

Human factors in interaction design

Projects

- Project Phase One reports are due in three weeks: March 25.
- Submit a printed hard-copy of your report in class on March 25.
- You are going to have two months after Phase One to finish your project and present it in class.
- Check the newsgroup for possible announcements related to the project.

Projects

- What do I want to see in Phase One reports apart from a general description?
 - Description of your potential users
 - Age, gender, physical and cognitive abilities, education, cultural or ethnic background, training, motivation, goals and personality
 - Skill level of your users: Novice or first-time users, Knowledgeable users, or expert frequent users
 - Identification of the tasks
 - Users' needs?
 - Observing and interviewing users
 - Decomposition of high level tasks
 - Relative task frequencies

Projects

- What type of interaction style will be employed?
 - Direct manipulation?
 - Command language?
 - Natural language, speech?
 - Vision?
- Which tools (software/hardware) are you planning to use in your project?

Many kinds of interaction styles available...

- Command
- Speech
- Data-entry
- Form fill-in
- Query
- Graphical
- Web
- Pen
- Augmented reality
- Gesture and even...



for Human-Computer Interaction

understand your materials

- understand computers
 - limitations, capacities, tools, platforms
- understand people
 - psychological, social aspects
 - human error
- and their interaction ...

Usability measures

- 5 human factors central to interface evaluation:
 - Time to learn
 - How long does it take for typical members of the community to learn relevant task?
 - Speed of performance
 - How long does it take to perform relevant benchmarks?
 - Rate of errors by users
 - How many and what kinds of errors are made during benchmark tasks?
 - Retention over time
 - Frequency of use and ease of learning
 - Subjective satisfaction
 - Allow for user feedback via interviews, free-form comments and satisfaction scales

Designing for people:

- Example airplane errors:
 - If booster pump fails, turn on fuel valve within 3 seconds
 - Tests showed it took at least five seconds to actually do it!



- Result
 - Human factors became critically important

Differences Between The Designer And Operator



Darn these hooves! I hit the wrong switch again!
Who designs these instrument panels, raccoons?

The human

- Information i/o ...
 - visual, auditory, haptic, movement
- Information stored in memory
 - sensory, short-term, long-term
- Information processed and applied
 - reasoning, problem solving, skill, error
- Emotion influences human capabilities
- Each person is different

Core cognitive aspects

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

Vision

Two stages in vision

- physical reception of stimulus
- processing and interpretation of stimulus

The Eye - physical reception

- mechanism for receiving light and transforming it into electrical energy
- light reflects from objects
- images are focused upside-down on retina
- retina contains rods for low light vision and cones for color vision
- ganglion cells (brain!) detect pattern and movement

Interpreting the signal

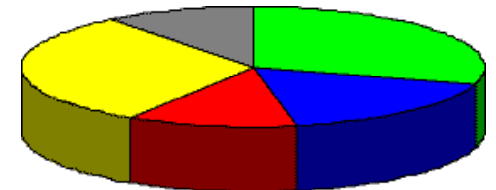
- Size and depth
 - visual angle indicates how much of view object occupies
(relates to size and distance from eye)
 - visual acuity is the ability to perceive detail
(limited)
 - familiar objects perceived as constant size
(in spite of changes in visual angle when far away)
 - cues like overlapping help perception of size and depth

Interpreting the signal (cont)

- Brightness
 - subjective reaction to levels of light
 - affected by luminance of object
 - measured by just noticeable difference
 - visual acuity increases with luminance as does flicker
- Color
 - made up of hue, intensity, saturation
 - cones sensitive to color wavelengths
 - blue acuity is lowest
 - 8% males and 1% females color blind

color and 3D

- both often used very badly!
- color
 - older monitors limited palette
 - color over used because 'it is there'
 - beware color blind!
 - use sparingly to **reinforce** other information
- 3D effects
 - good for physical information and some graphs
 - but if over used ...
e.g. text in perspective!! 3D pie charts



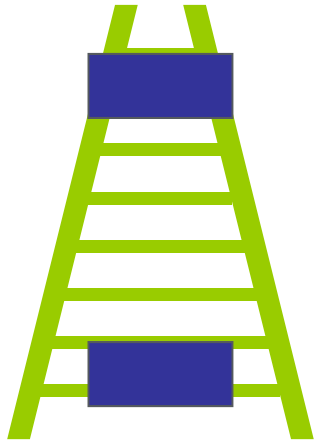
bad use of color

- over use - without very good reason (e.g. kids' site)
- colour blindness
- poor use of contrast
- do adjust your set!
 - adjust your monitor to greys only
 - can you still read your screen?

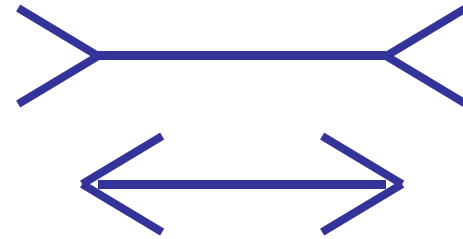
Interpreting the signal (cont)

- The visual system compensates for:
 - movement
 - changes in luminance.
- Context is used to resolve ambiguity
- Optical illusions sometimes occur due to over compensation

Optical Illusions



the Ponzo illusion



the Muller Lyer illusion

Reading

- Several stages:
 - visual pattern perceived
 - decoded using internal representation of language
 - interpreted using knowledge of syntax, semantics, pragmatics
- Reading involves saccades and fixations
- Perception occurs during fixations
- Word shape is important to recognition
- Negative contrast improves reading from computer screen

Hearing

- Provides information about environment:
distances, directions, objects etc.
- Physical apparatus:
 - outer ear – protects inner and amplifies sound
 - middle ear – transmits sound waves as vibrations to inner ear
 - inner ear – chemical transmitters are released and cause impulses in auditory nerve
- Sound
 - pitch – sound frequency
 - loudness – amplitude
 - timbre – type or quality

Hearing (cont)

- Humans can hear frequencies from 20Hz to 15kHz
 - less accurate distinguishing high frequencies than low.
- Auditory system filters sounds
 - can attend to sounds over background noise.

Touch

- Provides important feedback about environment.
- May be key sense for someone who is visually impaired.
- Stimulus received via receptors in the skin:
 - thermoreceptors – heat and cold
 - nociceptors – pain
 - mechanoreceptors – pressure

(some instant, some continuous)
- Some areas more sensitive than others e.g. fingers.
- Kinethesis - awareness of body position
 - affects comfort and performance.

Movement

- Time taken to respond to stimulus:
 reaction time + movement time
- Movement time dependent on age, fitness etc.
- Reaction time - dependent on stimulus type:
 - visual ~ 200ms
 - auditory ~ 150 ms
 - pain ~ 700ms

Movement (cont)

- Fitts' Law describes the time taken to hit a screen target:

$$Mt = a + b \log_2(D/S + 1)$$

where: a and b are empirically determined constants

Mt is movement time

D is Distance

S is Size of target

⇒ targets as large as possible
distances as small as possible

Attention

- Selecting things to concentrate on from the mass around us, at a point in time
- Focussed and divided attention enables us to be selective in terms of the mass of competing stimuli but limits our ability to keep track of all events
 - magicians use this to their advantage!
- Information at the interface should be structured to capture users' attention, e.g. use perceptual boundaries (windows), **color**, reverse video, sound and flashing lights

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 - follow the google.com example of crisp, simple design
- Avoid using too much because the software allows it

An example of over-use of graphics



Our Situation

- ◆ State the bad news
- ◆ Be clear, don't try to obscure the situation

Perception and recognition

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

Which is easiest to read and why?

What is the time?

What is the time?

What is the time?

What is the time?

What is the time?

Memory

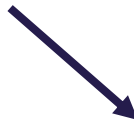
There are three types of memory function:

Sensory memories



Attention

Short-term memory or working memory



Rehearsal

Long-term memory

Memory

- Involves encoding and recalling knowledge and acting appropriately
- We don't remember everything - involves filtering and processing
- Context is important in affecting our memory
- We recognize things much better than being able to recall things
 - The rise of the GUI over command-based interfaces
- Better at remembering images than words
 - The use of icons rather than names

sensory memory

- Buffers for stimuli received through senses
 - iconic memory: visual stimuli
 - echoic memory: aural stimuli
 - haptic memory: tactile stimuli
- Example
 - stereo sound
- Continuously overwritten

Short-term memory (STM)

- Scratch-pad for temporary recall
 - rapid access $\sim 70\text{ms}$
 - rapid decay $\sim 200\text{ms}$
 - limited capacity - 7 ± 2 chunks

Examples

212348278493202

0121 414 2626

HEC ATR ANU PTH ETR EET

The problem with the classic '7±2'

- George Miller's theory of how much information people can remember
- People's immediate memory capacity is very limited
- Many designers have been led to believe that this is useful finding for interaction design

What some designers get up to...

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



Why?

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

Long-term memory (LTM)

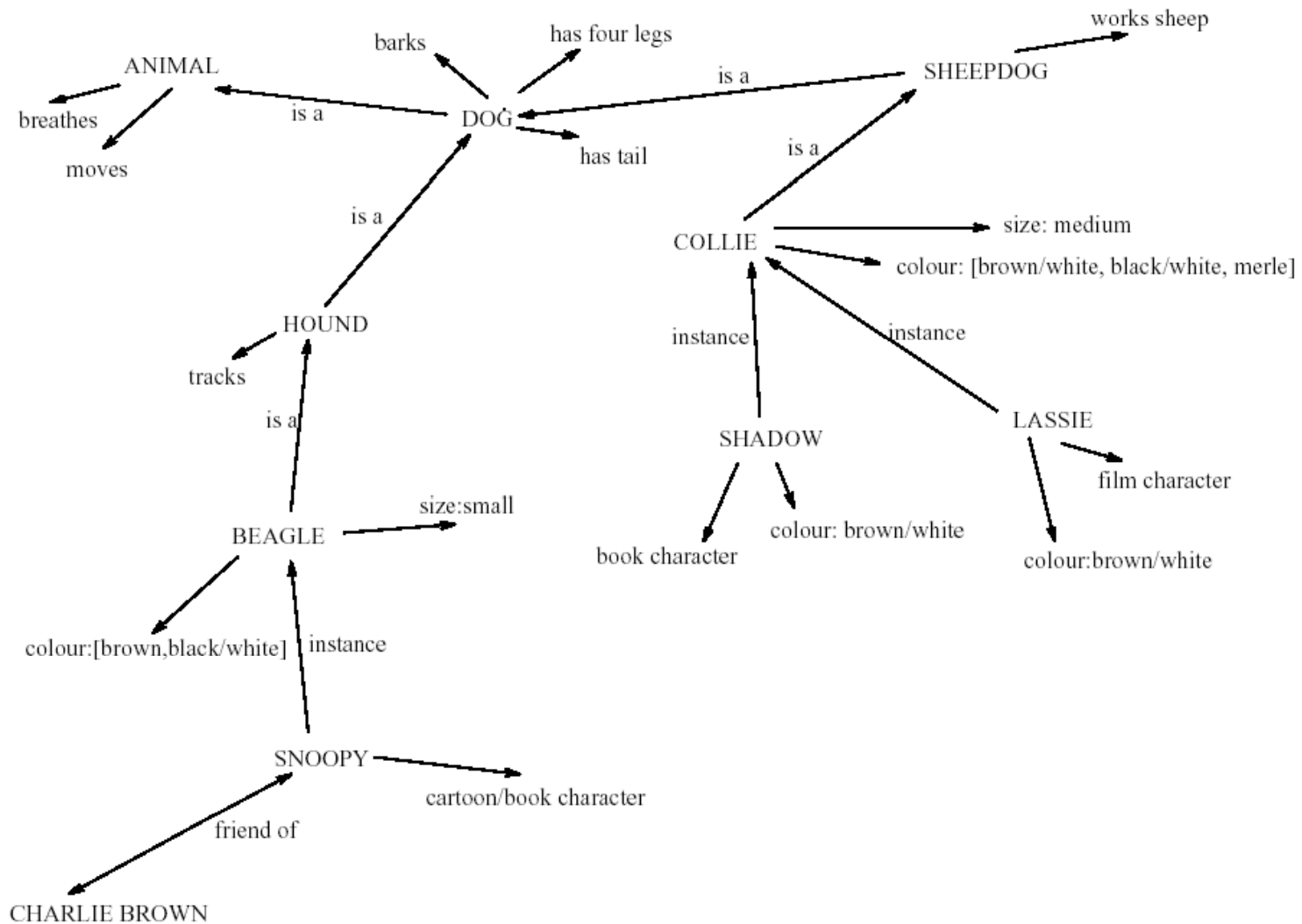
- Repository for all our knowledge
 - slow access $\sim 1/10$ second
 - slow decay, if any
 - huge or unlimited capacity
- Two types
 - episodic – serial memory of events
 - semantic – structured memory of facts, concepts, skills

semantic LTM derived from episodic LTM

Long-term memory (cont.)

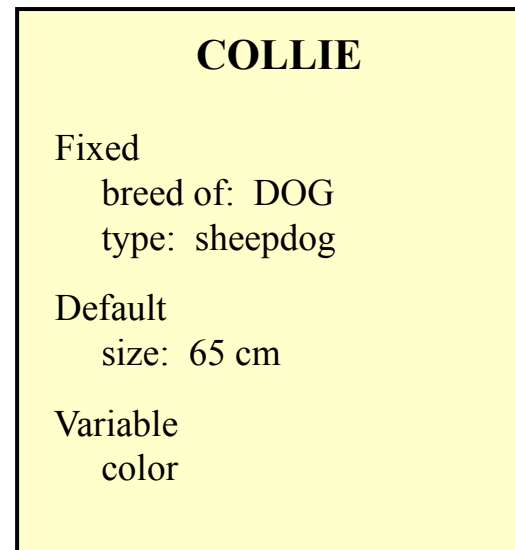
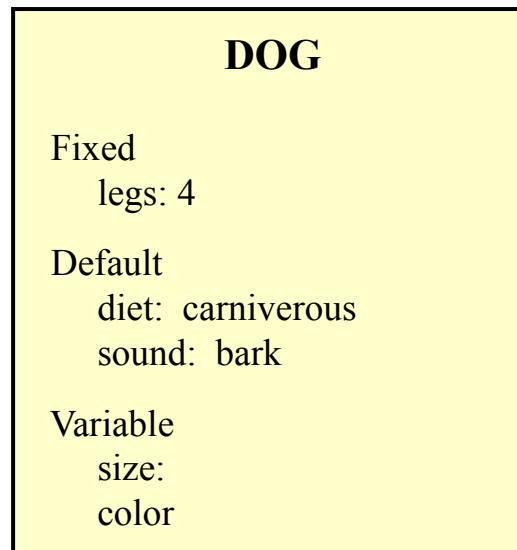
- Semantic memory structure
 - provides access to information
 - represents relationships between bits of information
 - supports inference
- Model: semantic network
 - inheritance – child nodes inherit properties of parent nodes
 - relationships between bits of information explicit
 - supports inference through inheritance

LTM - semantic network



Models of LTM - Frames

- Information organized in data structures
- Slots in structure instantiated with values for instance of data
- Type-subtype relationships



Models of LTM - Scripts

Model of stereotypical information required to interpret situation

Script has elements that can be instantiated with values for context

Script for a visit to the vet			
Entry conditions:	<i>dog ill</i> <i>vet open</i> <i>owner has money</i>	Roles:	<i>vet examines</i> <i>diagnoses</i> <i>treats</i>
Result:	<i>dog better</i> <i>owner poorer</i> <i>vet richer</i>		<i>owner brings dog in</i> <i>pays</i> <i>takes dog out</i>
Props:	<i>examination table</i> <i>medicine</i> <i>instruments</i>	Scenes:	<i>arriving at reception</i> <i>waiting in room</i> <i>examination</i> <i>paying</i>
		Tracks:	<i>dog needs medicine</i> <i>dog needs operation</i>

Models of LTM - Production rules

Representation of procedural knowledge.

Condition/action rules

if condition is matched

then use rule to determine action.

IF dog is wagging tail
THEN pat dog

IF dog is growling
THEN run away

LTM - Storage of information

- rehearsal
 - information moves from STM to LTM
- total time hypothesis
 - amount retained proportional to rehearsal time
- distribution of practice effect
 - optimized by spreading learning over time
- structure, meaning and familiarity
 - information easier to remember

LTM - Forgetting

decay

- information is lost gradually but very slowly

interference

- new information replaces old: retroactive interference
- old may interfere with new: proactive inhibition

so may not forget at all memory is selective ...

... affected by emotion – can subconsciously `choose' to forget

LTM - retrieval

recall

- information reproduced from memory can be assisted by cues, e.g. categories, imagery

recognition

- information gives knowledge that it has been seen before
- less complex than recall - information is cue

Thinking

Reasoning

deduction, induction, abduction

Problem solving

Deductive Reasoning

- Deduction:
 - derive logically necessary conclusion from given premises.
e.g. If it is Friday then she will go to work
It is Friday
Therefore she will go to work.

Deduction (cont.)

- When truth and logical validity clash ...

e.g. Some people are babies

Some babies cry

Inference - Some people cry

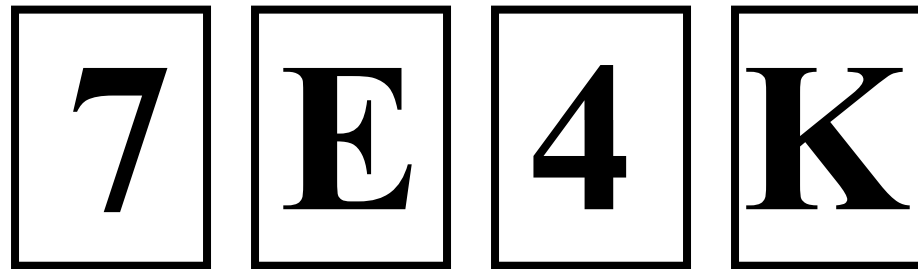
Correct?

Inductive Reasoning

- Induction:
 - generalize from cases seen to cases unseen
e.g. all elephants we have seen have trunks
therefore all elephants have trunks.
- Unreliable:
 - can only prove false not true

... but useful!
- Humans not good at using negative evidence
 - e.g. Wason's cards

Wason's cards



If a card has a vowel on one side it has an even number on the other

Is this true?

How many cards do you need to turn over to find out?

.... and which cards?

Abductive reasoning

- reasoning from event to cause
 - e.g. Sam drives fast when drunk.
If I see Sam driving fast, assume drunk.
- Unreliable:
 - can lead to false explanations

Problem solving

- Process of finding solution to unfamiliar task using knowledge.
- Several theories.
- Gestalt
 - problem solving both productive and reproductive
 - productive draws on insight and restructuring of problem
 - attractive but not enough evidence to explain 'insight' etc.
 - move away from behaviourism and led towards information processing theories

Problem solving (cont.)

Problem space theory

- problem space comprises problem states
- problem solving involves generating states using legal operators
- heuristics may be employed to select operators
e.g. means-ends analysis
- operates within human information processing system
e.g. STM limits etc.
- largely applied to problem solving in well-defined areas
e.g. puzzles rather than knowledge intensive areas

Problem solving (cont.)

- Analogy
 - analogical mapping:
 - novel problems in new domain?
 - use knowledge of similar problem from similar domain
 - analogical mapping difficult if domains are semantically different
- Skill acquisition
 - skilled activity characterized by chunking
 - lot of information is chunked to optimize STM
 - conceptual rather than superficial grouping of problems
 - information is structured more effectively

Errors and mental models

Types of error

- slips
 - right intention, but failed to do it right
 - causes: poor physical skill, inattention etc.
 - change to aspect of skilled behaviour can cause slip
- mistakes
 - wrong intention
 - cause: incorrect understanding
 - humans create mental models to explain behaviour.
 - if wrong (different from actual system) errors can occur

Mental models

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

Mental models

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

Everyday reasoning & mental models

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

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

Heating up a room or oven that is thermostat-controlled

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

Heating up a room or oven that is thermostat-controlled

- Same is often true for understanding how interactive devices and computers work:
 - Poor, often incomplete, easily confusable, based on inappropriate analogies and superstition (Norman, 1983)
 - e.g. frozen cursor/screen - most people will bash all manner of keys

External cognition

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

Externalizing to reduce memory load

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

Computational offloading

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

Annotation and cognitive tracing

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

Emotion

- Various theories of how emotion works
 - James-Lange: emotion is our interpretation of a physiological response to a stimuli
 - Cannon: emotion is a psychological response to a stimuli
 - Schacter-Singer: emotion is the result of our evaluation of our physiological responses, in the light of the whole situation we are in
- Emotion clearly involves both cognitive and physical responses to stimuli

Emotion (cont.)

- The biological response to physical stimuli is called *affect*
- Affect influences how we respond to situations
 - positive → creative problem solving
 - negative → narrow thinking

“Negative affect can make it harder to do even easy tasks; positive affect can make it easier to do difficult tasks”

(Donald Norman)

Emotion (cont.)

- Implications for interface design
 - stress will increase the difficulty of problem solving
 - relaxed users will be more forgiving of shortcomings in design
 - aesthetically pleasing and rewarding interfaces will increase positive affect

Individual differences

- long term
 - gender, physical and intellectual abilities
- short term
 - effect of stress or fatigue
- changing
 - age

Ask yourself:

will design decision exclude section of user population?

Psychology and the Design of Interactive System

- Some direct applications
 - e.g. blue acuity is poor
 - ⇒ blue should not be used for important detail
- However, correct application generally requires understanding of context in psychology, and an understanding of particular experimental conditions

Involving users in the design

- At the very least, talk to users
 - It's surprising how many designers don't!
- Contextual Inquiries
 - **Interview** users **in their usage place** (e.g., office), **during their normal routine** (e.g., while working)
 - Used to discover user's culture, requirements, expectations, etc.

Involving users in the design

- Create prototypes
 - It's hard to comment on something that doesn't yet exist
 - Users are good at giving feedback for something that is even partially built