Human perception:
Information processing

- 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
The sensors on human body - sensory modalities

**On muscles:**
- Muscle receptors

**(Proprioception):**
- Within muscles

**On joints:**
- Changes in joint position
- Speed of movement
- Position of the joint
- Pain sensation

**On the skin:**
- Heat-cold
- Pain
- Touch-Pressure

**On the head:**
- Vision
- Hearing
- Balance
- Taste
- Smell
Relation between sensory processing
hand size of body part

The misshapen somatic sensory cortex
Human Visual System

- Light passes through lens
- Focused on retina
The human eye as an optical system

The human eye consists of spherical interfacing surfaces and represents a complex optical system itself (Figure 2.12). Its approximate diameter is 25 mm, and it is filled with two different fluids—both having a refraction index of ∼1.336. The iris is a muscle that regulates the amount of the incoming light by expanding or shrinking. The cornea and the elastic biconvex lens (refraction index ∼1.4) below the iris bundle the transmitted light in such a way that different light rays which are diffused by the same point light source are projected to the same point on the retina. Note that the projection is flipped in both directions—horizontally and vertically. The retina consists of many small conic and cylindrical light-detecting cells called photoreceptors (approximate size 1.5 μm-5 μm) that are categorized into rods and cones. The resolution of the eye depends on the density of these cells—which varies along the retina. If the distance between two point projections is too small, only one cell is stimulated and the brain cannot differentiate between the two points. To recognize two individual points, the two stimulated cells have to be separated by at least one additional cell. If the angle between two light rays that are emitted from two different point light sources and enter the eye is below 1.5 arc minutes, the points cannot be differentiated. The limited resolution of the human eye is the reason why light rays that are emitted from a single object point and pass through an optical system which does not support true stigmatism, still appear to intersect at a single image point. Thus, small aberrations of non-stigmatic and non-absolute optical systems are not detected. Consequently, the observer perceives a single—possibly deformed—image of the object. The area with the highest resolution of detector cells is called the fovea.

Interpreting the signal

- Size and depth
  - visual angle, visual acuity (detail), familiarity of objects, cues (overlapping)

- Brightness

- Colour
  8% of males, 1% of females colour blind
Color Sensitivity
Ratio of these 3 gives any color (RGB, here “BGR”)

Sensitivity

A representation of additive color mixing.

http://en.wikipedia.org/wiki/RGB
Interpreting the signal

- Visual processing involves the transformation and interpretation of a complete image
- Expectations affects the way an image is perceived
- The visual system compensates for:
  - Movement and changes in luminance.
- Context is used to resolve ambiguity
Optical Illusions 1/5
Optical Illusions 2/5
Optical Illusions 3/5
Optical Illusions 4/5

Retinal image is moving, but our perception of the image is stable. Optical illusions sometimes occur due to over compensation

the Ponzo illusion

the Muller Lyer illusion
Mauritz Cornelis Escher

- Dutch
- 1898 – 1972
- Graphical designer
- World’s first Virtual Reality (VR) Artist
Projection onto a wallpapered area
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 and **color** is important to recognition

- Negative contrast improves reading from computer screen (continued)

16/50
Reading: saccades and fixations

http://www.mrcophth.com/eyeclipartchua/saccadeabnormality.html
Reading: Negative contrast improves reading from computer screen

http://vision.arc.nasa.gov/personnel/al/papers/03vss/03vsshandout.pdf
Researcher: http://vision.arc.nasa.gov/personnel/al/ahumada.html
The ear

- Ear Drum
- Middle Ear
- Inner Nose
- Eustachian Tube
Hearing (Adult: 20Hz – 15 KHz)

• 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
  20/50
3D-audio sensing

The two most important localization cues are the Interaural Time Difference, or \textit{ITD}, and the Interaural Intensity Difference or \textit{IID}.

Interaural time difference, ITD
Difference in traveling time

Read more:
www.aip.org/pt/nov99/locsound.html
3D-audio sensing

Interaural intensity difference, IID
Difference due to shadow effect

Read more:
www.aip.org/pt/nov99/locsound.html
Touch sensing

- 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.
- Kinesthesia - awareness of body position
  - affects comfort and performance.
Touch sensing in UI design (FTIR)

http://www.i-cherubini.it/mauro/blog/uploads/images/multi-touch.png

24/50
Touch sensing in UI design
(Sebastian Hartman and Deniz Chaban, 2007)

http://www.touchtech.se/en based on BSc thesis at CSE, Chalmers TH
Touch sensing in UI design

http://www.cbc.ca/gfx/photos/virtualclay_040714.jpg

http://www.vrlab.buffalo.edu/images/kesh_virtualclay.jpg
Example for a screen-based video see-through display. The locomotion of a dinosaur is simulated over a physical footprint.

(Image reprinted from IEEE.)
Touch sensing in UI design

ZKOUT - The Social Network That Follows You
Reaction and movement sensing

• 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 (partly correct)
Memory

- Sensory memory (touch sensing)
  - Buffers from stimuli received through senses
- Working memory (short term)
  - small capacity (7 ± 2 “chunks”)
  - rapid access (~70ms) & decay (~200 ms)
    - pass to LTM after a few seconds
- Long-term memory
  - huge (if not “unlimited”)
  - slower access time (~100 ms) w/ little decay
Short- and long-term memory

- **Sensory Image Store**: decay
- **Working Memory**: decay, displacement
- **Long Term Memory**: chunking/interference?

Maintenance rehearsal
Long-term memory (LTM)

- Repository for all our knowledge
  - slow access ~ 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
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 - retrieval

- **Recall**
  - info reproduced from memory

- **Recognition**
  - presentation of info provides knowledge that info has been seen before
  - easier because of cues to retrieval
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
Reading, speaking, and listening

- Written language is permanent while listening is transient
- Reading can be quicker than speaking or listening (but not always!)
- Listening requires less cognitive effort
- Written language is grammatical
- Speaking has redundant information
Table 2-2. The differences between speech perception and reading text

<table>
<thead>
<tr>
<th>Reading the text</th>
<th>Listening to speech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each word can be seen as a whole</td>
<td>Spoken word is spread out in time</td>
</tr>
<tr>
<td>Less ambiguous</td>
<td>More ambiguous and unclear signal</td>
</tr>
<tr>
<td>The text can be continuously available</td>
<td>Higher memory demand, the information is transient, a word is heard and then it ends.</td>
</tr>
<tr>
<td>There is no so many redundant information behind the word itself</td>
<td>Contain numerous hints, such as pitch, intonation, stress, timing, to sentence structure and meaning.</td>
</tr>
<tr>
<td>Be accessible only in the focus visual area</td>
<td>Can take input from any direction</td>
</tr>
</tbody>
</table>
Human Cognition, or:
Human Thinking
Deductive, inductive, and abductive reasoning

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.

Logical conclusion not necessarily true:
  e.g. If it is raining then the ground is dry
       It is raining
       Therefore the ground is dry

When truth and logical validity clash ... 
  e.g. Some people are babies
       Some babies cry
       Inference - Some people cry

PROBLEM: Correct?

People bring world knowledge to work for them
Deductive, inductive, and abductive reasoning

Inductive reasoning:
Induction: generalize from cases seen to cases unseen
  e.g. all elephants we have seen have trunks
       therefore all elephants have trunks.

PROBLEM: Unreliable: can only prove false not true ... but useful!

Humans not good at using negative evidence e.g. Wason's cards.

Abductive reasoning: reasoning from event to cause
  e.g. Sam drives fast when drunk.
       If I see Sam driving fast, assume drunk.

PROBLEM: Unreliable: can lead to false explanations
What is human cognition?

• Human cognition is a field studying human’s capacity and limitation in thinking
• Related to HCI
• Norman (1993) distinguishes between two general modes:
  - Experiential and reflective cognition
Cognitive process

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

43/50
Wason's cards

The study of Wason (1966):

- Do people think logically? If yes, they should be able to solve a logically simple **deductive reasoning task**: Wason’s selection task.
- You see four cards. The rule is: If there is a vowel on one side of a card, then there is an even number on the other side of the card.
- Which of these four cards **need** to be turned in order to test that the rule applies?
- Most people select just the E-card, but not the 7-card. However, others have shown that the task is simpler if it is less abstract (Griggs & Cox, 1982).
- The problem includes modus ponens inference and modus tollens:
  - **Modus ponens**: If vowel then even number; E is a vowel → there must be an even number.
  - **Modus tollens**: If vowel then even number; 7 is not an even number → there must be no vowel.
Mental models

- People use mental model to make inferences about how to carry out tasks when using the interactive products.
- It is used to fathom (....) what to do when something unexpected happens with a system and when encountering unfamiliar systems.
- Engineers mental model (conceptual models) and users mental model is different.
Generally 3 alternative models

- Mental model
- Cognitive model
- Conceptual model
CASE STUDY:
Example of How Human Cognition and Perception Functions:

“Epistemic Action Increases With Skill”

• A scientific study of Tetris players
• How does playing technique change as skill increases?
• Tetris
• Extra actions and speed-up
Background

- **Power law of practice**
  

- **Tetris,**
  
  - Seven shapes (zoids)
  - Falls, rotate, move left to right
  - Clear rows
Test

- Two players - beginners
- 20 hours each
- Episodes at slow speed
- Three measurements in time:
  - Time to place zoid
  - Between two actions
  - Make the first action
Test

Zoid Appears
\[ t_1 \]

Series of Actions

Final Action
\[ t_2 \]

Time to Place the Zoid

Zoid Appears
\[ t_1 \]

First Action
\[ t_2 \]

Time of First Action

Rotate

Translate

Drop

First Action
\[ t_1 \]

Second Action
\[ t_2 \]

Third Action
\[ t_3 \]

Time Between Actions

50/50
Results

• Speed-up occurred according to power law of practice
Results

• Extra actions increase along with skill increase

• Not due to motor or perceptual errors
  - Zoid type played a role

• Epistemic actions
Epistemic actions

• Simplify computation
• Reduce memory load
• Reduce time
• Reduce error probabilities

• Early in the decision process
• Helps with placement decisions