Human Computer Interaction

Perception, Attention, and Interface Design

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Outline

Upcoming

Upcoming classes

This Week

- Today: L&G and Perception
- Tomorrow: NO CLASS
- Friday, 3 November: Attention and Flow

Next Week

- Tuesday 7 November: The MVC Paradigm
- Wednesday 8 November: GUI Lab II (and a mini-project)
- Friday, 10 November: NO CLASS

Review

Review

- We saw Don Norman's seven-stage, cyclic model of action and interaction.
- We also saw how perception is heavily biased by experience.
- We have already seen how the Gestalt rules of perceptual organization are central to the correct interpretation of visual phenomena (and therefore graphical interfaces).
- We also saw how our brains seek visual structure from the low-level features that our sense organs deliver.

Color and Visual Perception

Color and Visual Perception

- Human color perception has strengths and limitations, and many of those strengths and limitations are relevant to user interface design:
  - Our vision is optimized to detect contrasts (edges), not absolute brightness.
  - Our ability to distinguish colors depends on how they are presented.
  - Some people have color-blindness.
  - The user's display and the viewing conditions affect color perception.
- To understand these qualities of human color vision, we must look at how how the human visual system processes color information.

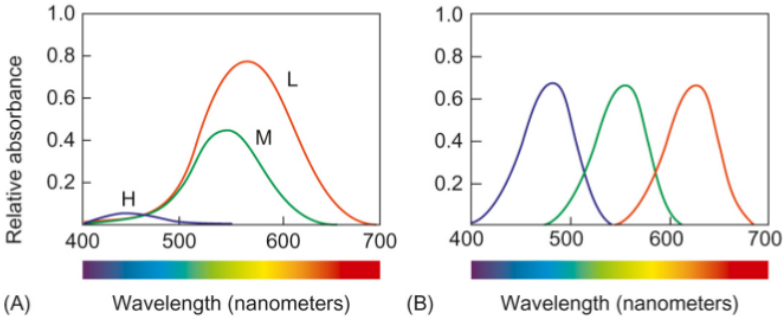
Color: how it works

- Most of us learned that the retina at the back of the human eye – the surface onto which the eye focuses images – has two types of light receptor cells: rods and cones.
- And we also learned that the rods detect light levels but not colors, while the cones detect colors.
- Finally, we probably learned that there are three types of cones, sensitive to red, green, and blue light, respectively.
- This suggests that our visual system is comparable to video cameras and computer displays, which detect or project a wide variety of colors through combinations of red, green, and blue pixels.
- This is only partially correct:
  - First, those of us who live in industrialized societies hardly use our rods at all.
  - Rods function only at low levels of light, and are for getting around in poorly lighted environments – the environments our ancestors lived in until the nineteenth century.

Color: how cones work

- So how do our cones work? Are the three types of cones sensitive to red, green, and blue light, respectively?
- In fact, each type of cone is sensitive to a wider range of light frequencies than, and the sensitivity ranges of the three types overlap considerably.
- In addition, the overall sensitivity of the three types of cones differs greatly:
  - Low frequency cones: are sensitive to light over almost the entire range of visible light, but are most sensitive to the middle (yellow) and low (red) frequencies.
  - Medium frequency cones: respond to light ranging from the high-frequency blues through the lower middle-frequency yellows and oranges. Overall, they are less sensitive than the low-frequency cones.
  - High frequency cones: are most sensitive to light at the upper end of the visible light spectrum but they also respond weakly to middle frequencies. These cones are much less sensitive than the other two types of cones, and also less numerous: this is why our eyes are much less sensitive to blues and violets than to other colors.

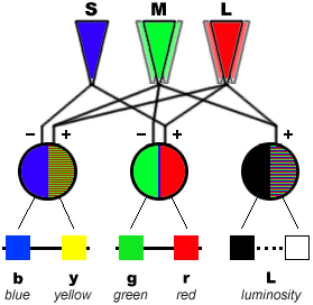
- These two graphs show the light sensitivity of our retinal cone cells (A) compared to what the graph might look like if electrical engineers designed our retinas as a mosaic of receptors sensitive to red, green, and blue, like a camera (B).

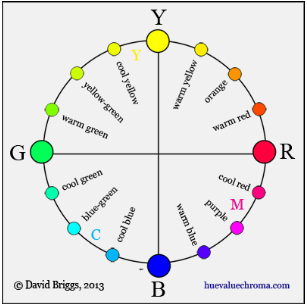


Color: contrast and opposition

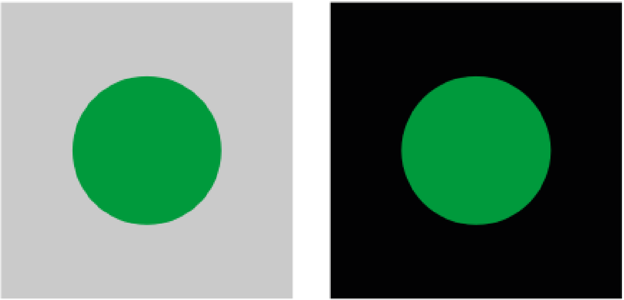
- Given the odd relationships between the sensitivities of our three types of retinal cones cells, how does our brain combines the signals to allow us to see a broad range of colors?
- The answer is by subtraction:
  - Neurons in the visual cortex subtract the signals coming over the optic nerves from the medium- and low-frequency cones, producing a red-green difference signal channel.
  - Other neurons in the visual cortex subtract the signals from the high- and low-frequency cones, yielding a yellow-blue difference signal channel.
  - A third group of neurons in the visual cortex adds the signals coming from the low- and medium-frequency cones to produce an overall luminance signal channel.
  - These three channels are called the color-opponent channels.
- The brain then applies additional subtractive processes to all three color-opponent channels: signals from an area of the retina are subtracted from similar signals coming from nearby areas of the retina.

- These two images explain the model fairly well:





- All this subtraction makes our visual system much more sensitive to differences in color and brightness
- That is, we are more sensitive to contrasting edges than to absolute brightness levels.
- The two circles below are the same exact shade of green, but the different backgrounds make the one on the left appear darker to our contrast-sensitive visual system.

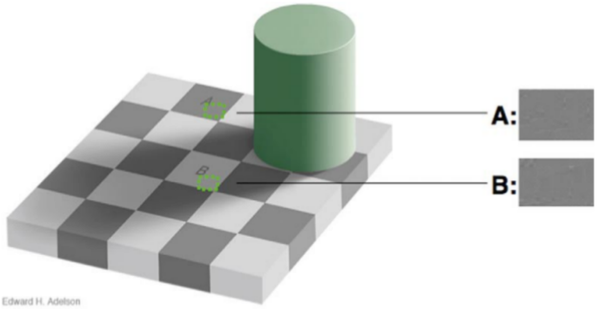


Color: edge contrast (continued)

- The sensitivity to contrast rather than to absolute brightness is an advantage: it helped our ancestors recognize a leopard in bushes whether they saw it in bright sunlight or on a cloudy day.
- This property is an invariant and it makes learning efficient by restricting the space of input patterns.
- Similarly, being sensitive to color contrast rather than to absolute colors allows us to see a rose as the same red whether it is in the sun or the shade.
- This property is known as color constancy and is also essential to making learning generalize to new phenomena.

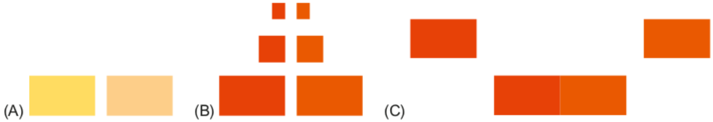
Color: edge contrast (continued)

- Below is a well-known image created by brain researcher Edward H. Adelson.
- It illustrates our visual system's insensitivity to absolute brightness and its sensitivity to contrast.
- As difficult as it may be to believe, square A on the checkerboard is exactly the same shade as square B.

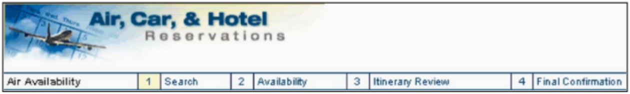


Color: discrimination and presentation

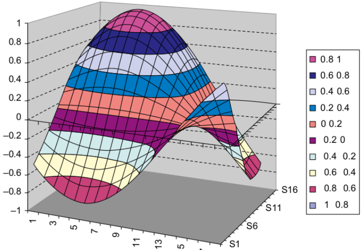
- Even our ability to detect differences between colors is limited. Because of how our visual system works, three presentation factors affect our ability to distinguish colors from each other:
  - Paleness: the paler two colors are, the harder it is to tell them apart (A).
  - Color patch size: the smaller or thinner objects are, the harder it is to distinguish their colors text is often thin, so the exact color of text is often hard to determine (B).
  - Separation: The more separated color patches are, the more difficult it is to distinguish their colors (C).



- An online travel website once used two pale colors – white and pale yellow – to indicate which step of the reservation process the user was on:

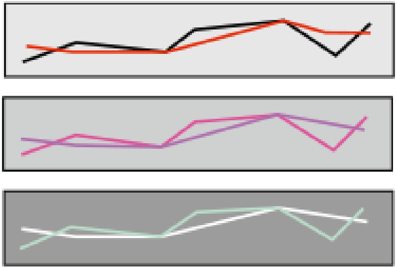


- Color patches in chart legends should be large to help people distinguish the colors:

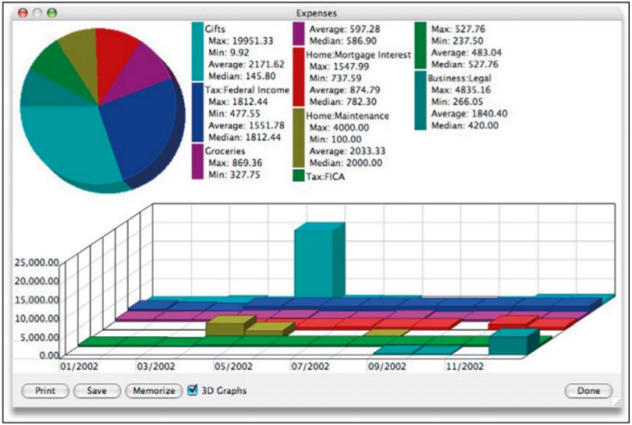


Color: color blindness

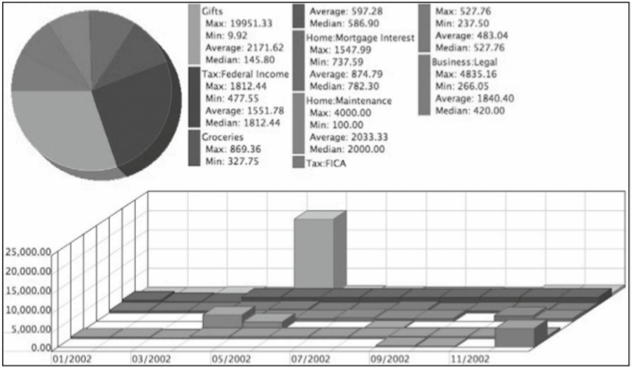
- Another factor of color presentation affecting design is whether the colors can be distinguished by people who have common types of color-blindness.
- Color-blindness means that one or more of the color subtraction channels doesn't function normally, making it difficult to distinguish certain pairs of colors.
- About 8% of men and slightly under 0.5% of women have a color perception deficit.



- This is an example graphic that contains colors difficult for some users to distinguish:



- Rather than use rules to determine which color pairs to avoid, a good way to evaluate a potential color scheme for color-blind users is to render it in grayscale:



Color: external factors

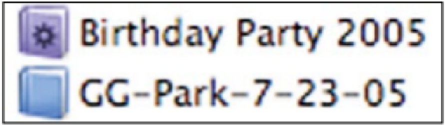
- Factors concerning the external environment also impact peoples ability to distinguish colors:
  - Variation among color displays: screens vary in how they display colors – even monitors of the same model with the same settings may display colors slightly differently and Something that looks yellow on one display may look beige on another.
  - Display angle: some displays, particularly LCD screens, work much better when viewed straight on than when viewed from an angle. When LCD displays are viewed at an angle, colors and color differences are altered.
  - Ambient illumination: strong light on a display washes out colors before it washes out light and dark areas, reducing color displays to grayscale ones. In offices, glare and venetian blind shadows can mask color differences.
- These external factors are usually out of the software designer's control, but designers should therefore keep in mind that they don't have full control of the color viewing experience of users.

Color: guidelines for use

1. Distinguish colors by saturation and brightness as well as hue. Avoid subtle color differences and make sure contrast between colors is high (but see guideline 5). One way to test whether colors are different enough is to view them in grayscale.
2. Use distinctive colors. Recall that our visual system combines the signals from retinal cone cells to produce three color opponent channels: red-green, yellow-blue, and black-white (luminance). The colors that people distinguish most easily cause a strong signal (positive or negative) on one of the three color-perception channels, and neutral signals on the other two channels. Those colors are: red, green, yellow, blue, black, and white.

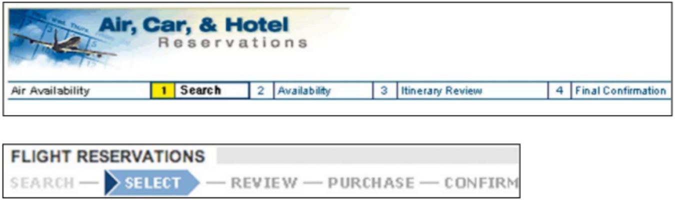
Color: guidelines for use (continued)

3. Avoid color pairs that color-blind people cannot distinguish. Such pairs include dark red versus black, dark red versus dark green, blue versus purple, light green versus white. Dont use dark reds, blues, or violets against any dark colors. Instead, use dark reds, blues, and violets against light yellows and greens. Use vischeck.com to check Web pages and images to see how people with various color vision deficiencies would see them.
4. Use color redundantly with other cues. Dont rely on color alone. If you use color to mark something, mark it another way as well. Apples iPhoto uses both color and a symbol to distinguish "smart" photo albums from regular albums:



5. Separate strong opponent colors. Placing opponent colors right next to or on top of each other causes a disturbing shimmering sensation, and so should be avoided:

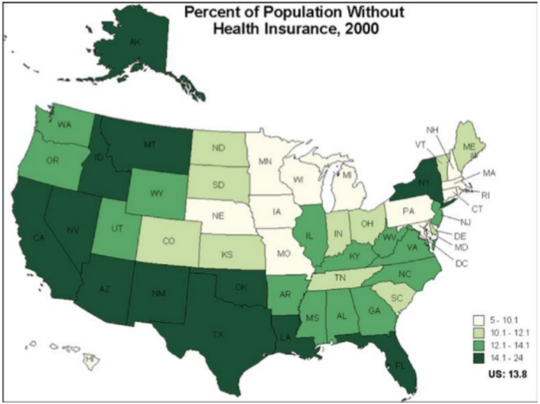
- The current version of the travel website indicates the current state in two ways:



(A)

(B)

- In this graphic, all colors are easily distinguished by every user:



Peripheral Vision

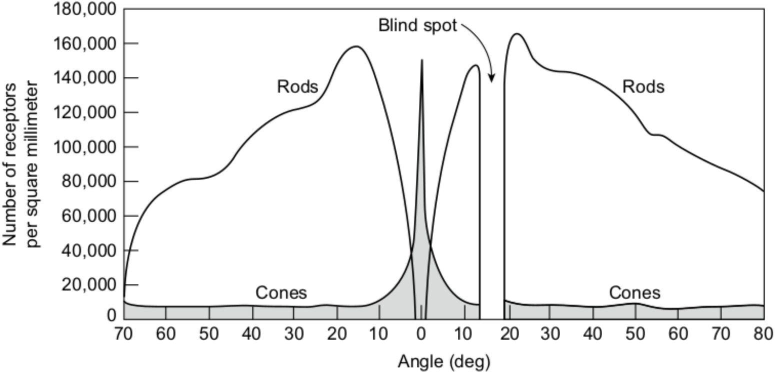
Peripheral vision (PV)

- We just saw how the human visual system differs from a digital camera in the way it detects and processes color.
- Our visual system also differs from camera in its resolution: on a digital photo sensor, photoreceptive elements are spread uniformly in a tight matrix – spatial resolution is constant across the entire image frame.
- The human visual system is not like that:
  - Stationary items in muted colors presented in the periphery of peoples visual field often will not be noticed.
  - Hoever, motion in the periphery is usually noticed.

PV: resolution of fovea versus periphery

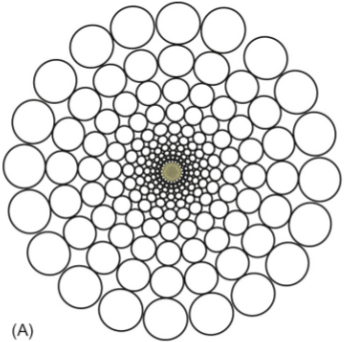
- The spatial resolution of the human visual field drops greatly from the center to the edges.
- Each eye has approximately six million retinal cone cells packed much more tightly in the center of our visual field – a small region called the fovea – than they are at the edges of the retina
- The fovea is only about 1% of the retina, but the brain's visual cortex devotes about 50% of its area to input from the fovea.
- Furthermore, information from the visual periphery is compressed (with data loss) before transmission to the brain, while information from the fovea is not.
- This causes our vision to have much, much greater resolution in the center of our visual field than elsewhere.

- The following diagram illustrates the spatial distribution of photoreceptor cells across the retina



PV: high-resolution fovea

- In the fovea, people with normal vision have very high resolution: they can resolve several thousand dots within that region.
- Just outside of the fovea, the resolution is already down to a few dozen dots per inch viewed at arm's length.
- At the edges of our vision, the "pixels" of our visual system are as large as a melon (or human head) at arm's length:



(A)

(B)

PV: pixel size and foveation

- If our peripheral vision has such low resolution, why don't we see the world in a kind of tunnel vision where everything is out of focus except what we are directly looking at now?
- We experience this illusion because our eyes move rapidly and constantly about three times per second, focusing our fovea on different parts of our environment (this is called saccade).
- Our brain fills in the rest in a gross, impressionistic way based upon what we know and expect.
- Our brain does not have to maintain a high-resolution mental model of our environment because it can order the eyes to sample and resample details in the environment as needed.

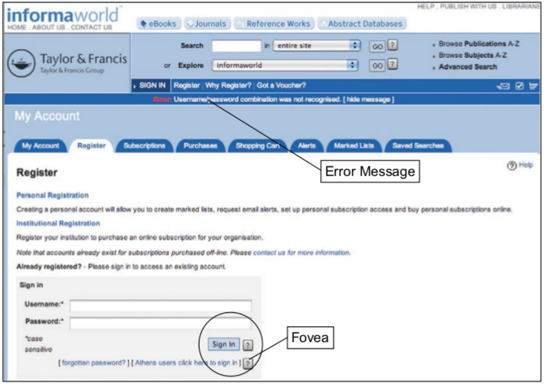
PV: what good is the periphery?

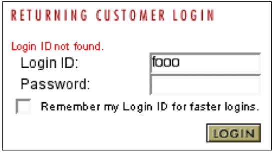
- One might wonder why we even have peripheral vision. What is it good for?
- The answer is that our peripheral vision exists mainly to provide low-resolution cues to guide our eye movements.
- The fuzzy cues on the periphery of our visual field provide the data that helps our brain plan where to move our eyes.
- Another advantage of peripheral vision is that it is good at detecting motion.
- Anything that moves in our visual periphery, even slightly, is likely to draw our attention – and hence our fovea – toward it.
- The reason for this phenomenon is that our ancestors – including pre-human ones – were selected for their ability to spot food and avoid predators.

PV: peripheral vision and UIs

- The low acuity of our peripheral vision explains why software and website users sometimes fail to notice error messages.
- When someone clicks a button or a link, that is usually where his or her fovea is positioned.
- Everything on the screen that is not within 1-2 centimeters of the click location is in peripheral vision.
- If, after the click, an error message appears in the periphery, it should not be surprising that the person might not notice it.
- For example, at InformaWorld.com, if a user enters an incorrect username or password an error message appears in a message bar far away from where the user's eyes are focused.
- Even when an error message is placed nearer to center of the viewer's visual field, other factors can diminish its visibility.

PV: peripheral vision and UIs





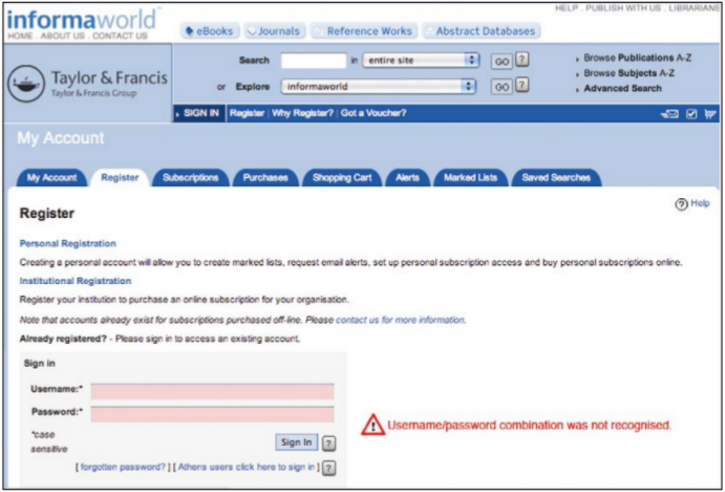
PV: guidelines for making things visible

1. Put it where users are looking: People focus in predictable places when interacting with GU Is. In Western societies, people tend to scan forms and control panels from upper left to lower right. While moving the screen pointer, people usually look either at where it is or where they are moving it to. When people click a button or link, they can be assumed to be looking directly at it, at least for a few moments afterward. Designers can use this predictability to position error messages near where they expect users to be looking.
2. Mark the error: Somehow mark the error prominently to indicate clearly that something is wrong. Often this can be done by simply placing the error message near what it refers to, unless that would place the message too far from where users are likely to be looking.
3. Use an error symbol: Make errors or error messages more visible by marking them with an error symbol.

PV: guidelines for making things visible

4. Reserve red for errors: By convention, in interactive computer systems the color red connotes alert, danger, problem, error, etc. Using red for any other information on a computer display invites misinterpretation.

PV: guidelines for making things visible



PV: really getting the user's attention

There are three stronger method for getting the user's attention, but they should be used sparingly:

- Pop-up message in dialog box. Displaying an error message in a dialog box sticks it right in the users face, making it hard to miss.
  - The annoyance of pop-up messages rises with the degree of modality.
  - Application-modal error pop-ups should be used sparingly, only when application data may be lost if the user doesnt attend to the error.
  - System-modal pop-ups should be used extremely rarely – only when the system is about to crash and take hours of work with it or if people will die if the user misses the error message.
  - On the Web, an additional reason to avoid pop-up error dialog boxes is that some people set their browsers to block all pop-up windows.

PV: really getting the user's attention

- Use a sound. When a computer beeps, that tells its user something has happened that requires attention, and the person's eyes reflexively begin scanning the screen for whatever caused the beep.
- This can allow the user to notice an error message that is someplace other than where they were just looking.
  - However, many people work in a cubicle farms, and if all using an application that signals all errors and warnings by beeping, such a workplace is very annoying (trust me).
  - Worse, people often aren't able to tell whether their own computer or another is beeping.
  - In noisy work environments, e.g. factories or computer server rooms, beeps might be masked by ambient noise.
  - Finally, sound is often muted or turned down on some people's computers.

PV: really getting the user's attention

- Flash or wiggle slightly. Our peripheral vision is good at detecting motion, and motion in the periphery causes reflexive eye movements that bring the motion into the fovea.
- User interface designers can make use of this by wiggling or flashing messages briefly, but it doesnt take much motion to trigger eye movement toward the motion.
  - However, motion, like pop-up dialog boxes and beeping, must be used sparingly.
  - Most experienced computer users consider wiggling, blinking objects on screen to be annoying (I'm looking at you, *Clippy*).
  - Most of us have learned to ignore displays that blink because many such displays are advertisements.
  - If motion or blinking is used, it should be brief: it should last about a quarter- to a half-secondno longer, otherwise it quickly goes from an unconscious attention-grabber to a conscious annoyance.

Attention and Memory

Attention and memory

- Just as the human visual system has strengths and weaknesses, so does human memory.
- Psychologists historically distinguished short-term memory from long-term memory.
- Short-term memory covers situations in which information is retained for very short intervals (seconds), while long-term memory covers situations in which information is retained over longer periods (days, years, even lifetimes).
- It is tempting to think of short-term and long-term memory as separate memory stores, and indeed some theories of memory have considered them separate.
- 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.

Memory: long-term memory

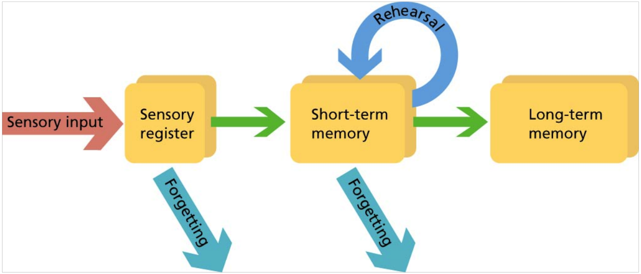
- Perceptions enter through the visual, auditory, olfactory, gustatory, or tactile sensory systems and trigger responses starting in areas of the brain dedicated to each sense.
- The sensory-modality-specific areas of the brain detect only simple features of the data, such as a dark-light edge, diagonal 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, Uncle Kevin, minor key, threat, or the word "duck."
- 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: long-term memory

- Memory formation consists of long-lasting in the neurons involved in a neural activity pattern, which make the pattern easier to reactivate in the future.
- Activating a memory consists of reactivating the same pattern of neural activity that occurred when the memory was formed.
- 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.

Memory: short-term memory

- Where is short-term memory in all of this? The answer is suggested by the word awareness.
- Short-term memory is not a store – it is not a place where memories and perceptions go to be worked on.
- Each sense has its own very brief short-term memory that is the result of residual neural activity.
- While activated, a memory pattern is a candidate for our attention.



Memory: memory and attention

- 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 of the available information from our perceptual systems and our long-term memories that we are conscious of right now is the main component of our short-term, or working memory.
- Working memory is the combined focus of attention – the currently activated neural patterns of which we are aware.
- The number of items in short-term memory at any given moment is extremely limited and volatile.

- Information can easily be lost from short-term memory.
- If items in short-term 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 short-term 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.

Memory: short-term memory and UI design

- The capacity and volatility of short-term 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.
- Here we will see some specific examples of how this can be done.

Memory: modes and memory

- The limited capacity and volatility of short-term 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:
  - 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 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.

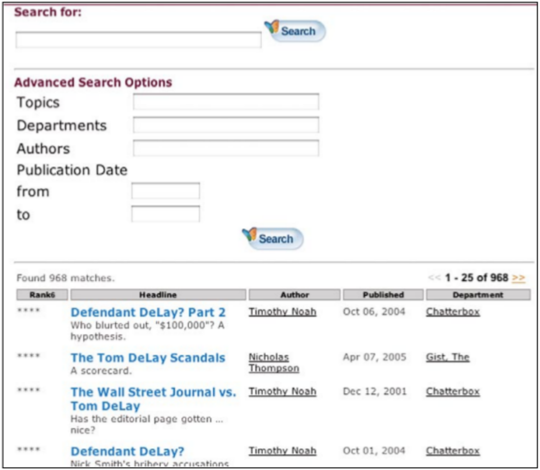
Memory: modes and memory

- Moded user interfaces have advantages: they allow a device to have more functions than controls, and they allow an interactive system to assign different meanings to the same gestures in order to reduce the number of gestures users must learn.
- However, one well-known disadvantage of modes is that people often make mode-errors: they forget what mode the system is in and do the wrong thing by mistake.
- This is especially true in systems that give poor feedback about what the current mode is.
- Human short-term memory is too unreliable for designers to assume that users can (without 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.

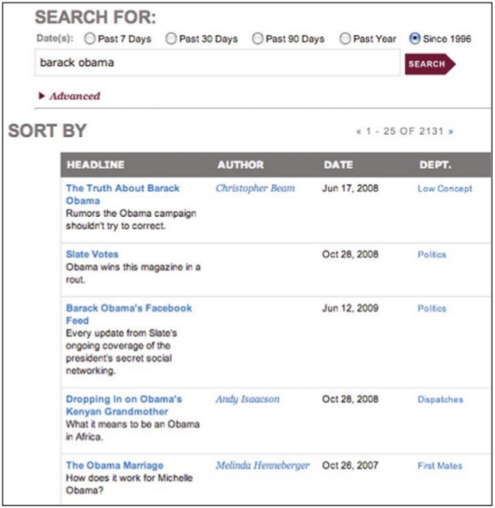
Memory: search results

- When people use a search engine to find information, they enter search terms, start the search, and then review the results.
- Evaluating the results often requires knowing what the search terms were.
- If short-term memory were less limited, people would always remember, when browsing the results, what they had entered as search terms just a few seconds earlier.
- When the results appear, the person's attention naturally turns away from what they entered and toward the results.

- Many custom search engines for custom web applications commit this sin:



- While it is relatively easy to leave the form in a state that aids recall:


SEARCH FOR:

Date(s): Past 7 Days | Past 30 Days | Past 90 Days | Past Year | Since 1996

barack obama

SEARCH

▸ *Advanced*

SORT BY

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HEADLINE	AUTHOR	DATE	DEPT.
The Truth About Barack Obama Rumors the Obama campaign shouldn't try to correct.	*Christopher Beam*	Jun 17, 2008	Low Concept
Slate Votes Obama wins this magazine in a rout.		Oct 28, 2008	Politics
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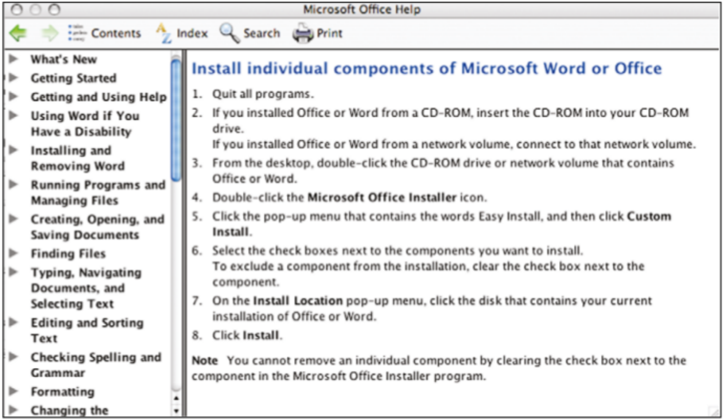
Dropping In on Obama's Kenyan Grandmother What it means to be an Obama in Africa.	*Andy Isaacson*	Oct 28, 2008	Dispatches
The Obama Marriage How does it work for Michelle Obama?	*Melinda Henneberger*	Oct 26, 2007	First Mates

Memory: instructions and modality

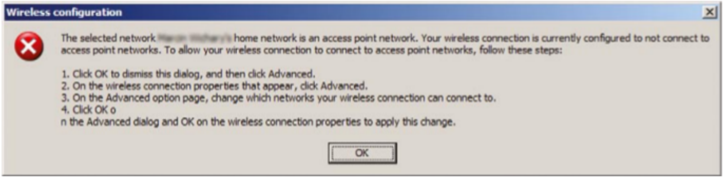
- If you asked a friend for a recipe or for directions to her home, and she gave you a long sequence of steps, you probably would not even try to remember it all.
- You would know that you could not reliably keep all of the instructions in your short-term memory, so you would write them down or ask your 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.

- A non-modal instruction window allows user to consult instructions while performing the action.



Memory: instructions and modality

- A modal instruction window asks the user to close the instructions as the first step:



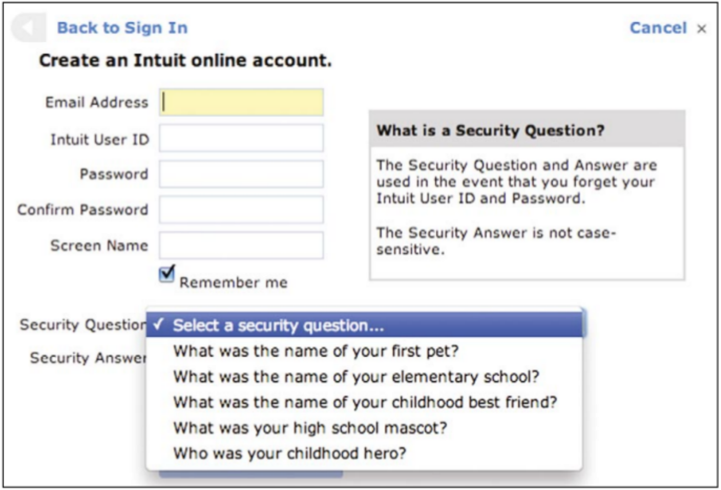
Memory: long-term memory is error-prone

- Unlike short-term memory, the capacity of human long-term memory seems almost unlimited.
- 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 lossless compression that drops 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.

Memory: implications to UI design

- The main thing that the characteristics of long-term memory imply is that people need tools to augment it.
- Given we need 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 longterm memory – yet that is exactly what many interactive systems do.
- Authentication is one functional area in which many software systems place burdensome demands on long-term memory.

- Even well-intentioned mnemonics might leave some users out:



- Better to leave open-ended:

Homework

Homework

[None]