Human Factor Theories – Part II

Part of the Human Computer Interaction course Notes

2008-2009

Where we are

- Model of how our mind works
- **Cognition**
  - Mental models
  - Problem solving
  - **Learning**
- Attention and memory
- Perception (visual and auditory)
- Motor skills
- Social science, dialog with computer
- Design guidelines

Learning

- Acquiring
  - new concepts
  - new skills
  - new knowledge
- In the HCI context, it refers to how users learn to use new interfaces
- It is difficult for an adult to learn
- Solution: <u>minimize learning</u>

How to minimize learning?

- Skill transformation (learn new things by establishing analogies)
- Skill replacement (unlearn things to make room for new ones)

Minimize learning by metaphors

- Metaphor (American Heritage Dictionary): “a figure of speech in which a word or phrase that ordinarily designates one thing is used to designate another, thus making an implicit comparison, as in *a sea of troubles*”
- (HCI purpose) <u>The use of familiar objects to convey the meaning of unfamiliar objects</u>
- Purpose
  - function as natural models
  - leverages our knowledge of familiar, concrete objects/experiences to understand abstract computer and task concepts
- Warning
  - metaphor may portray inaccurate or naive conceptual model of the system

Design metaphors

- Use metaphors that matches user's mental models
  - desktop metaphor for office workers, paintbrush metaphor for artists...
- Given a choice, choose the metaphor close to the way the system works

Design metaphors

- Ensure emotional tone is appropriate to users
  - E.g., file deletion metaphors
    - trashcan
    - black hole
    - paper shredder
    - pit bull terrier
    - nuclear disposal unit...

Metaphors continued

- Caveat
  - metaphors can be overdone!
- Common pitfalls
  - overly literal
    - unnecessary fidelity
    - excessive interactions VR
  - overly cute
    - novelty quickly wears off

  - overly restrictive
    - cannot move beyond
  - mismatched
    - does not match user’s task and/or thinking

Inappropriate metaphors

- See the following link for a good critique by former student
  - http://hci.epfl.ch/teaching/hci_student/2002/homework/Bullot/2/Assignment2.htm

Icons

- A small graphics or image in an interface to represent an object that can be manipulated by the user
- A metaphor is not always an icon (e.g., the desktop metaphor)
- An icon is not always a metaphor
- A successful iconic interface can be achieved by a consistent metaphor (floppy disk for saving document, scissors for deleting, magnifying glasses for preview)

Minimize learning by being consistent

- Consistency of effects
  - same words, commands, actions will always have the <u>same effect in equivalent situations</u>
  - predictability
- Consistency of language and graphics
  - same information/controls in <u>same location on all screens / dialog boxes</u>
  - same <u>visual appearance</u> across the system (e.g. widgets)
  - e.g. different scroll bars in a single window system!

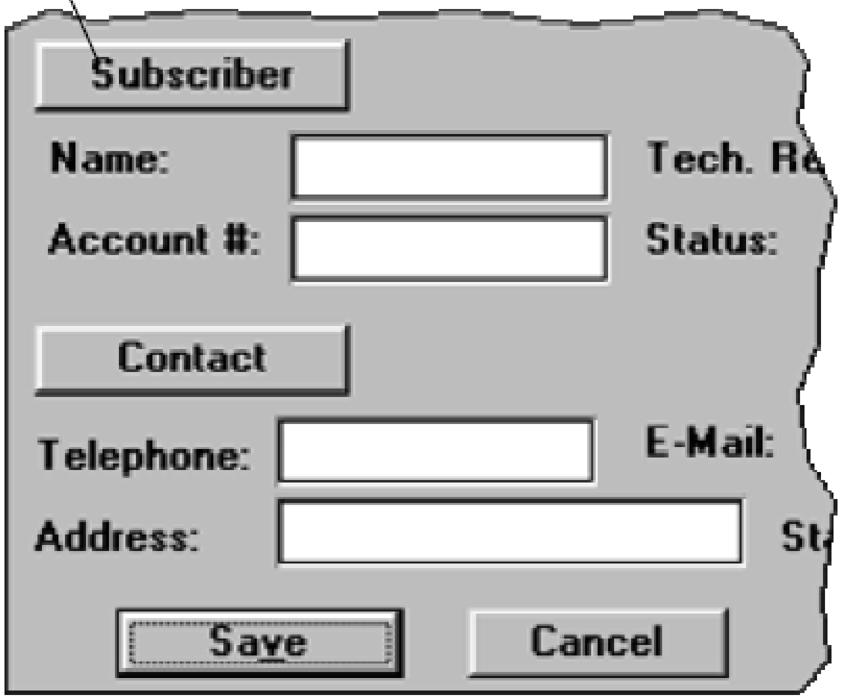
Maintain display inertia

- A good interaction design changes as little as possible from one screen to the next.
- Static objects such as buttons, words, and icons that appear on many screens should always appear in exactly the same location on all screens, for consistency.

Be consistent

These are labels with a raised appearance.

Is it any surprise that people try and click on them?



Critiquing of screen inconsistency

- See the following link for a critique of screen inconsistency by our former students
  - http://hci.epfl.ch/teaching/hci_student/2002/homework/Berger/1/index.htm
- Check under Learning – Consistency of effects

“What is a user-friendly interface?”

- “Easier to use” is easy to say, but it suggests little about how to *reduce errors and frustration* and *promote faster learning*.
- The definition of a user-friendly interface should be reformulated as “how can accelerate the process whereby novices begin to perform like experts.”
- Advance the elevation stage of the learning curve.

Acquisition of cognitive skills

- Anderson (1980)
- Experts and novices differ in the *coarseness of granularity* with which they view the constituent elements of a particular problem or task.

Novices: attentive to low-level details

- For example, operational details such as finding a particular character on the keyboard (novice typist) or remembering the name of a command involve problem solving.
- The result is that valuable cognitive resources are diverted from the central problem at hand.

Experts: solve large chunks of problems

- With experts, these low-level details can be performed automatically.
- The size of the chunks of the problem are much larger.
- The skills that permit these tasks to be performed automatically, however, must be highly learned, usually through repetition (Newell &Rosenbloom, 1980).

Def: acquisition of skills

- The acquisition of skills, therefore, can be characterized by developing an ability to perform ever-larger chunks of a problem automatically.

Trade-off: power tools vs. loss of control

- Powerful tools make problem solving easier by working out the details for the user
- However, if the details differ for each user, then automating the process may annoy the user (they do not feel in control of the situation)
- Most successful applications offer the <u>right amount of intelligence</u> in their software so that users can solve their problems by using powerful tools, and they are in total control of the tools.

Example 1: the pinball constr. set

- One can construct his own pinball sets before playing the game
- Most novice users do not understand the constraints and rules that must be taken into account during construction
- Thus they build pinball sets where the balls get stuck in weird corners

Example 2 : design tools for kitchens

- One has to put in by hand every unit and their sizes have to fit the dimensions.
- Sometimes users can place refrigerator very far from the sink, resulting in unpractical circulation pattern.
- It’s better to have users specify their requirements and desires, and the system configures the kitchen automatically.

Accommodate user's experience levels

- Three user groups are identified : <u>novice, intermittent, frequent users</u>.
- *Novice* users are those who do not have enough syntactic knowledge of the system and only a little semantic knowledge. He is mostly doing *problem solving*.
- A novice user needs <u>clarity</u> and <u>simplicity</u> in an interface, a small number of meaningful functions, lucid error messages, and informative feedback.

Intermittent users

- *Intermittent* users maintain semantic knowledge of the system but loose syntactic knowledge.
- In the interface, he prefers simple consistent commands, meaningful sequencing of steps, easy to remember functions and tasks, online assistance and help, and concise manuals.

Frequent users

- *Frequent* users have both semantic and syntactic knowledge, “power user.” They want fast interaction, powerful tools, accelerator keys, brief error messages with access to detail at their own request, concise feedback, and customization of their own interface.

Now meet all these different user needs in one design !

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Memory

- American heritage dictionary: “memory is the mental faculty of retaining and recalling past experience”
  - Sensory store, short and long term stores
- Short-term memory has two important characteristics.
  - First, short-term memory can contain at any given time seven, plus or minus two, "chunks" of information.
  - Second, items remain in short-term memory around twenty seconds.

Memory skills: recognition vs recall

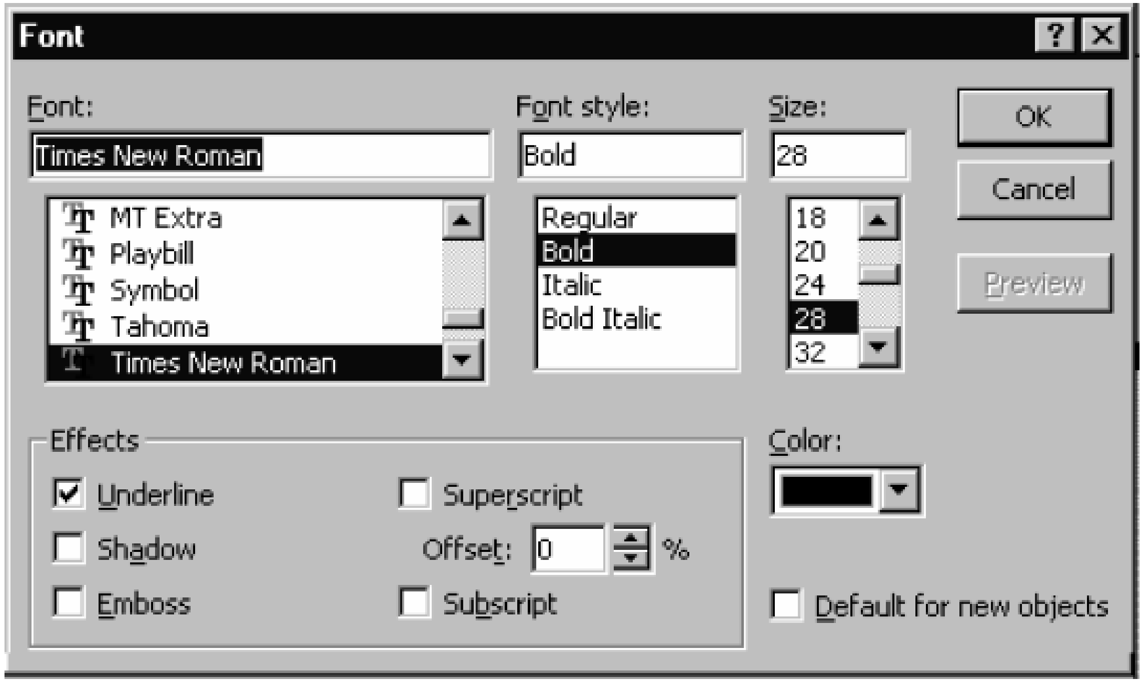
- We can recognize objects far more easily than we can recall them from memory.
- Norman (1988) has developed the notion of recognition and recall in terms of knowledge in the head and knowledge in the world**.**

- Driving to Geneva airport via back roads. Describe the roads to a friend.

Memory skills: recognition vs recall

- Ask users to fill in forms versus ask users to choose one of the items to fill in forms.
- In early days, users had to remember all commands, e.G., Unix commands.

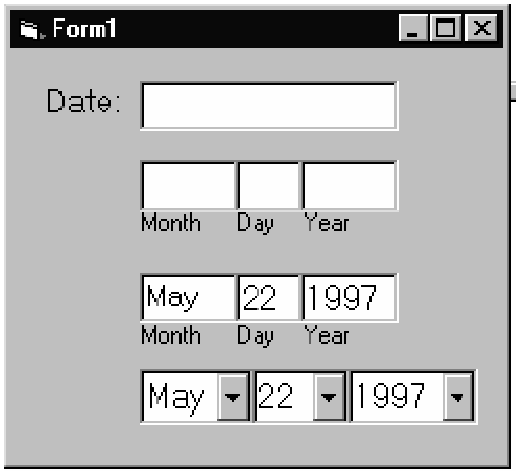
Minimize user’s memory load

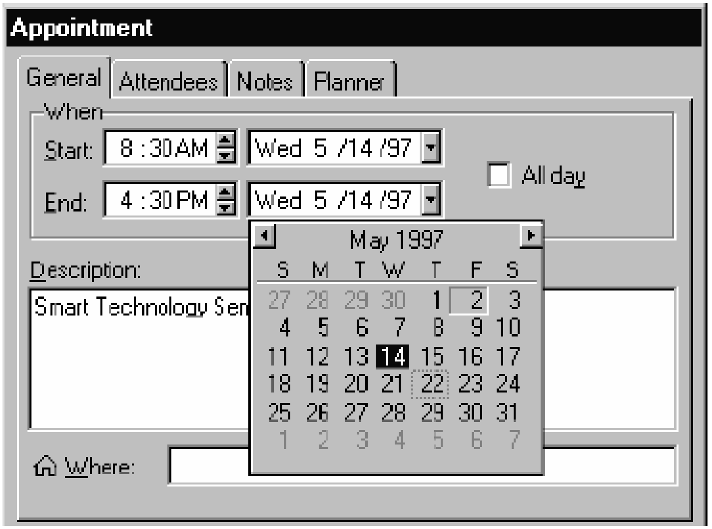


Minimize user's memory load

- Describe required input format and example, and default
- Small number of rules applied universally
  - generic commands
    - same command can be applied to all interface objects
      - *interpreted in context of interface object*
  - copy, cut, paste, drag 'n drop, ... for characters, words, paragraphs, circles, files

Minimize user's memory load





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Attention

- “Everyone knows what attention is. It is the taking possession of mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought... It requires withdrawal from some things in order to deal effectively with others.” William James

Techniques for getting attention

- Spatial and temporal cues (layouts and animations)
- Color
- Alerting techniques such as flashing and reverse video and auditory warnings
- Using interface standards that are familiar to users (same look & feel)

GET *users'* **ATTENTION** judiciously

- Attention-getting techniques can be over and misused. Here are some tips on how to use them:

- <u>Only two levels of intensity of text on a single screen</u>. Use underlining, bold, inverse video and other forms of marking sparingly to achieve the most effects.

Use of fonts

- Use no more than four different font sizes on a single screen.
- Fonts with a serif are easier to read, because the serifs help a user's eye glide across the text. Helvetica type is a sans serif type.

Fonts and colors

- THE SPEED FOR READING UPERCASE LETTERS IS MORE THAN 10% SLOWER.
- USE NO MORE THAN 4 DIFFERENT COLORS ON A SINGLE SCREEN, ESPECIALLY IF IT IS MOSTLY TEXT, AND NO MORE THAN SEVEN DIFFERENT COLORS THROUGHOUT A SINGLE APPLICATION.

Background colors

- Background of a display is not the area users should be paying attention.
- Blue or black is best as a background color, especially for text, with white or yellow characters, respectively.
- Blue should not be used for text since it is one of the hardest colors to read.
- Staring at a constant bright background for long periods of time can cause eye strain.
  - Online teaching notes are made in white background to prevent some students from accidentally printing them.

Fore and Background colors

- A good combination of fore and background colors is one with a good contrast between the two.
- Color as coding technique, that is, assigning meanings or abstract concept to certain colors (talk more of this on the subject of visualization).

- Consider color conventions carefully. Green, yellow, and especially red have special connotations. Green for go, yellow for raising caution, and red for stop.
- Less saturated colors, pastel, are better than intensive ones.
- Reserve the big attention-getters (audio or visual) for the most important situations.

Allocation of attention

You are a medium level skier. You are coming down a steep slope for the first time. Try to spell your name backward while you do that.

Why is this task difficult if not possible?

Allocation of attention

On the other hand, as you drive your car, you can listen to the music, watch out for road signs, and sometimes make phone calls.

How can this be?

Multitasking

- People are accustomed to carry out numerous tasks at the same time.
- But in a demanding environment like the cockpit, when multitasking is performed, humans need cognitive aids to get reminded of certain crucial moments.

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Perception

- Definition: *recognition and interpretation* of sensory stimuli based chiefly on memory.
- Less formal definition: perceiving the environment with body sensors (eye, ear, and other parts of the body)
- Perception influences how we react in environment

Perception and HCI

- Perception is key in processing information
- Visual & auditory perception

Visual perception

- Definition: recognition and interpretation of visual stimuli
- How do we process visual information?
  - Text information processing
  - Visual information processing
  - Affordance and visual mapping
  - Color perception
- Cognitive system helps visual processing by providing knowledge stored in memory

Minimize information process time

- Structure and organize textual information
- Once structured, consider grouping, ordering, hiding irrelevant information

- In the first figure, note how long it takes you to find 1) the phone number of Holiday House and 2) the name of the hotel that offers a double room for $27.
- In the second figure, note how long it takes you to 1) find the phone number of Howard Johnsons in Columbia and 2) the name of the hotel that offers a double room for $46 dollars?

Pennsylvania

Bedford Motel/Hotel: Crinoline Courts
(814) 623-9511 S: $18 D: $28

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: $18 D: $25

Bedford Motel/Hotel: Quality Inn
(814) 623-5188 S: $23 D: $28

Bedford Motel /Hotel: Terrace
(814) 623-5111 S: $22 D: $24

Bradley Motel/Hotel: De Soto
(814) 326-3567 S: $28 D: $24

Bradley Motel/Hotel: Holiday House
(814) 362-4511 S: $22 D: $25

Bradley Motel/Hotel: Holiday Inn
(814) 362-4581 S: $32 D: $40

Breezewood Motel/Hotel: Best Western Plaza
(814) 735-4352 S: $28 D: $27

Breezewood Motel/Hotel: Motel 78
(814) 735-4385 S: $16 D: $18

City	Motel/Hotel	Area Code	Phone	Rates Single	Rates Double
Charleston	Best Western	883	747-8961	$26	$38
Charleston	Days Inn	883	881-1888	$18	$24
Charleston	Holiday Inn N	883	744-1621	$36	$46
Charleston	Holiday Inn SW	883	556-7188	$33	$47
Charleston	Howard Johnsons	883	524-4140	$31	$36
Charleston	Ramada Inn	883	774-8281	$33	$48
Charleston	Sheraton Inn	883	744-2401	$34	$42
Columbia	Best Western	883	796-9400	$29	$34
Columbia	Carolina Inn	883	799-8200	$42	$48
Columbia	Days Inn	883	736-0828	$23	$27
Columbia	Holiday Inn NW	883	794-9448	$32	$39
Columbia	Howard Johnsons	883	772-7288	$25	$27
Columbia	Quality Inn	883	772-8278	$34	$41
Columbia	Ramada Inn	883	796-2700	$36	$44
Columbia	Vagabond Inn	883	796-6240	$27	$38

What’s being processed?

- Even if you can very quickly find the right information in the first figure, you have done some kind of mental structuring yourself.
- The worst interface is one where users have to traverse the entire screen to look for details.

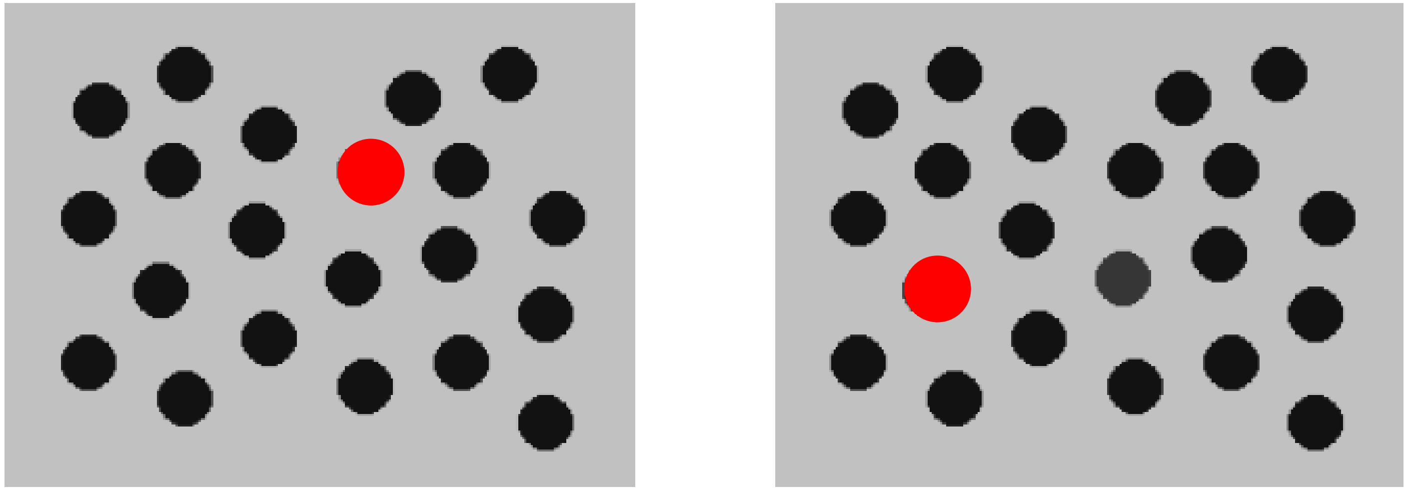
Other techniques

- information should appear in <u>natural order</u> (alphabetical, temporal, numerical, semantic)
- related information is graphically clustered
- remove or hide irrelevant or rarely needed information which competes with important information on screen (gray out)
- use windows frugally don’t make navigation and window management excessively complex

Visual information processing

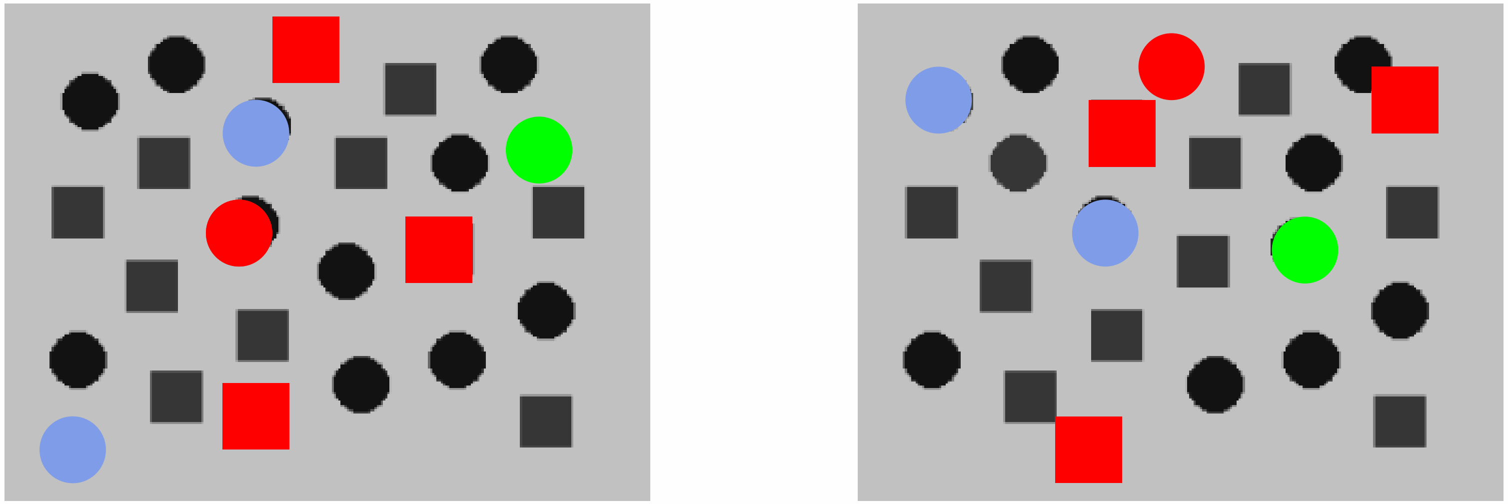
- How our visual system processes images vs. processing text
  - Get the “gist” of an image in 110 ms
  - Read less than a word, or skim two words in 110 ms
- Graphical information can speed many tasks

Is the red circle present in the picture?



- This task takes less than 200-250 msec.
- Why is this identification task fast?
- Pre-attentive task (pop-out effects)

Why finding a red circle here takes longer?



- Conjunction of unique features
- Target – red and circle
- Distracter – (red square) (blue and green circles)

Time for an experiment

- name the color of the items in the two lists of words in the figure. Try to say them as quickly as possible
  - ETZZZR (answer: red)

ZYP	ROSSO
QLERK	NERO
SURGJU	BLU
EGGTH	GIALLO

Conflicts of automatic processes

- the automatic process of reading the word conflicts with the automatic process of perceiving the color.

Perception and interaction

- **Affordance**: The perception of an object helps determine how we interact with the object

Affordance

- Some affordances are obvious, some learned
  - Glass can be seen through
  - Glass breaks easily
- Some constrain an action
  - Floppy disk
    - Rectangular – can't insert sideways
    - Tabs on the disk prevent the drive from letting it be fully inserted backwards

Affordance

- Some objects lack affordance

From Catalogue d'objets introuvable, Jacques Carelman, Paris

Which door do you prefer?

Which door do you prefer?

Many people push the wrong button when holding a door open for another people in an elevator

- You have half a second to decide which button is for open, and which one is for close. Can you design better buttons?

Affordance

- Perceived can differ from real affordance
  - Chair: real affordance
    - Affords sitting
    - Affords standing for changing a lightbulb
    - Affords keeping a door open
  - Chair: false affordance
    - Used to throw at somebody

Why it's hard to design affordance

- Devices and software are more complex than door knobs, chairs.
- Controls function differently depending on their states (modes)
  - Microwave buttons (time, power, etc)
  - Imaging your chair going into these modes

Software designers have a difficult task

- Designer only has control over *perceived* affordances
  - Display screen, pointing device, selection buttons, keyboard
  - These afford touching, pointing, looking, clicking on every pixel of the display.

Affordances in screen-based interfaces

- Most of this affordance is of no value
  - Example: if the display is not touch-sensitive, even though the screen affords touching, touching has no effect.
  - Example:
    - does a graphical object on the screen afford clicking?
    - yes, but the real question is “does the user perceive this affordance; does the user recognize that clicking on the icon is a meaningful, useful action?”

Perception of colors

- The best way to color code an interface is not to use color
  - 8% of male population is color-blind, that is, unable to distinguish between various colors.
- Study shows that color coding does not provide more advantages over identification tasks than achromatic coding, less advantage than alphanumeric coding

Perception of colors

- People often have the misconception that the more color an interface uses, the more attention it gets from users.
- Excessive use of color results in color pollution, particularly when highly saturated colors are used.

If you have to use colors

- Opposite colors, related colors, color hue, color spectrum
- Besides variations on a spectrum from one color to another, it’s also possible to vary on the hue.
- URL for colors, names of colors, use of colors

Mapping principle: visual -> cognitive

- Mapping is the relationship between controls and their movements and the results in the problem solving process.
- Example
  - To turn the car to the right, one turns the steering wheel clockwise.
  - This mapping is good because it's visibl (it invites you), closely related to the desired outcome, and providing feedback.

Mappings

- For devices, appliances
  - Natural mappings use constraints an correspondences in the physical world
    - Controls on a stove
    - Controls on a car
      - Radio volume
      - Knob goes left to right to control volume
      - Should also go in and out for front to rear speakers
  - For computer UI design
    - Mapping between controls and their actions on the computer
    - Controls on a digital watch
  - Controls on a word processor program

Natural mapping leads to understanding

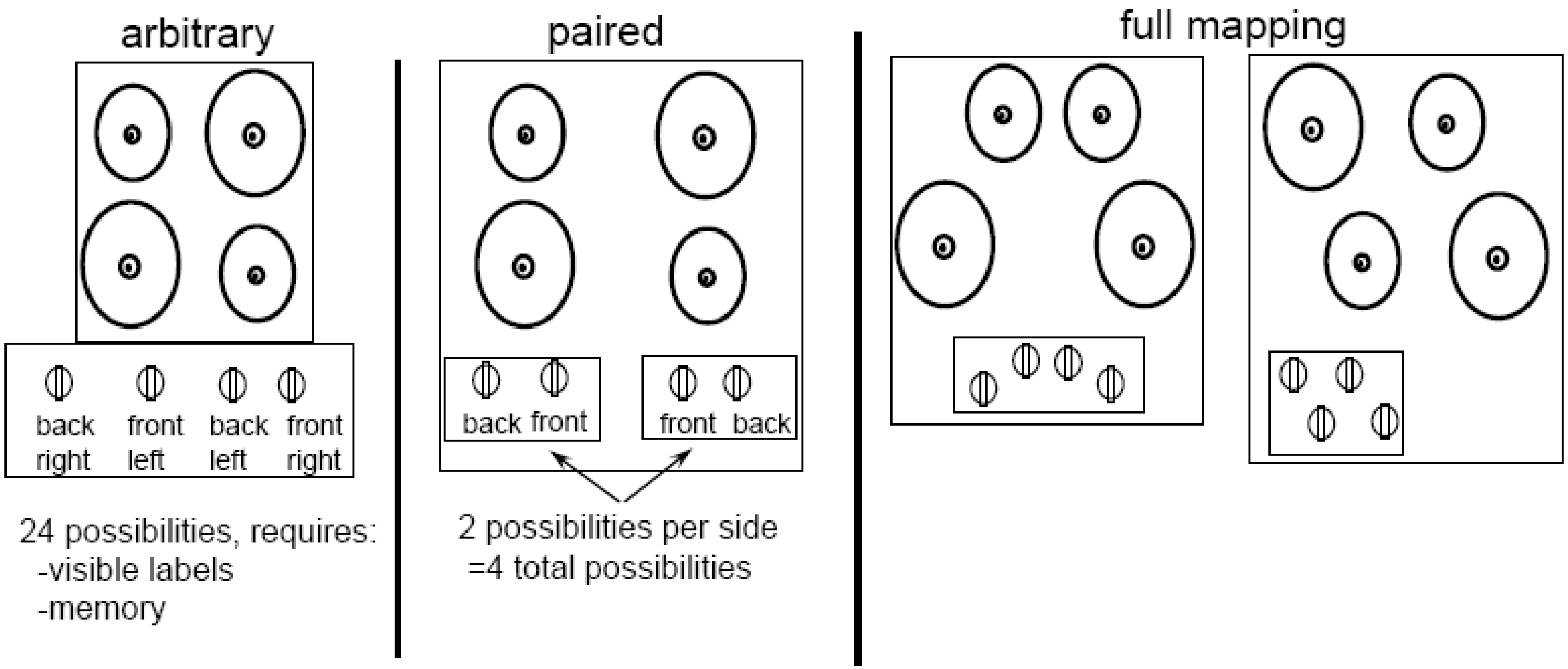
- We need to also take advantage of physical analogies and cultural standards in developping natural mappings in interfaces.
  - Trash can, sliders, and desktop environment.
  - Seat adjustment control from a Mercedes-Benz is a good example of natural mapping.

Bad examples of mapping

- Light switches in living room, machine room, etc.
- N switches are mapped to M lights
- …

Mapping: control of physical outcomes

Mapping: control of physical outcomes



Mapping goes the other way

- Perception is to confirm problem solving
- Feedback is to confirm the effect of a control
- Examples :
  - typing on a keyboard, the keys give back appropriate feel -- tactile feedback, as well as the characters appearing on the screen.
  - When downloading information, there is a time device indicating the progress of the action (feedback of computer's progress).
- Mapping deals with *expectations*

Mental models

- Mental models built from
  - affordances
  - constraints
  - mappings
  - system feedback (evaluation)
  - cultural associations/standards
  - instructions
  - interactions
- Mental models are often wrong!
  - A wrong mental model leads to wrong interaction with the system

People explain things using m. models

- Mental models often extracted from fragmentary evidence
- People find ways to explain things
  - Computer terminal breaks when accessing the library catalog

Updates on mental models

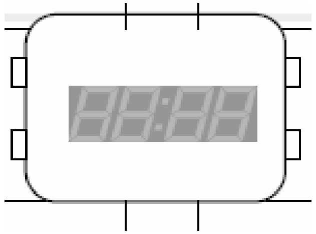
- Human action has two aspects: execution and evaluation
- Execution: doing something
- Evaluation: comparison of what happened to what was desired

Good example

- Scissors
- affordances:
  - holes for insertion of fingers
  - blades for cutting
- constraints
  - big hole for several fingers, small hole for thumb
- mapping
  - between holes and fingers suggested and constrained by appearance
- positive transfer
  - learnt when young
- conceptual model
  - implications clear of how the operating parts work

Bad example

- Digital Watch
- affordances
  - four push buttons, not clear what they do
  - contraints and mapping unknown
  - no visible relation between buttons and the end result of their actions
- negative transfer
  - (exploitation of experience gained by “previous versions”)
  - little association with analog watches
- cultural standards
  - somewhat standardized functionality, but highly variable
- conceptual model (as opposed to natural)
  - must be taught; not obvious



Digital Watch Redesigned for Affordances (Rachna Dhamija)

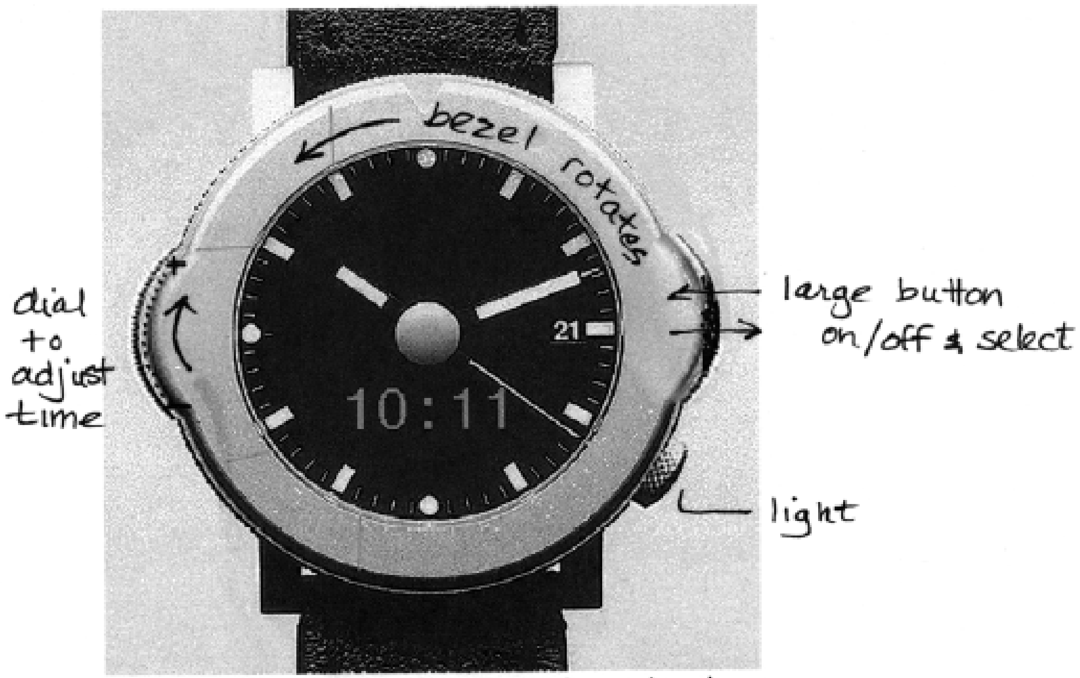


Fig 1: Time reading mode displays combined analog/digital view

Digital Watch Redesigned for Affordances (Ping Yee)

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Auditory sensors

- Auditory processor is a separate entity than the visual processor. That explains why we can use them for different purposes at the same time.
  - Warming signals in audio tones.
- Auditory feedback is very powerful
  - Gives “visibility” to “invisible things”
    - Ex: tone in the phone connection
- Warning
  - Auditory feedback must be only for exceptional events
    - If the same feedback is give for “usual” actions it is annoying and leads to volountary deactivation of the controls
    - Multiple auditory feedbacks generate interference and confusion

SonicFinder (Gaver 1989, Shneiderman)

- added sound to the Mac interface by offering a dragging sound when a file was being dragged, a click when a window boundary was passed, and a thunk when the file was dropped into the trashcan for deletion.
- For visually impaired users, the sounds are vital.

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Motion skills

- Our competence in manipulating and controlling motions
- Haptic devices
  - Keyboards, mice, touch screens,
  - joysticks, etc
  - But very few devices explore other haptic sensors, like a foot pedal for computers, except for computer games.

C:D ratio

- The C:D (controller : display) ratio is the ratio between the distance the controller must be moved in order to cause the tracker to move a given distance on the display.
- For example, if the C:D ratio was 2:1, two centimeters of motion by the controller would result in only one centimeter of motion by the tracking symbol on the display.

Non-linear C-D ratio

- When the ratio is non-linear, such as the case with most of mouse movement, the ratio varies with the speed of mouse motion. Slower speed, higher C:D ratio.
  - In Macintosh, the amount of variation is selectable from “slow” to “fast” in 4 steps.
- Pros and cons
  - A high C:D ratio is useful for fine cursor positioning, and for users who do not have well developed motor coordination (such as the aged or physically disabled).
  - A low C:D ratio permits one to traverse the display with relatively little motion of the controller.

Question

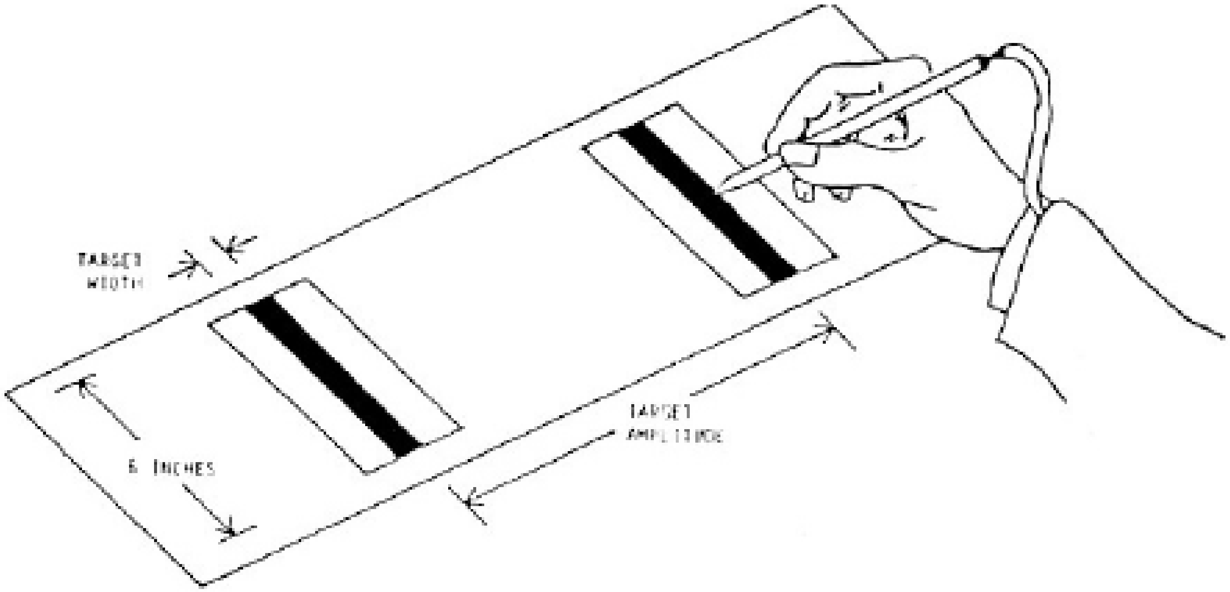
- When devices are used for both control and display, such as touch-screens and light-pens, what should the correct C:D ratio be?
- Answer: 1

Fitts' law

- In human-computer interaction and ergonomics, **Fitts's law** (often cited as **Fitts' law**) is a model of human movement which predicts the time required to rapidly move to a target area, as a function of the distance to the target and the size of the target.
- Fitts's law is used to model the act of *pointing*, both in the real world (e.g., with a hand or finger) and on computers (e.g., with a mouse). It was published by Paul Fitts in 1954.

Fitt's law (the speed in tracking targets)

- Fitts (1954, right after World War II) ran some experiments to study the effect of target size and distance on target acquisition time. That is, how long did it take to point at something.



The results

- States that the time to acquire a target with a *continuous linear* controller has a logarithmic relationship to the *distance* over the target size.

$$MT = a + b \log_2(2A/W)$$

- where MT is the movement time,
  - A is the distance (or amplitude) between two targets,
  - W is the width of the targets,
  - a is a constant, and
  - b=100[70 - 120] msec/bit.

- Index of difficulty

$$ID = \log_2(2A/W)$$

$$MT = a + b\log_2(2A/W + 1)$$

Shannon formulation

- Holds for movements along one direction

$$MT = a + b \cdot \log_2\left(\frac{D}{W} + 1\right)$$

  - *T* is the average time taken to complete the movement. (Traditionally, researchers have used the symbol *MT* for this, to mean *movement time*.)
  - *a* represents the start/stop time of the device and *b* stands for the inherent speed of the device. These constants can be determined experimentally by fitting a straight line to measured data.
  - *D* is the distance from the starting point to the center of the target. (Traditionally, researchers have used the symbol *A* for this, to mean the *amplitude* of the movement.)
  - *W* is the width of the target measured along the axis of motion. *W* can also be thought of as the allowed error tolerance in the final position, since the final point of the motion must fall within ± *W*/2 of the target's centre.

Shannon formulation

- From the equation, we see a speed-accuracy tradeoff associated with pointing, whereby targets that are smaller and/or further away require more time to acquire.
- Advantages
  - Always positive number
  - Better fit to experimental data
- Limitations
  - It describes simple motor response of, say, the human hand, failing to account for software acceleration usually implemented for a mouse cursor;
  - Untrained movements