, we cannot notice and keep track of everything that happens around us. Nonetheless, it is surprising to most people how little we notice of what goes on around us. Because of our extremely limited short-term memory and attention, we don't waste those resources. When an event happens, the few details about it that we notice and remember later are usually those that were important for our goals at the time of the event. This is demonstrated by two related psychological phenomena: *inattentional blindness* and *change blindness.*

Inattentional blindness

When our mind is intensely occupied with a task, goal, or emotion, we sometimes fail to notice objects and events in our environment that we otherwise would have noticed and remembered. This phenomenon has been heavily studied by psychologists and labeled *inattentional blindness* (Simons and Chabris, 1999; Simons, 2007).

A clear demonstration of inattentional blindness is an experiment in which human subjects watched a video of two basketball teams passing a ball from one player to another. Subjects were told to count the number of times the white-suited team passed the ball. While they watched the video and counted the ball-passes, a person in a gorilla suit sauntered onto the basketball court, thumped his chest, then walked out of view (see Fig. 8.1). Afterwards, subjects were asked what they remembered from the video. Surprisingly, about half of them did not notice the gorilla. Their attention was fully occupied with the task (Simons and Chabris, 1999).

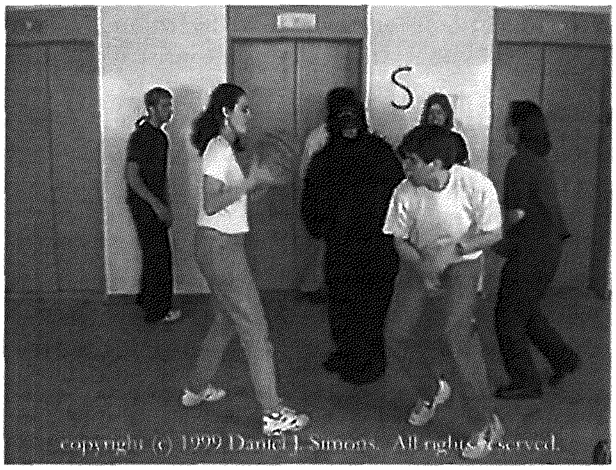


FIGURE 8.1

Scene from video used in "invisible gorilla" study. *Figure provided by Daniel Simons.* For more information about the study and to see the video, go to www.dansimons.com or www.theinvisiblegorilla.com.

Change blindness

Another way researchers have shown that our goals strongly focus our attention and memory is through the following: show people a picture, then show them a second version of the same picture and ask them how the two pictures differ. Surprisingly, the second picture can differ from the first in many ways without people noticing. To explore further, researchers gave people questions to answer about the first picture, affecting their goals in looking at it, and therefore what features of the picture they paid attention to. The result was people don't notice differences in features other than those their goals made them pay attention to. This is called *change blindness* (Angier, 2008).

A particularly striking example of how our goals focus our attention and affect what we remember comes from experiments in which experimenters holding city maps posed as lost tourists and asked local people walking by for directions. When the local person focused on the tourist's map to figure out the best route, two workmen—actually, more experimenters—walked between the tourist and the advice-giver carrying a large door, and in that moment the tourist was replaced by another experimenter-tourist. Astoundingly, after the door passed, over half of the local people continued helping the tourist without noticing any change, even when the two tourists differed in hair color or in whether they had a beard (Simons and Levin, 1998).[1] Some people even failed to notice changes in gender. In summary,

[1] For demonstrations of change blindness, search YouTube for those words, or for "door study" and "person swap."

people focus on the tourist only long enough to determine if he or she is a threat or worth helping, record only that the person is a tourist who needs help, and then focus on the map and the task of giving directions.

When people interact with software, electronic appliances, or online services, it is not uncommon for them to fail to notice important changes in what is displayed. For example, in a study of seniors using travel websites, changes in price resulting from user actions were often not obvious. Even after spotting the price information, participants were prone to change blindness: when they changed trip options (e.g., departure city, additional excursions, cabin class), they often would not notice that the price changed (Finn and Johnson, 2013). The study only used older adults, so we don't know whether younger participants would have had the same trouble noticing price changes.

The user-interface design guideline that follows from such findings is to make changes obvious—that is, highly salient—and take steps to draw users' attention to the change. For example, a way to draw users' attention to a new error message is to vibrate it briefly when it first appears (see Chapter 6), or highlight it briefly before it reverts to a "normal" appearance.

What happens in our brains

Using functional magnetic resonance imagery (fMRI) and electrical encephalography (EEG), researchers have studied the effect of attention on how our brains respond to objects displayed on a computer screen.

When people passively watch a computer display with objects appearing, moving around, and disappearing, the visual cortex of their brains registers a certain activity level. When people are told to look for (i.e., pay attention to) certain objects, the activity level of their visual cortex increases significantly. When they are told to ignore certain objects, the neural activity level in their visual cortex actually drops when those objects appear. Later, their memory for which objects they saw and didn't see corresponds to the degree of attention they paid to them and to the level of brain activity (Gazzaley, 2009).

WE USE EXTERNAL AIDS TO KEEP TRACK OF WHAT WE ARE DOING

Because our short-term memory and attention are so limited, we learn not to rely on them. Instead, we mark up our environment to show us where we are in a task. Examples include:

- ***Counting objects.*** If possible, we move already counted objects into a different pile to indicate which objects have already been counted. If we cannot move an object, we point to the last object counted. To keep track of the number we are on, we count on our fingers, draw marks, or write numbers.

- ***Reading books.*** When we stop reading, we insert bookmarks to show what page we were on.
- ***Arithmetic.*** We learn methods of doing arithmetic on paper, or we use a calculator.
- ***Checklists.*** We use checklists to aid both our long- and short-term memory. In critical or rarely performed tasks, checklists help us remember everything that needs to be done. In that way, they augment our faulty long-term memory. While doing the task, we check off items as we complete them. That is a short-term memory aid. A checklist that we can't mark up is hard to use, so we copy it and mark the copy.
- ***Editing documents.*** People often keep to-be-edited documents, documents that are currently being edited, and already edited documents in separate folders.

One implication of this pattern is that interactive systems should indicate what users have done versus what they have not yet done. Most email applications do this by marking already-read versus unread messages, most Web sites do it by marking visited versus unvisited links, and many applications do it by marking completed steps of a multipart task (see Fig. 8.2).

A second design implication is that interactive systems should allow users to mark or move objects to indicate which ones they have worked on versus which ones they have not worked on. Mac OS lets users assign colors to files. Like moving files between folders, this technique can be used to keep track of where one is in a task (see Fig. 8.3).

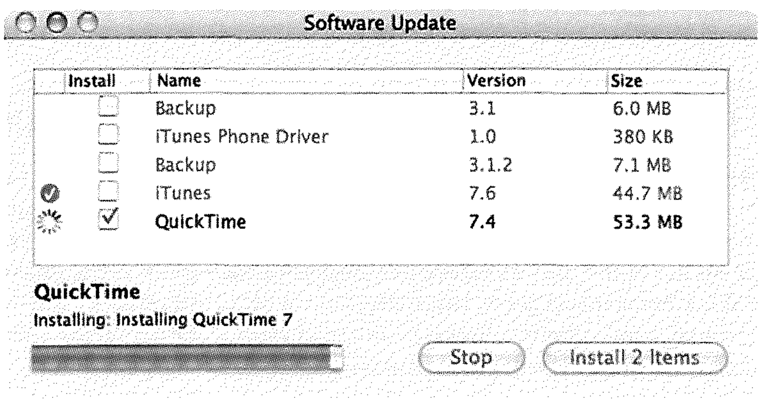


FIGURE 8.2

The Mac OS Software Update shows which updates are done (green check) versus which are in progress (rotating circle).

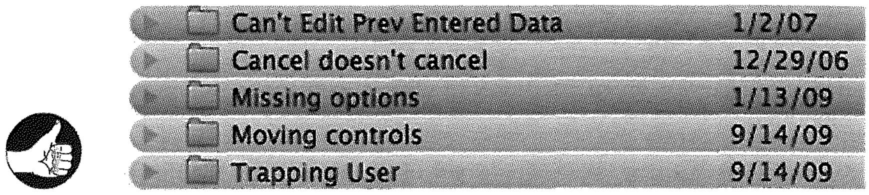
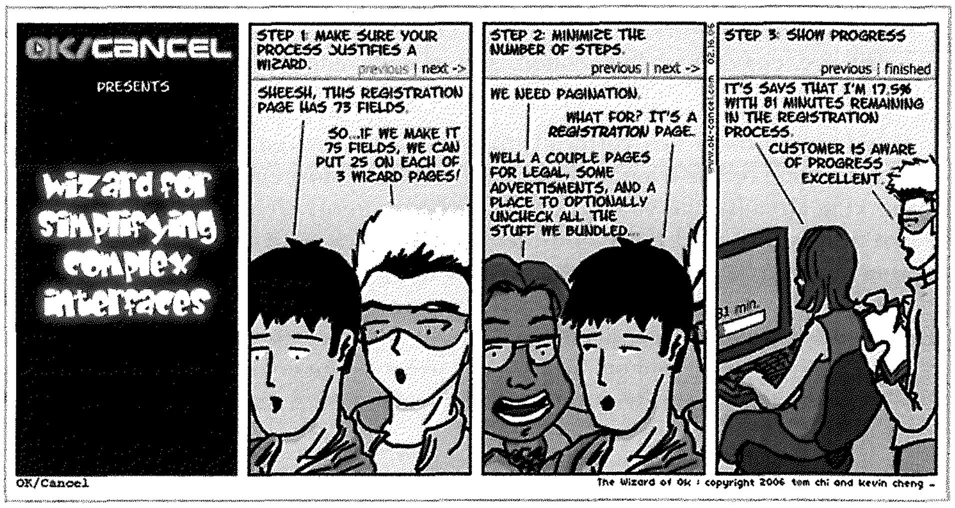


FIGURE 8.3

Mac OS lets users assign colors to files or folders; users can use the colors to track their work.



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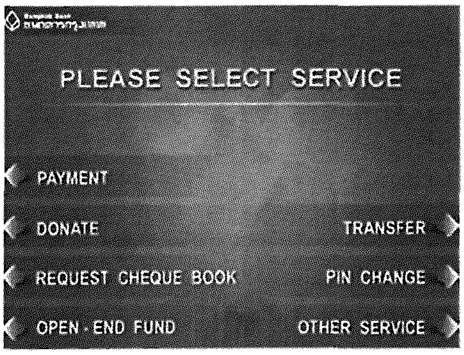
WE FOLLOW THE INFORMATION "SCENT" TOWARD OUR GOAL

Focusing our attention on our goals makes us interpret what we see on a display or hear in a telephone menu in a very *literal* way. People don't think deeply about instructions, command names, option labels, icons, navigation bar items, or any other aspect of the user interface of computer-based tools. If the goal in their head is to make a flight reservation, their attention will be attracted by anything displaying the words "buy," "flight," "ticket," or "reservation." Other items that a designer or marketer might think will attract customers, such as "bargain hotels," will not attract the attention of people who are trying to book a flight, although they might be noticed by people who are looking for bargains.

This tendency of people to notice only things on a computer display that match their goal, and the literal thinking that they exhibit when performing a task on a computer, has been called "following the *scent* of information toward the goal" (Chi



For each goal below, what on the screen would attract your attention?

- Pay a bill
- Transfer money to your savings account
- Pay your dentist by funds transfer
- Change your PIN
- Open a new account
- Purchase travelers' cheque

FIGURE 8.4

ATM screen—our attention is drawn initially toward items that match our goal literally.

et al., 2001; Nielsen, 2003). Consider the ATM machine display shown in Figure 8.4. What is the first thing on the screen that gets your attention when you are given each of the goals listed?

You probably noticed that some of the listed goals direct your attention initially to the wrong option. Is "Pay your dentist by funds transfer" under "Payment" or "Transfer"? "Open a new account" probably sent your eyes briefly to "Open-End Fund," even though it is actually under "Other Service." Did the goal "Purchase traveler's cheques" make you glance at "Request Cheque Book" because of the word they share?

The goal-seeking strategy of following the information scent, observed across a wide variety of situations and systems, suggests that interactive systems should be designed so that the scent is strong and really leads users to their goals. To do that, designers need to understand the goals that users are likely to have at each decision point in a task, and ensure that each choice point in the software provides options for every important user goal and clearly indicates which option leads to which goal.

For example, imagine that you want to cancel a reservation you made or a payment you scheduled. You tell the system to cancel it, and a confirmation dialog box appears asking if you really want to do that. How should the options be labeled? Given that people interpret words literally in following the information scent toward their goal, the standard confirmation button labels "OK" (for yes) and "Cancel" (for no) would give a misleading scent. If we compare a cancellation confirmation dialog box from Marriott.com to one from WellsFargo.com, we see that Marriott.com's labeling provides a clearer scent than Quicken.com's (see Fig. 8.5).

As a second example, imagine that you forgot that a certain document was already open, and you tried to open it again. The designers of Microsoft Excel did a better job than the designers of Microsoft Word in anticipating this situation, understanding the goals you might have at this point, and presenting you with instructions and options that make it clear what to do (see Fig. 8.6).

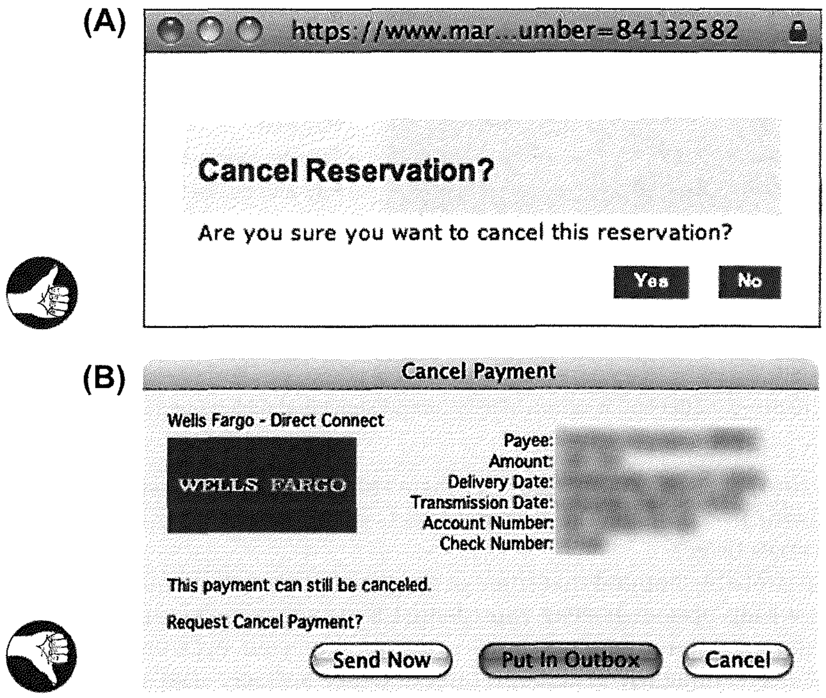


FIGURE 8.5
Marriott's cancellation confirmation (A) provides a clearer scent than Wells Fargo's (B).

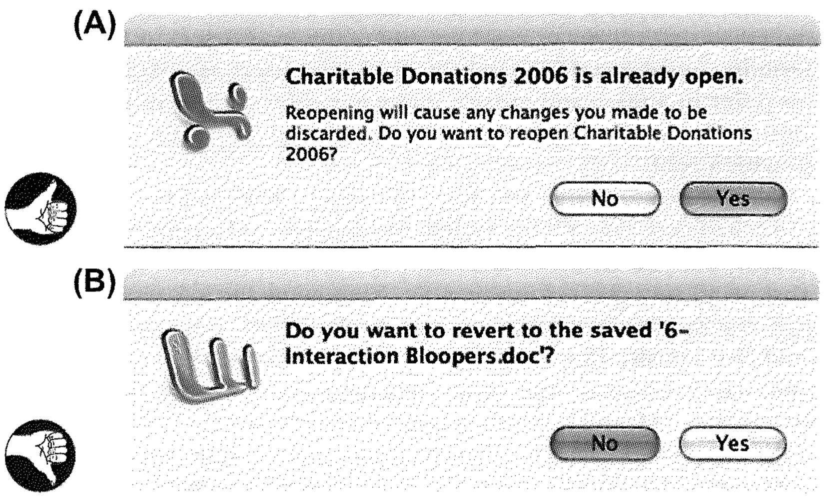


FIGURE 8.6
Microsoft Excel's (A) warning when users try to open an already-open file is clearer than Microsoft Word's (B).

WE PREFER FAMILIAR PATHS

People know that their attention is limited, and they act accordingly. While pursuing a goal, they take *familiar* paths whenever possible rather than exploring *new* ones, especially when working under deadlines. As explained more fully in Chapter 10, exploring new paths is problem solving, which severely taxes our attention and short-term memory. In contrast, taking familiar, well-learned routes can be done fairly automatically and does not consume much attention and short-term memory.

Years ago, in a usability test session, a test participant in the middle of a task said to me:

> I'm in a hurry, so I'll do it the long way.

He knew there probably was a more efficient way to do what he was doing, but he also knew that learning the shorter way would require time and thought, which he was unwilling to spend.

Once we learn one way to perform a certain task using a software application, we may continue to do it that way and *never* discover a more efficient way. Even if we discover or are told that there is a "better" way, we may stick with the old way because it is familiar, comfortable, and, most important, requires little thought. Avoiding thought when using computers is important. People are willing to type *more* to think *less*.

Why is that? Are we mentally lazy? Usually, yes. Conscious thought is slow, strains working memory, and consumes much energy. We essentially run on batteries—that is, the food we eat—so energy conservation is an important feature that is part of our makeup. Operating via automatic processes is fast, doesn't strain working memory, and conserves energy. So the brain tries to run on automatic as much as possible (Kahneman, 2011; Eagleman, 2012).

The human preference for familiar, mindless paths and "no-brainer" decisions has several design implications for interactive systems:

- ***Sometimes mindlessness trumps keystrokes.*** With software intended for casual or infrequent use, such as bank ATM machines or household accounting applications, allowing users to become productive quickly and reducing their need to problem-solve while working is more important than saving keystrokes. Such software simply isn't used enough for the number of keystrokes per task to matter much. On the other hand, in software that is used all day by highly trained users in intensive work environments, such as airline telephone reservation operators, unnecessary extra keystrokes needed to perform a task are very costly.
- ***Guide users to the best paths.*** From its first screen or homepage, software should show users the way to their goals. This is basically the guideline that software should provide a clear information scent.

- ***Help experienced users speed up.*** Make it easy for users to switch to faster paths after they have gained experience. The slower paths for newcomers should show users faster paths if there are any. This is why most applications show the keyboard accelerators for frequently used functions in the menu-bar menus.

OUR THOUGHT CYCLE: GOAL, EXECUTE, EVALUATE

Over many decades, scientists studying human behavior have found a cyclical pattern that seems to hold across a wide variety of activities:

- Form a ***goal*** (e.g., open a bank account, eat a peach, or delete a word from a document).
- Choose and ***execute*** actions to try to make progress toward the goal.
- ***Evaluate*** whether the actions worked—that is, whether the goal has been reached or is nearer than before.
- Repeat until the goal is reached (or appears unreachable).

People cycle through this pattern constantly (Card et al., 1983). In fact, we run through it at many different levels simultaneously. For example, we might be trying to insert a picture into a document, which is part of a higher-level task of writing a term paper, which is part of a higher-level task of passing a history course, which is part of a higher-level task of completing college, which is part of a higher-level goal of getting a good job, which we want to achieve our top-level goal of having a comfortable life.

As an example, let's run through the cycle for a typical computer task: buying an airline ticket online. The person first forms the primary goal of the task and then begins to break that down into actions that appear to lead toward the goal. Promising actions are selected for execution, executed, and then evaluated to determine if they have moved the person closer to the goal.

- ***Goal:*** Buy airline ticket to Berlin, using your favorite travel Web site.
- ***Step 1:*** Go to travel Web site. You are still far from the goal.
- ***Step 2:*** Search for suitable flights. This is a very normal, predictable step at travel Web sites.
- ***Step 3:*** Look at search results. Choose a flight from those listed. If no flights on the results list are suitable, return to Step 2 with new search criteria. You are not at the goal yet, but you feel confident of getting there.
- ***Step 4:*** Go to checkout. Now you are getting so close to your goal that you can almost smell it.

- ***Step 5:*** Confirm flight details. Check it—all correct? If no, back up; otherwise proceed. Almost done.
- ***Step 6:*** Purchase ticket with credit card. Check credit card information. Everything look okay?
- ***Step 7:*** Print e-ticket. Goal achieved.

In the airline ticket example, to keep the example short, we didn't get down into the details of each step. If we had, we would have seen substeps that followed the same *goal-execute-evaluate* cycle.

Let's try another example, this time examining the details of some of the higher-level steps. This time the task is sending flowers to a friend. If we simply look at the top level, we see the task like this:

Send flowers to friend.

If we want to examine the goal-execute-evaluate cycle for this task, we must break down this task a bit. We must ask: *How* do we send flowers to a friend? To do that, we break the top-level task down into subtasks:

Send flowers to friend.
  Find flower delivery Web site.
  Order flowers to be delivered to friend.

For many purposes, the two steps we have identified are enough detail. After we execute each step, we evaluate whether we are closer to our goal. But *how* is each step executed? To see that, we have to treat each major step as a subgoal, and break it down into substeps:

Send flowers to friend.
  Find flower delivery Web site.
    Open web browser.
    Go to Google web search page.
    Type "flower delivery" into Google.
    Scan the first page of search results.
    Visit some of the listed links.
    Choose a flower delivery service.
  Order flowers to be delivered to friend.
    Review service's flower selection.
    Choose flowers.
    Specify delivery address and date.
    Pay for flowers and delivery.

After each substep is executed, we evaluate to see if it is getting us closer to the subgoal of which it is part. If we want to examine how a substep is executed and evaluated, we have to treat it as a sub-subgoal and break it into its component steps:

Send flowers to friend.
  Find flower delivery Web site.
    Open web browser.
      - Click browser icon on taskbar, startup menu, or desktop.
    Go to Google web search page.
      - If Google isn't browser's starting page, choose "Google" from favorites list.
      - If Google is not on favorites list, type "Google.com" into browser's address box.
    Type "flower delivery" into Google.
      - Set text-insertion point in search box.
      - Type the text.
      - Correct typo: "floowers" to "flowers."
    Visit some of the resulting links.
      - Move screen pointer to link.
      - Click on link.
      - Look at resulting web page.
    Choose a flower delivery service.
      - Enter chosen service's URL into browser.

...

You get the idea. We could keep expanding, down to the level of individual keystrokes and individual mouse movements, but we rarely need that level of detail to be able to understand the task well enough to design software to fit its steps and the goal-execute-evaluate cycle that is applied to each step.

How can software support users in carrying out the goal-execute-evaluate cycle? Any of these ways:

- ***Goal.*** Provide clear paths—including initial steps—for the user goals that the software is intended to support.
- ***Execute.*** Software concepts (objects and actions) should be based on the task rather than the implementation (see Chapter 11). Don't force users to figure out how the software's objects and actions map to those of the task. Provide a clear information scent at choice points to guide users to their goals. Don't make them choose actions that seem to take them away from their goal to achieve it.
- ***Evaluate.*** Provide feedback and status information to show users their progress toward the goal. Allow users to back out of tasks that didn't take them toward their goal.

An example of the evaluate guideline—clear feedback about the user's progress through a series of steps—is provided by ITN.com's flight reservation system (see Fig. 8.7). By the way, does the figure seem familiar? If so, it is because you saw it in Chapter 4 (see Fig. 4.16B), and your brain recognized it.

FIGURE 8.7

ITN.com's flight reservation system clearly shows users' progress toward making a reservation.

AFTER WE ACHIEVE A TASK'S PRIMARY GOAL, WE OFTEN FORGET CLEANUP STEPS

The goal-execute-evaluate cycle interacts strongly with short-term memory. This interaction makes perfect sense: short-term memory is really just what the focus of attention is at any given moment. Part of the focus of attention is our current goal. The rest of our attentional resources are directed toward obtaining the information needed to achieve our current goal. The focus shifts as tasks are executed and the current goal shifts from high-level goals to lower-level ones, then back to the next high-level goal.

Attention is a very scarce resource. Our brain does not waste it by keeping it focused on anything that is no longer important. Therefore, when we complete a task, the attentional resources focused on that task's main goal are freed to be refocused on other things that are now more important. The impression we get is that once we achieve a goal, everything related to it often immediately "falls out" of our short-term memory—that is, we forget about it.

One result is that people often forget loose ends of tasks. For example, people often forget to do these things:

- Turn car headlights off after arrival.
- Remove the last pages of documents from copiers and scanners.
- Turn stove burners and ovens off after use.
- Add closing parentheses and quotation marks after typing text passages.
- Turn off turn signals after completing turns.
- Take books they were reading on a flight with them when they exit the plane.
- Log out of public computers when finished using them.
- Set devices and software back into normal mode after putting them into a special mode.

These end-of-task short-term memory lapses are completely predictable and avoidable. When they happen to us, we call ourselves "absent-minded," but they are the result of how the brain works (or doesn't), combined with a lack of support from our devices.

To avoid such lapses, interactive systems can and should be designed to remind people that loose-end steps remain. In some cases, it may even be possible for the system to complete the task itself. For example:

- Cars already turn off turn signals after a turn.
- Cars should (and now do) turn off headlights automatically when the car is no longer in use, or at least remind drivers that the lights are still on.
- Copiers and scanners should automatically eject all documents when tasks are finished, or at least signal that a page has been left behind.
- Stoves should signal when a burner is left on with no pot present for longer than some suitable interval, and ovens should do likewise when left on with nothing in them.
- Computers should issue warnings if users try to power them down or put them to sleep before the computer has finished a background task (e.g., saving files or sending a document to a printer).
- Special software modes should revert to "normal" automatically, either by timing out—as some appliances do—or through the use of spring-loaded mode controls, which must be physically held in the non-normal state and revert to normal when released (Johnson, 1990).

Software designers should consider whether the tasks supported by a system they are designing have cleanup steps that users are likely to forget, and if so, they should design the system either to help users remember, or eliminate the need for users to remember.

CHAPTER

Recognition is Easy; Recall is Hard

9

Chapter 7 described the strengths and limitations of long-term memory and their implications for the design of interactive systems. This chapter extends that discussion by describing important differences between two functions of long-term memory: recognition and recall.

RECOGNITION IS EASY

The human brain was "designed," through millions of years of natural selection and evolution, to recognize things quickly. By contrast, recalling memories—that is, retrieving them without perceptual support—must not have been as crucial for survival, because our brains are much worse at that.

Remember how our long-term memory works (see Chapter 7): Perceptions enter through our sensory systems, and their signals, when they reach the brain, cause complex patterns of neural activity. The neural pattern resulting from a perception is determined not only by the features of the perception, but also by the context in which it occurs. Similar perceptions in similar contexts cause similar patterns of neural activity. Repeated activation of a particular neural pattern makes that pattern easier to reactivate in the future. Over time, connections between neural patterns develop in such a way that activating one pattern activates the other. Roughly speaking, each pattern of neural activity constitutes a different memory.

Patterns of neural activity, which is what memories are, can be activated in two different ways:

1. By more perceptions coming in from the senses.
2. By other brain activity.

If a perception comes in that is similar to an earlier one and the context is close enough, it easily stimulates a similar pattern of neural activity, resulting in a sense of

Designing with the Mind in Mind. http://dx.doi.org/10.1016/B978-0-12-407914-4.00009-9

recognition. Recognition is essentially perception and long-term memory working in concert.

As a result, we assess situations very quickly. Our distant ancestors on the East African savannah had only a second or two to decide whether an animal emerging from the tall grasses was something they would regard as food or something that would regard *them* as food (see Fig. 9.1). Their survival depended on it.

Similarly, people recognize human faces very quickly—usually in a fraction a second (see Fig. 9.2). Until recently, the workings of this process were considered a mystery. However, that was when scientists assumed that recognition was a process

FIGURE 9.1

Early hominids had to recognize quickly whether animals they spotted were prey or predators.

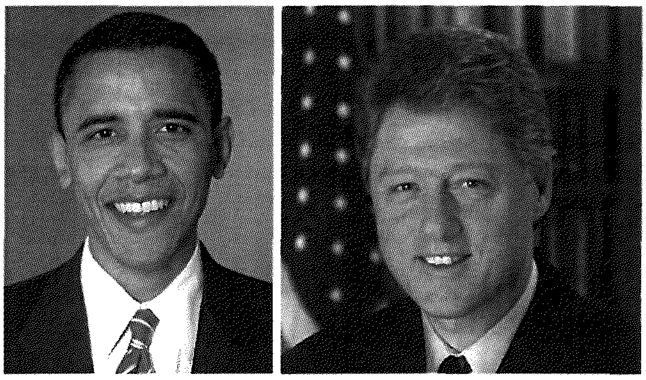


FIGURE 9.2

How long did it take you to recognize these faces?[1]

[1] U.S. Presidents Barack Obama and Bill Clinton.

in which perceived faces were stored in a separate short-term memory and compared with those in long-term memory. Because of the speed with which the brain recognizes faces, cognitive scientists assumed that the brain must search many parts of long-term memory simultaneously, via what computer scientists call *parallel processing*. However, even a massively parallel search process could not account for the astounding rapidity of facial recognition.

Nowadays, perception and long-term memory are considered closely linked, which demystifies the speed of facial recognition somewhat. A perceived face stimulates activity in millions of neurons in distinct patterns. Individual neurons and groups of neurons that make up the pattern respond to specific features of the face and the context in which the face is perceived. Different faces stimulate different patterns of neural response. If a face was perceived previously, its corresponding neural pattern will already have been activated. The same face perceived again reactivates the same pattern of neural activity, only more easily than before. That *is* the recognition. There is no need to search long-term memory: the new perception reactivates the same pattern of neural activity, more or less, as the previous one. Reactivation of a pattern *is* the reactivation of the corresponding long-term memory.

In computer jargon, we could say that the information in human long-term memory is *addressed by its content*, but the word "addressed" wrongly suggests that each memory is located at a specific spot in the brain. In fact, each memory corresponds to a pattern of neural activity extending over a wide area of the brain.

That explains why, when presented with faces we have not seen before and asked if they are familiar, we don't spend a long time searching through our memories to try to see if that face is stored in there somewhere (see Fig. 9.3). There is no search.

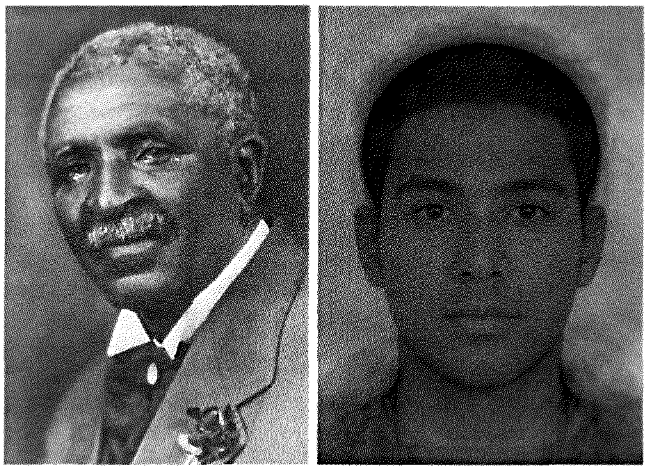


FIGURE 9.3

How long did it take you to realize that you do not recognize these faces?[2]

[2] George Washington Carver (American scientist, educator, and inventor) and average male face (FaceResearch.org).

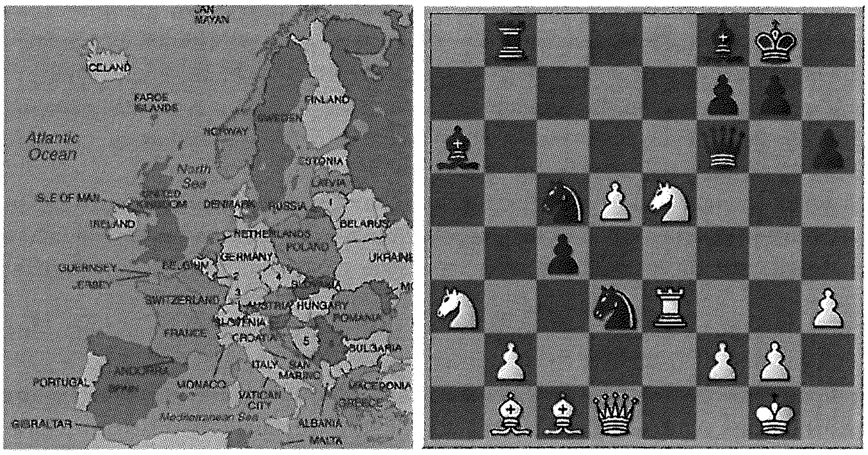


FIGURE 9.4

We can recognize complex patterns quickly.

A new face stimulates a pattern of neural activity that has not been activated before, so no sense of recognition results. Of course, a new face may be so similar to a face we have seen that it triggers a *misrecognition*, or it may be just similar enough that the neural pattern it activates triggers a familiar pattern, causing a feeling that the new face reminds us of someone we know.

An interesting aside is that face recognition is a special type of recognition: it has its own dedicated mechanisms in our brains, hardwired in by evolution; we do not have to learn to recognize human faces (Eagleman, 2012).

Similar mechanisms make our visual system fast at recognizing complex patterns, although unlike face recognition, they develop largely through experience rather than being wired in from birth. Anyone with at least a high school education quickly and easily recognizes a map of Europe and a chessboard (see Fig. 9.4). Chess masters who have studied chess history may even recognize the chess position as Kasparov versus Karpov 1986.

RECALL IS HARD

In contrast, *recall* is long-term memory reactivating old neural patterns without immediate similar perceptual input. That is much harder than reactivating a neural pattern with the same or similar perceptions. People *can* recall memories, so it obviously *is* possible for activity in other neural patterns or input from other areas of the brain to reactivate a pattern of neural activity corresponding to a memory. However, the coordination and timing required to recall a memory increase the likelihood that the wrong pattern or only a subset of the right pattern will be activated, resulting in a failure to recall.

Whatever the evolutionary reasons, our brain did not evolve to recall facts. Many schoolchildren dislike history class because it demands that they remember facts, such as the year the English Magna Carta was signed, the capital city of Argentina, and the names of all 50 U.S. states. Their dislike is not surprising; the human brain is not well suited for that sort of task.

Because people are bad at recall, they develop methods and technologies to help them remember facts and procedures (see Chapter 7). Orators in ancient Greece used the *method of loci* to memorize the main points of long speeches. They imagined a large building or plaza and mentally placed their talking points in spots around it. When presenting the speech, they mentally "walked" through the site, picking up their talking points as they passed.

Today we rely more on external recall aids than on internal methods. Modern-day speakers remember their talking points by writing them down on paper or displaying them in overhead slides or presentation software. Businesses keep track of how much money they have, owe, or are owed by keeping account books. To remember contact information of friends and relatives, we use address books. To remember appointments, birthdays, anniversaries, and other events, we use calendars and alarm clocks. Electronic calendars are best for remembering appointments, because they actively remind us; we don't have to remember to look at them.

RECOGNITION VERSUS RECALL: IMPLICATIONS FOR USER-INTERFACE DESIGN

The relative ease with which we recognize things rather than recall them is the basis of the graphical user interface (GUI) (Johnson et al., 1989). The GUI is based on two well-known user interface design rules:

- ***See and choose is easier than recall and type.*** Show users their options and let them choose among them, rather than force users to recall their options and tell the computer what they want. This rule is the reason GUIs have almost replaced command-line user interfaces (CLIs) in personal computers (see Fig. 9.5).

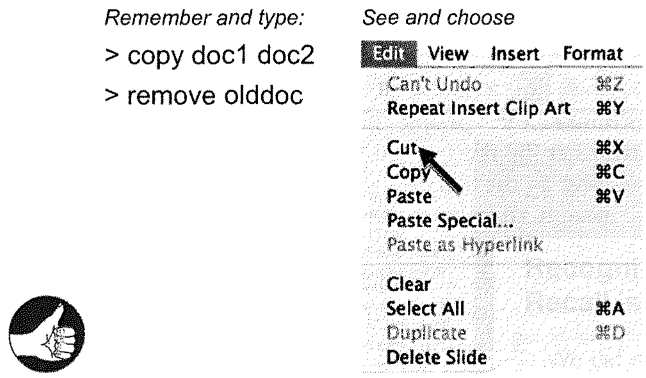


FIGURE 9.5

The main design rule behind today's GUI: "See and choose is easier than remember and type."

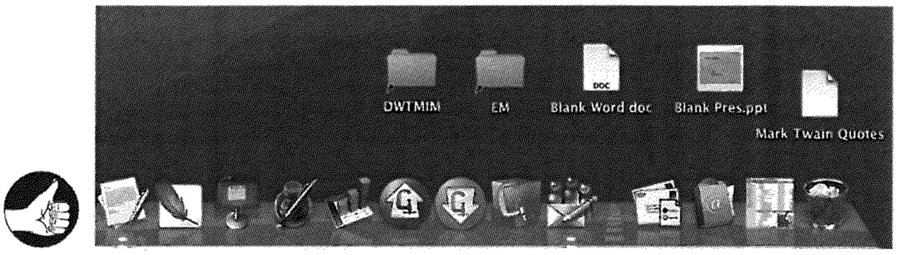


FIGURE 9.6

Desktop icons convey function via recognition—by analogy with physical objects or by experience.

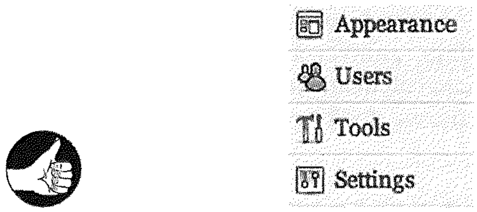


FIGURE 9.7

Wordpress.com uses symbols plus text to label functional pages on the Dashboard.

"Recognition rather than recall" is one of Nielsen and Molich's (1990) widely used heuristics for evaluating user interfaces. By contrast, using language to control a software application sometimes allows more expressiveness and efficiency than a GUI would. Thus, *recall and type* remains a useful approach, especially in cases where users can easily recall what to type, such as when entering target keywords into a search box.

- ***Use pictures where possible to convey function.*** People recognize pictures very quickly, which also stimulates the recall of associated information. For this reason, today's user interfaces often use pictures to convey function (see Figs. 9.6 and 9.7), such as desktop or toolbar icons, error symbols, and graphically depicted choices. Pictures that people recognize from the physical world are useful because they can be recognized without needing to be taught. This recognition is good as long as the familiar meaning matches the intended meaning in the computer system (Johnson, 1987). However, using familiar pictures from the physical world is not absolutely crucial. Computer users can learn to associate new icons and symbols with their intended meaning if these graphics are well designed. Memorable icons and symbols hint at their meaning, are distinguishable from others, and consistently mean the same thing, even across applications.

The GUI originated in the mid-1970s and became widespread in the 1980s and 1990s. Since then, additional design rules have arisen that are based on human

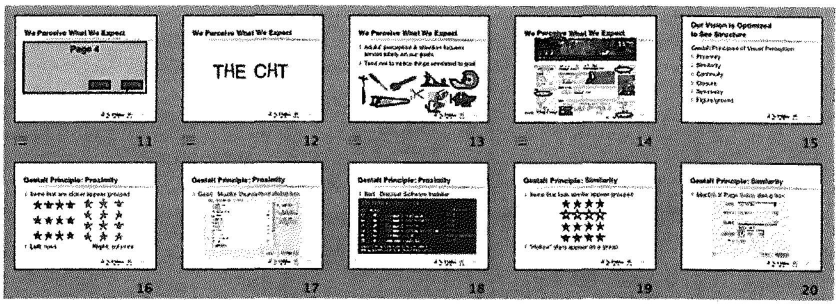


FIGURE 9.8

Microsoft PowerPoint can show slides as thumbnails, providing an overview based on recognition.

perception in general and on recognition and recall in particular. The following sections outline a few of these newer rules.

Use thumbnail images to depict full-sized images compactly

Recognition is fairly insensitive to the size in which objects and events are displayed. After all, we have to be able to recognize things independently of their distance from us. What is important are features: as long as most of the same features are present in the new picture that were in the original one, the new perception stimulates the same neural pattern, resulting in recognition.

Therefore, a great way to display pictures people have already seen is to present them as small thumbnail images. The more familiar a picture, the smaller the thumbnails of it can be and still be recognizable. Displaying small thumbnails instead of full-sized images allows people to see more of their options, their data, their history, etc., at once.

Photo management and presentation applications use thumbnail images to give users an overview of their images or slides (see Fig. 9.8). Web browsers use thumbnails to show pages a user has recently visited (see Fig. 9.9).

The larger the number of people who will use a function, the more visible the function should be

For the reasons described before, recall often fails. If a software application hides its functionality and requires its users to recall what to do, some percentage of users will fail. If the software has a lot of users, that percentage who fail to recall—even if it is small—adds up to a significant number. Software designers obviously don't want a significant number of users to fail in using their product.

The solution is to make functions that many people need highly visible, so users see and *recognize* their options rather than having to *recall* them. By contrast, functionality that few people will use—especially when those few people are highly trained—can be hidden, for example, behind "Details" panels, in right-click menus, or via special key combinations.

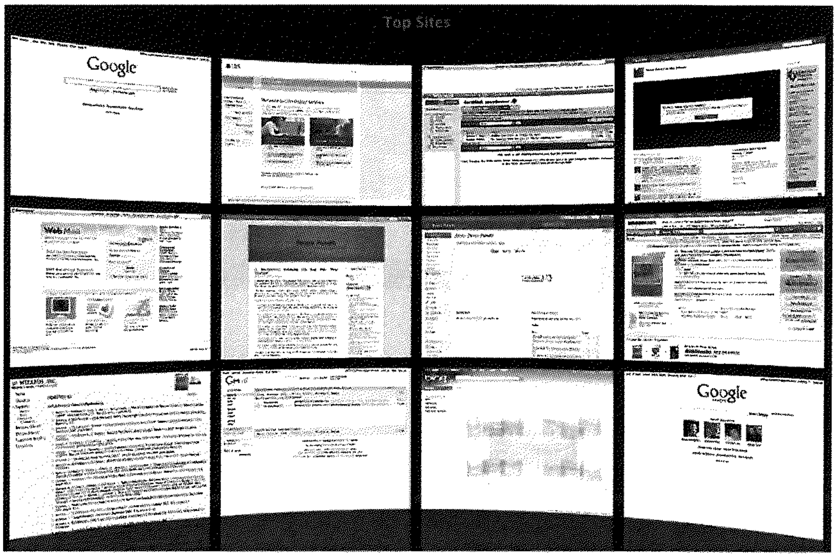


FIGURE 9.9

Apple Safari can show recently visited pages as thumbnail images, for quick recognition and choice.

Use visual cues to let users recognize where they are

Visual recognition is fast and reliable, so designers can use visual cues to show users instantly where they are. For example, it is a well-known Web design rule that all pages in a Web site should have a common distinctive visual style so people can easily tell whether they are still on the site or have gone to a different one. Slight but systematic variations on a site's visual style can show users which section of the site they are in.

Some desktop operating systems allow users to set up multiple desktops ("rooms" or "workspaces") as locations for different categories of work. Each has its own background graphic to allow easy recognition.

Some corporate Web sites use pictures to assure users that they are on a secure site. Users choose a picture as a personal account logo, and the site displays the logo whenever it recognizes the user from cookies or after the user has entered a valid login name but not yet a password (see Fig. 9.10). This lets users know they are at the real company site and not a fake site hosted by someone running a phishing scam.

Make authentication information easy to recall

People know that it is hard to recall arbitrary facts, words, and sequences of letters or digits. That is why they often write passwords and challenge-question answers down and keep the information in places that are easy to reach and thus insecure. Or they base passwords on their children's initials, their birthdates, their street

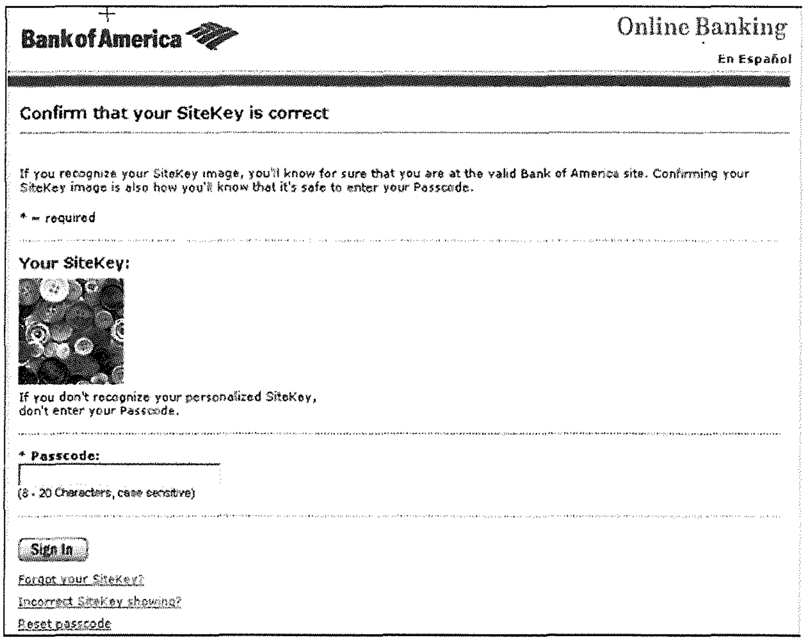


FIGURE 9.10

BankOfAmerica.com shows recognized customers their self-selected account logo (SiteKey) to assure them that it is the real bank's site.

address, and other information they know they can recall. Unfortunately, such passwords are too often easy for other people to guess (Schrage, 2005). How can designers help users avoid such unsafe behavior?

For starters, we can at least not make it hard for people to recall their login information, like the systems cited in Chapter 7 that impose burdensome password restrictions or offer a limited choice of challenge questions.

Instead, we can give users the freedom to create passwords they can remember and challenge questions for which they can remember the correct response. We can also let users supply password *hints* that the system can present to them, under the assumption that users can devise hints that will serve as a recall probe for them but not identify the password to third parties.

Authentication methods that do not rely on users to recall the authentication data would seem to be a solution. Biometric authentication methods, such as iris scans, digital fingerprint scans, and voice identification, fall into this category. However, many people regard these methods as privacy threats because they require the collection and storage of individuals' biometric data, creating the potential for information leaks and abuse. Therefore, while biometric authentication does not burden users' memory, it would have to be implemented in a way that meets stringent privacy requirements to be widely accepted.

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