Terminalske naprave in uporabniški vmesniki

Terminal devices and user interfaces

Zapiski predavanj

Bolonjski študijski program 1. stopnja (UNMM)

Bolonski študijski program 2. stopnja (MAG)

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Terminal devices and user interfaces (Human-Computer Interaction)

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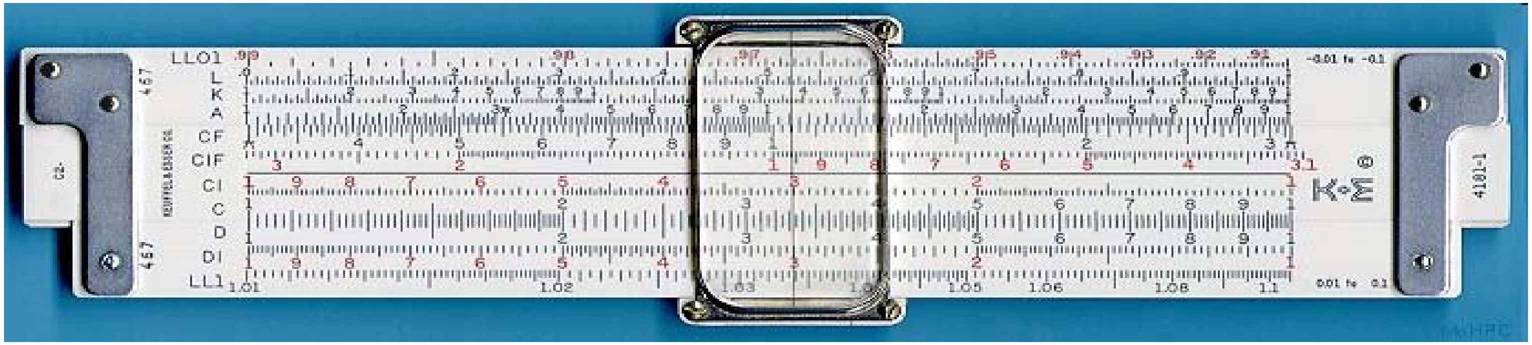
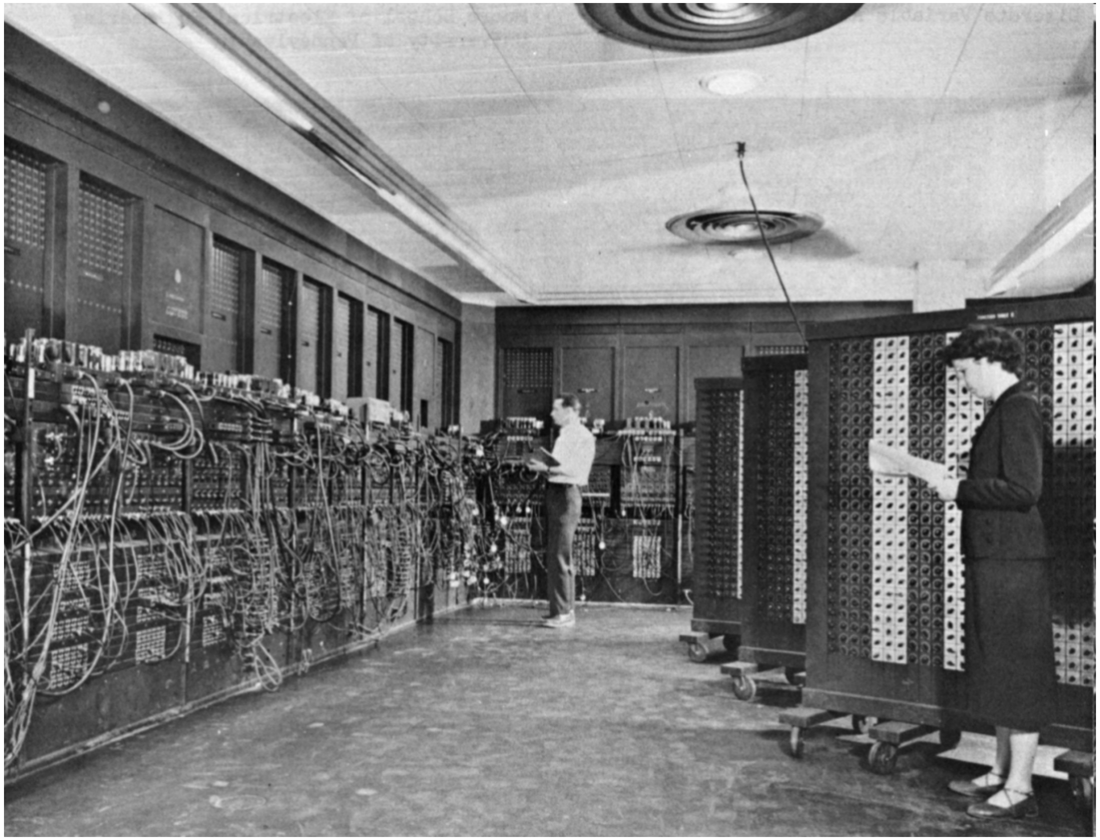
Syllabus outline

- **Man-machine communication**: overview and historical background
- **Human perception and information processing**: the senses, memory, thinking, emotions and ergonomics
- **Properties and operation of terminal equipment**: input and output technologies, sensors and biometrics, visual interfaces, audio interfaces, haptic interfaces, multimedia interfaces, embedded systems, mobile devices
- **The design of human-machine interaction**: visual interaction, verbal interaction, multi-modal and mobile interaction, interaction and the Web, virtual environments.
- **Design, development and evaluation** of user interfaces by taking into account the specific limitations of different terminals and providing the best user experience.
- **Specific user interfaces** and interaction styles: medical, vehicles and aircrafts, games, older users, blind and visually impaired.

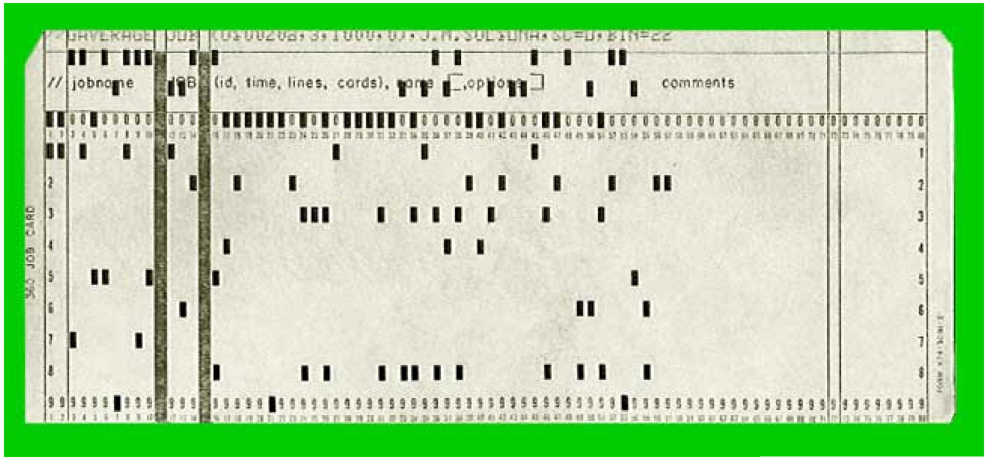
History of HCI

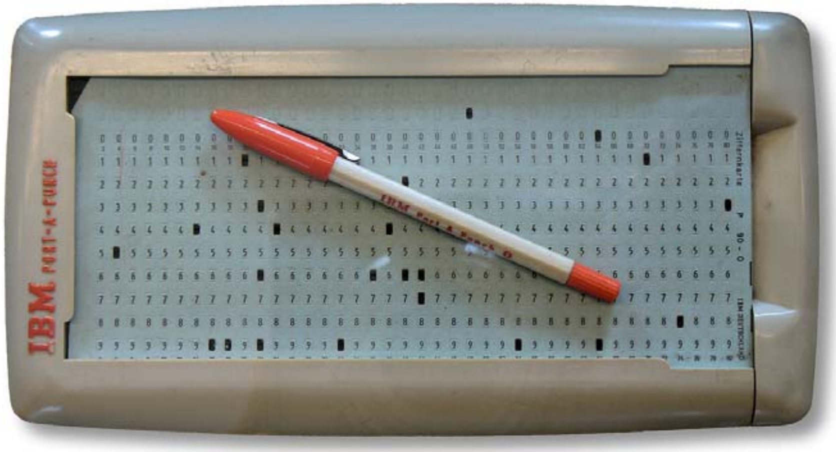


- ENIAC (1946) and CURTA (1948)



- Punch cards


// jobname JOB (id, time, lines, cards), name [,options] comments
360 JOB CARD


IBM PORT-A-PUNCH

History of HCI

- Internet
  - Sputnik (1957)
  - Joseph Carl Robnett Licklider (MIT)
    - Article: Man-Computer Symbiosis (1960)

"A network of such [computers], connected to one another by wide-band communication lines [which provided] the functions of present-day libraries together with anticipated advances in information storage and retrieval and [other] symbiotic functions."

- Internet
  - DARPA (Defense Advanced Research Projects Agency)
  - J. C. R. Licklider
    - Goal: Connecting Pentagon with SAC HQ (1962)
    - Connecting three locations: 2 in California and 1 in Boston
    - Three terminals at each location (one terminal for each connection)
    - Circuit switching
    - Connection of UCLA and Stanford
      - 29th of October, 1969 at 10:30 pm

History of HCI

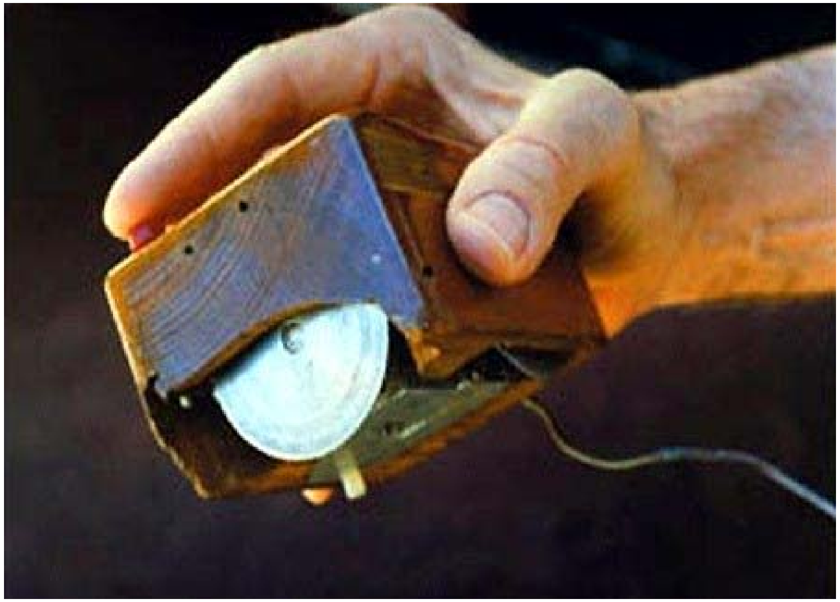
- World Wide Web (WWW)
  - Tim Berners-Lee (1980) – “father of web”, CERN Definition of “hypertext” in a form of a database
    - ENQUIRE
    - Predecessor to WWW
    - “Cards” with hyperlinks
    - First implementation of HTTP (1989)
    - First browser (1991): WorldWideWeb (later renamed to Nexus)
      - Only for NeXT computers
    - First web page: http://info.cern.ch/
  - First WWW server outside Europe (Stanford, 1991)

History of HCI

- Direct manipulation of graphical objects
  - Sketchpad demo (Ivan Sutherland)
    - Lincoln Labs (MIT) - 1963
    - Manipulation of objects using a light-pen, including grabbing objects, moving them, changing size, and using constraints
  - AMBIT/G
    - Lincoln Labs (MIT) – 1968
    - Iconic representations, gesture recognition, dynamic menus with items selected using a pointing device, selection of icons by pointing
  - Xerox PARC – 1979
    - WYSIWYG (What you see is what you get)
    - Including text editor and drawing program

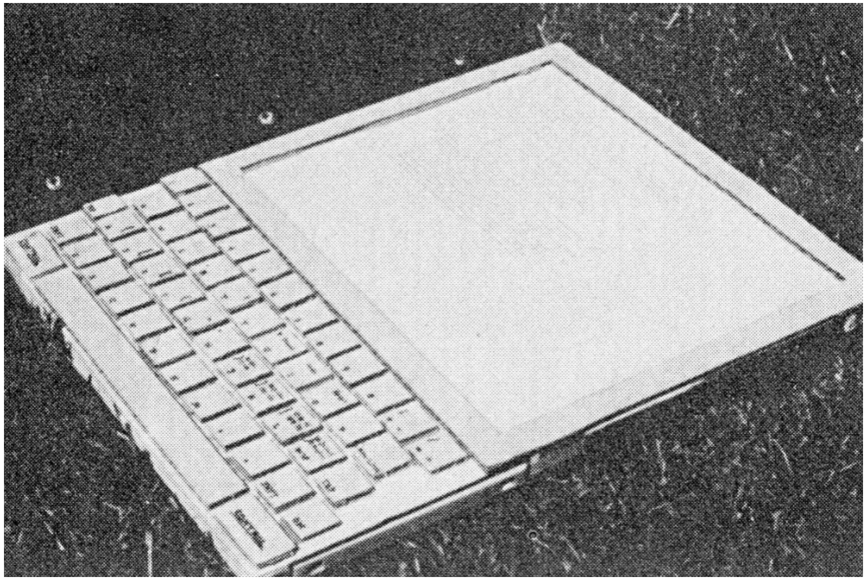
History of HCI

- The Mouse
  - Doug Engelbart (1968)
  - Stanford Research Lab
  - Two orthogonal wheels (potentiometers)
  - First commercially used in Xerox Star



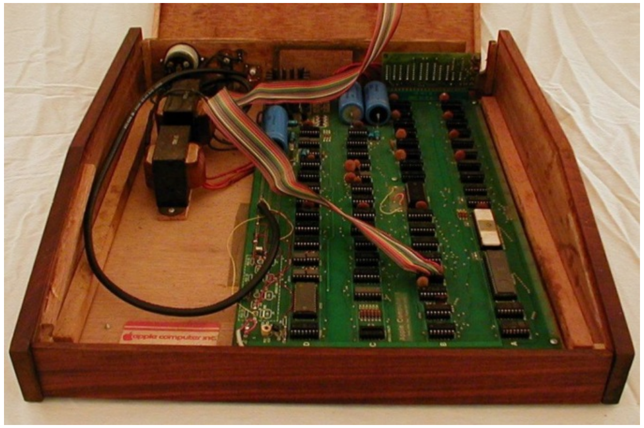
- Engelbart’s law
  - digital technology would became increasingly miniaturized and affordable,
  - its injection into all levels of business and society would become increasingly widespread and rapid
  - this would cause a disruptive ripple effect in society like never before seen -- on a scale more massive than the introduction of fire, written language, agriculture, bronze, printing press and industry combined, all in a significantly compressed timeframe -- shifting us onto an unsustainable trajectory where important challenges are becoming increasingly complex and urgent, with potentially disastrous consequences to humanity and the planet if this phenomenon is not well understood and adequately addressed
  - it is no longer an option to get incrementally smarter and faster; organizations must become exponentially more intelligent and agile, using successive gains in Collective IQ to accelerate progress toward that goal; those that lag will be rendered increasingly ineffective
  - Bootstrapping Strategy for Collective IQ

- Dynabook
  - Alan Kay, PhD thesis at Stanford (1968)
  - Prototype made of cardboard (never actually built)
  - Computer for children of all ages
  - The GUI was realized in Xerox STAR

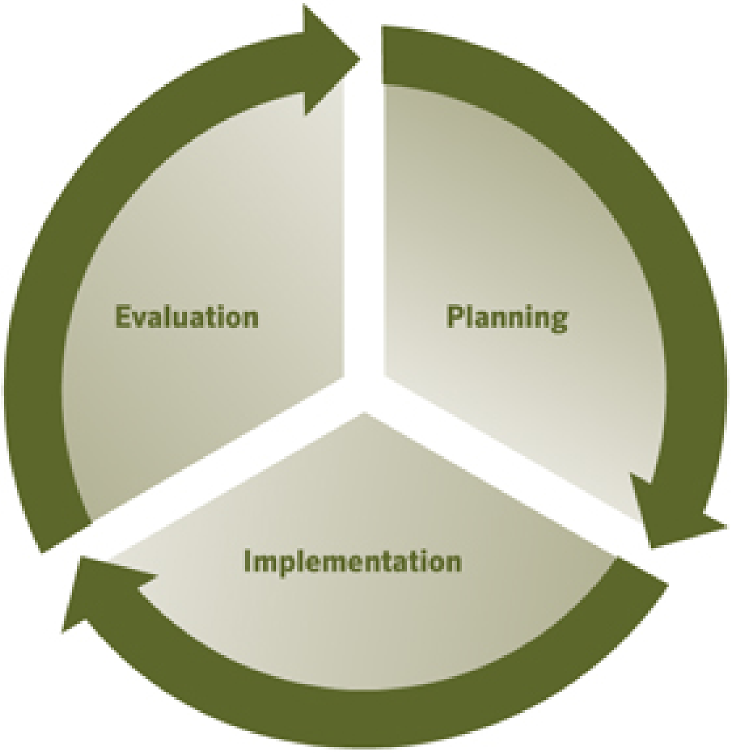


History of HCI

- Personal computers with Graphical User Interfaces
  - Apple LISA (1983)
  - Microsoft Windows (1985)
  - Linux Slackware (1993)



HUMAN
COMPUTER
INTERACTION



Human-computer interaction

- Multidisciplinary field
  - Computer science
  - Behavioral sciences and human factors
  - Design
- The term “Human-computer interaction”
  - Popularized by Stuart K. Card and Allen Newell (“The Psychology of Human-Computer Interaction”, 1983)
- Open-ended dialog between the user and the computer
- Human-computer interface
  - The point of communication between the human user and the computer

- Designing the HCI
  - Early focus on user(s) and task(s)
  - Iterative design
    - Design the interface
    - Test (evaluate) it
    - Analyze results
    - Repeat
- Prototyping
  - Communication based on the artifact
  - The goal is to get feedback
  - Identification of potential improvements

Human-computer interaction

- Prototyping
  - A strategy for efficiently dealing with things that are hard to predict
  - Design process should be a convergent process
  - Prototype
    - Incomplete
    - Easy to change
    - Gets retired with time

Human-computer interaction

- Evaluation of design
  - How good is the interface?
  - Usability studies
    - Special evaluation sessions in a lab
    - Formal and informal
    - “Please me” bias
  - Participant observations
  - Surveys
    - Quick feedback from large group of users
    - Screenshots and mockups
  - Focus Groups
    - Colleagues at work
    - “Taboo” topics
  - Feedback from experts
    - Heuristic Evaluation
  - Comparative experiments

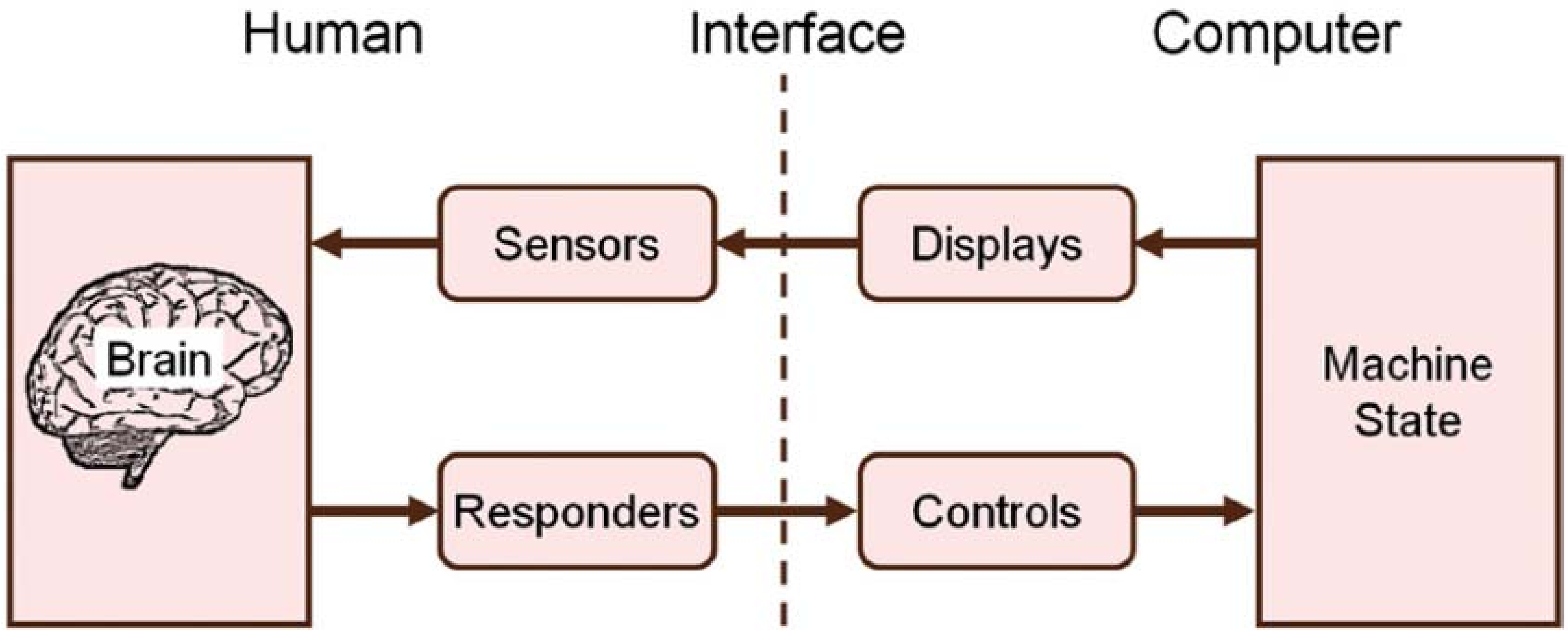
Common issues

- Reliability / precision
- Generalizability
- Realism
- Comparison
- Work involved

Human

Human sensorics and emotions

- Human processor model



Kantowitz and Sorkin, 1983

- Three subsystems
  - Perceptual, motor and cognitive

Human

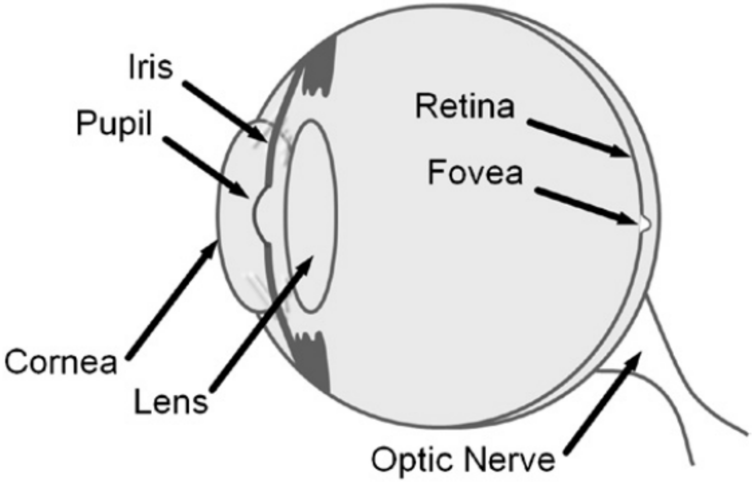
- Interaction with the environment
  - **Senses**: vision, hearing, touch, taste and smell (detection of different physical properties)
  - **Effectors** (responders): limbs, fingers, eyes, head and vocal system (manipulation of environment)
- Typical interaction with the computer
  - Mouse and keyboard
  - Visual display (graphical interface: windows, menus, icons, texts…)
  - Speakers

Vision

- Vision(Sight)
  - Ability to receive information from the environment in the form of visible light
    - 80% of information
  - Perceived by the eye and the brain
  - Two stages
    - Physical reception of the stimulus
    - Interpretation of information

Vision

- The human eye
  - Perception of light and transformation to electrical energy
  - Cornea and lens focus the light onto retina
    - Reflection from objects in space
  - Photoreceptors (rods and cones)
  - Rods
    - 120 M
    - Highly sensitive to light
    - Peripheral vision
    - On the edges of retina
  - Cones
    - 6 M
    - Three types (different wavelengths)
    - Less sensitive
    - On the fovea
  - Blind spot



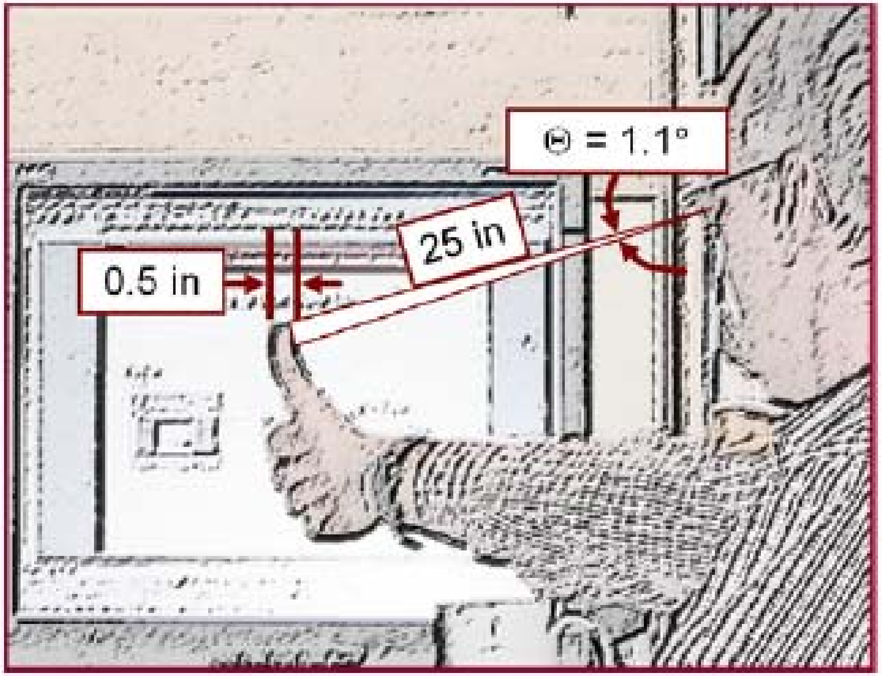
HCI, I. Scott MacKenzie, 2013

Vision

- Retina
  - Light-sensitive layer of tissue
  - Part of the brain (visual association cortex)
  - Chemical and electrical events that trigger nerve pulses
  - Several layers of neurons interconnected by synapses
    - Photoreceptors
    - Ganglion cells
      - X-cells: early detection of pattern (just fovea)
      - Y-cells: early detection of motion (all retina)

Vision

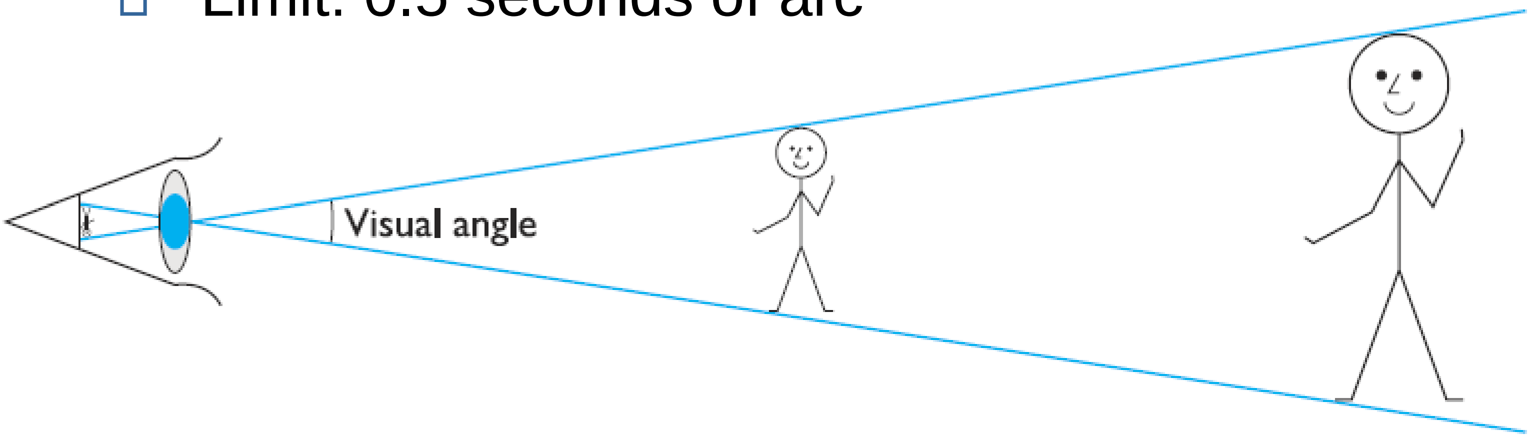
- Visual “window“
  - 80° horizontally in 60° vertically
    - Sharp vision (focus): 2° around the center



HCI, I. Scott MacKenzie, 2013

Vision

- Distance and size
  - Upside-down image on the retina
  - Visual angle
    - Depends on size and distance
    - Limit: 0.5 seconds of arc

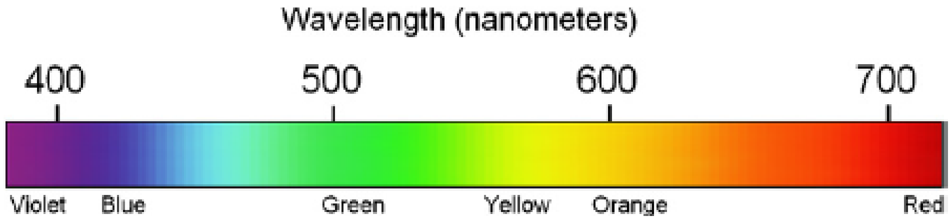


HCI, A. Dix, 2004

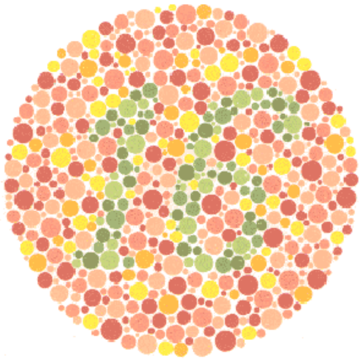
  - Law of size constancy
  - Cues and familiarity

Vision

- Colors
  - Hue: wavelength (frequency)

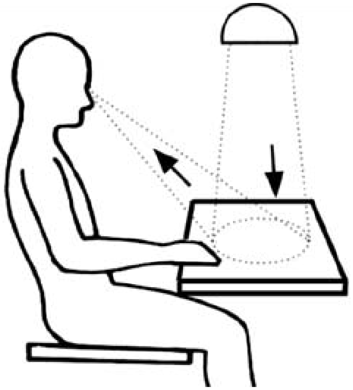


    - 150 different hues can be discriminated
  - Intensity: brightness of the color
  - Saturation: amount of whiteness in the color
  - Differentiation of colors: 7M (only 10 without training)
- Color blindness
  - 8% male and1% female



Vision

- Brightness
  - Subjective reaction to levels of light
  - Luminance: amount of light falling on the object's surface + its reflective properties
    - Measured with photometer (cd/m2)
  - Contrast: luminance of object versus luminance of background



- Vision in different lightning conditions
  - Rods and cons
- Flicker
  - f < 50 Hz
  - Luminance depended

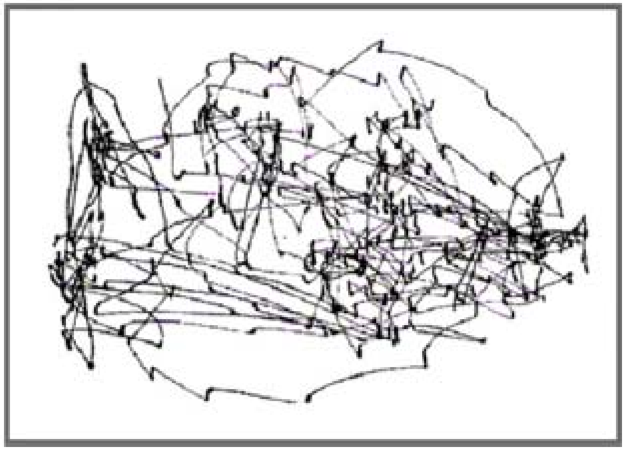
Vision

- Fixations and saccades
  - Basic mechanism for focusing
  - Fixations
    - Visual details from the environment
    - At least 200 ms
  - Saccades
    - Repositioning of eyes
    - 30 – 120 ms
    - Speed: 900° / s
    - Saccadic masking
      - Stopped-clock illusion

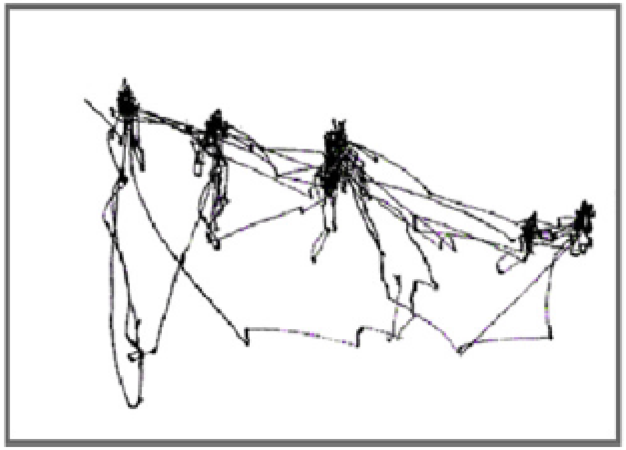
Vision

- Fixations and saccades

HCI, I. Scott MacKenzie, 2013



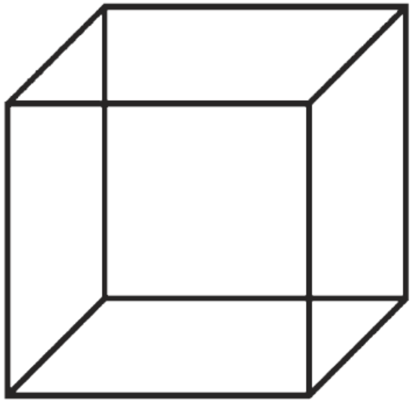
Task: Position of people and objects



Task: Ages of the poeple

Vision

- Interpretation and perception
  - Measureable properties of real-world versus human‘s subjective interpretation
  - Expectations and associations
    - Example: size of objects
  - Just noticeable difference (JND)
    - Compression algorithms such as MP3
  - Ambiguity



Necker cube

Rubin vase

- Interpretation and perception
  - Ambiguity and context

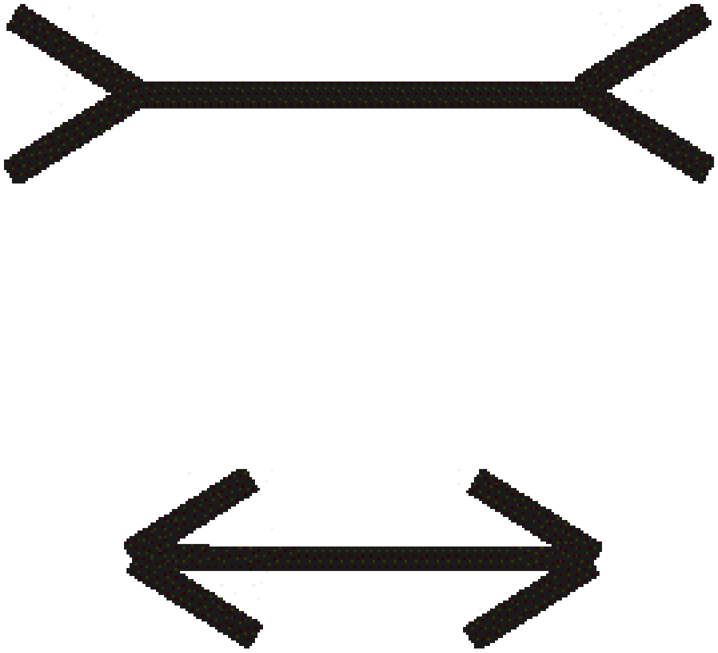
- Interpretation and perception
  - Ambiguity and context

Vision

- Interpretation and perception
  - Ambiguity and context

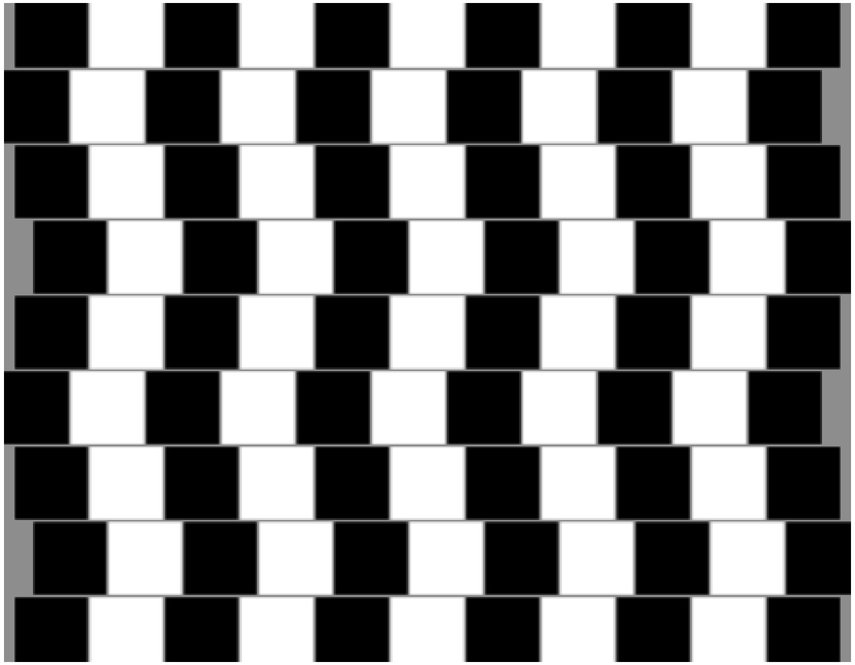
Vision

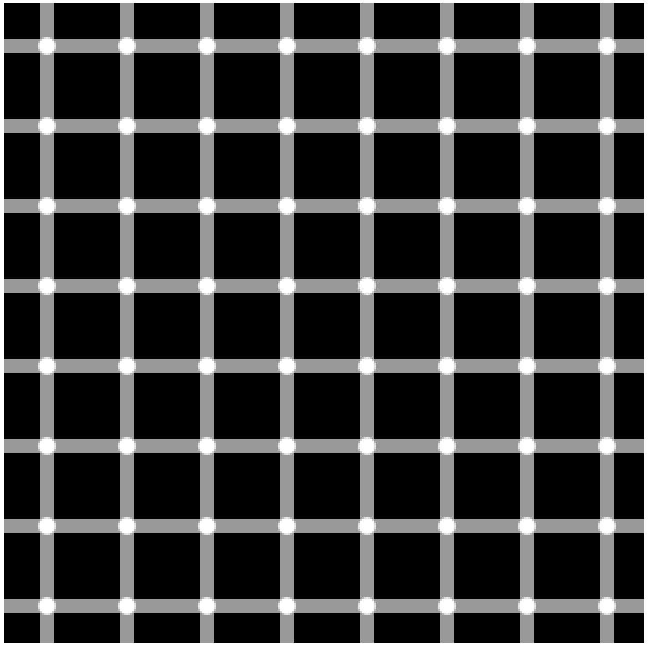
- Interpretation and perception
  - Illusion



Vision

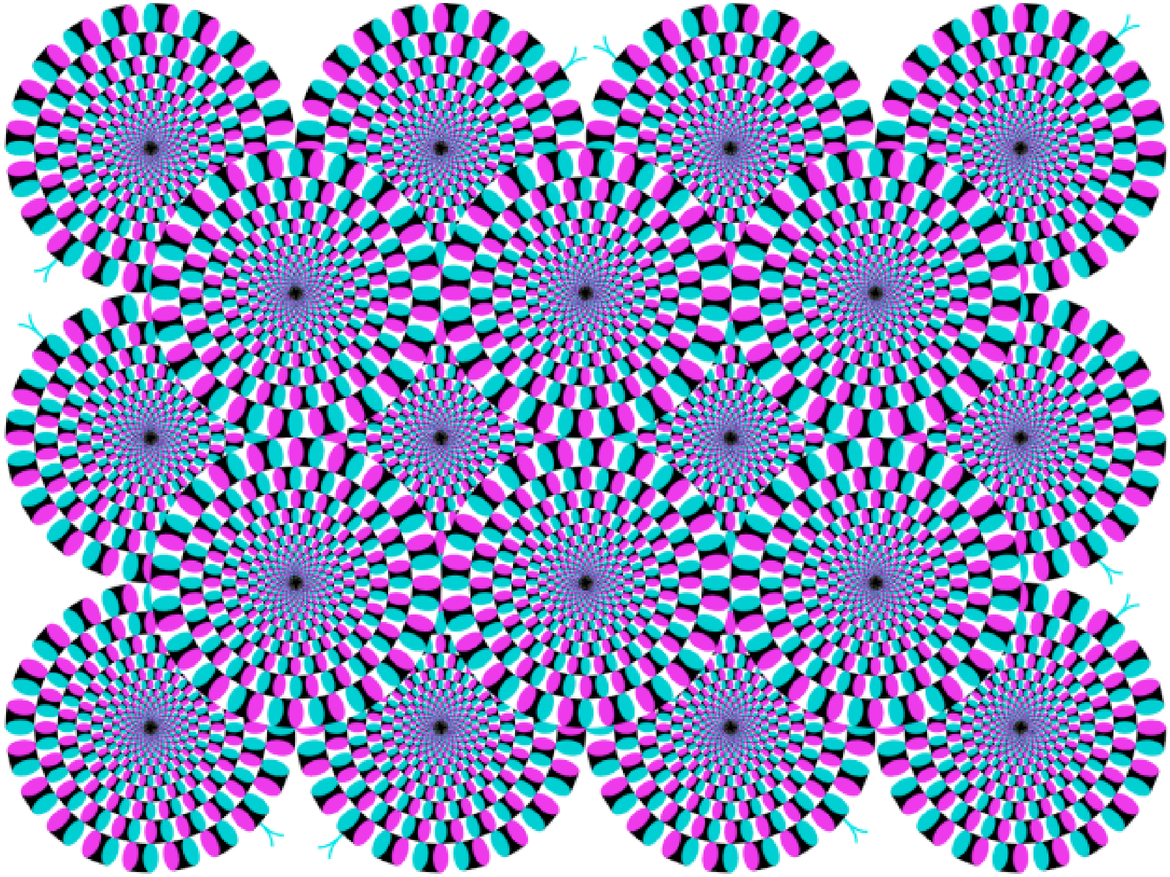
- Interpretation and perception
  - Illusion





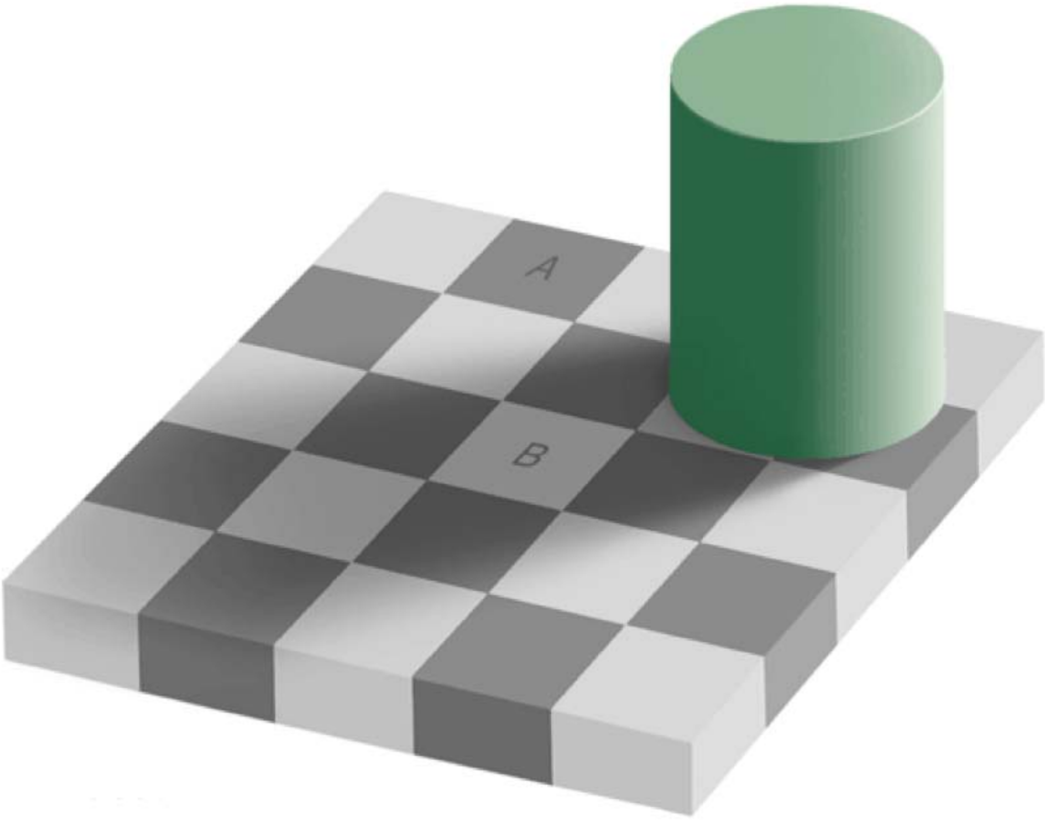
Vision

- Interpretation and perception
  - Illusion



Vision

- Interpretation and perception
  - Illusion



Vision

- Interpretation and perception
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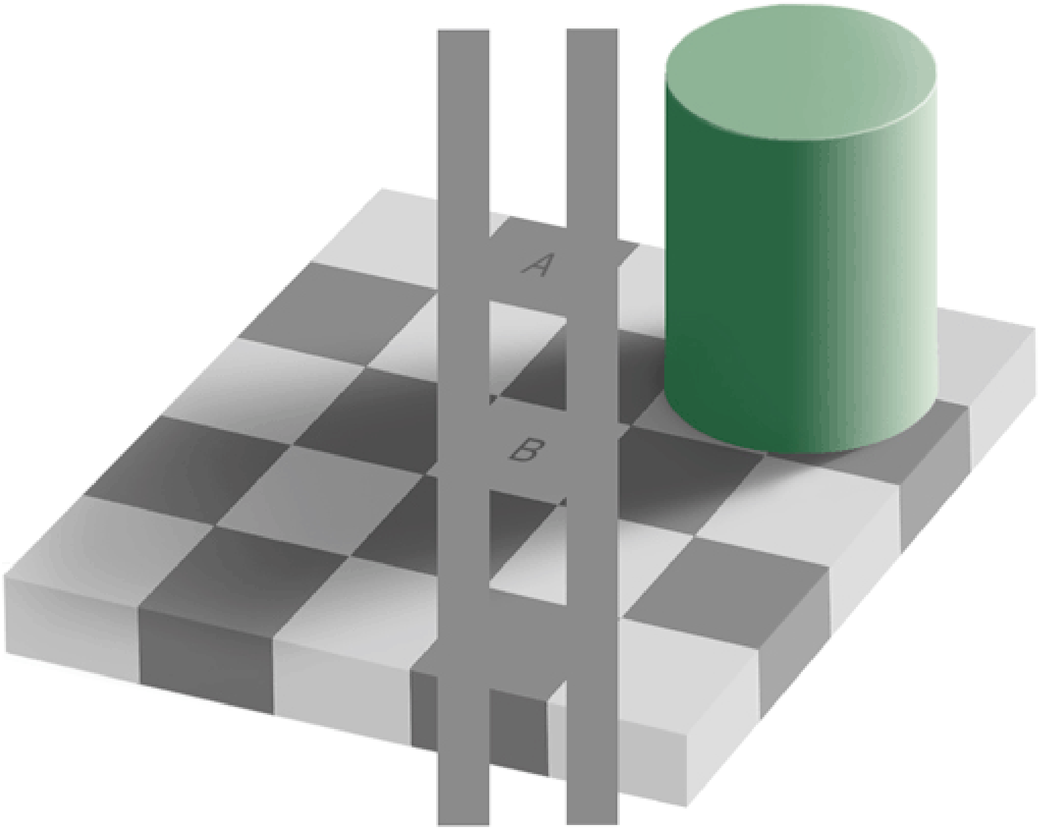


Vision

- Reading
  - Recognition of visual pattern
  - Internal representation of language (words)
  - Syntactic and semantic analysis (phrases and sentences)
- Saccades and fixations
  - The eye moves forwards and backwards
  - Perception occurs during fixations periods
    - 94% of the time
- Speed of reading
  - Approx. 250 words per minute
  - Font size: 9-12 points
  - Line lengths: 58 – 132 mm
- Contrast
  - Negative

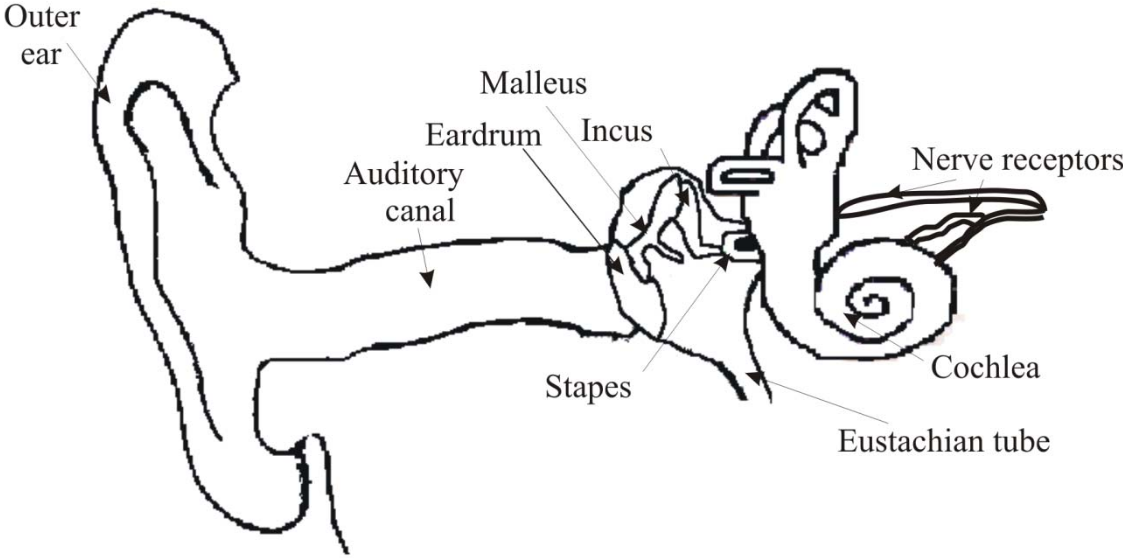
  - Positive

Sound and hearing

- Sound is a longitudinal mechanical wave of pressure and displacement

$$\frac{\partial^2 p}{\partial x^2}+\frac{\partial^2 p}{\partial y^2}+\frac{\partial^2 p}{\partial z^2}=\frac{1}{c^2}\frac{\partial^2 p}{\partial t^2}$$

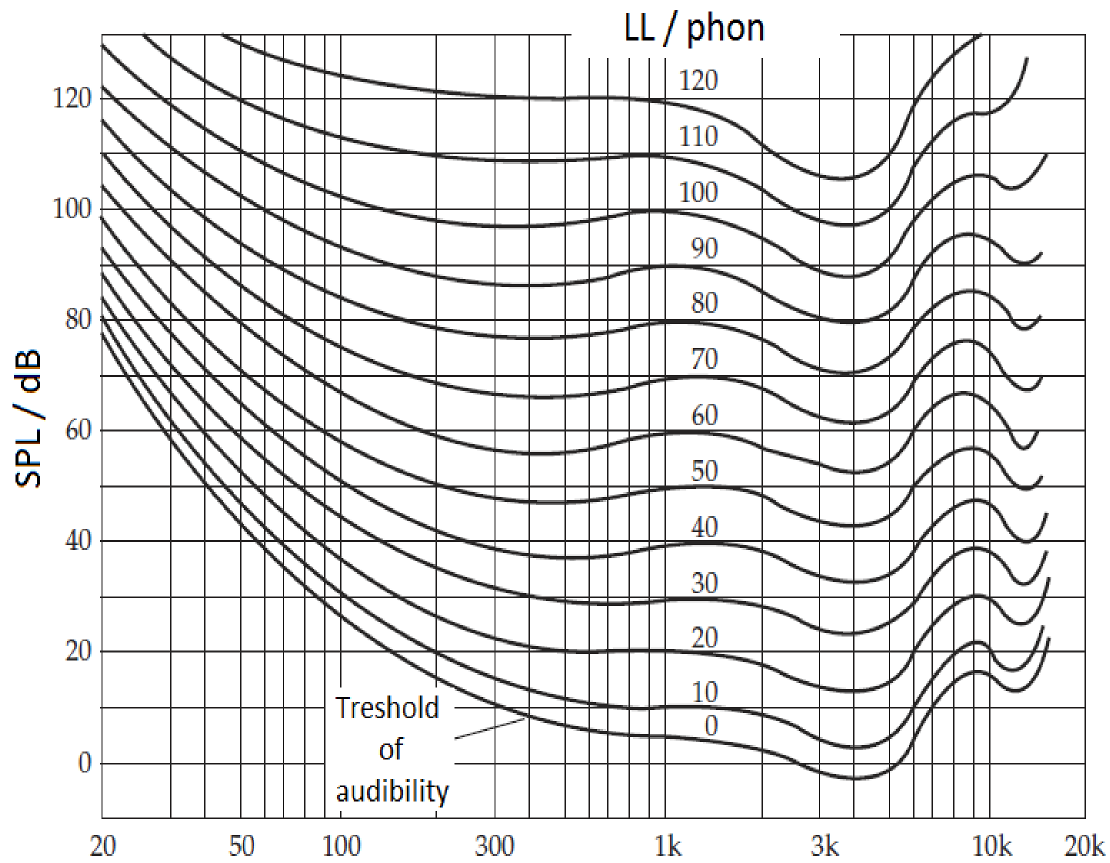
- Human ear
  - Outer, middle and inner ear



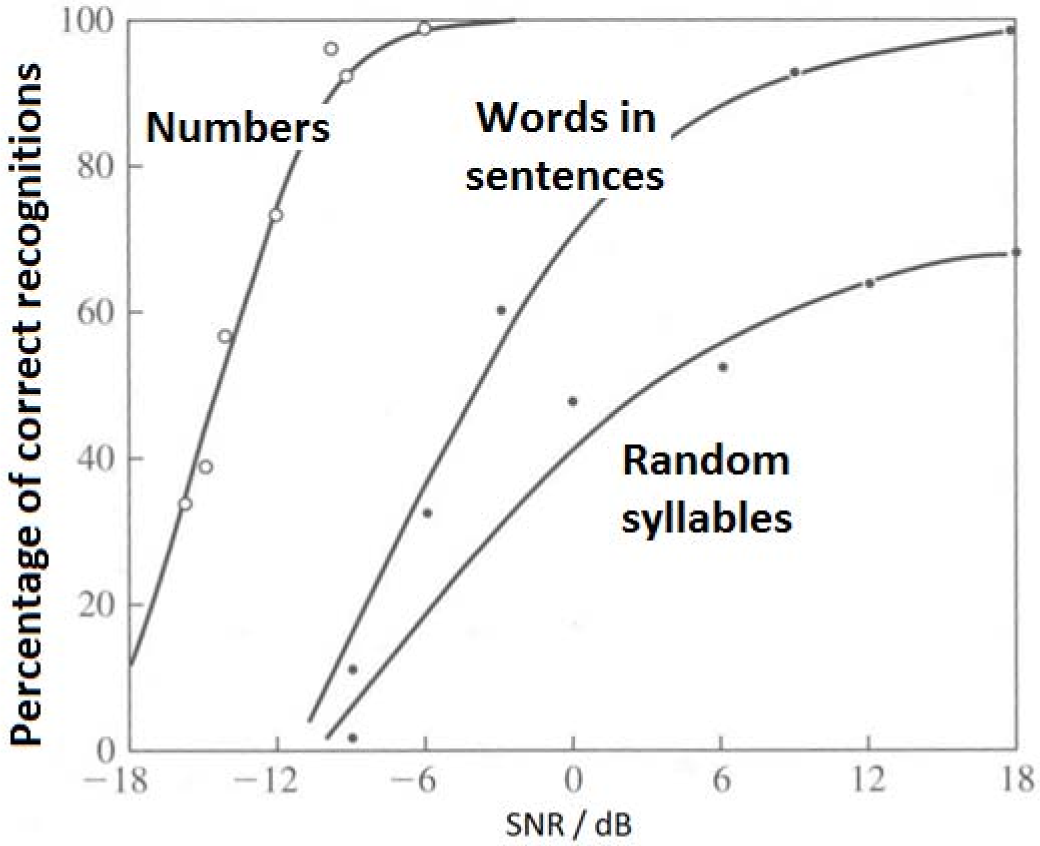
Sound and hearing

- Audible range
  - Frequency (pitch)
    - 20 ~ 20.000 Hz (young people)
    - 20 ~ 14.000 Hz (adults)
    - Infrasound (below 20 Hz) – elephants
    - Ultrasound (above 20 kHz) – bets
- Omnidirectional hearing
- Filtering of sound
  - Cocktail party effect
  - Capacity: 10 kbit /s (hearing) vs. 4 Mbit/s (sight)
- Localization of sound
  - Localization of azimuth and elevation

- Loudness
  - Equal-loudness contours

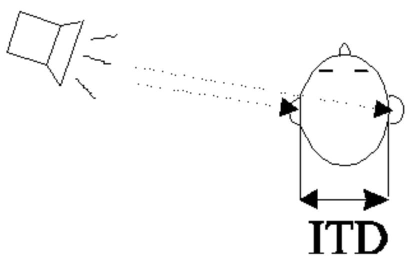


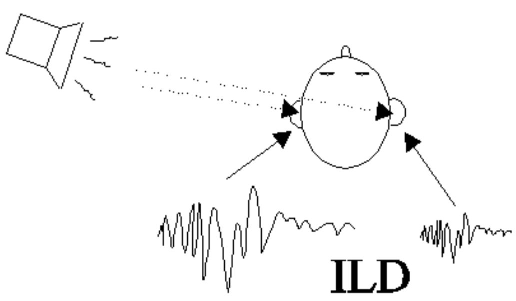
- Recognition of speech signals in a noisy environment (Miller, Heise, Lichten)

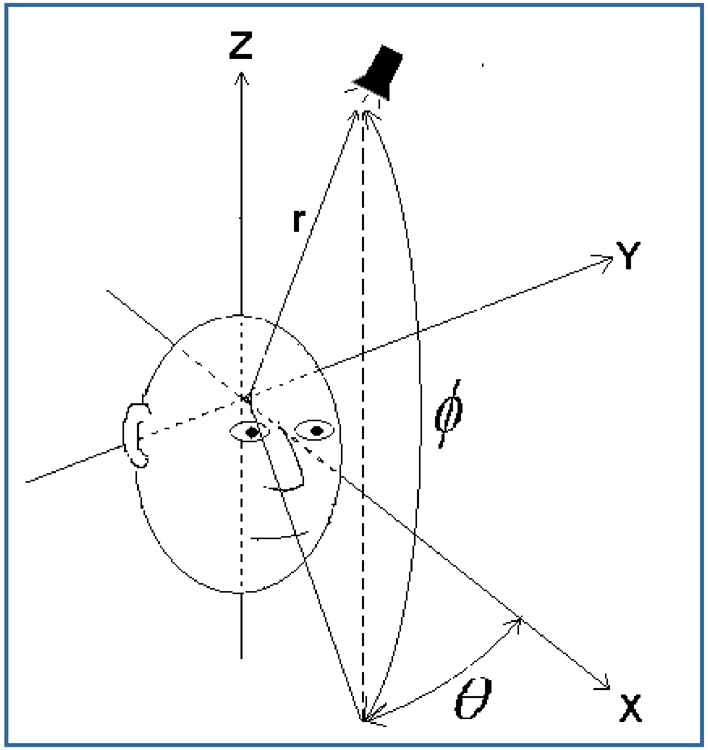


Sound and hearing

- Localization of sound
  - Coordinate system
    - ϕ – azimuth
    - θ – elevation
    - r – distance
  - Inter-aural time difference
  - Inter-aural level difference







- Head Related Transfer Functions (HRTF)
  - Measured as Head Related Transfer Responses (HRIR)

Touch and haptic perception

- Vital information and feedback about the environment
- Stimuli through entire skin
- Three types of sensory receptors
  - Thermoreceptors (heat and cold)
  - Nociceptors (intense pressure, heat, pain)
  - Mechanoreceptors (pressure)
    - Rapidly adapting mechanoreceptors
    - Slowly adapting mechanoreceptors
- No-equal sensitivity
  - Fingers vs. forearm (two-point threshold test)

Touch and haptic perception

- Kinesthesis
  - Awareness of the position of the body and limbs
  - Receptors in joints
    - Rapidly adapting
    - Slowly adapting
    - Positional receptors
- Tactile interfaces
  - Keyboards and mice
  - Braille interfaces

Smell and taste

- Smell
  - The ability to perceive odors
  - Sensory cells in nasal cavity
- Taste
  - Direct chemical reception of sweet, salty, bitter and sour sensations (+ „umami“)
  - Taste buds in the tongue and oral cavity
- Flavor
  - Perceptual process in the brain – combination of smell and taste

Smell and taste

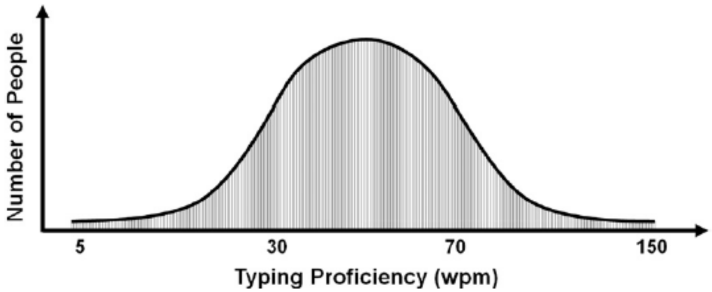
- Smell and taste in HCI
  - Smell has links to memory – smell cues may help in recall
  - Photo albums
    - Smell and text
  - Notification of incoming messages
    - Smell, auditory and visual modalities
  - Poor performance with smell

Reaction and movement

- Perception, reaction, movement
  - Complex chain of processing stages
- Reaction time
  - Auditory signal (150 ms)
  - Visual signal (200 ms)
  - Pain (700 ms)
  - Combined signal
  - Skill or practice
- Movement time
  - Physical characteristic of the subject
    - Age and fitness

Reaction and movement

- Accuracy and performance
  - Speed-accuracy trade-off
  - Less skilled users
  - Skilled operators



- Fitts' law
  - The time taken to hit a target is a function of the size of the target and the distance that has to be moved

Movement time = $a + b \log_2(\text{distance/size} + 1)$

Responders

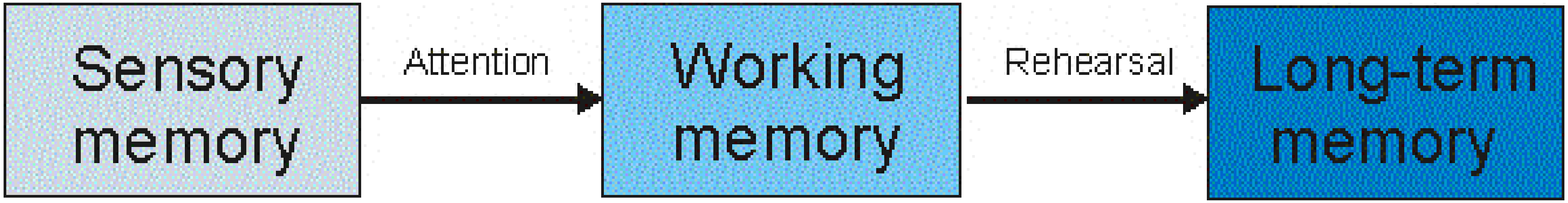
- Humans‘ response to environment
  - Pointing, walking, squinting, speaking, etc.
- Limbs
  - Fingers, hands and arms
  - Somatosensory system: coordination of limb movement and position through the perception of stimuli within muscles and tendons
  - Left-handed, right-handed and ambidextrous people
    - Touch-sensing displays (smart phone)

Responders

- Voice
  - Vocal cords
  - Larynx, oral cavity, pulmonary pressure in the lungs
  - Speech and speech interfaces
- Eyes
  - Fixations and saccades
  - Eye tracking
    - Gaze location and movement

Human memory

- Information storage in human beings
- Input: senses
- Sense of identity (past experiences)
- Three types of memory
  - Sensory
  - Short-term (*working*) memory
  - Long-term memory



Sensory memory

- Buffer for stimuli received through the senses
  - Iconic memory (visual stimulti)
  - Echoic memory (aural stimuli)
  - Haptic memory (touch)
- Constantly overwritten (0.5 s)
- Attention passes information from sensory memory to short-term memory

Short-term memory

- General properties
  - Temporary recall of information
  - Rapid access: ~ 70 ms
  - Rapid decay (short storage time): 10-20s
    - Mental repetition -> rewrite
- Example: 45 x 5 = ?
- Limited capacity
  - 7 ± 2 chunks of information
  - Closure: formation of chunks
- Examples
  - Rubik‘s Cube

Short-term memory

748592385

Short-term memory

Short-term memory

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Short-term memory

RTH EPHON EISRIN GINGF ORON EHOU

Short-term memory

Short-term memory

THE PHONE IS RINGING FOR ONE HOUR

Short-term memory

THE PHONE IS RINGING FOR ONE HOUR

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Short-term memory

- Working memory
  - Chunks
- Recency effect
- Interference
  - Simultaneous use of different channels

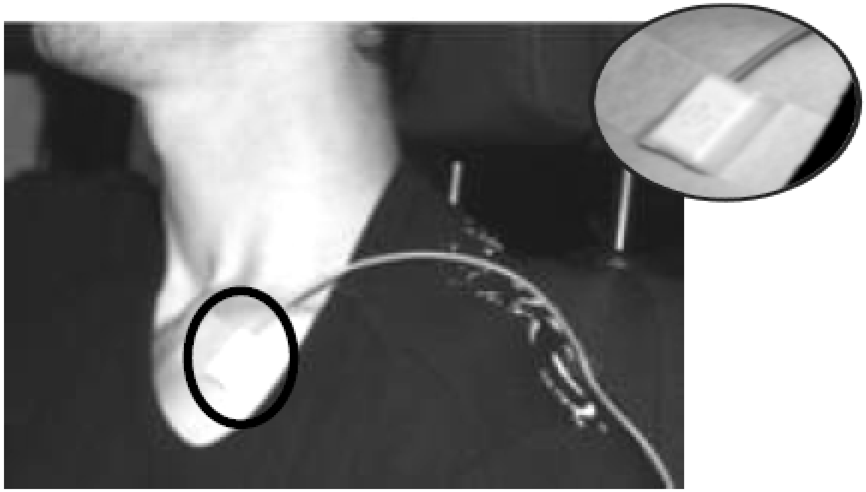
Attention and distraction

- Attention
  - Concentration of mind on one of the competing stimuli or thoughts
  - Divided and selected attention
    - Interests and needs
    - Example: Test of selective attention
- Distraction
  - Primary and secondary tasks
    - Mobile devices
    - In-vehicle interaction
  - Limitations and overload

Attention and distraction

- Cognitive (mental) workload
  - Demands imposed on the human’s limited mental resources
  - Assessment of cognitive workload
    - Psychophysiological measurements
      - Electroencephalogram (EEG)
      - Electrocardiogram (EKG)
      - Ocular activity
        - Blink duration and frequency
    - NASA TLX
      - Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort and Frustration

- Cognitive (mental) workload
  - Detection response task measurement (DRT)



Long-term memory

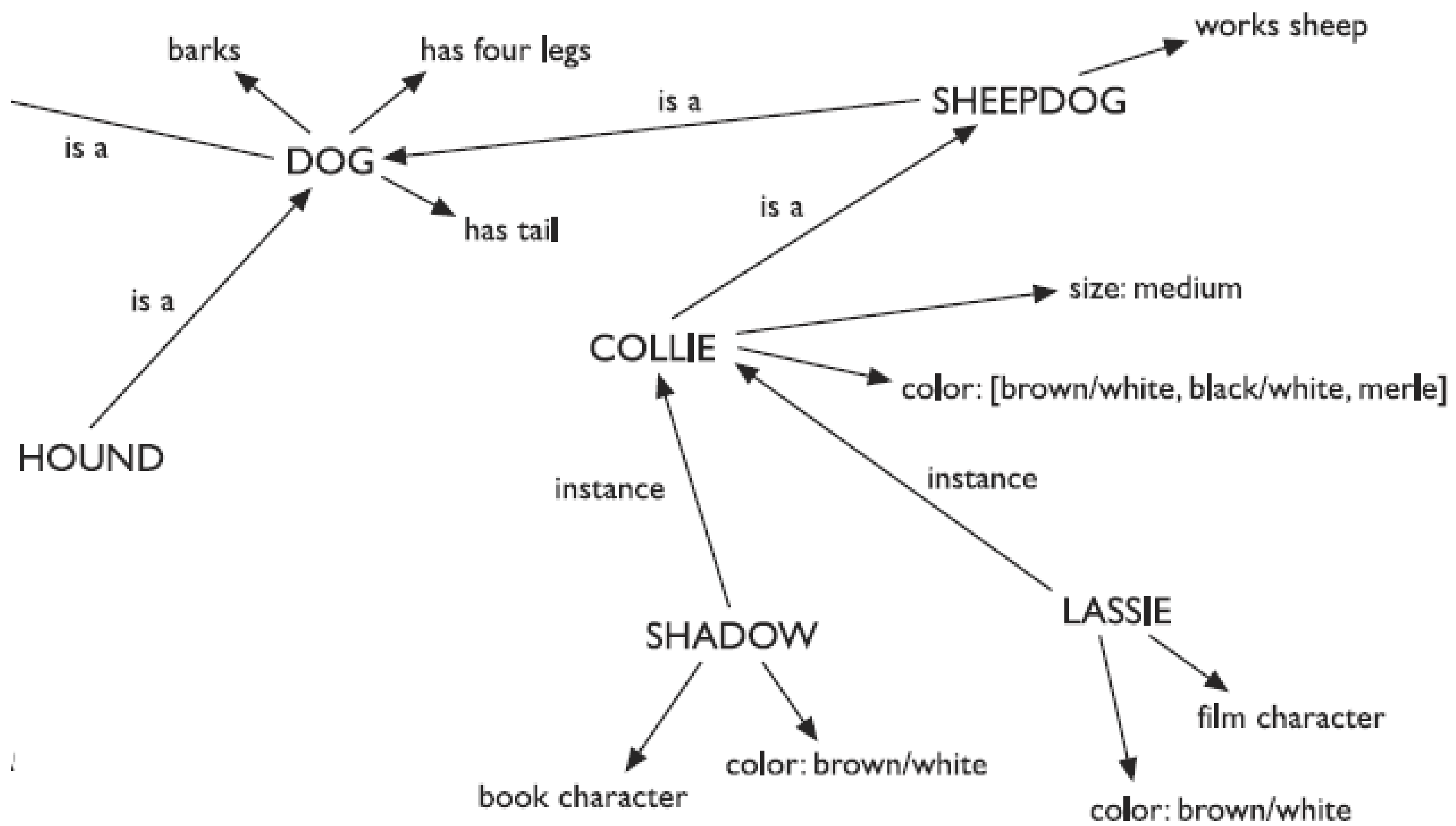
- Huge (unlimited capacity)
  - Factual information, experiential knowledge, procedural rules of behavior, etc.
- Slow access time: 0.1s
- Slow forgetting
  - Little decay
- Input from short-term memory through rehearsal

Long-term memory

- Structure
  - Episodic memory
    - Memory of events and experiences in a serial form
  - Semantic memory
    - Structured record of facts, concepts and skills
    - Semantic network
      - Relationships between pieces of information and interference

Long-term memory

- Structure



Long-term memory

- Long-term memory processes
  - Storage or remembering
    - Total time hypothesis
    - Distribution of practice effect
    - Meaning
      - Objects vs. concepts
    - Sentences and stories
    - Example: passwords

Long-term memory

- Long-term memory processes
  - Forgetting
    - Decay
      - Logarithmic forgetting
      - Jost‘s law
        - If two memory traces are equally strong at a given time the older one will be more durable
    - Interference
      - Retroactive interference
        - New information causes loss of old information
      - Proactive inhibition
        - When old memory trace breaks through and interferes with new information
    - Emotional factors
      - We tend to remember positive information rather than negative

Long-term memory

- Long-term memory processes
  - Information retrieval
    - Forgetting or just unable to retrieve information
    - Recall
      - Reproduction from the memory
      - Retrieval cues (categories)
    - Recognition
      - Information provides the knowledge that the information has been seen before
    - Vivid imagery
    - Exercises for memory improvement
    - Special cases: savant syndrome

Language

- Language
  - Universally available to all humans
  - Speaking vs. Writing
  - Corpus
    - British National Corpus: 100 M words
    - Slovenian corpus ?
  - Redundancy
    - SMS messages (gr8, u, gf, …)
    - Superflous words
  - Entropy
    - Shannon: entropy of English

Ham and ____ sandwitch

A picture is worth a thousand _____

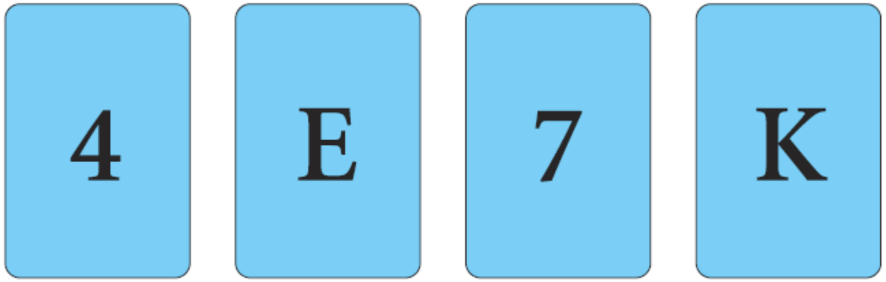
To be or ____ _____ _____

Thinking

- Processing and manipulation of stored information
  - Partial and unavailable information
  - Self-awareness and thoughts
    - Action-reaction??
  - Reasoning
    - Deductive
    - Inductive
      - Wason's cards
    - Abductive

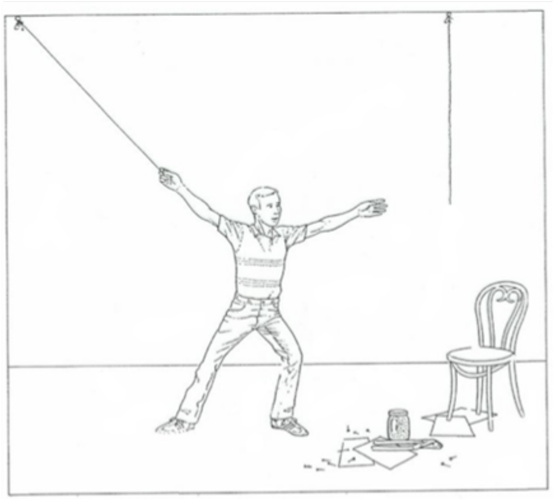
If it is Friday then she will go to work
It is Friday
Therefore she will go to work.

If it is raining then the ground is dry
It is raining
Therefore the ground is dry.



Thinking

- Processing and manipulation of stored information
  - Problem solving
    - Finding a solution to an unfamiliar task using the existing knowledge
    - Gestalt theory
      - Productive and reproductive
        - Maier's pendulum problem
    - Analogy
      - Mapping knowledge from one domain to the other



Thinking

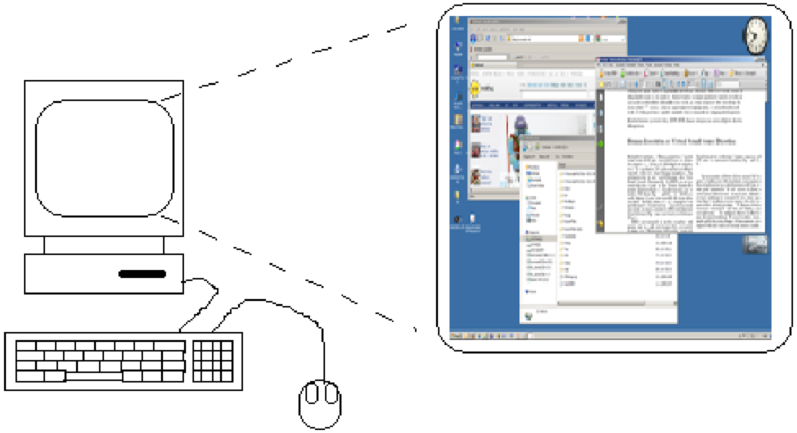
- Processing and manipulation of stored information
  - Skill acquisition
    - Chess players: experts and less experienced
      - Expert players “chunk” the board configuration
    - Computer programmers
      - Reused patterns and solution
  - Errors
    - Familiar pattern of behavior
      - Example: Spitfires jets
    - Incorrect understanding
      - Mental models (expectations and experiences)
    - “Human error”
      - Design problem?
  - Emotions
    - Emotions and performance

Computer

Input and output technologies

Computer

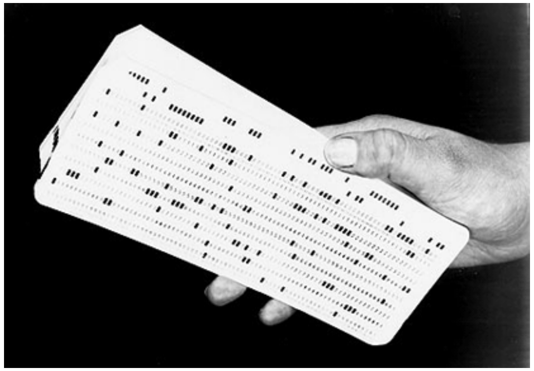
- "Typical" computer system
  - Output devices
    - Display with graphical interface
    - Soundcard
    - Printer
  - Input devices
    - Keyboard
    - Mouse



- Variations of hardware
  - Desktop computer
  - Laptop
  - Tablet
  - Mobile phone
- Interaction with the computer is based on the available input-output devices

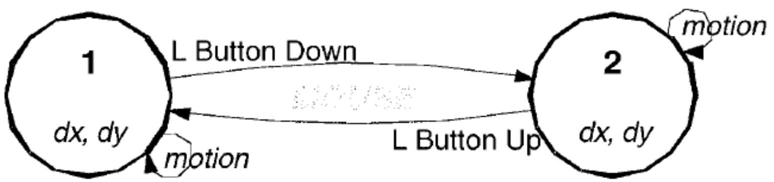
Interakcija

- Batch processing
  - Punched cards
  - Results printed on a paper
  - Interactive pace measured in hours or days
  - No interactivity!!!
- Interactivity
  - Immediate response
  - Real-time control

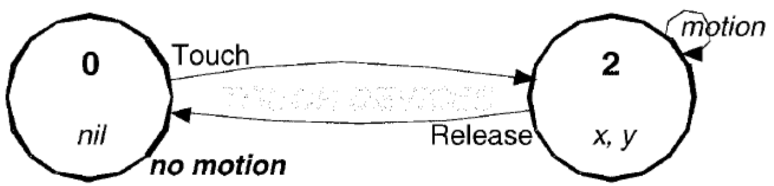


Input technologies

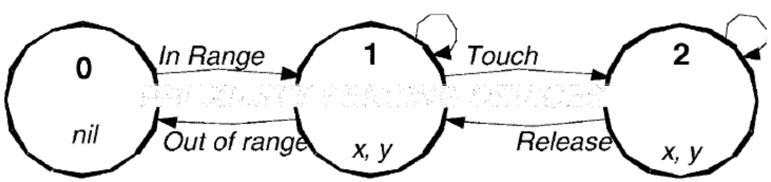
- Input device states
  - 0: out-of-range
  - 1: tracking
  - 2: dragging
- Mouse
  - Two-state device
    - 1 (cursor tracking state)
    - 2 (dragging state)



- Touchscreen
  - Two-state device
    - 0 (no contact)
    - 2 (dragging state)

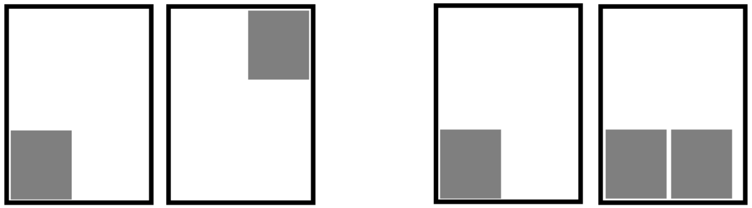


- Tablet with pen



Input technologies

- General properties
  - Sense physical properties of people, places and things
    - Property sensed
    - States sensed
    - Number of dimensions
    - Device acquisition time
  - Feedback (visual, auditory or tactile)
  - Naturality of interface
    - Clear and intuitive



Input technologies

- Elemental Tasks
  - Text (entering symbolic data)
  - Select (indicating object from a set of options)
  - Position (pointing to a screen coordinate)
  - Quantify (specifying exact numeric value)
  - Location, images, identity??
- Input device influences the level at which the user is required to think about the individual actions

- Evaluation and analysis
  - Fitts' Law

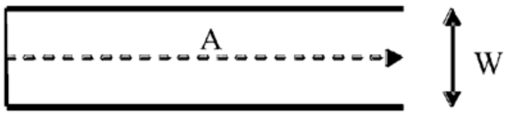
$$MT = a + b \cdot \log_2\left(A/W + 1\right)$$

  - Hick's Law

$$H = \log_2(n+1)$$

  - The steering Law

$$MT = a + b \cdot A/W$$



- Transfer function
  - Mathematical transformation that scales the data from an input device
    - Position-to-position
    - Velocity-to-velocity
    - Force-to-velocity
  - Self-centering devices

$$dx = Kx^{\alpha}$$

  - Motion-sensing devices
    - Acceleration function (exponential transformation of mouse velocity)
  - Absolute devices

Input technologies

Text entry devices

Text entry devices

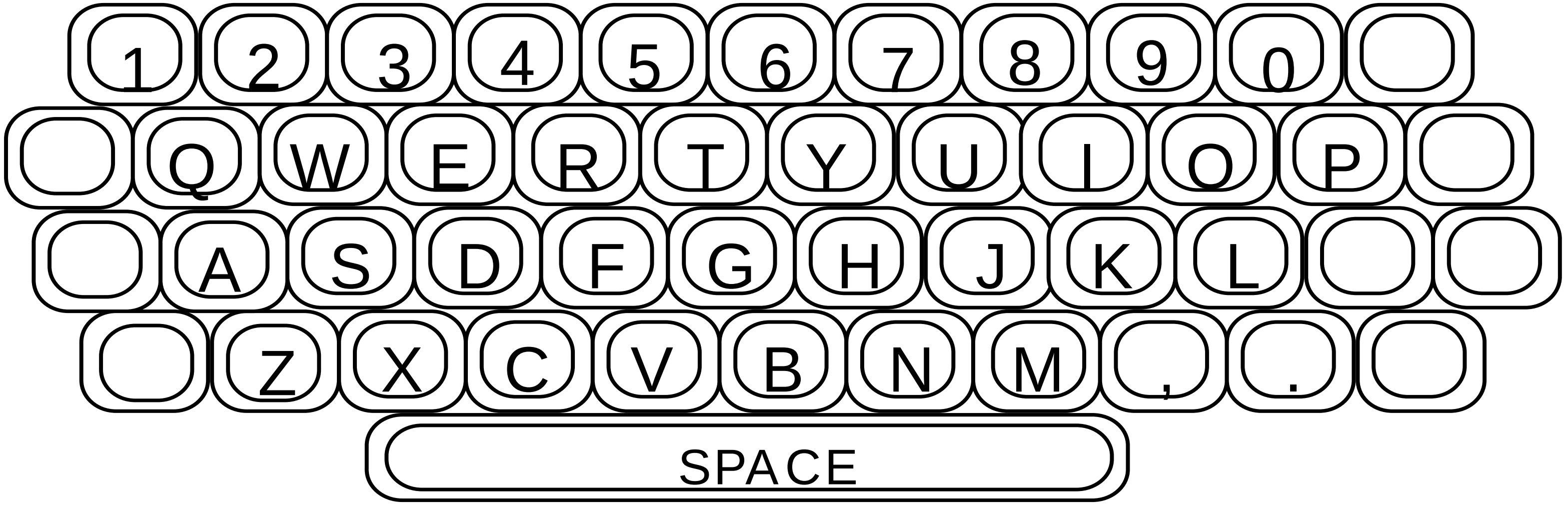
- Alphanumeric keyboard
  - “Still“ the most common input device
  - Entering textual data and commands
  - Keys
    - Average size: 12 mm^2
    - The most commonly used keys are larger (Space, Enter, Ctrl, etc.)
    - Concave shape
    - Pressure from 40 to 125 g, amplitude from 3 to 5 mm
      - “Half-travel“ keyboards
    - Sound and tactile feedback

Text entry devices

- Alphanumeric keyboard
  - Functional keys
  - Combinations of keys
  - Directional keys
  - Automatic repetition
  - Typing speed: from 1 to 5 letters / s (from 50 to 150 letters / min)
  - Procedural (muscle) memory
  - Automation of skills
    - Power law of practice

$$T = aP^b$$

- Key layouts
  - QWERTY
    - The most common form (manual typewriters)
    - Language variations (QWERTZ)
    - Tactile feedback on basic letters (F in J)



Text entry devices

- Key layouts
  - DVORAK
    - Shorter finger paths
    - Increased typing speed (up to 200 letters / min)
      - Power law of practice??
    - Common letters in the range of stronger fingers
    - Biased towards right-handed people
      - Alternation of hands

Text entry devices

- Key layouts
  - ABCDE
    - Alphabetical order
    - Novice and occasional users
      - Slower typing

Text entry devices

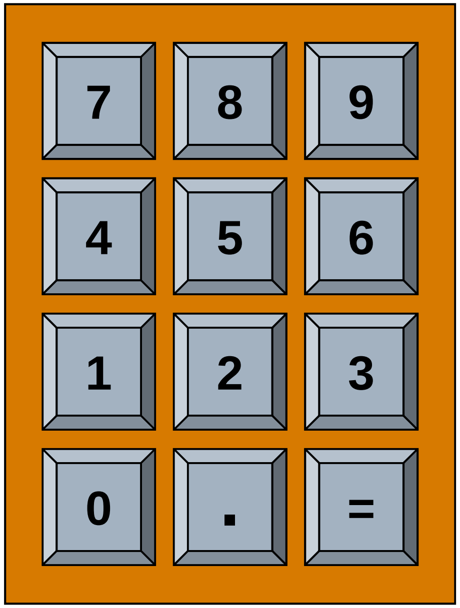
- Specially shaped keyboards
  - Relieve the strain of typing
  - Ergonomic positions
  - Single-handed use

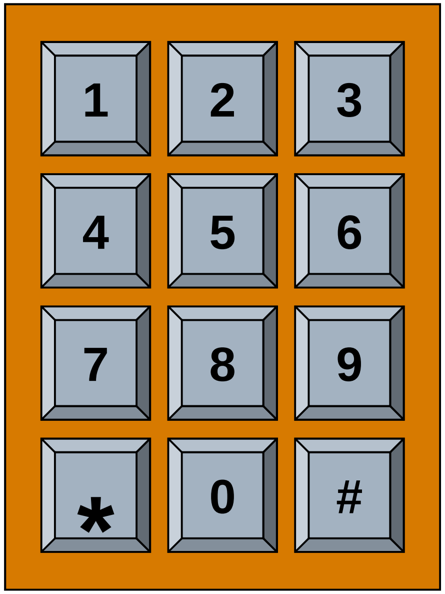
Text entry devices

- Specially shaped keyboards
  - Kinesis

Text entry devices

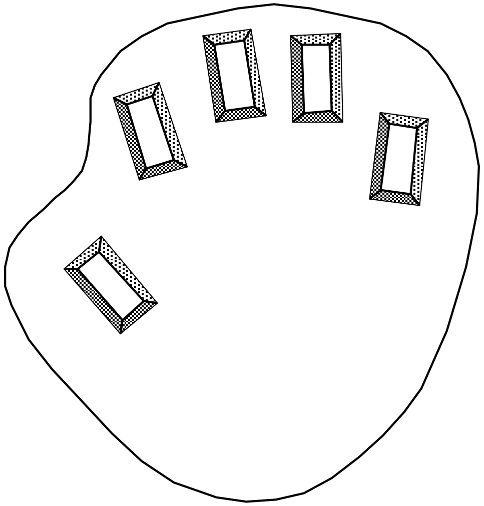
- Numeric keypads
  - Faster entry of digits: calculator, telephones, ATMs, etc.
  - 2 types

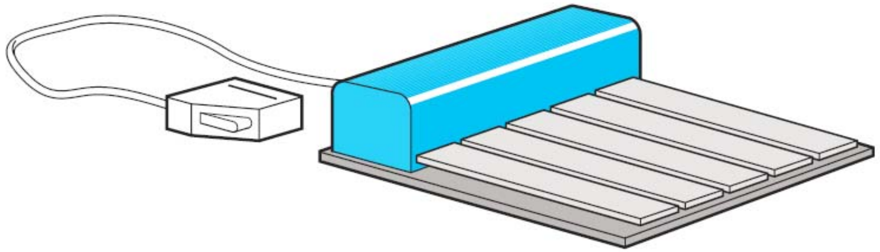


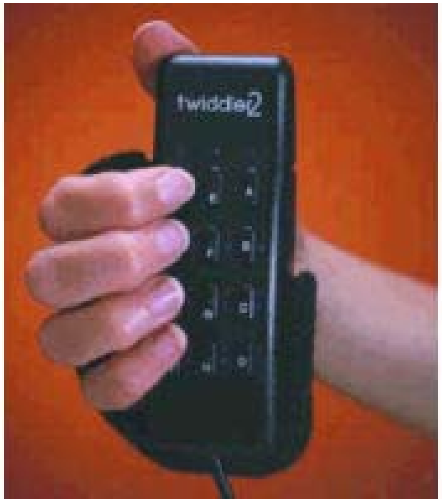


Text entry devices

- Chord keyboards
  - Only 4 or 5 keys
  - Letters are represented as combination of keys
  - Compact (small dimensions)
    - One-handed use
  - Short learning time
  - Fast typing speed for competent users







Text entry devices

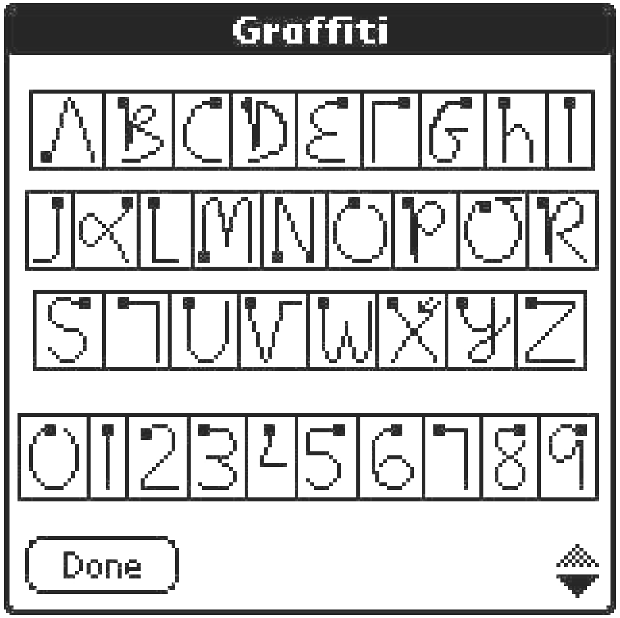
- “Old “Mobile phones
  - Number-to-letter mapping (repetiton)
    - 2 a b c, 3 d e f, 4 g h i, etc.
    - Different modes of buttons
  - “Softkeys”
  - Predictive techniques
    - T9 algorithm

Text entry devices

- Touch-screen keyboards
  - Intuitive
  - Problems
    - Key size is dictated by the screen dimensions
      - Occlusion of screen space
    - No tactile feedback
    - Artificial sound feedback
    - Significant visual attention
    - Accidental screen brushes
    - Fatigue
      - No resting

Text entry devices

- Handwriting recognition
  - Natural speed (paper): 15 wpm
  - Difficult recognition of natural handwriting
  - Individual differences in handwriting
  - Shape and stroke information
  - Slow
    - Half the speed of average typist
  - Special domains
    - Pen-based systems
    - Gesture recognition
    - Signature identification



Direct and indirect input devices

- Four types of interaction
  - Selecting
  - Positioning
  - Orienting
  - Drawing
- Direct and indirect input devices

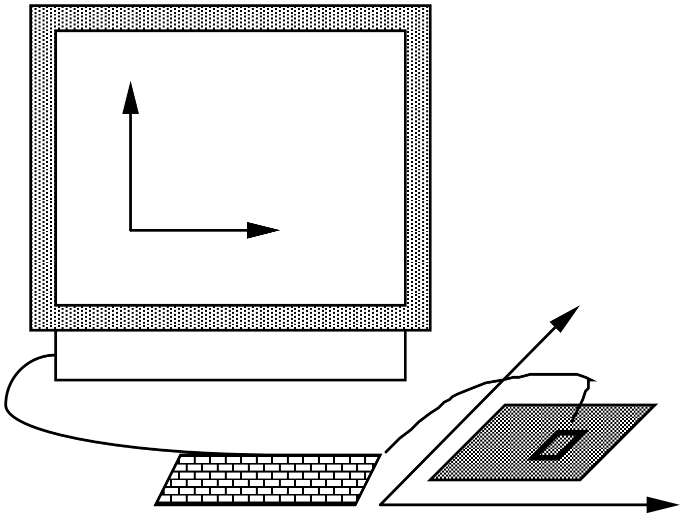
Input technologies

Indirect-input devices

- Indirect-input devices
  - Physical spaces of input and output are separated
  - Absolute devices
    - Sensing the position of an input
    - Drawing, handwriting, tracing, etc.
  - Relative devices
    - Sensing changes in position
    - Selecting, navigating through menus, etc.
  - Mixed input
    - Emulation of indirect input using direct input
    - Offset between apparent input target and its physical location

Indirect-input devices

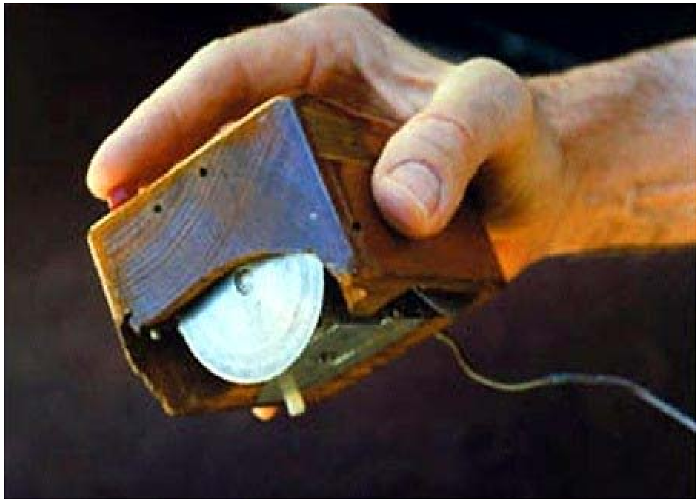
- The mouse
  - Invented by Douglas C. Engelbart (1964)
  - Major component of desktop computers
  - Indirect manipulation of cursor
  - Detection of relative motion in two dimensions
  - Buttons
    - Click and double click
    - Ortohogonal force
  - Transformation
    - Horizontal desktop to vertical screen
  - Physical space
  - Contribution of all muscle groups



Indirect-input devices

- The mouse
  - Mechanical mouse
    - Weighted ball rolls two potentiometers
    - Surface independent
  - Optical mouse
    - Red light-emitting diode
      - Fluctuations in reflected intensity
    - Special or ordinary mat
    - Less susceptible to dust and dirt

Vhodne naprave – kazalne naprave



Indirect-input devices

- Trackball
  - Upside-down mouse (static housing with weighted ball facing upwards)
  - Small footprint
  - Often repositioning of hand
    - Different muscle groups
  - Suitable for games (spinning and fast rotations)
- Thumbwheel
  - Two orthogonal dials
    - Only horizontal or vertical movement
    - CAD software (straight lines)

Indirect-input devices

- Touchpad
  - Touch-sensitive surface for moving a cursor (5 – 8 cm)
    - Click support
    - Micro switch (mechanical click)
  - Used in many laptops and notebooks
  - Acceleration settings
    - Screen distance varies with the speed of movement
  - Multitouch pad

Indirect-input devices

- Joystick and keyboard nipple
  - Absolute joystick
    - Position of joystick corresponds to position of cursor
  - Isometric joystick (velocity-controlled)
    - Pressure on the stick corresponds to the velocity of the cursor
    - The stick returns to initial position when released
  - Various number of buttons at various positions
  - Keyboard nipple
    - Tiny isometric joystick

Indirect-input devices

- Joystick

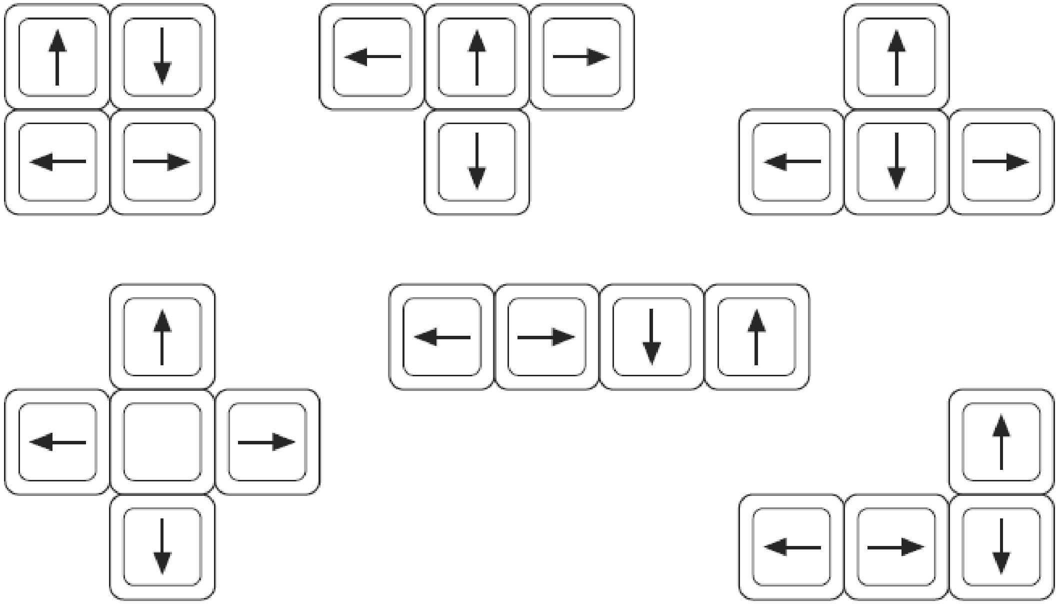
Indirect-input devices

- Joystick

- Leg-operated controls
  - Musicians, drivers, dentists

Indirect-input devices

- Cursor keys
  - 2D discrete positioning
  - Ideal for positioning within sequential lists
    - Menus, 2D cells in spreadsheets, etc.
  - No standardized layout



Input technologies

Direct-input devices

Direct-input devices

- Touchscreen
  - Unified input and output surface
    - Direct manipulation of objects
    - Very intuitive
  - “Soft“ touch or “hard“ touch
    - Measurement of force enables multiple states
  - How many points of contact
    - Multi-touch gestures
  - Shape of contact or just a point (x,y)
    - Rapid interaction with multiple widgets
  - In-air or surface hand postures
  - Finger differentiation and user differentiation

Direct-input devices

- Touchscreen
  - Bare finger or special stylus (combination)
  - Special stylus (passive or active)?
  - Pen contact versus finger touch?
    - Separation or simultaneous use?
  - Parallax
    - Mismatch between sensed and apparent position due to viewing angle (max. 2mm)
  - Latency
    - End-to-end time between the moment of physical action and system feedback (max. 100 ms)

Direct-input devices

- Touchscreen
  - “Land-on” and “lift-off”
  - Ideal for selecting items in the menus
  - Robustness
    - No separate hardware for input
  - Problems
    - Screen occlusion
    - Inaccurate
    - Greasy marks and dirt

Direct-input devices

- Touchscren technologies
  - Capacitive touchscreen
    - Human body capacitance
    - Finger or conductive stylus near the surface of the sensor changes the local electric field and reduces the mutual capacitance
  - Resistive touchscreen
    - Two large transparent conductive overlays with varying resistance over length
    - Finger causes contact of overlays
    - The voltage applied determines the position of contact
  - Surface acoustic wave systems
  - Computer vision techniques

Direct-input devices

- Digitizing tablet (graphic tablet)
  - Positional information of some device on a special pad
  - Different technologies:
    - Resistive tablet (no specialized stylus)
    - Magnetic tablet (small loop coil in a special pen)
    - Sonic tablet (no special surface, 3D input)
  - High resolution
  - Relative or absolute motion
  - Drawing (handwriting)
    - Used also as indirect-input device

Input technologies

Sensors and sensing modes

Sensors and sensing modes

- Occupancy and motion (presence)
  - Air pressure sensors
  - Acoustic sensors
  - Vibration detectors
  - Capacitive sensors
  - Photoelectric and laser-based sensors
  - Optoelectronic sensors
  - Microwave and ultrasonic detectors
  - Infrared motion detectors
  - Video cameras and computer vision

Sensors and sensing modes

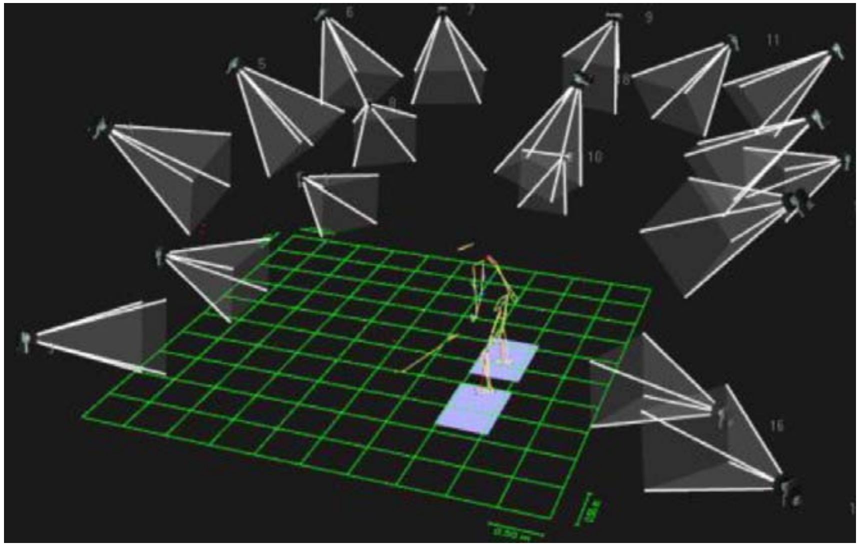
- Range sensing
  - Distance to a given object
  - IR ranger
    - Light-emitting LED and array of recievers
    - Trigonometry
  - Stereo computer vision
  - Time of flight
    - Narrow ultrasonic “chirp” signal

Sensors and sensing modes

- Position
  - Global Positioning System (GPS)
  - RF receiver and triangulation
    - WiFi, Bluetooth, GSM, etc.
    - Signal strength approximates distance
    - “Signature”
  - Motion capture systems
    - Electromagnetic trackers
    - Inertial systems
      - Accelerometers
      - Gyroscopes
    - Computer vision
    - Acoustic tracking

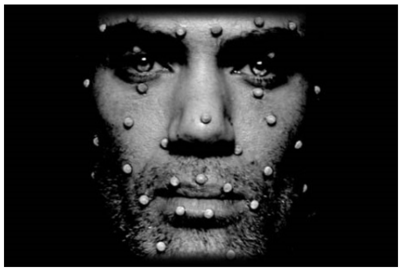
Sensors and sensing modes

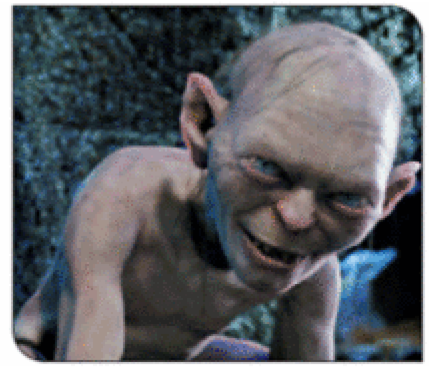
- Position
  - Optical motion capture systems
    - Infrared cameras (transceivers and receivers)
    - Triangulation of 3D position from 2D images
    - Pasive (retroreflective material) or active (LED) markers
    - Calibration procedure

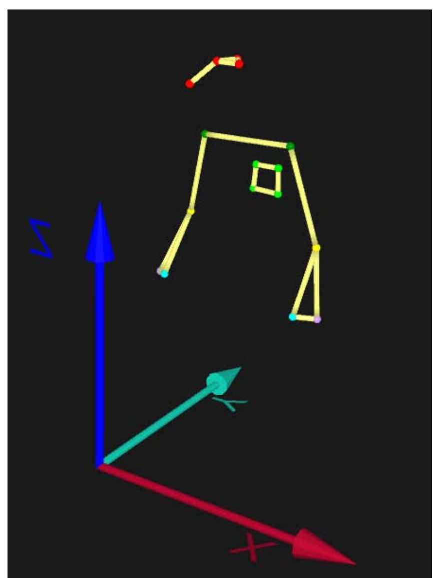
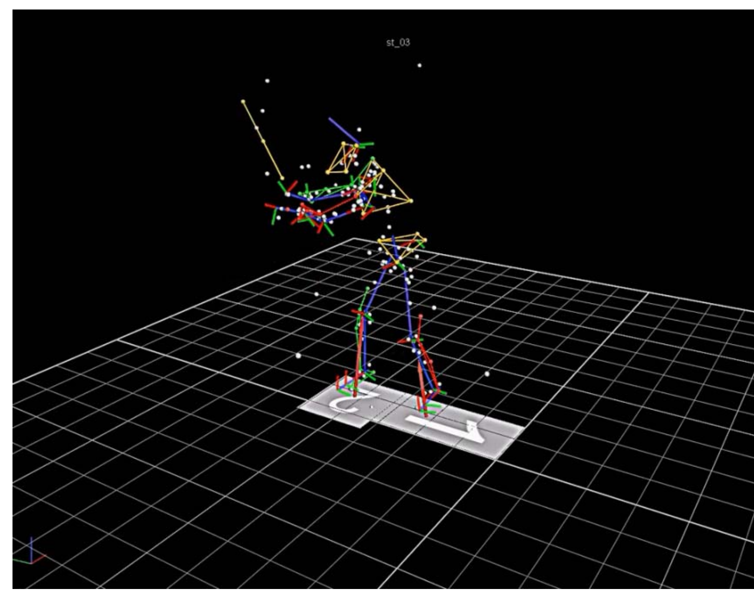


Sensors and sensing modes

- Position
  - Optical motion capture systems

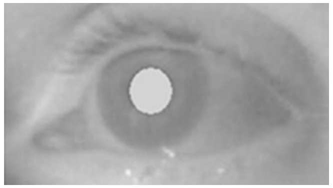


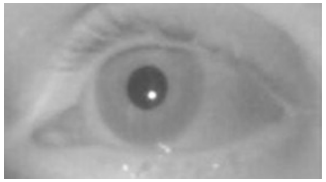


Sensors and sensing modes

- Eye tracking (eyegaze)
  - Measuring rotations of the eye
    - Eye-attached tracking (special contact lenses)
    - Optical tracking without direct contact
    - Electric potential with electrodes around eyes
  - Video-based eye trackers
    - Vector between the pupil center and the corneal reflection
      - Bright-pupil: coaxial illumination (reflection to the camera)
        - Better contrast, more robust tracking
      - Dark-pupil tracking: offset illumination (reflection away from the camera)
    - Calibration

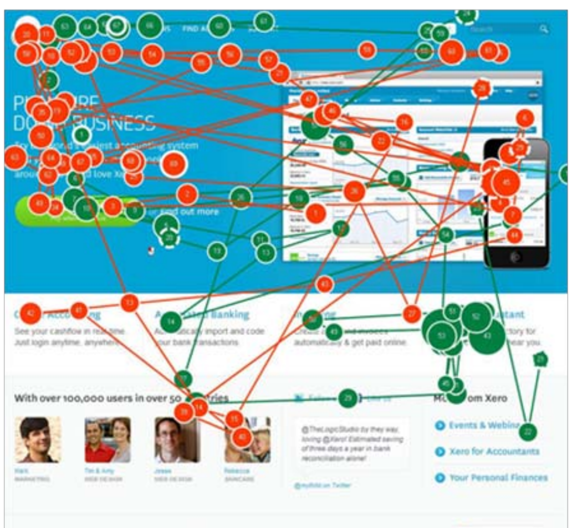




Sensors and sensing modes

- Eye tracking (eyegaze)
  - Head-mounted or remote trackers
  - Sampling rate: from 50Hz to 1.2 kHz
    - Scanpath
      - A series of fixations and saccades
      - Analyzing cognitive intent, points of interest and salience

- Eye tracking (eyegaze)
  - Output data
    - Animated representations of a point on the interface
    - Static representations
    - Heat maps
      - Hot zones (zones with higher density)
    - Blind zones maps

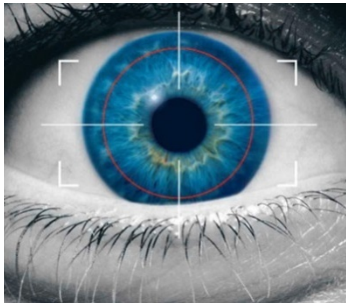


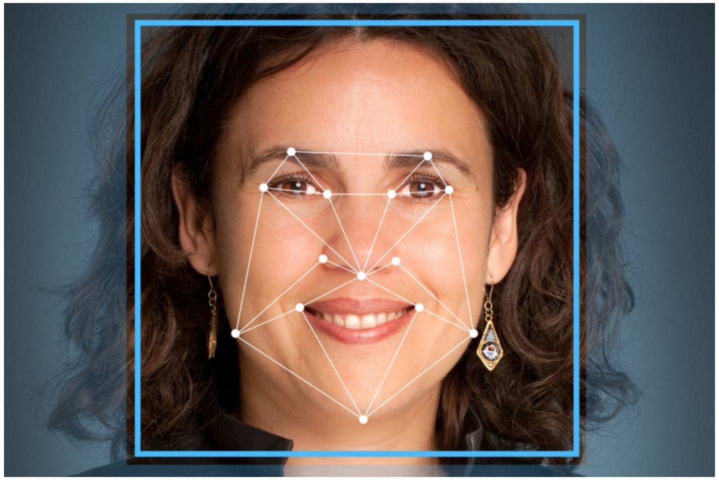
Sensors and sensing modes

- Wired glove (dataglove)
  - Optical sensors for detecting angles of knuckles and fingers
  - Motion trackers for detecting global position / orientation of the glove
  - Gestures
    - Closed or open, individual fingers, etc.
    - Sign language (deaf persons)
  - Haptic feedback

Sensors and sensing modes

- Identity
  - Computer vision (biometrics)
    - Face recognition
    - Fingerprint recognition
    - Iris, retina, hand geometry, vascular pattern, etc.
  - Tags
    - Bar code
    - QR (Quick Response) code
    - RFID





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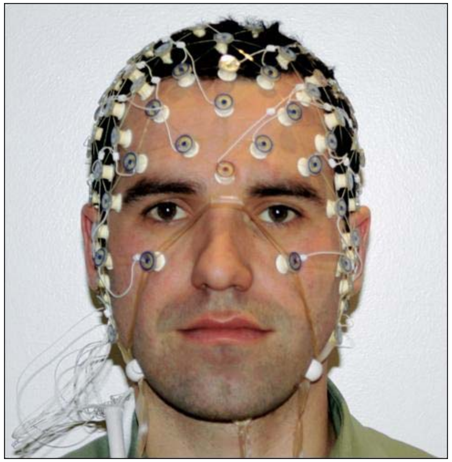
Sensors and sensing modes

- Speech
  - Microphone or array of microphones
  - Vision-based lip reading
- Context
  - Location, temperature, lightning, air pressure, etc.
  - Microphone (environmental sound)
- Affect
  - Boredom, interest, pleasure, stress, frustration
  - Galvanic skin response
  - Blood pressure
  - Respiration rate

Sensors and sensing modes

- Brain-Computer Interfaces (BCI)
  - Manipulation of brain activity
    - Learned with practice
  - Emulation of traditional interfaces
    - Keystrokes, cursor control
  - Electroencephalograph (EEG)
    - Electrical activity of local parts of the brain
    - Low spatial but good temporal resolution
  - Functional near infrared imaging
    - Blood flow in local regions of the brain



Sensors and sensing modes

- General considerations and problems
  - Computational cost
  - Cost of failure
    - Robustness
  - The role of feedback
  - Implicit interaction
    - Users‘ existing patterns of behavior (history)
    - Silent adaptations or recommendations
      - Smart homes
  - A priori knowledge
    - Higher level rules (gesture, music, dance, math, etc.)

Computer

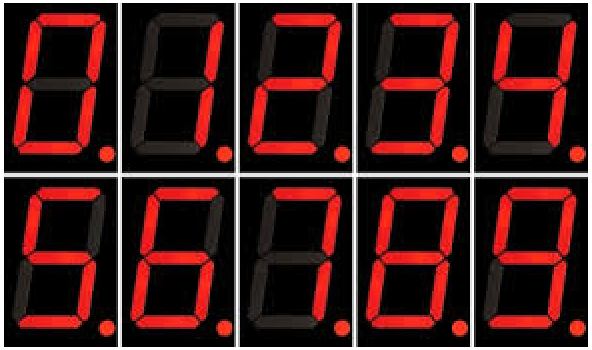
Input and output technologies

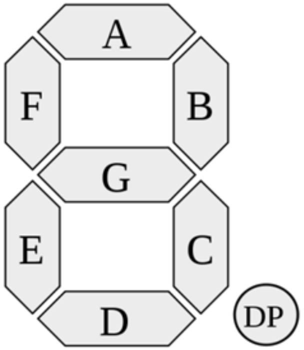
Output technologies

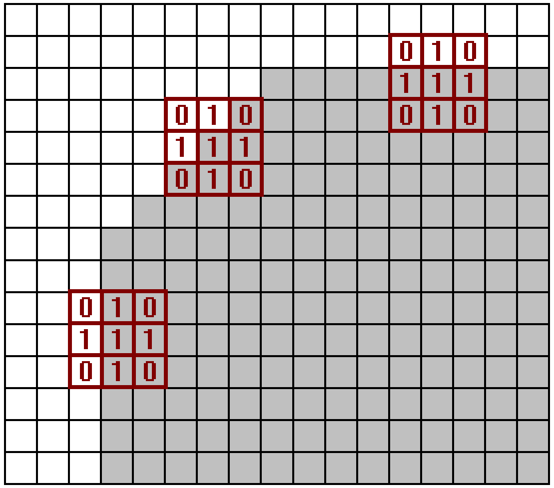
Visual displays

Visual displays

- Visual display
  - Image generation
    - List emission, transmission or reflection
  - Display segmentation and dimension
    - 1D (binary elements)
    - 2D pixel matrix (rows and columns)
      - Location of pixels (x,y)
      - Color or grey scale

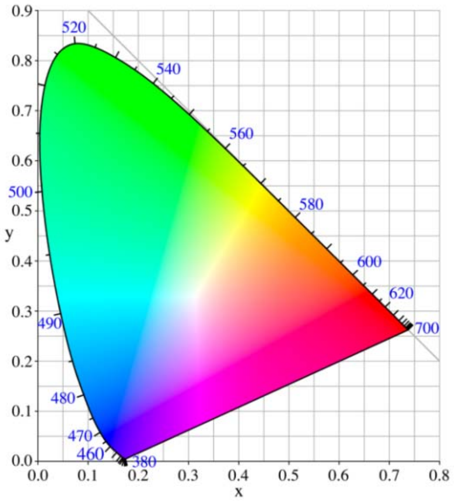






Visual displays

- Colors
  - Cone cells - photoreceptors for color perception
    - Short wavelengths (420 – 440 nm)
    - Medium wavelengths (530 – 540 nm)
    - Long wavelengths (560 – 580 nm)
  - Tristimulus values (X, Y and Z)
    - Hypothetical primary colors
      - Commission International de l'Eclairage (CIE) chromaticity diagram
      - Equal amounts of X,Y and Z result in white light
      - Relative amounts are denoted by x, y and z
      - Luminance: xyY - system



Visual displays

- Colors
  - RGB values are used in computer systems

    - Three values: RED, GREEN and BLUE
      - Usually 8-bit (from 0 to 255)
    - The sum of full extend of all colors is WHITE
  - CMYK values are used for printing onto paper

    - Four values: CYAN, MAGENTA, YELLOW and BLACK
      - Usually in % (from 0 to 100)
    - Subtractive process
    - The sum of full extend of all colors is “BLACK”

$$R = 255 \times (1 - C) \times (1 - K)$$

$$G = 255 \times (1 - M) \times (1 - K)$$

$$B = 255 \times (1 - Y) \times (1 - K)$$

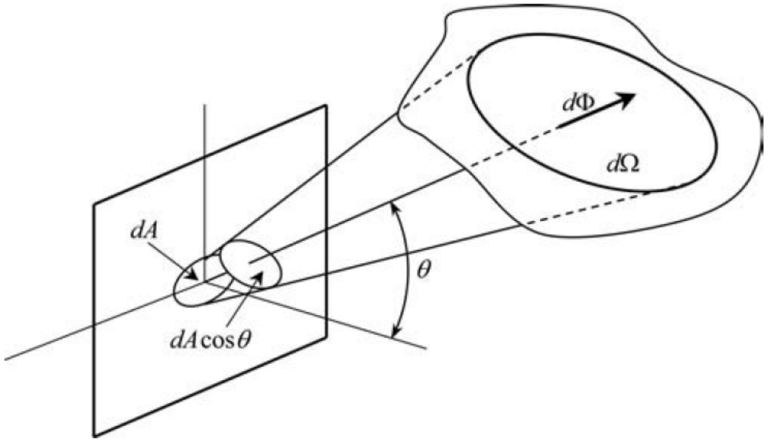
Visual displays

- Brightness
  - Luminous intensity
    - Measured in **candela** (cd); lumen per steradian

$$I = \frac{d\phi}{d\Omega} \qquad \phi = \int_{\lambda=380}^{\lambda=770} K(\lambda)P(\lambda)d\lambda$$

  - Brightness depends on the size of the surface the light is emanating from
  - Brightness of a display

$$L = \frac{dI}{dA\cos\theta}$$



    - L: luminance
      - Intensity of light (I) emitted from light source per unit surface area normal to the direction of light flux (cd/m2)

Visual displays

- Contrast

$$C = \frac{L_{object}}{L_{background}}$$

- Resolution
  - Arrangement of pixels into rows and columns
  - Screen diagonal and pixels per inch (PPI or DPI)
    - Pixels per degree of arc (HMD) (10 – 20 p / °)
  - Pixel consits of number of triads (RGB)
    - Low resolution: < 50 PPI
    - Medium resolution: < 51 - 70 PPI
    - High resolution: < 71 - 120 PPI
    - Ultrahigh resolution: < 120 PPI
  - Ergonomic resolution
    - At 50 cm, 175 PPI should be distinguished

Visual displays

- Refresh rate and response time
  - Number of times the image is drawn per second (Hz)
  - Retina retains a precise image for 10-20 ms
  - LCD
    - Shutters remain at the opacity level last addressed
    - Reponse time between two visible states is important
    - 60 Hz
    - Motion blur
      - Long response time + high-dynamic scene
      - Short response time + low frame rate (rendering)
  - CRTs
    - Motion is not critical because pixels turn black before they re-lite
    - 60 - 80Hz

Visual displays

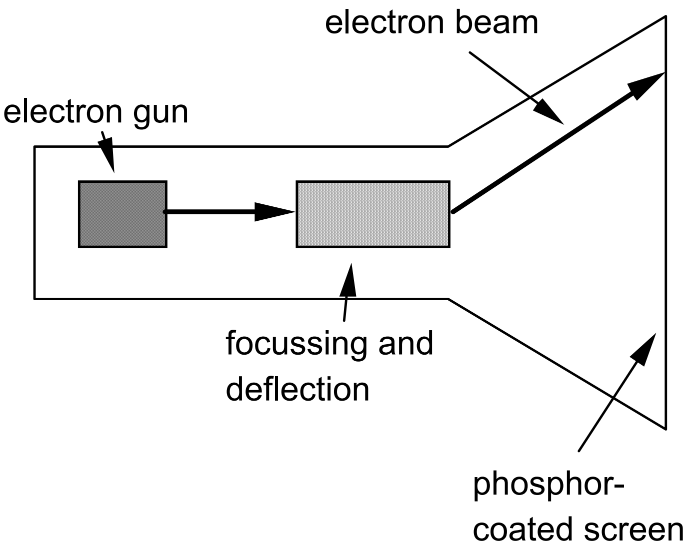
- Depth
  - Monocular cues
    - Perspective
    - Occlusion
    - Motion parallax
    - Comparison of familiar size
  - Binocular cues
    - Stereopsis (retinal disparity)
      - Triangulation and pattern matching
    - Convergence (binocular oculomotor cue)
    - Shadows

Visual displays

- Displaying technologies
  - Direct-view displays
    - No bouncing off a screen
    - Plasma television, TFT (thin-film-transistor) LCD
  - Projection displays
    - Projection onto a screen
    - Front (reflective screen) and rear (transmissive screen) projections
  - Off-screen display systems
    - No special screen
    - Natural medium (windshield, retina)
    - Virtual retinal display (VRD), 3D holographic HUD

Visual displays

- Cathode Ray Tube (CRT)
  - Excitement of luminescent material with energetic electrons
  - Color and monochrome system
    - Three electronic guns, RGB phosphors
  - Wide viewing angles
  - Large and heavy
  - High power consumption
  - Low robustness
  - Max diagonal 40in
  - Flicker



Visual displays

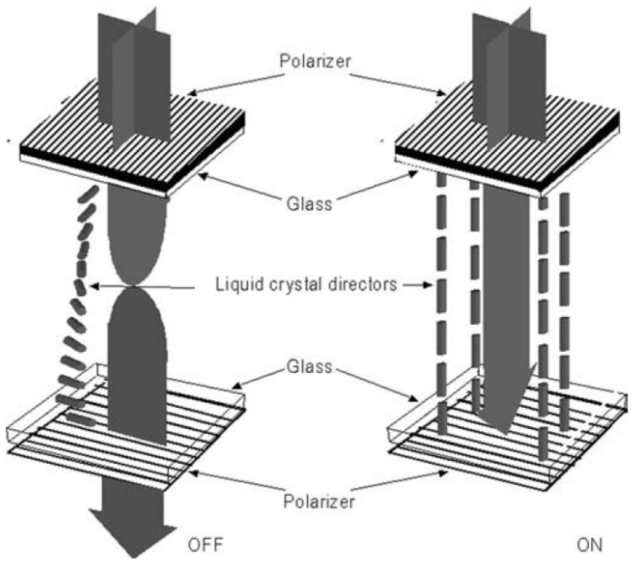
- Liquid Crystal Displays
  - Low power consumption
  - Operation at low voltages
  - Long lifetime
  - Direct view (transmission or reflection) or projected view (large screens)
  - Ultrahigh resolution
    - Laptops, handheld computers, HMDs, smartphones, watches, etc.

Visual displays

- Liquid Crystal Displays
  - Two glass plates with microscopic lines
  - Liquid crystal materials in between
    - Changing properties: from solid to liquid
    - Electrical states changes the alignment of crystals (translucence)
    - Light can pass through when no voltage is applied (bright pixels)
  - Ambient light or light source behind (or at the sides) of the LCD
    - Light emitting diodes (LED) used as source of light

Visual displays

- Liquid Crystal Displays
  - Passive matrix: Twisted Nematic (TN) LCD
    - Electric field applied to entire horizontal or vertical line
    - Slower response time
  - Active matrix
    - Each pixel is addressed separately
    - Thin-film transistors (TFTs)
    - An example
      - Resolution 1920 x 1080
      - Three subpixels for three colors
      - 6.22 M transistors
  - Darker image when viewed from the side



Visual displays

- Plasma displays
  - Electrical discharge in gas
  - Two glass plates with a gap filled with gas mixture
  - The inside of one gas plate is coated with phosphorus layer (three different kinds – three colors)
  - When high voltage is applied the gas turns to plasmatic state and emits ultraviolet radiation (causes phosphorus to glow)
  - Performs well in various light conditions
  - High energy consumption and high voltage
  - Phosphorus degrade over time
  - Oversized pixels

Visual displays

- ELD (Electroluminescent) displays
  - Sandwiched layer of electroluminescent material between two layers of conductors
  - Radiation in the form of visible light
  - Sharp pixel edges
  - Good contrast
  - Limited color capabilities
  - High voltage
  - Medical, industrial and instrumentation applications
  - OLED (organic light-emitting diode)
    - PMOLED and AMOLED

Visual displays

- Laser displays
  - Spatially coherent light and low-divergence beams
  - Manipulated with lenses – row by row (as CRT)
- Virtual retinal displays (VRD)
  - Image is formed directly on the retina
  - Three photon sources generate coherent beam of light
  - Light beam is intensity modulated
  - Lines that form the image are drawn directly

Visual displays

- 3D displays
  - Stereoscopic displays
    - Light fields of two plain images of different views on a scene
    - Temporal multiplex
      - Synchronized shutter
    - Spectral multiplex
      - Light polarization (linear or circular)
      - Spectral
        - Anaglyphs (red and cyan)
        - Six narrow bands (R1, R2, G1, G2, B1, B2)

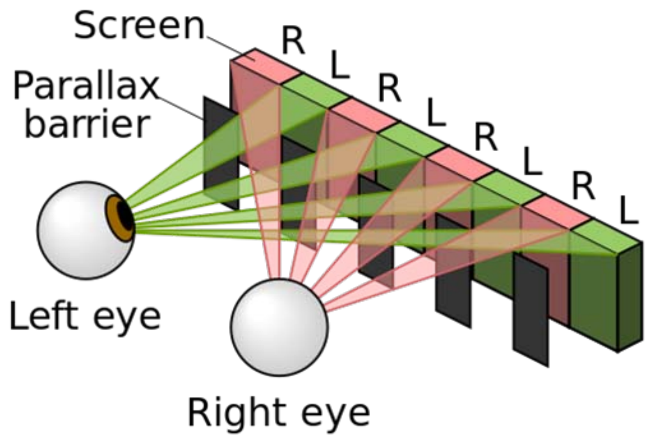
Visual displays

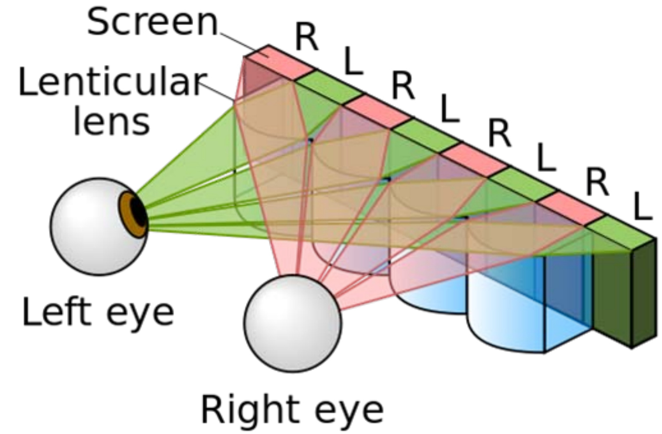
- 3D displays
  - Stereoscopic displays
    - Spatial multiplex: Head-mounted Display (HMD)
      - Separate image for each eye
      - Two types
        - Virtual image
        - Optical HMD (see-through)



Visual displays

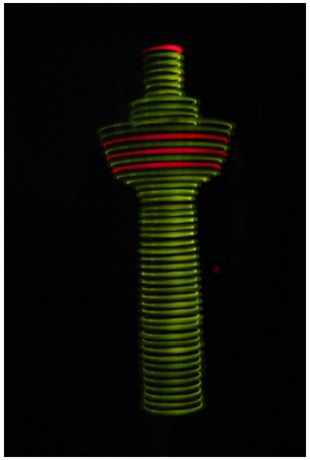
- 3D displays
  - Autostereoscopic displays
    - Two separate images without glasses
    - Spatial multiplexing
    - Zones for each eye
    - Limited number of views
    - No depth cues from motion parallax
      - Head tracking





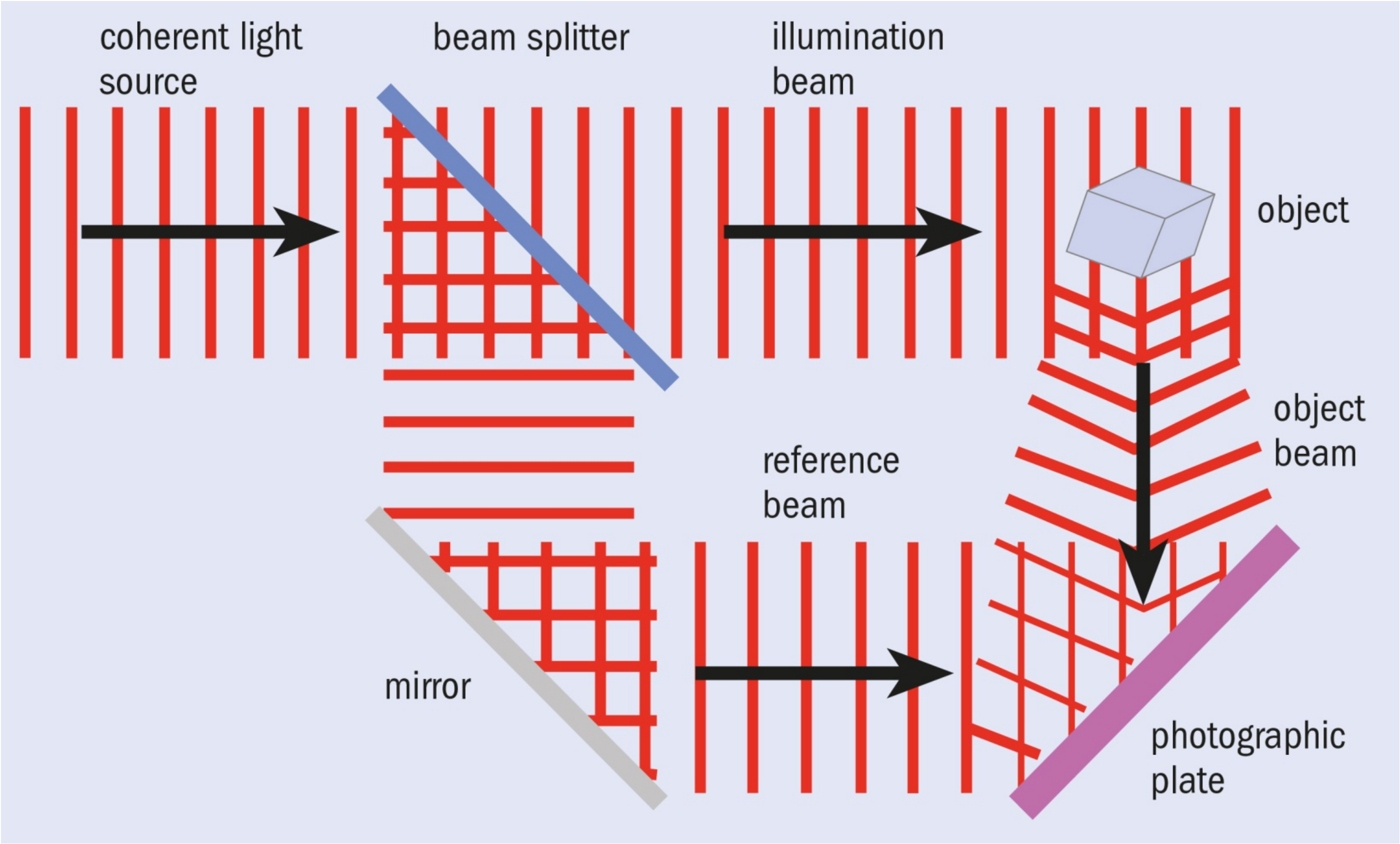
Visual displays

- 3D displays
  - Volumetric displays
    - Voxels instead of pixels (x,y,z + color)
    - Swept volume displays
      - Rotating 2D surface (LEDs or laser)
      - Persistence of human vision
    - Static volumetric displays
      - Intersections of laser beams in solid, liquid or gas
      - Multistacked planes
        - Switching between transparent and light scattering state



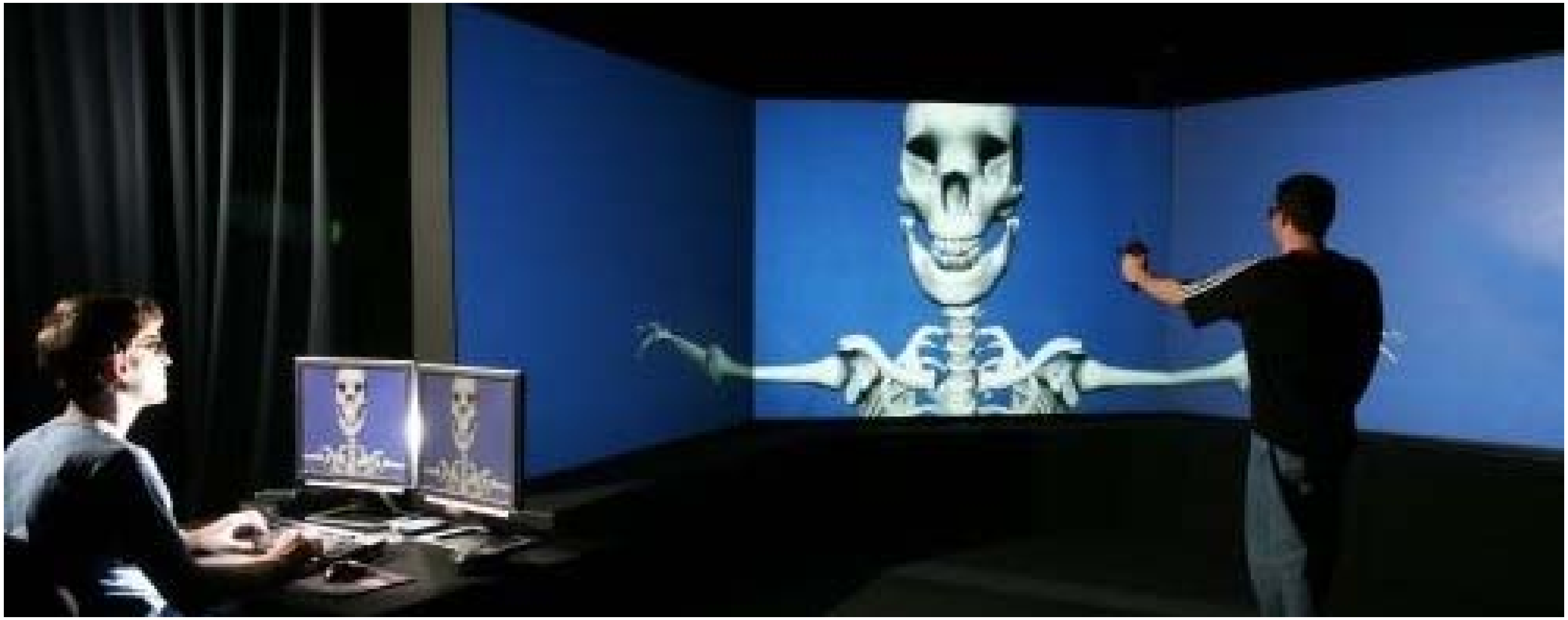
Visual displays

- 3D displays
  - Hologram (light field display)



Visual displays

- Simulators and VR environments
  - Computer Animated Virtual Environment (CAVE)
  - Multiple screens with stereoscopic projections
  - Multiple users
  - Motion tracking systems



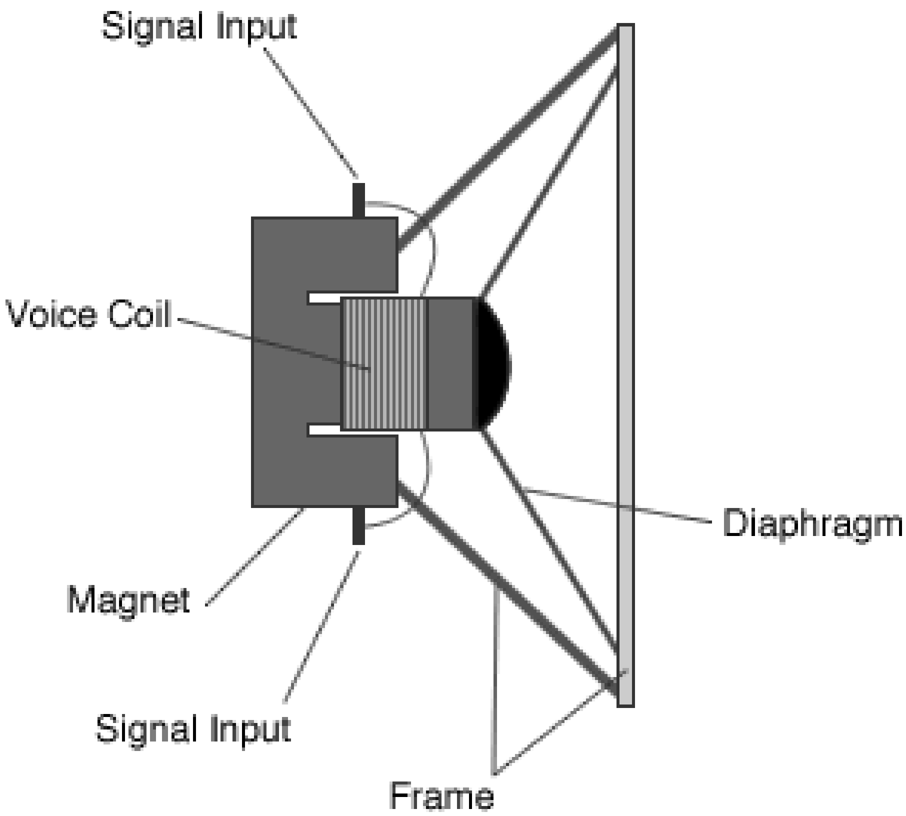
Visual displays

- Projection screens (heads-up displays) - HUD
  - Various technologies (optical waveguides, scanning lasers, etc.)

Output technologies

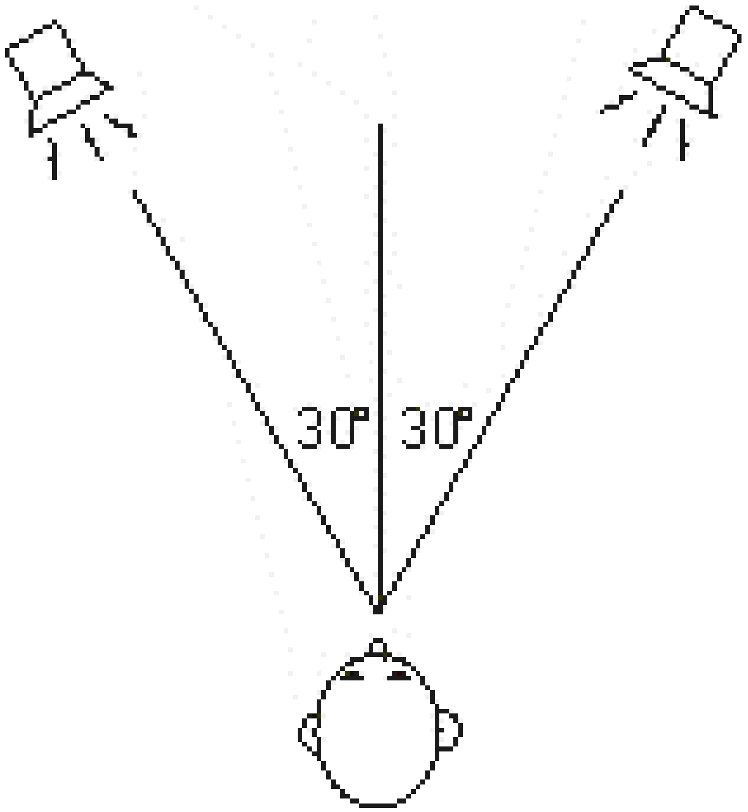
Auditory displays

- Sound reproduction
  - Loudspeaker: an electroacoustic transducer



Auditory displays

- Two-channel stereo (2-0)
  - Optimal configuration: equilateral triangle



Auditory displays

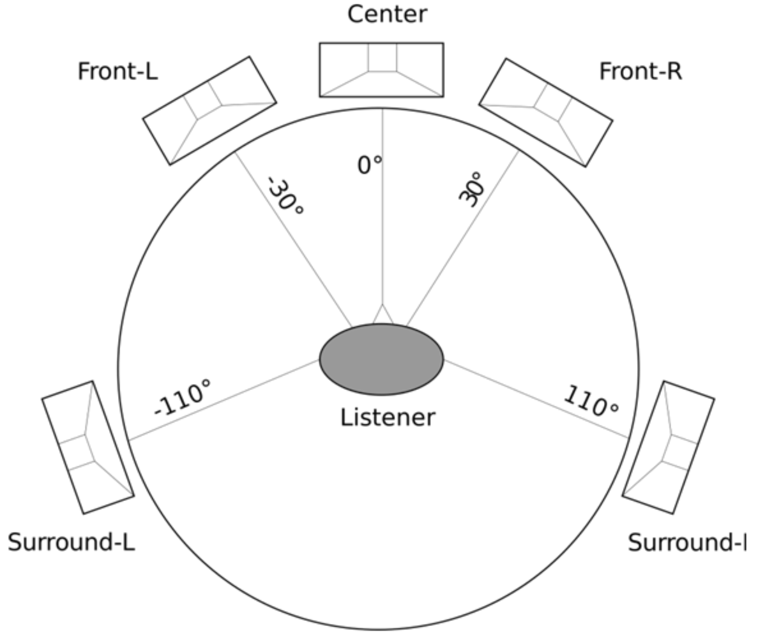
- Two-channel stereo
  - Virtual sound source
    - Amplitude ratio of L and R signal (15 – 18 dB)
    - Time difference (delay) between L and R signal (0.5 – 1.5 ms)
  - Signal formats
    - L and R
    - M and S
      - M = (L+R) – 3dB or (L+R) – 6dB
      - S = (L-R) – 3dB or (L-R) – 6dB
  - "Hot-spot"!!

Auditory displays

- Three-channel (3.0) stereo
  - L, R,C
  - Wider angle between L and R channel (> 30°)
    - Compatibility with two-channel stereo?
  - Older movie theaters
    - Speech?
  - Wider listening area
- Four-channel surround (3.1)
  - LCRS surround
  - Arbitrary number of speakers (positioned around the listener)
  - Common mono **S** (surround) signal on all speakers

Auditory displays

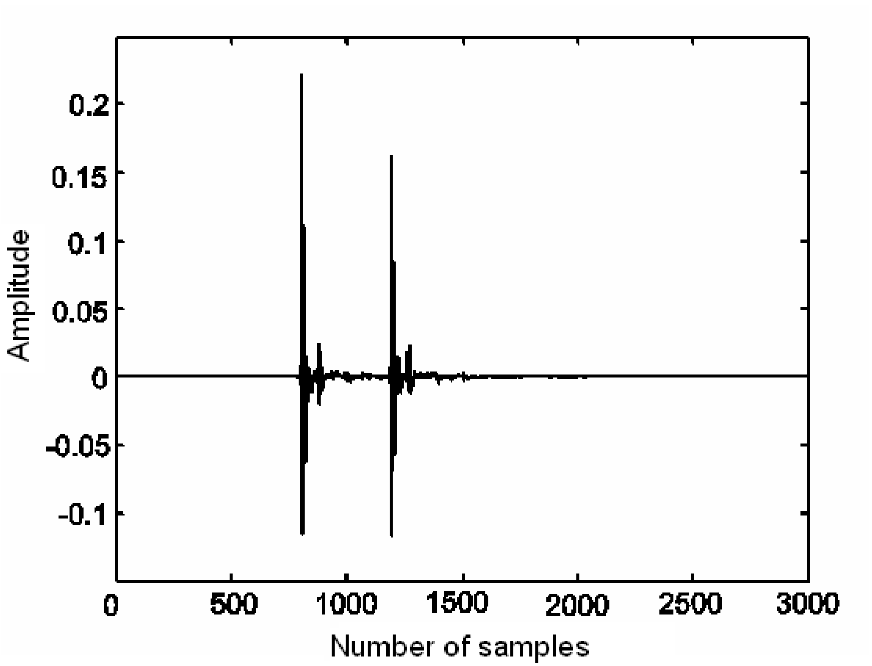
- 5.1 channel surround (3-2 stereo)
  - Frontal hemisphere (L, R, C), LS, RS
  - Set-up:
    - L(-30°), R(30°)
    - LS(-100° .. -120°), RS(100° .. 120°)
  - Dipole speakers for LS in RS (facing away from the listener)

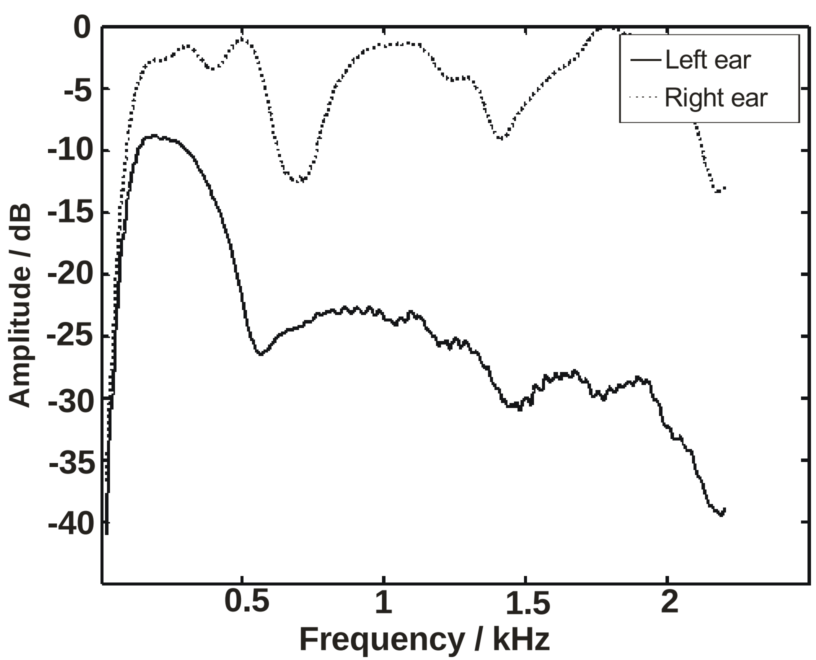


- 5.1 channel surround (3-2 stereo)
  - .1: LFE (Low Frequency Effects)
    - < 120 Hz
    - The use of LFE channel is optional
      - Subwoofer speakers (at movie theaters for special effects)
      - +10 dB (at reproduction time)
    - Frequency crossover (band pass filters)
      - 80 – 160 Hz
      - Smaller dimension of high-frequency speakers
      - Absence of LFE channel
  - Nonstandard use of channels
    - “Height“ channel (instead of LFE)
    - Additional side speakers (instead of C and LFE)

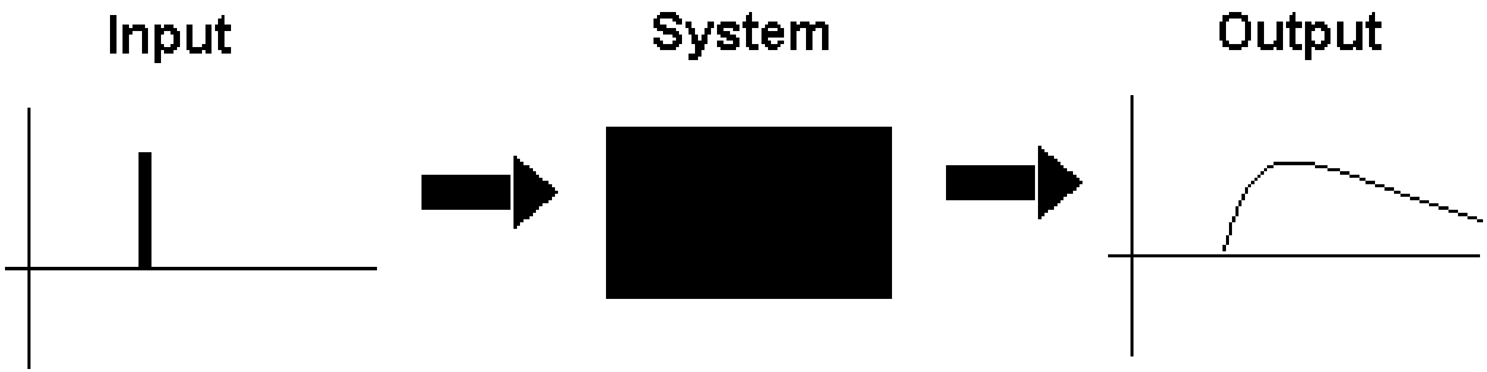
Auditory displays

- Headphone reproduction
  - Head Related Transfer Function (HRTF)
  - Measured as impulse response
    - Head Related Impulse Responses (HRIR)





- Headphone reproduction
  - Impulse response measurement



$$y(t) = x(t) * h(t)$$

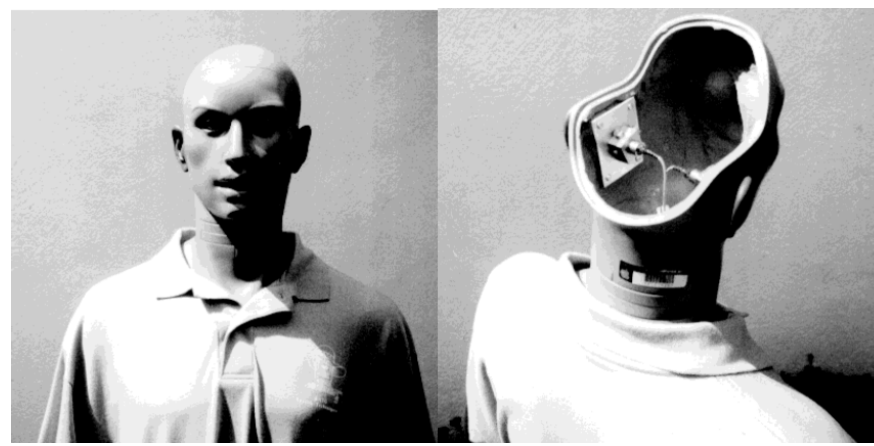
$$Y(\omega) = X(\omega)H(\omega)$$

- Headphone reproduction
  - Head-related impulse responses (HRIR)

Auditory displays

- Headphone reproduction
  - Head-related impulse responses (HRIR)

Individual impulse responses



General impulse responses

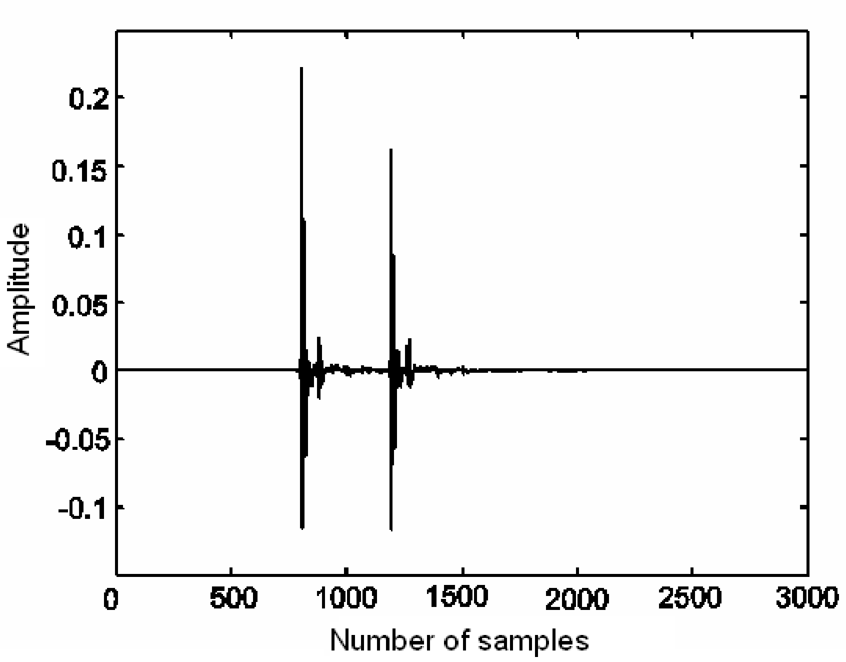
Auditory displays

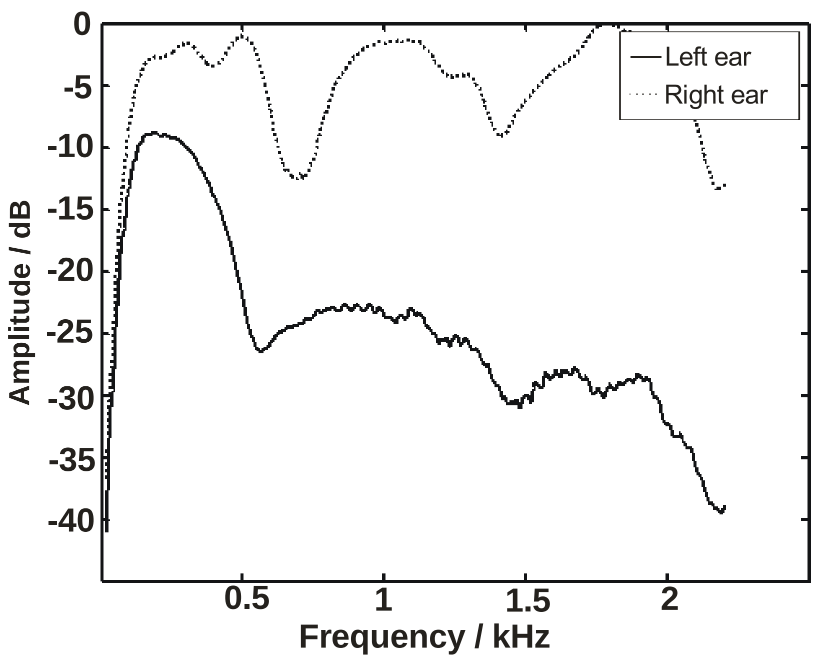
- Headphone reproduction
  - HRIR measurement
    - Anechoic chamber
    - Test signal: sequence of white noise
    - Constant amplitude specter + random phase (IFT)
  - Simultaneous replying and recording

$$H_{SIST} = \frac{H_{odz}}{H_{vzb}}$$

Auditory displays

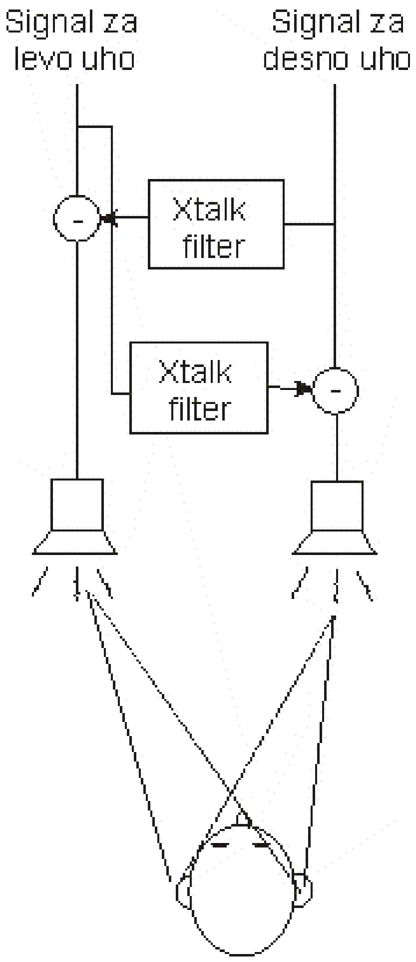
- Headphone reproduction
  - Head-related impulse responses
    - Used as FIR filters for generation of spatial sound
    - Available in various online libraries
    - Sound cards with HRIR filters (libraries with APIs)



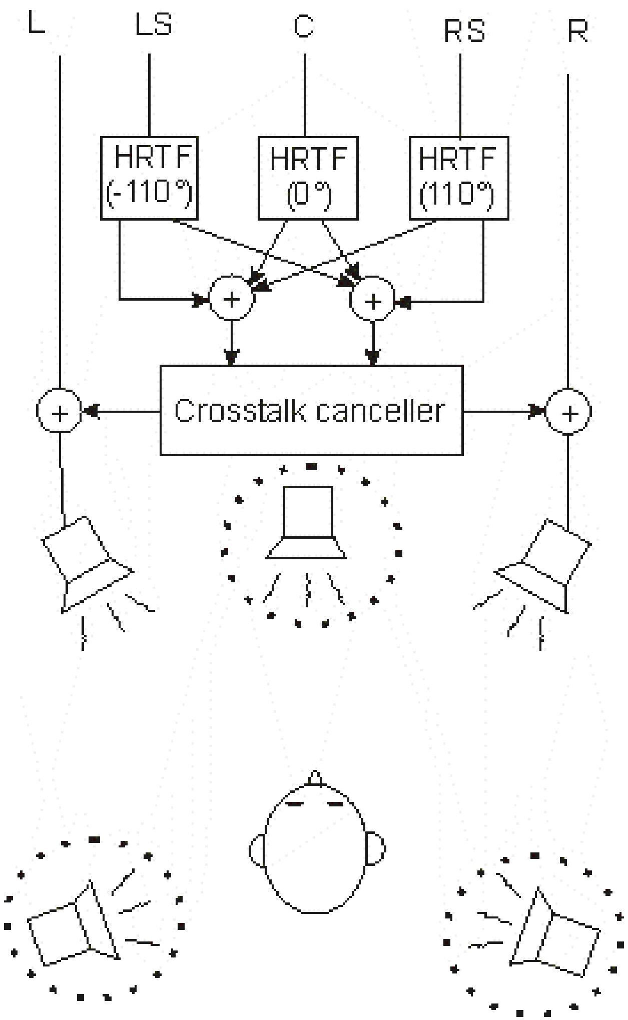


Auditory displays

- Spatial sound played through multiple speakers



“Hot spot”



Output technologies

Haptic technologies

Haptic technology

- Difficulty to synthesize
- Complements visual and aural perception
- Applies to any part of the human body
  - Sensation of force
    - Touch
    - Weight (gravitation)
    - Rigidity

Haptic technology

- Tool-handling-Type Force Display
  - Free from the need to be fitted to a hand or body
  - 6DOF force / torque feedback

Haptic technology

- Full-body haptics
  - Simulation of walking while the walker's body is maintained localized in the real world
  - Sliding device
    - Omnidirectional roller skates and parachute like harness
  - Treadmill
    - Ordinarily used for maintaining physical fitness
    - Omnidirectional treadmill

Haptic technology

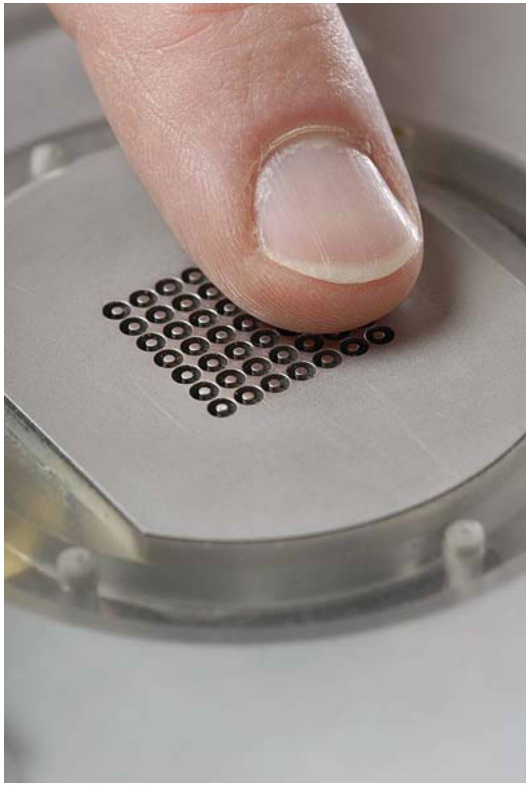
- Exoskeleton
  - Set of actuators attached to a hand or body
    - 6DOF parallel manipulator
    - 3D force and 3D torque
  - Large amount of hardware and high cost
  - Robotics, teleoperations, military, etc.

Haptic technology

- Full-body haptics
  - Motion platforms
    - Flight and driving simulators

Haptic technology

- Skin sensation and tactile display
  - Tactile display
  - Vibration display



User interfaces

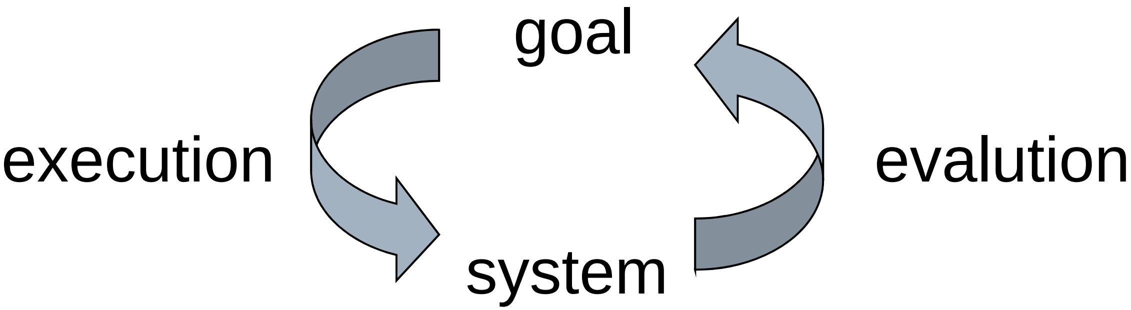
Visual interfaces

Interaction

- Models of interaction
  - Human – machine interaction
- Ergonomics
- User interfaces
  - Visual interfaces
  - Auditory interfaces
  - Haptic interfaces
  - Multimodal interfaces

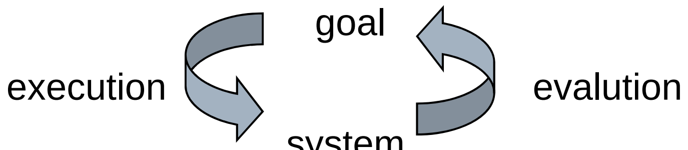
Models of interaction

- Norman's model of interaction (Donald Norman)



Models of interaction – Norman's model

- 7 stages of interaction
  1. Establishing the goal
  2. Forming the intention
  3. Specifying the action sequence
  4. Executing the action
  5. Perceiving the system state
  6. Interpreting the system state
  7. Evaluating the system state with respect to the goals and intentions

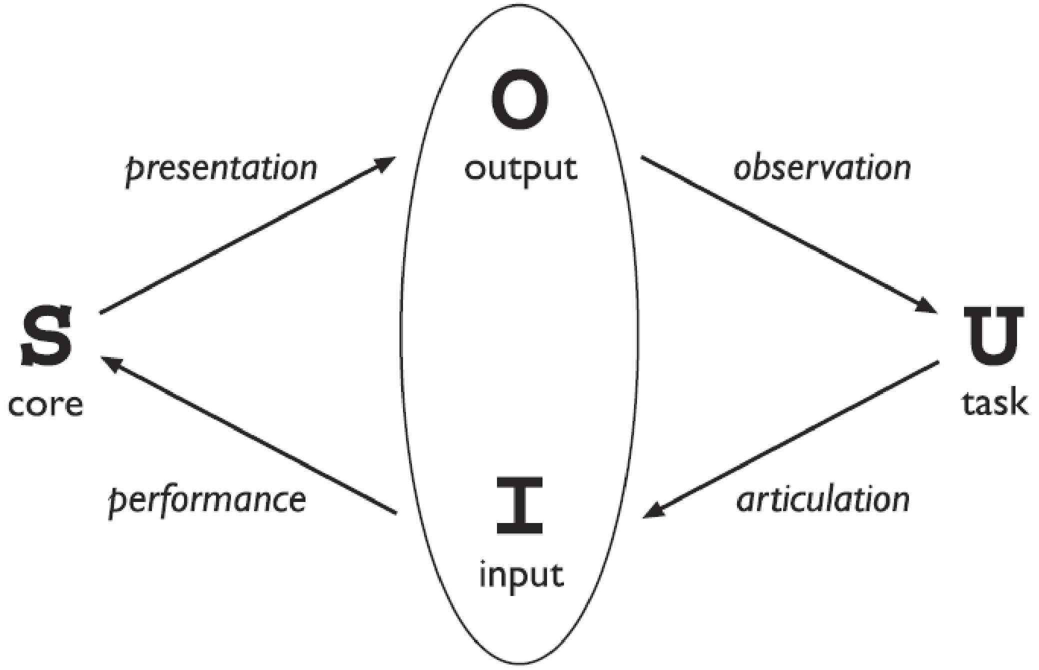


Models of interaction – Norman's model

- Some interfaces cause problems to users
- Gulfs of execution
  - User's formulation of the actions to reach the goal vs. the actions allowed by the system
- Gulfs of evaluation
  - Physical presentation of the system state vs. expectation of the user
- Human errors
  - Slips and mistakes

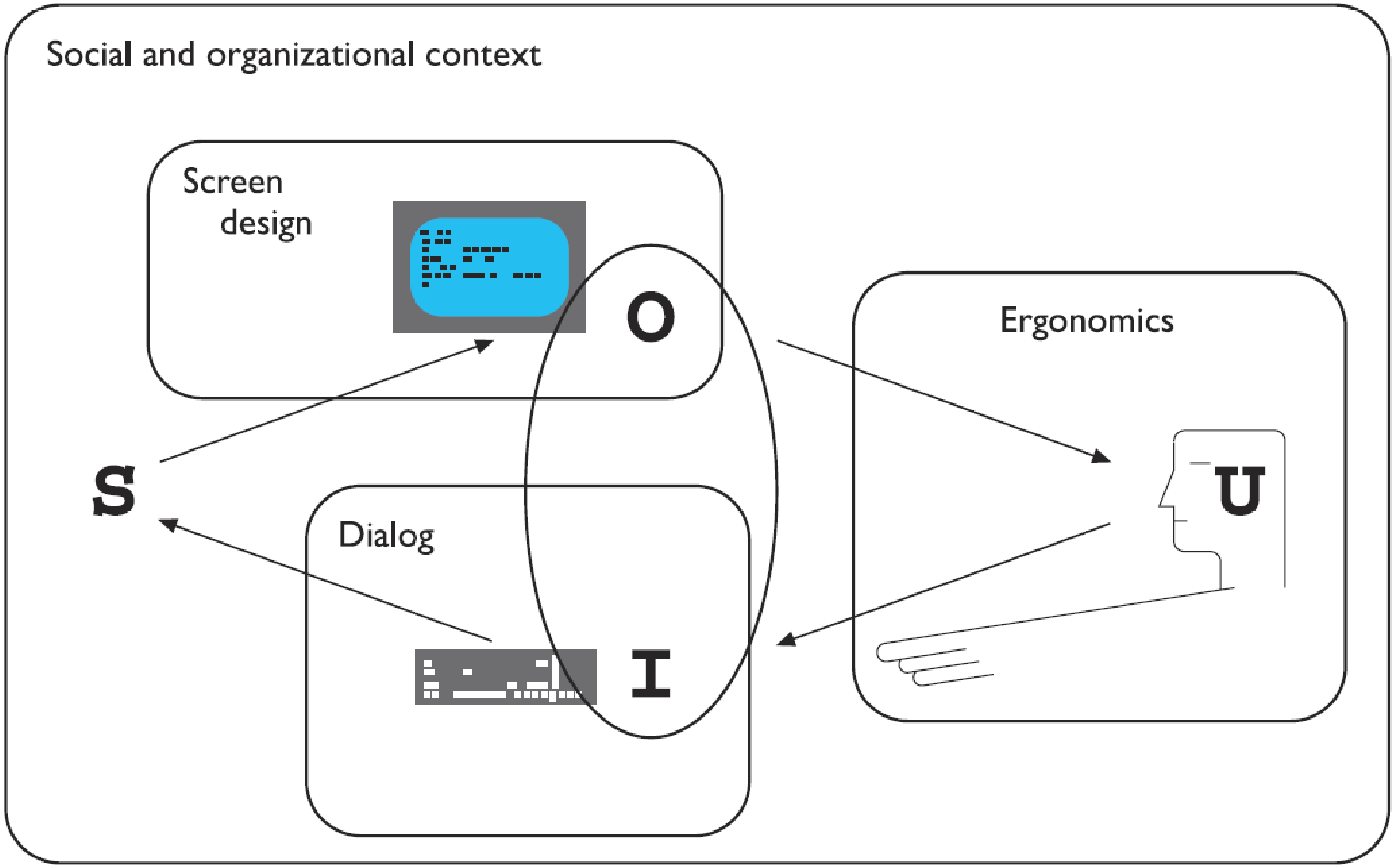
Interaction framework

- More realistic description of interaction
  - Four components
  - Each component has its own language



Interaction framework

- Social and organizational context



Ergonomics (human factors)

- Arrangement of controls and displays
  - Organization
    - Functional
    - Sequential
    - Frequency
  - No excessive body movements
    - Controls in relation to user’s position
    - Critical displays at eye level
    - No glare and reflections
    - Adequate room for the user to maneuvers

Ergonomics (human factors)

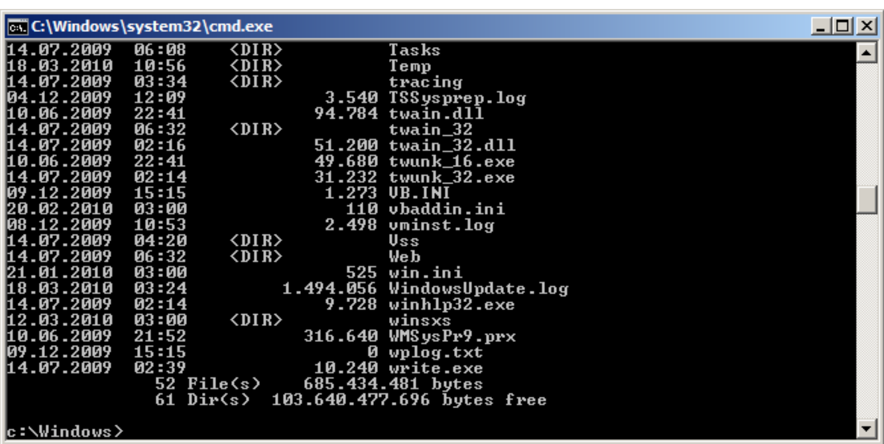
- The physical environment
  - Where will the system be used?
  - By whom will it be used?
  - Will the users be sitting, standing or moving around?
- Health issues
  - Physical position
  - Temperature
  - Lightning
  - Noise
  - Time
- The use of colors

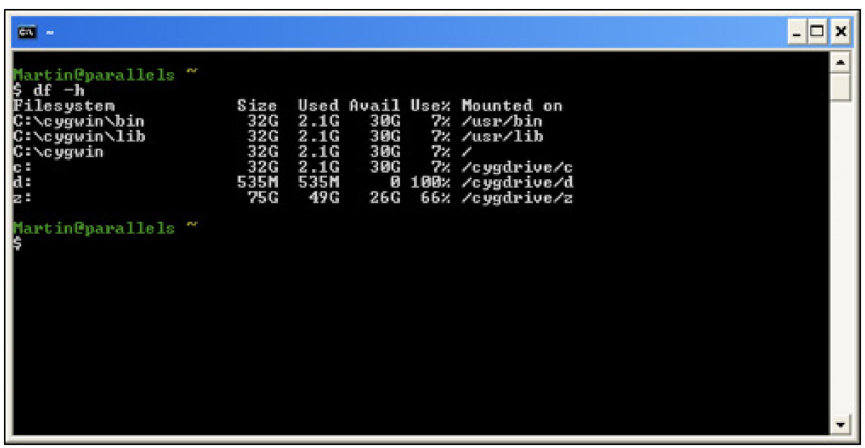
Visual interfaces

- Interaction styles
  - Command line interface
  - Menus
  - Forms and question / answer queries
  - WIMP
  - Point and click
  - 3D interfaces
  - Natural language

Visual interfaces

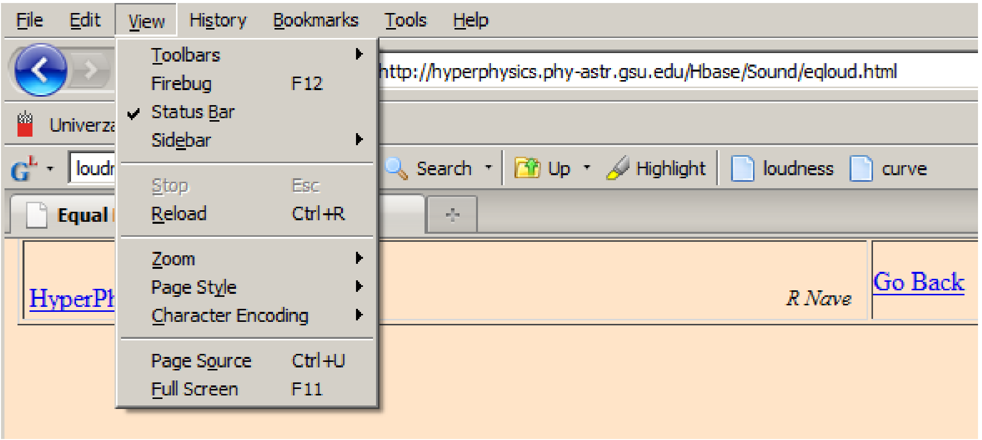
- Command line interface
  - Direct input of commands
  - Limited and restricted set of commands
  - Experienced users
  - Poor feedback

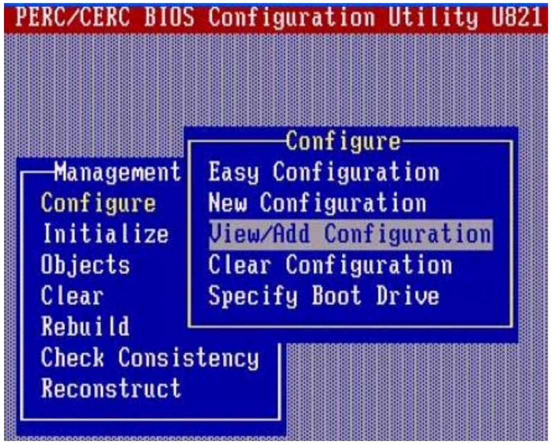




Visual interfaces

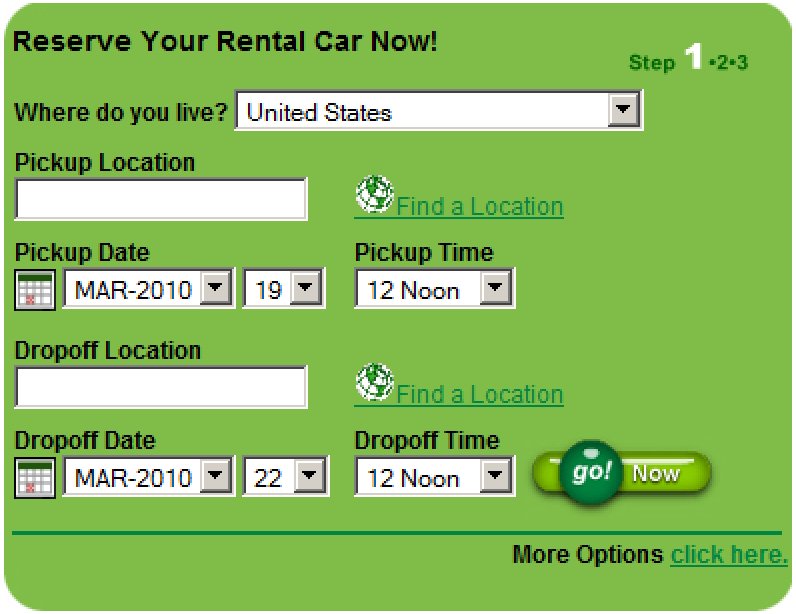
- Menus
  - A list of available commands
  - Lower cognitive workload
  - Meaningful and logical naming and grouping
  - The use of pointing device

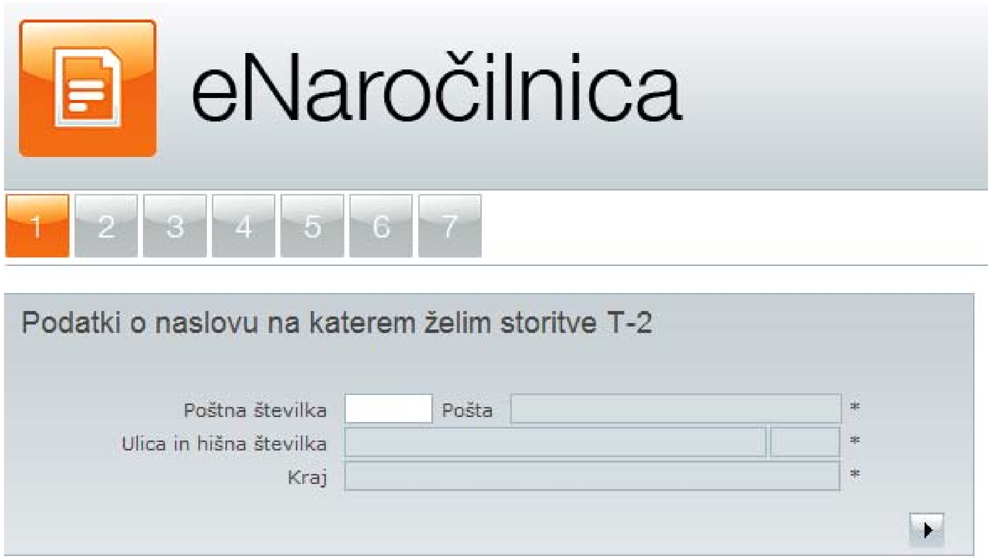




Visual interfaces

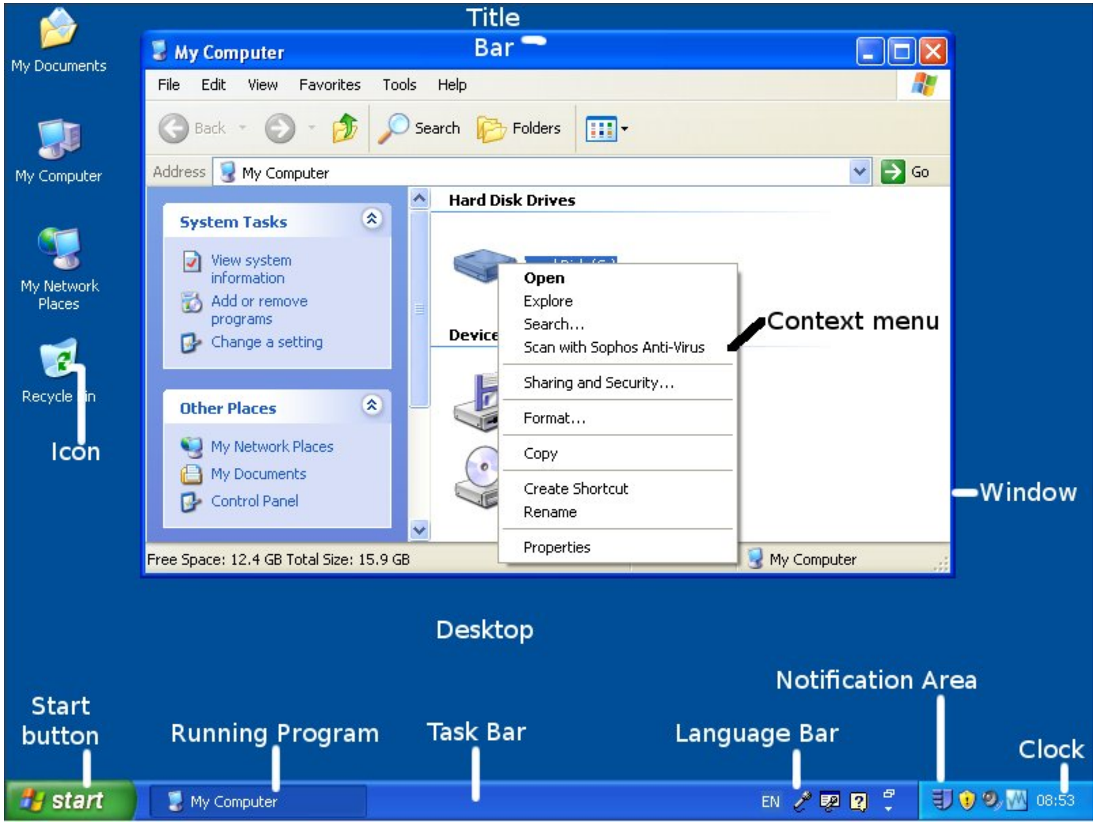
- Forms and question / answer queries
  - A set of question and answers
  - Query languages (e.g. SQL)
  - Form with multiple fields





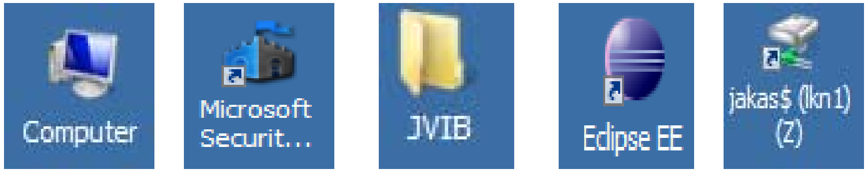
Visual interfaces

- The WIMP interface
  - Windows Icons Menus Pointers
  - The most common type of graphical interfaces



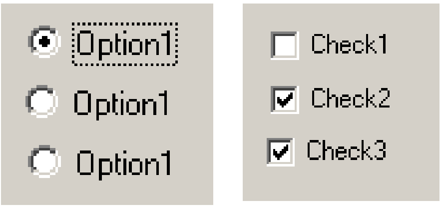
Visual interfaces

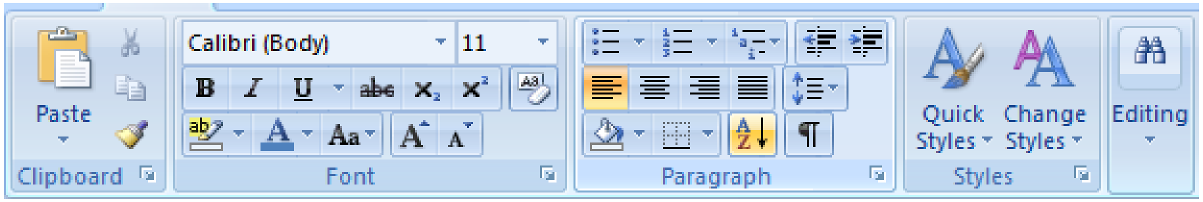
- Icons
  - Minimized version of a window
  - Associative icons
  - Abstract icons



Visual interfaces

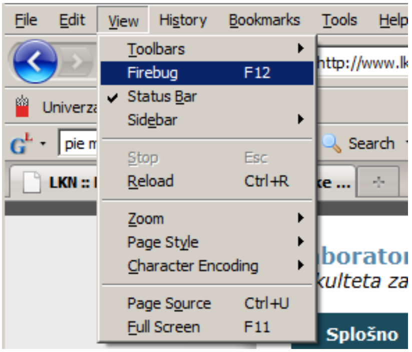
- Pointers
  - Element for pointing other elements
  - Controlled by a pointing device
  - Feedback on system status
- Buttons
  - Element for starting actions
- Toolbars
  - Set of icons and buttons
  - Customization

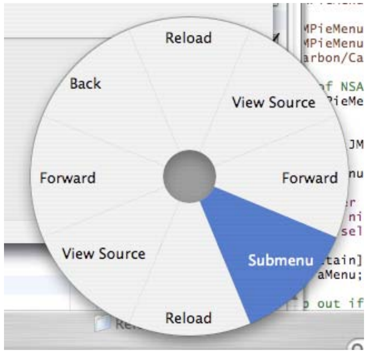


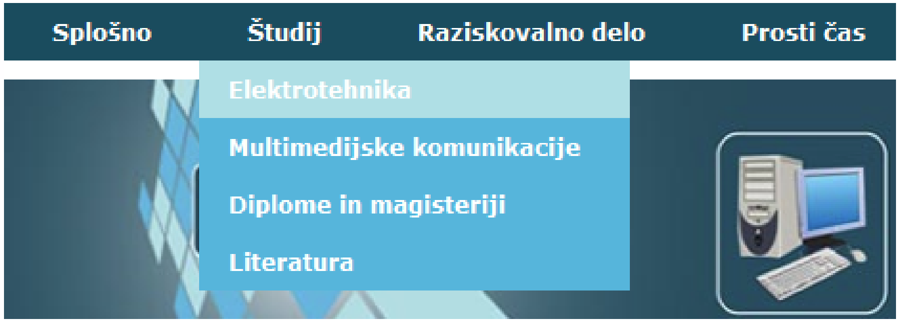


Visual interfaces

- Menus
  - Set of available options
  - Length and layout of menus
    - Menus and submenus
  - Types of menus
    - “Pull-down”
    - “Drop-down”??
    - “Fall-down”
  - Shortcuts
  - Circular menus



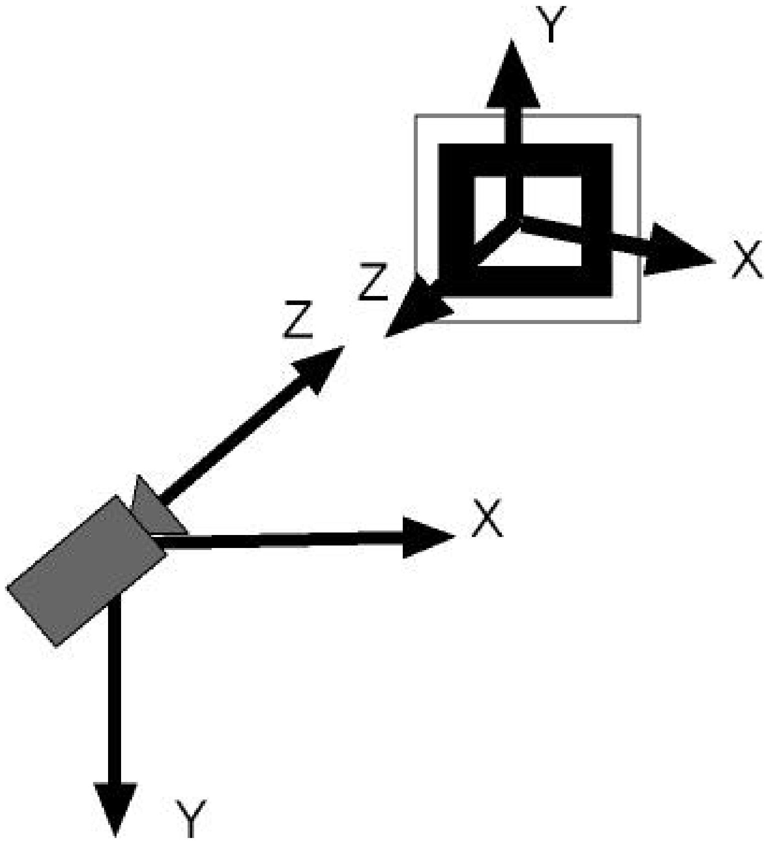




Visual interfaces

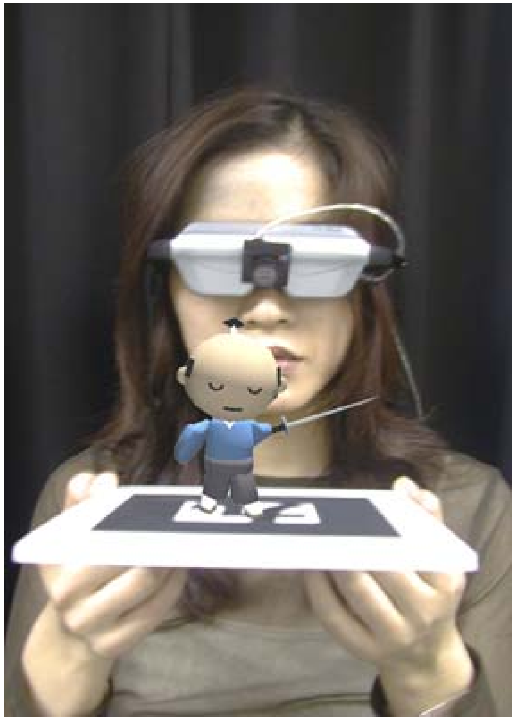
- Augmented reality
  - Augmentation of real world with virtual artifacts
  - Basic elements
    - Screen
      - Classic display, HMD – Head Mounted Display, windshield, etc.
    - Input devices
      - Video cameras
    - Tracking
      - Visual processing, GPS, various positioning technologies, etc.

- Augmented reality
  - Video processing based tracking
  - Markers

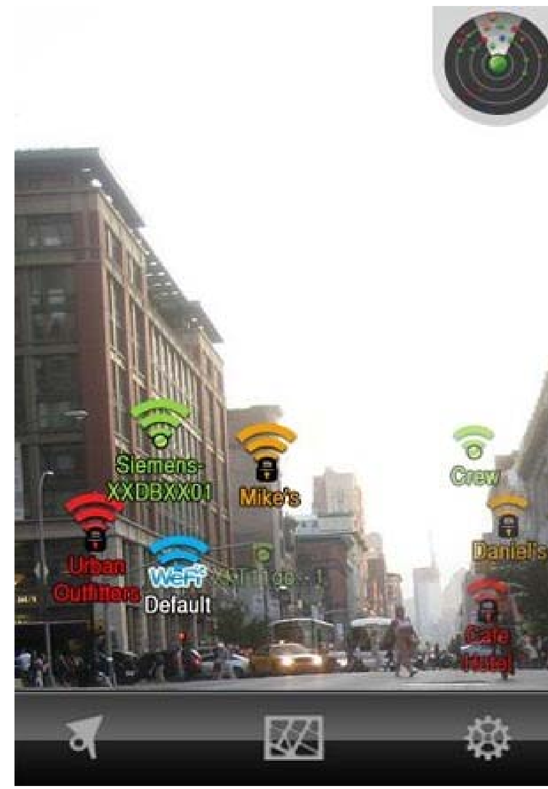


Visual interfaces

- Augmented reality
  - Video processing based tracking
  - Markers



- Augmented reality
  - “Mobile” augmented reality



User interfaces

Auditory interfaces

Auditory interfaces

- General properties
  - Gaining importance due with the raise of mobile and ubiquitous interactivity
  - Complement of visual interfaces
    - Alarms
    - Background processes
    - Entertainment
  - Main feedback about the system
    - Visually impaired users
    - In-vehicle information systems
    - Telephone based interfaces
  - Two main groups
    - Speech interfaces
    - Non-speech interfaces

Auditory interfaces

- Speech interfaces
  - Based on human speech
    - Detected and recognized
    - Recorded and replayed
    - Synthesized by the computer
  - Natural communication
    - No special learning
    - Simultaneous use of speech and visual interaction
  - Text-To-Speech (TTS)
  - Automatic Speech Recognition (ASR)

Auditory interfaces

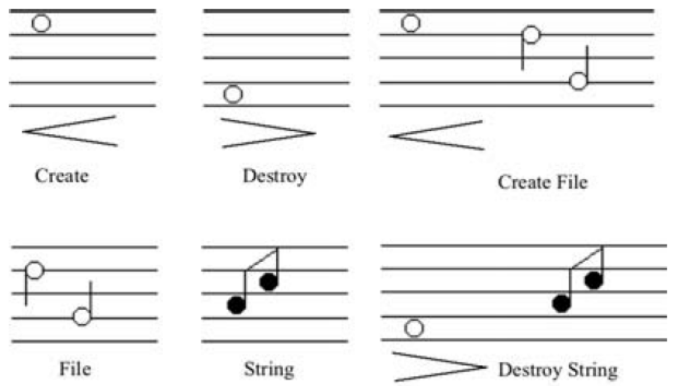
- Speech interfaces
  - TTS is simpler than ASR
    - Segmentation of text (letters and words)
    - Human capability of adaptation (poor quality, different accents, etc.)
  - Vocabulary
    - Predefined available commands and words
      - Dialog trees
      - Command and control interfaces
    - Unknown words and phrases
  - Silent Speech Interfaces (SSI)
    - Capture of movement of vocal tract
    - Optical imaging of tongue and lips

Auditory interfaces

- Constrains of speech interfaces
  - Low robustness and accuracy
  - Lack of privacy and anonymity
  - Slow way of communication
    - Inconvenient for describing ongoing processes
  - High level of human attention and focus
    - Sentences have to heard from the beginning to the end
    - Many words for little information

Auditory interfaces

- Non-speech interfaces
  - Auditory icons
    - Realistic representation (associative)
  - Earcons
    - Abstract and symbolic sounds
    - Timbre, pitch, rythm and duration, intensity
  - Spearcons
    - Speed-up texts and phrases

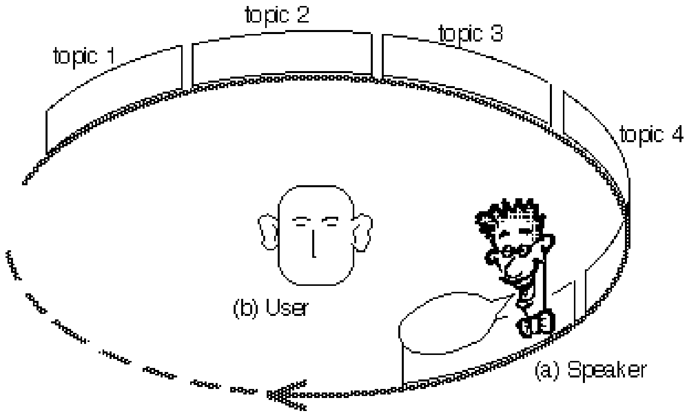


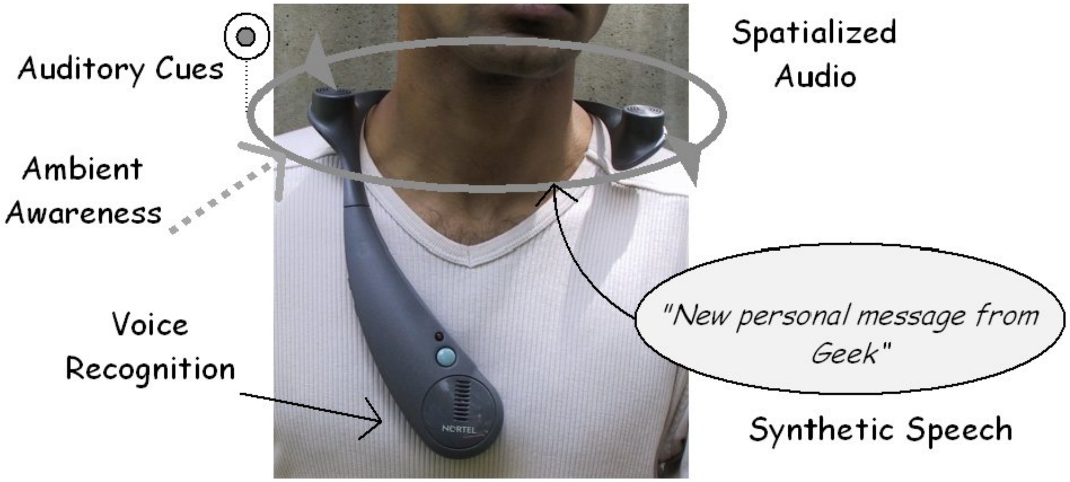
- Sonification
  - Presentation of complex data
- Tactons
  - Locus, intensity, duration, frequency, rhythm
- Interface metaphors (ring and dial, room)

Auditory interfaces

- Advantages of non-speech interfaces
  - Vision and hearing are interdependent
  - Sound has superior temporal resolution
  - Sound is attention grabbing
  - Sound reduces the amount of information needed on the screen
- Disadvantages of non-speech interfaces
  - Sound has low resolution
  - Presenting absolute data is difficult
  - Lack of orthogonality
  - Annoyance for user and others

- Auditory interfaces for portable devices
  - AudioStreamer
  - Touch player
    - Wearable PDA, headphones and head tracker
  - Nomadic Radio



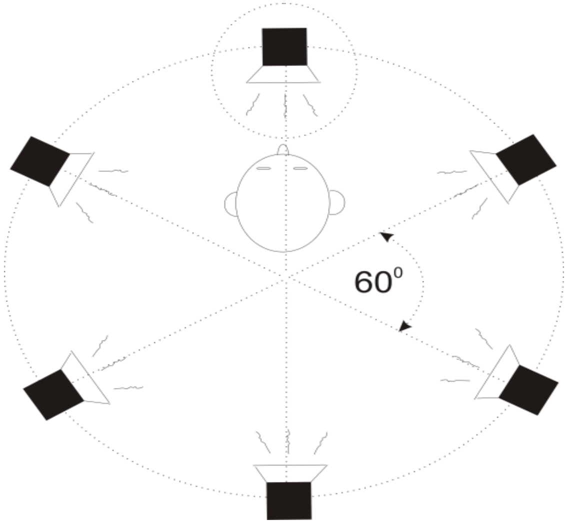


- Auditory interfaces in aircrafts
  - Traffic alert and Collision Avoidance system (TCAS)
    - Traffic advisory (visual)
    - Resolution of advisory (visual + aural)
    - Clear of conflict (visual + aural)
  - Indication of target with spatial sound
    - HRTFs and headphones
    - 12% faster response time
  - Jet fighters
    - Positions of enemy jets as spatial sources
  - Unmanned Aerial Vehicles (UAV)
  - Helicopters
    - Helmet-mounted earplugs (noise)
    - Speech, non-speech and mixed messages

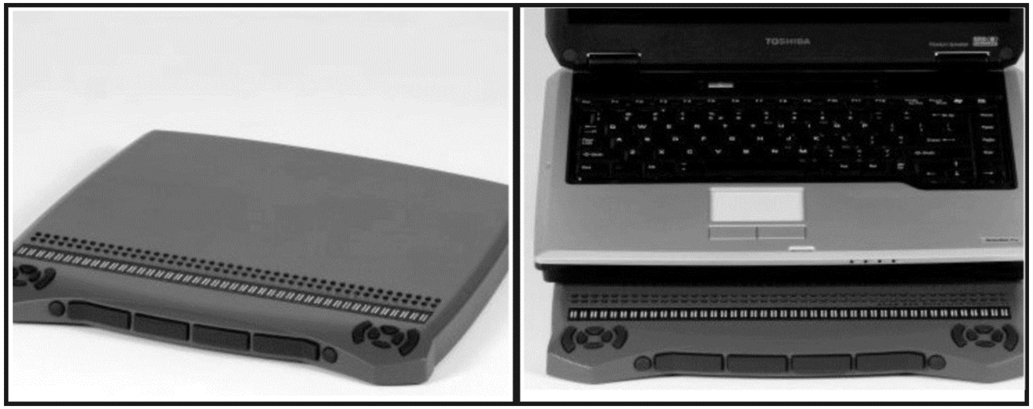
Auditory interfaces

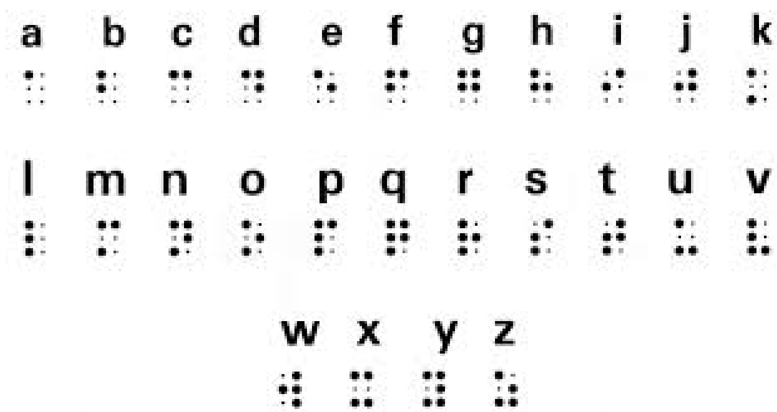
- Auditory interfaces in vehicles
  - Collision avoidance system (CAS)
    - Auditory icons indicating danger
  - Advanced Driver Assistance System (ASAD)
    - Automatic lateral and longitudinal control
    - Line deviations (audio vs. tactile)
      - Predicted (audio) and unpredicted (tactile) situations
    - Localized warnings for dangerous events
      - Front vs. rear events
  - In-vehicle Information system (IVIS)

- Auditory interfaces in vehicles
  - In-vehicle Information system (IVIS)
    - 3D auditory interface
      - Localized menu sources (spoken items)
      - Background music
      - Interaction based on a custom device



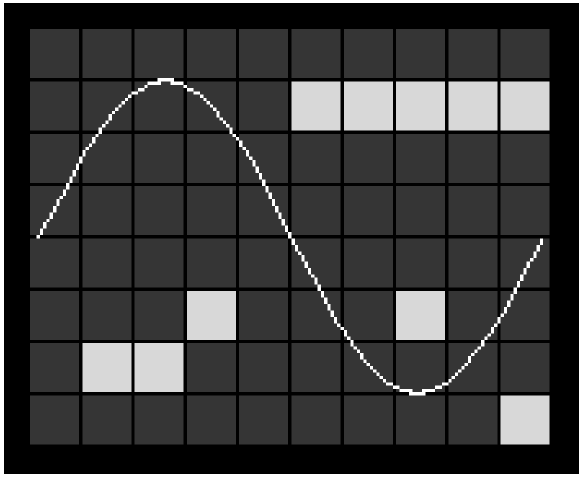
- Interfaces for visually impaired and blind
  - Screen reading software
    - Verbalization of GUI
    - TTS and keyboard control
  - Tactile interfaces
    - Braille keyboard

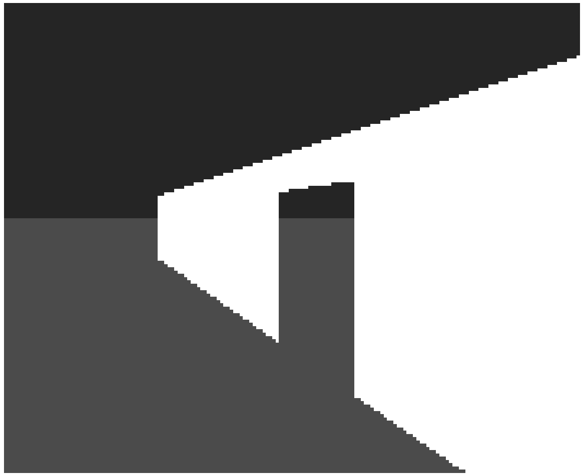




Auditory interfaces

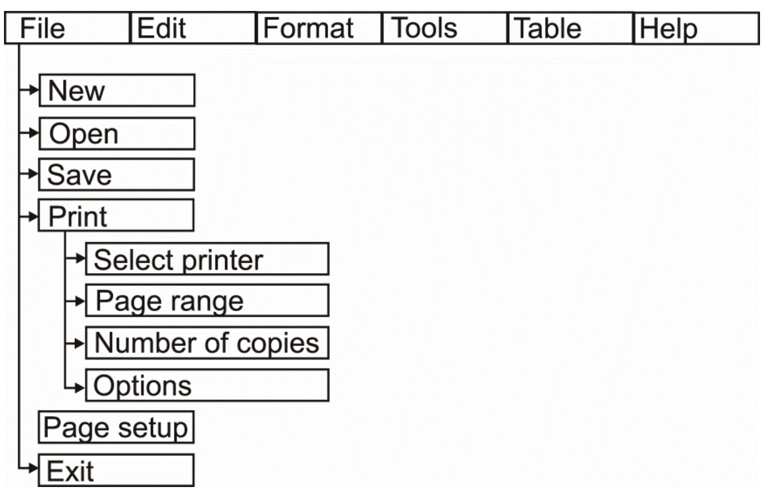
- Interfaces for visually impaired and blind
  - The vOICe
    - Time-multiplexed auditory representation
    - Horizontal position: Interaural Time Difference
    - Vertical position: orthogonal sinusoidal oscillators

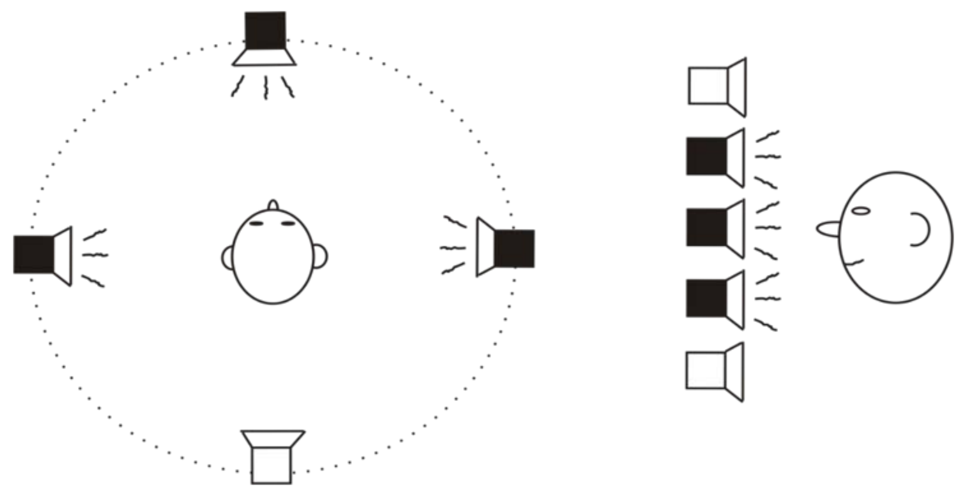




Auditory interfaces

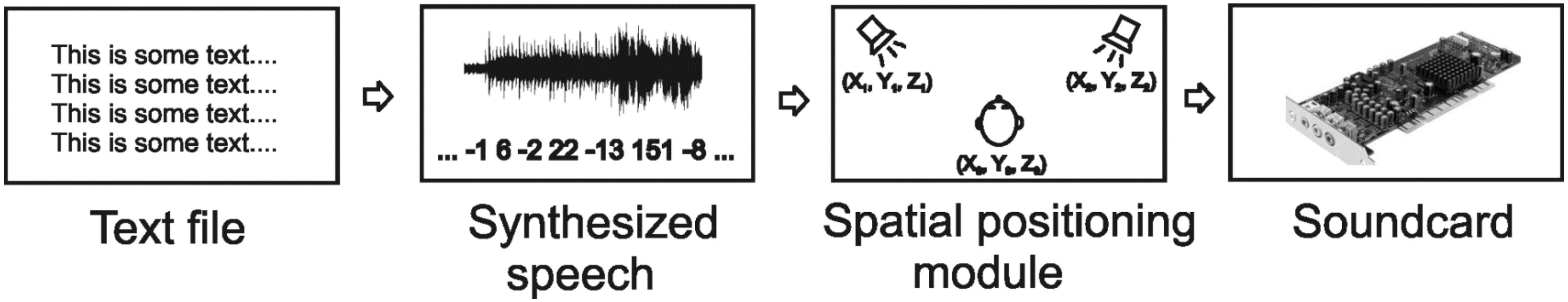
- Interfaces for visually impaired and blind
  - Spatial auditory interface for MS Word
    - Spoken menu items
    - Background music with changing pitch

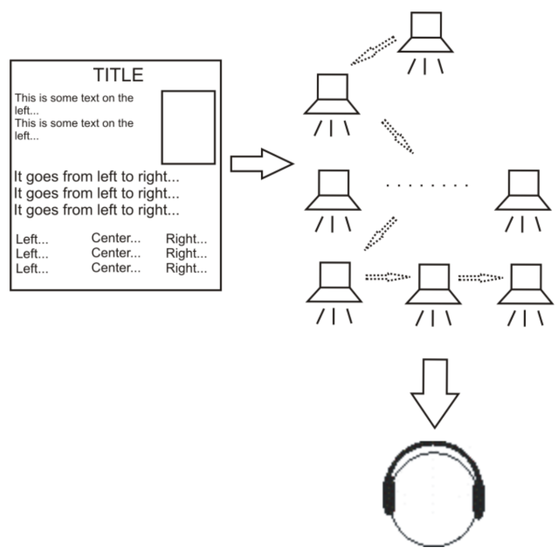




Auditory interfaces

- Interfaces for visually impaired and blind
  - Spatially augmented screen reader





User interfaces

Multimodal interfaces

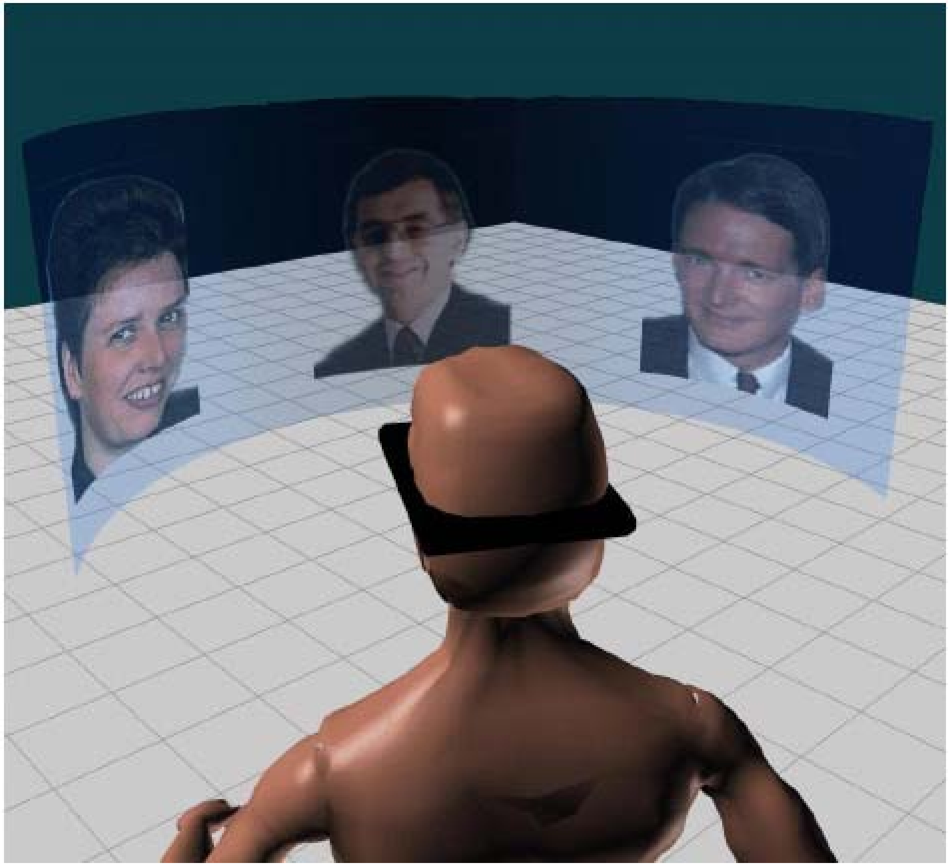
Multimodal interfaces

- Types of multimodal interfaces
  - Keyboard entry + speech commands
  - Mouse (touch) + speech commands
  - Pen input + speech commands
  - Vision based technologies (passive monitoring)
    - Lip movements
    - 3D gestures
    - Interpretation of gaze
    - Facial expressions
    - Large body movements
  - Blended interfaces
    - Combination of active and passive modes
    - Biometrics

Multimodal interfaces

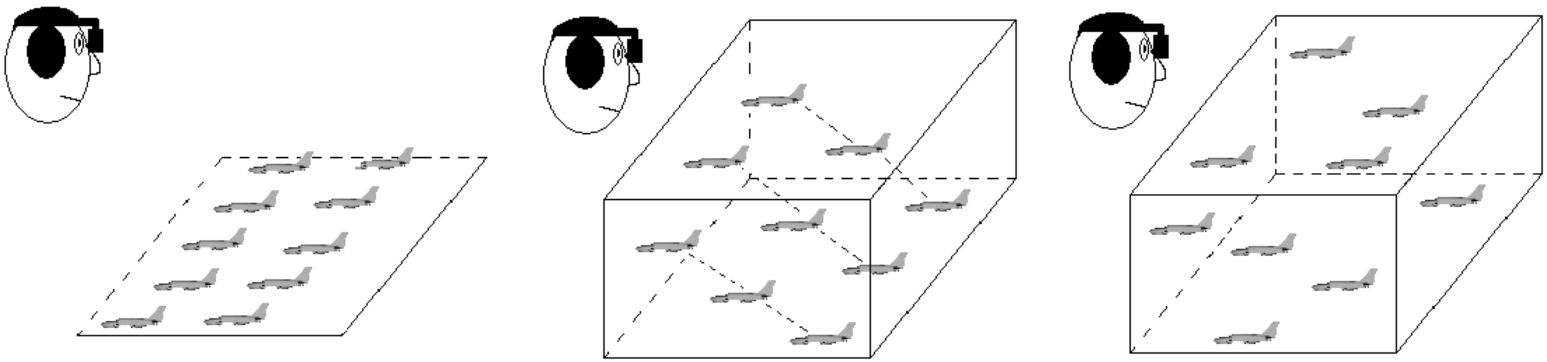
- Advantages of multimodal interfaces
  - Free alternation between available modalities
  - Comfortable for users of different age, skills, native languages, sensory impairments, etc.
  - Adaptability in changing conditions (mobile environment)
  - Strong preference of users (unimodality vs. multimodality)
  - Improved efficiency
  - Superior error handling

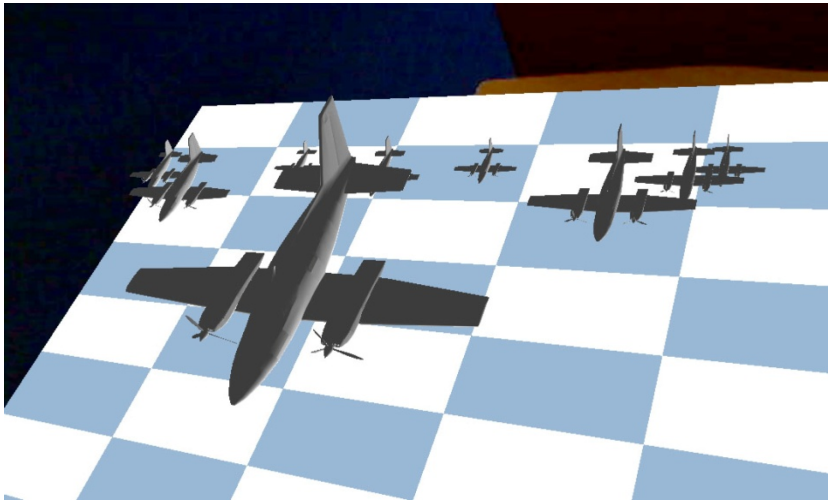
- Auditory interfaces for teleconferencing
  - Wearable communication space



Multimodal interfaces

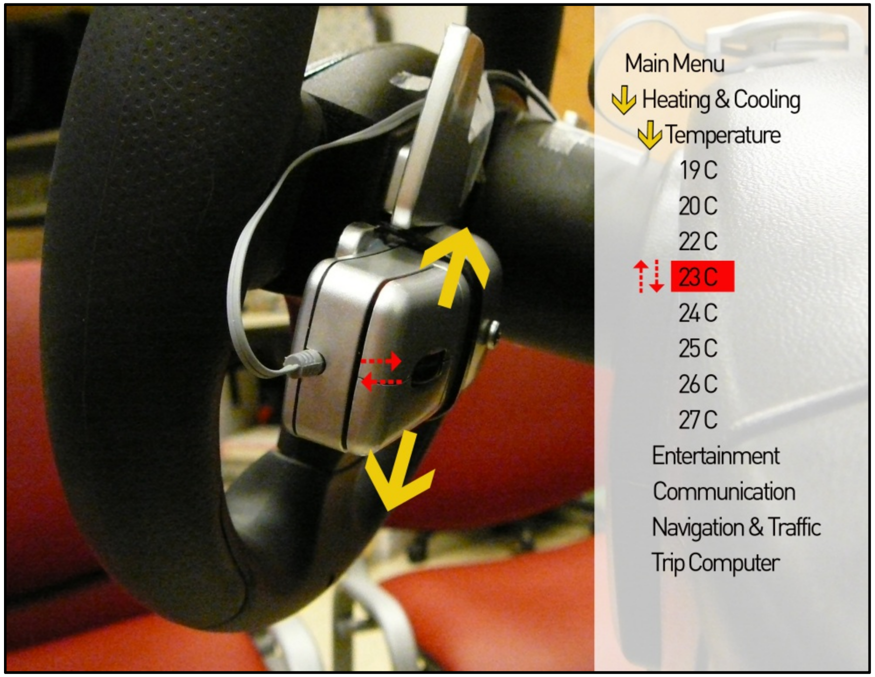
- Augmented reality
  - Sound localization experiment in AR





Multimodal interfaces

- HUD + auditory interface in a vehicle
  - No objective evidence of improvement
  - Preferred by the majority of users (over 60%)
  - “Auditory“ and “visual“ types of people



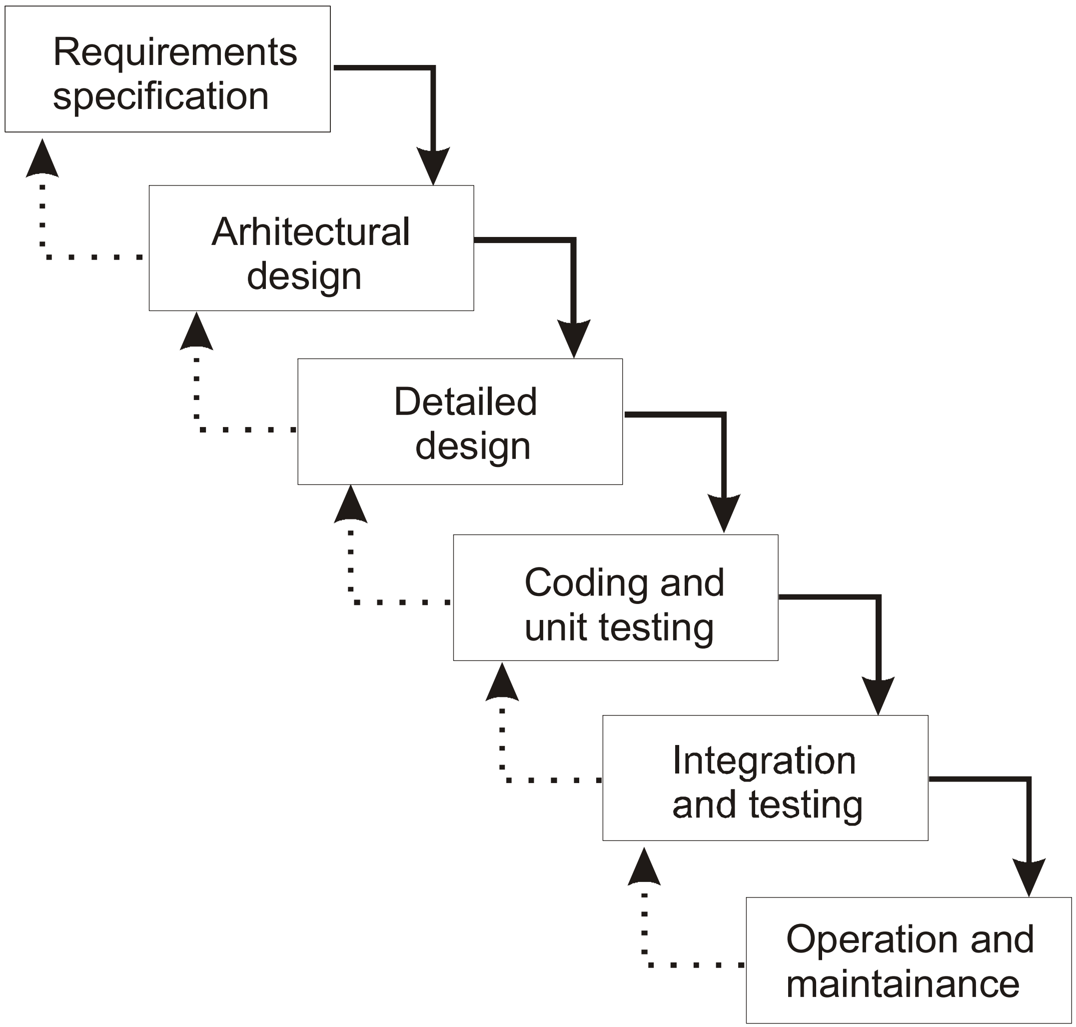
Interaction design

User-Centered Design

- Design goals
  - To design interactive products to support people in their everyday and working lives
  - Transformation of existing situation into preferred (better) one
  - All design is actually redesign
  - Connect observations to design
  - The goal is to create the interface that
    - Reflect workflows that are familiar or comfortable
    - Supports users' learning styles
    - Are compatible in the users' working environment
    - Have a consistency of presentation
  - To design something that users will actually use / do

Software design process

- Waterfall model



Software design process - Waterfall model

- Requirements specification
  - Interaction between a designer and financer (project leader)
  - Definition of functionalities and features
  - Definition of users and their specifics
    - Typical user?!
  - Natural language understood by all parties
  - The most critical part of the entire process
    - Poor definition leads to poor execution

Software design process - Waterfall model

- Architectural design
  - How to achieve the desired goals and plans?
  - High-level definition (object oriented)
  - Definition of the major components of the system and their inter-relations
- Detailed design
  - Study of available resources
  - Programming languages, database services, definition of software modules (classes, methods, data models, etc.)

Software design process - Waterfall model

- Coding and testing
  - Writing code in a selected programming language
    - Automatic process?
  - Modular development (simultaneous development and testing of various modules)
  - Errors (bugs)
    - Errors in the code
    - Errors in design

Software design process - Waterfall model

- Integration and testing
  - Integration of all components and deployment
  - Test of interactions among all modules and components
  - User-based testing
- Operation and maintenance
  - Post-development process
  - Actual use in real environment
    - Errors, errors, …

Software design process - Waterfall model

- General properties
  - Linear-sequential life cycle model
    - 20%-40% for the first two stages
    - 30%-40% for coding
    - The rest for testing and implementation
  - Each phase must be fully completed before the next phase begins
  - Brief review after each phase
  - Requirements gathering is the most critical part of the process
  - Importance of documentation and clear source code

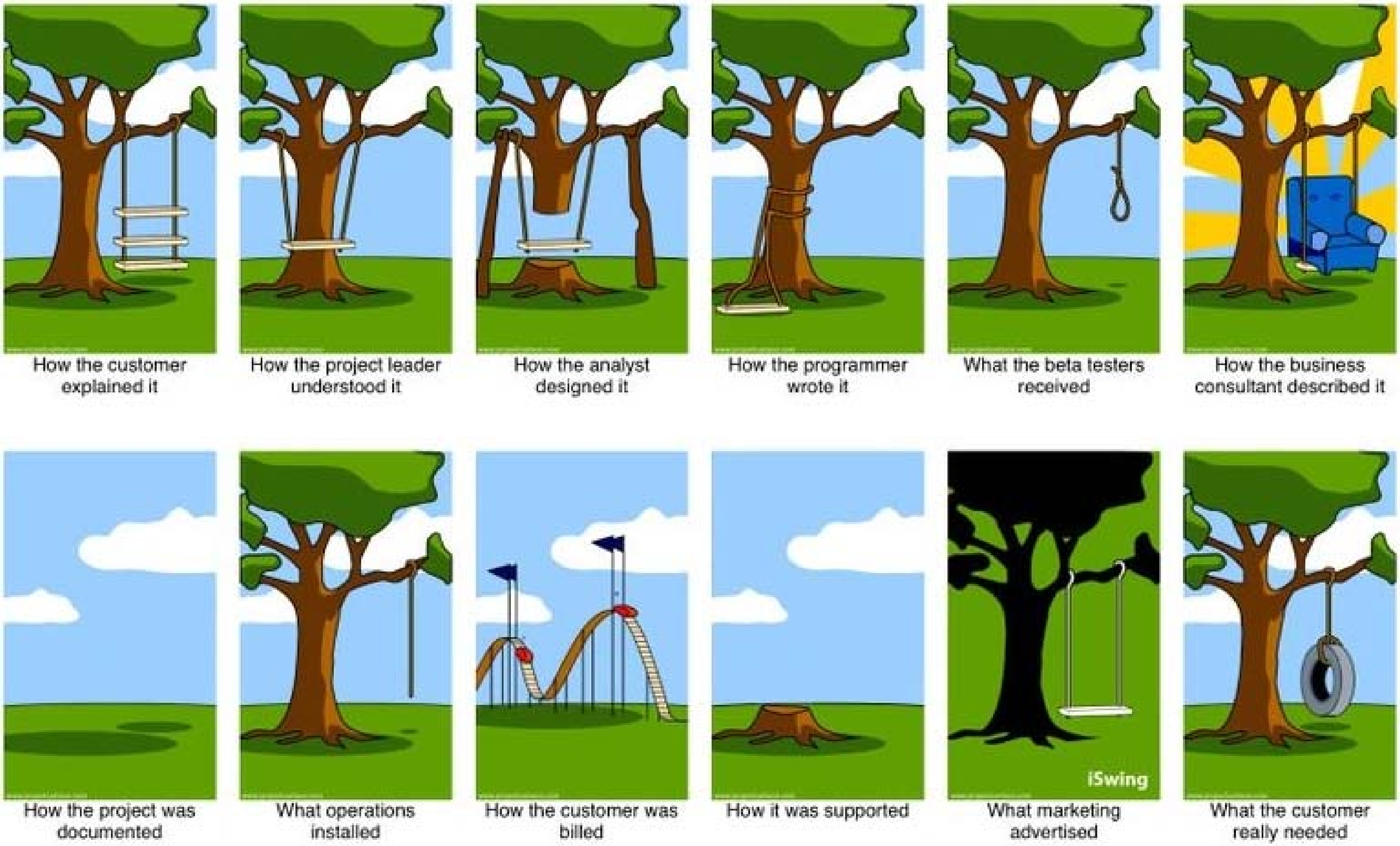
Software design process - Waterfall model

- Gantt chart
  - Timeline of activities (with milestones)

Software design process - Waterfall model

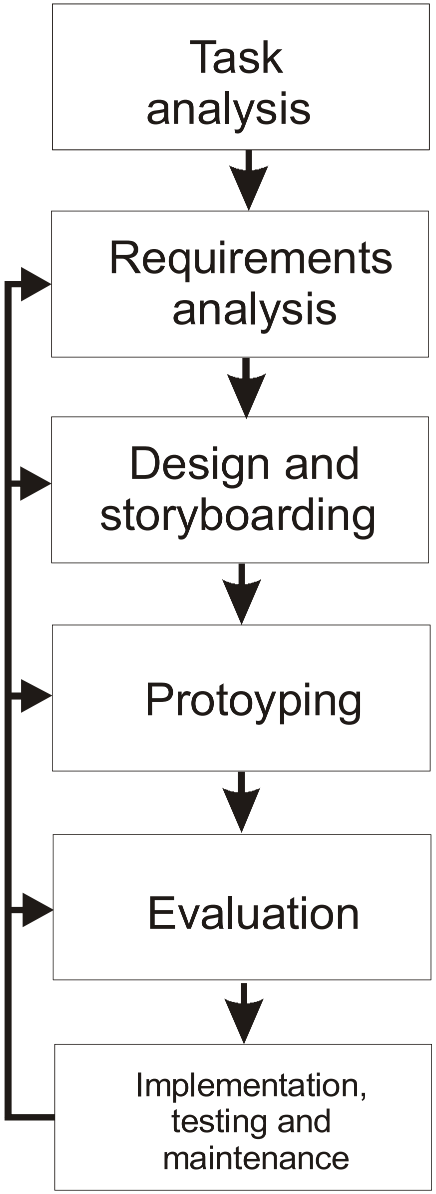
- Advantages of waterfall model
  - Simple and easy to understand
  - Easy to manage due to rigidity (each phase has specific and clear deliverables)
  - Phases are processed and completed one at a time (phases do not overlap)
  - Perfect for smaller projects where requirements are well defined and understood
- Disadvantages of waterfall model
  - Stress on the technology
  - Difficult to change the design when an application is in the testing phase
  - No working software is produced until the late testing phase
  - Poor model for long and ongoing projects
  - Not suitable for the projects wtih poorly defined requirements (high risk of changing in the later stages)

Software design process - Waterfall model



Design process

- UCD: User-Centered Design
  - Extensive attention is to the needs, wants and limitations of end users
  - Evaluation of ideas at each stage of design process



Interaction design

Task analysis

User-Centered Design

- Task analysis
  - The process of analyzing the way people perform tasks and jobs
    - Existing systems and procedures
    - Observation in various forms
  - Observable behavior and internal (cognitive) mental state
  - Three types of analysis
    - Task decomposition
    - Knowledge-based techniques
    - Entity-relation-based analysis
  - Informal and descriptive specifications

User-Centered Design

- Task analysis
  - The outcomes
    - What are the steps?
    - What are the artifacts?
    - What are the goals?
      - How are we going to measure success?
    - What are the pain points?
  - Designers, engineers, user on the same level
  - Different people may do things slightly differently
    - Different goals, expertise, etc.

- Task decomposition

0. In order to clean the house
    1. get the vacuum cleaner out
    2. fix the appropriate attachment
    3. clean the rooms
        3.1. clean the hall
        3.2. clean the living rooms
        3.3. clean the bedrooms
    4. empty the dust bag
    5. put the vacuum cleaner and attachments away

Plan 0: do 1 – 2 – 3 – 5 in that order.
when the dust bag gets full do 4

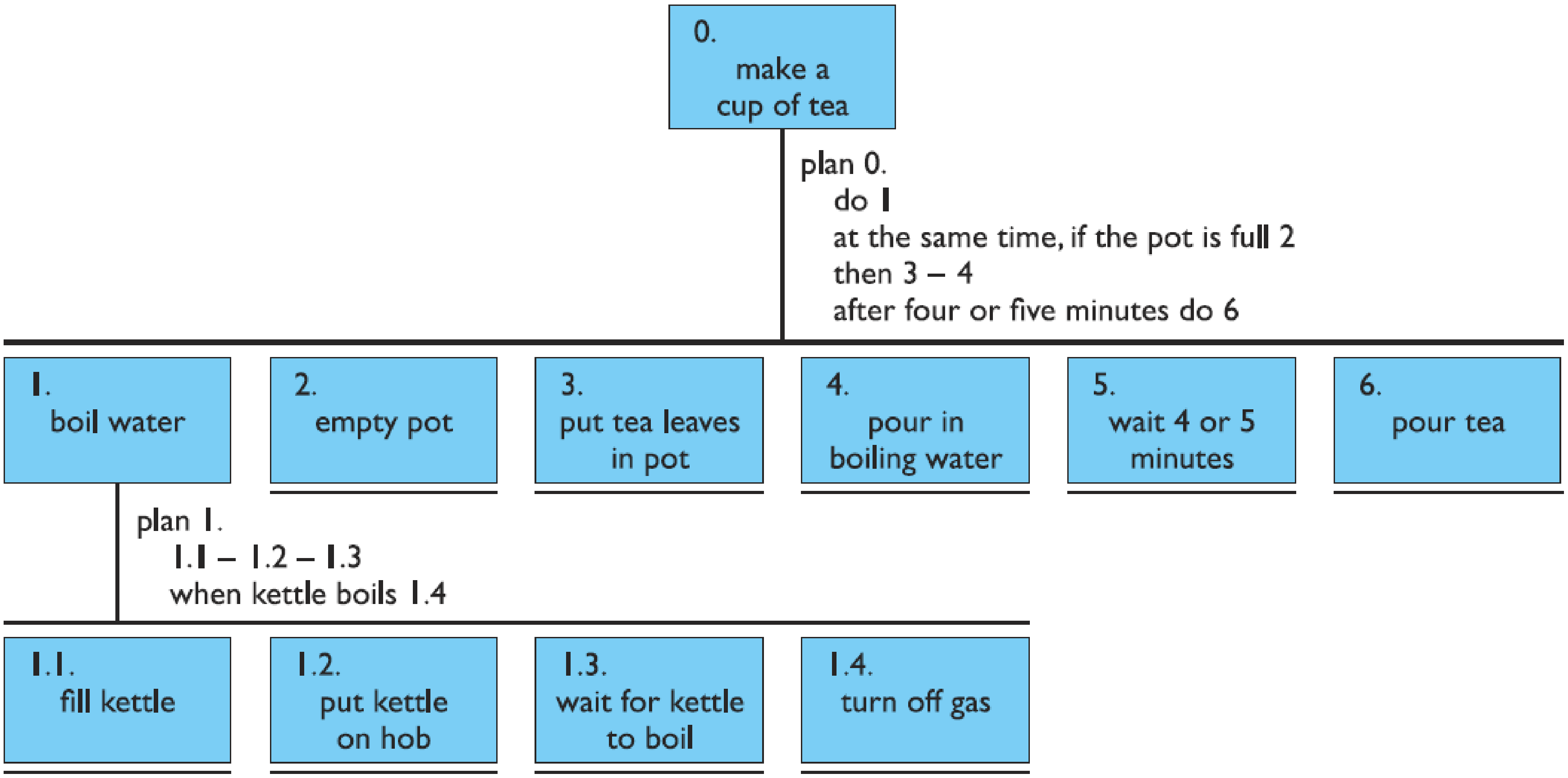
Plan 3: do any of 3.1, 3.2 or 3.3 in any order
depending on which rooms need cleaning

User-Centered Design - Task analysis

- Task decomposition
  - Hierarchical task analysis (HTA)
    - Outputs a hierarchy of tasks, subtasks and plans
    - The hierarchy can be presented diagrammatically or textually
    - Tasks are decomposed to the level of individual actions
      - P x C < M
      - Another stopping point is a complex motor response or internal cognitive actions
    - Plans are labeled by the task to which they correspond
      - The order of task executions
      - Mandatory and optional tasks
      - Simultaneity
      - Repetition
    - Iterative process

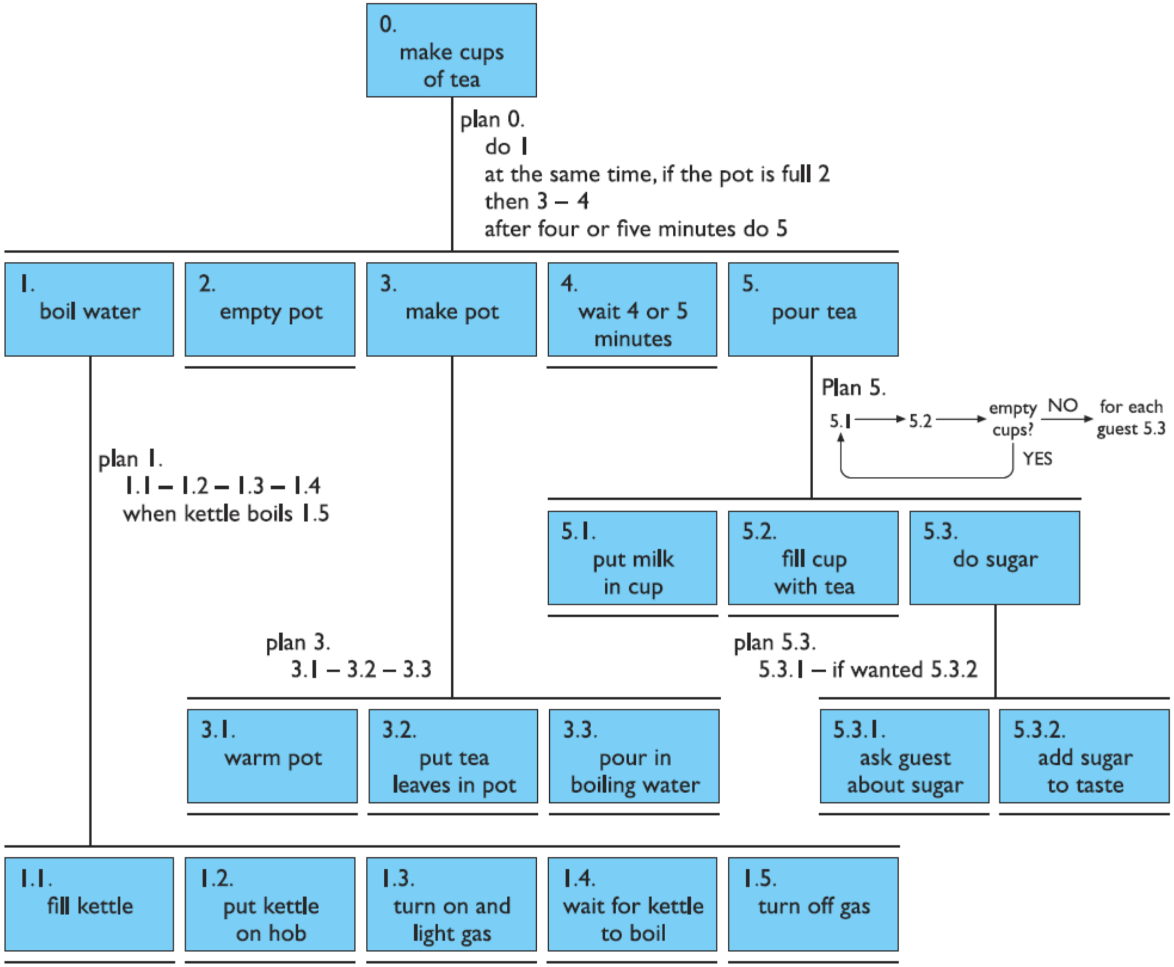
User-Centered Design - Task analysis

- Task decomposition
  - Hierarchical task analysis (HTA)



User-Centered Design - Task analysis

- Task decomposition
  - Hierarchical task analysis (HTA)



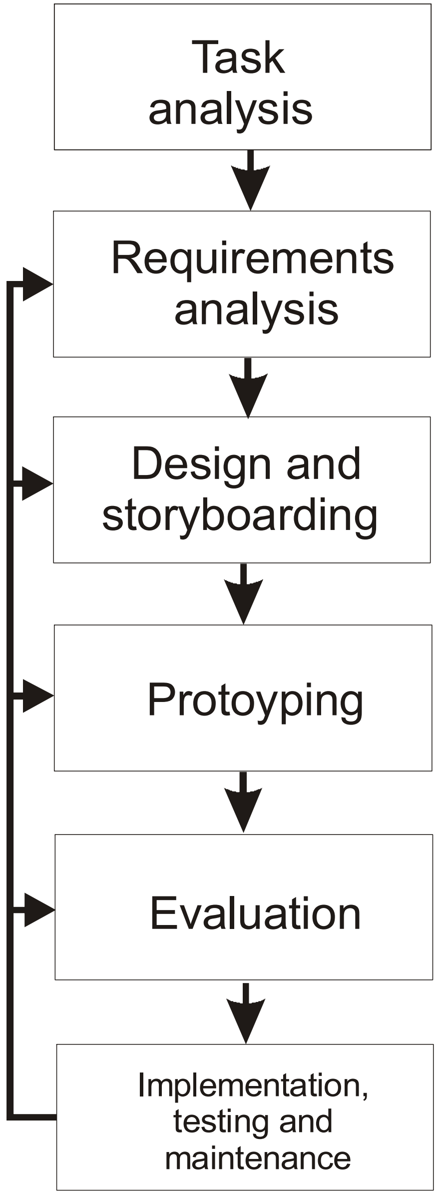
User-Centered Design

- Requirements analysis
  - Iterative process of collecting information and research
  - Deep analysis of collected requirements
- Requirements
  - Functional
  - Related to data
  - Environmental
  - Related to user
  - “Useful” and “Usable”
- Requirement -> justification -> metrics for evaluation
- Compromise solution to fit all

User-Centered Design

- Design based on requirements analysis
  - How are we going to realize all requirements and tasks?
  - Several alternatives
    - QOC method (Question Option Criteria)
    - Example
      - Question: How should we set (program) the size of fonts in the table?
      - Alternatives:
        - CSS commands in external file
        - CSS commands in the header
        - Inline style (in HTML tags in the body)
      - Criteria: What is a common pratice for this solution? What is the clearest solution?

User-Centered Design



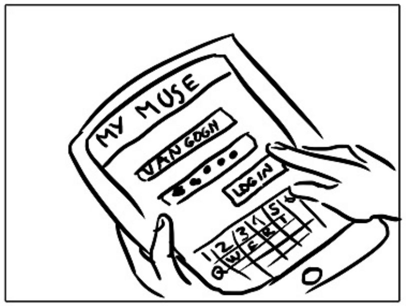
- Storyboarding
  - Alternative to define system's tasks
  - Simple pictures of different scenarios
    - It is not about pretty pictures
    - Star people (Bill Verplank)
  - Setting
    - People involved, environment, tasks
  - Sequence
    - Steps
  - Satisfaction
    - Motivation for people to use the system
    - What can be accomplished?

User-Centered Design

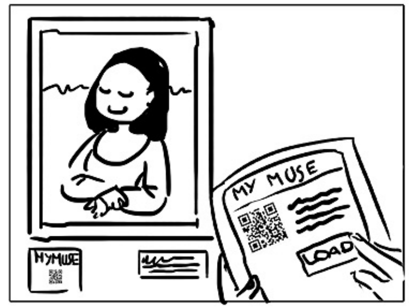
- Storyboarding
  - Holistic focus
    - How an interface accomplishes a task
    - Avoids commitment to a particular user interface
    - Helps determine a common goal for all stakeholders
  - Should be limited in time

User-Centered Design

- Storyboarding

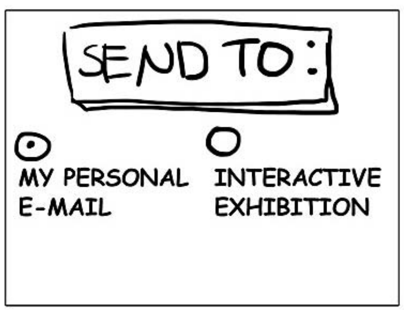


SINCE "MY MUSE" REQUIRES REGISTRATION, LOG IN IS ALWAYS A FIRST STEP

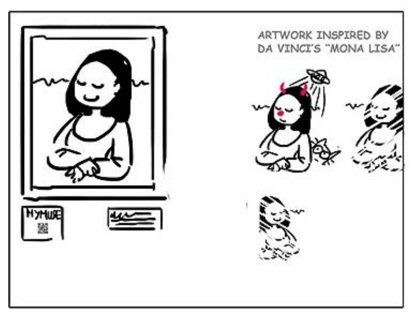


TO BEGIN CREATIVE PROCESS, USER NEEDS TO SCAN A CODE UNDER THE MUSEUM ARTEFACT

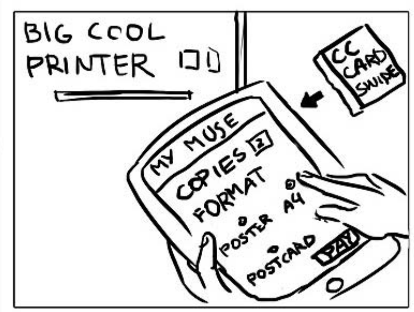
IMAGE LOADED AND OPENED IN THE GRAPHIC EDITOR OF "MY MUSE APP"



WHEN CHOOSING "FINISHED" USER IS PRESENTED WITH OPTIONS FOR SHARING



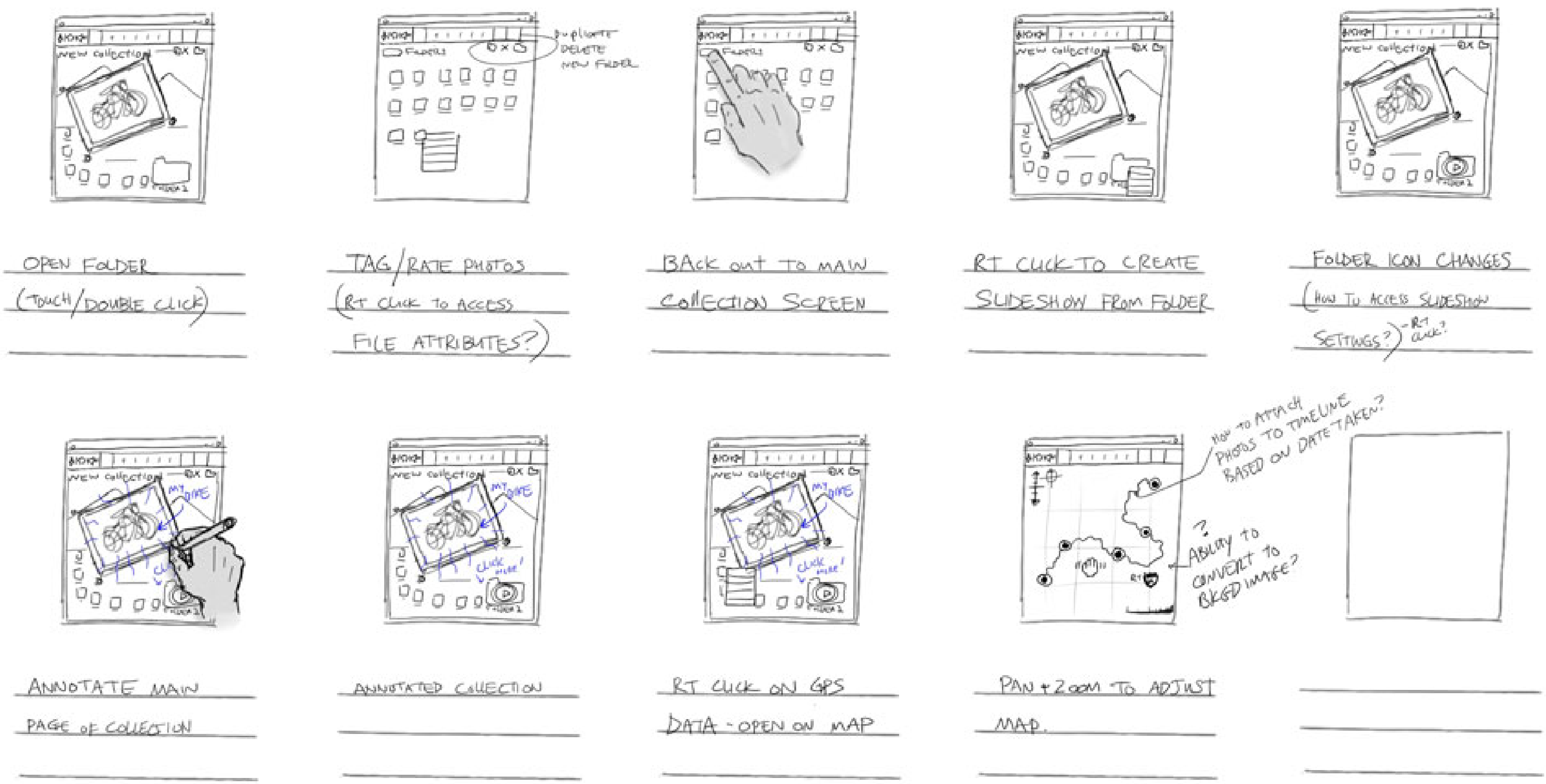
IF ONE CHOSES PUBLIC EXHIBITION, IMAGE APPEARS ON INTERACTIVE WALL



BEFORE LEAVING VISITOR CAN PRINT OUT HIS ARTWORK AND PAY BY CREDIT CARD SWIPER

User-Centered Design

- Storyboarding



User-Centered Design

- Sources of information
  - Collection, analysis and organization of data about users
  - Iterative process (limitations?)
  - Documentation
    - Existing manuals, instruction booklets, etc.
    - How people are supposed to perform task
    - Functions of the device
    - Basic actions and objects involved in a task
    - Very good for preparing interviews and observational studies

User-Centered Design

- Sources of information
  - Observation
    - Watching people and hanging out with them
    - Apprentice
      - Get to know all the steps and practices in detail
      - Validation with the people being observed
    - Formal observation
      - In the field or in the laboratory
      - Passive or active
    - Special attention workarounds, hacks and ***errors***
      - Personal notes and stickers
    - The difference between what people say and what they do

"You can observe a lot just by watching"
Yogi Berra

User-Centered Design

- Sources of information
  - Interviews
    - Participants
      - Representative of target users
      - Domain experts (possibly after observation)
      - Current users of a similar system
      - Non-users
    - Bad questions
      - “Is this feature important to you?”
      - “What would you like in this interface?”
      - How often they do things?
      - What do people want in a hypothetical scenario?
      - Binary questions
      - How much they like things on an absolute scale?

User-Centered Design

- Sources of information
  - Diary studies
    - To be completed at a specified time or interval
    - Journals, cameras, voice, video
    - Better time management than direct observation
    - Easier tools provide better results
      - Sometimes some practice or training is required
  - Experience sampling
    - “Ping” people at regular intervals to get feedback
    - Various technology possibilities for pinging

User-Centered Design

- Sources of information - USERS
  - Lead users
    - Very enthusiastic
    - Act as co-designers
    - Ready to update their equipment to adapt new technology
  - Extreme users
    - Very specific cases (1000 emails per day)
  - “Normal” users
  - Personas
    - A model of a person (demographic information, personal motivation, beliefs, intentions, behavior and goals)
    - Photo, name, personal story
    - Helps to build empathy

Interaction design

Prototyping

User-Centered Design

- Prototyping
  - Concrete representation of a part or of an entire interactive system
  - Self-explainable tangible artifact
  - Iterative process
  - Helps for
    - Creating and exchanging ideas
    - Facilitation of the exploration of a design space (designers, engineers, managers, programmers, customers, etc.)
    - Early evaluation of the system
  - Four dimensions
    - Representation
    - Precision
    - Interactivity
    - Evolution

User-Centered Design

- Prototyping
  - Representation
    - Offline (made without computer)
      - Rapid, simple, inexpensive
      - Best for exploring design space (alternatives)
      - Can be created by everybody
    - Online (software)
      - Intermediary idea
      - Require computer skills
      - Limitations of programming language
  - Precision
    - Details (pros and cons)
      - Relevant and irrelevant
    - Reflects the maturity of the prototype

User-Centered Design

- Prototyping
  - Interactivity
    - Contradictory with precision
    - A person (designer) provides feedback
    - Fixed, fixed-path, open
  - Evolution
    - Rapid prototypes
      - Early stages of design
      - Inexpensive and easy
    - Iterative prototypes
      - Evolving through design stages
      - Reflect current design problems and open questions
      - Discarded at the end
    - Evolutionary prototypes
      - Evolve into a part or into an entire system
      - Require more planning and practice
      - Software design

User-Centered Design

- Prototyping strategies
  - Horizontal prototype
    - One entire layer of the design at the same time
    - Wide set of features without real functionalities
    - Overall picture from the users‘ perspective
    - Addressed problems
      - Consistency, coverage, redundancy
  - Vertical prototype
    - Limited set of features with fully supported functionalities
    - Proof that the designer can implement full, working system (from UI to the backend)
    - High-precision software prototypes
  - Task-oriented prototype
    - A series of predefined (hardcoded) tasks
  - Scenario-based prototype
    - Based on real-use scenarios

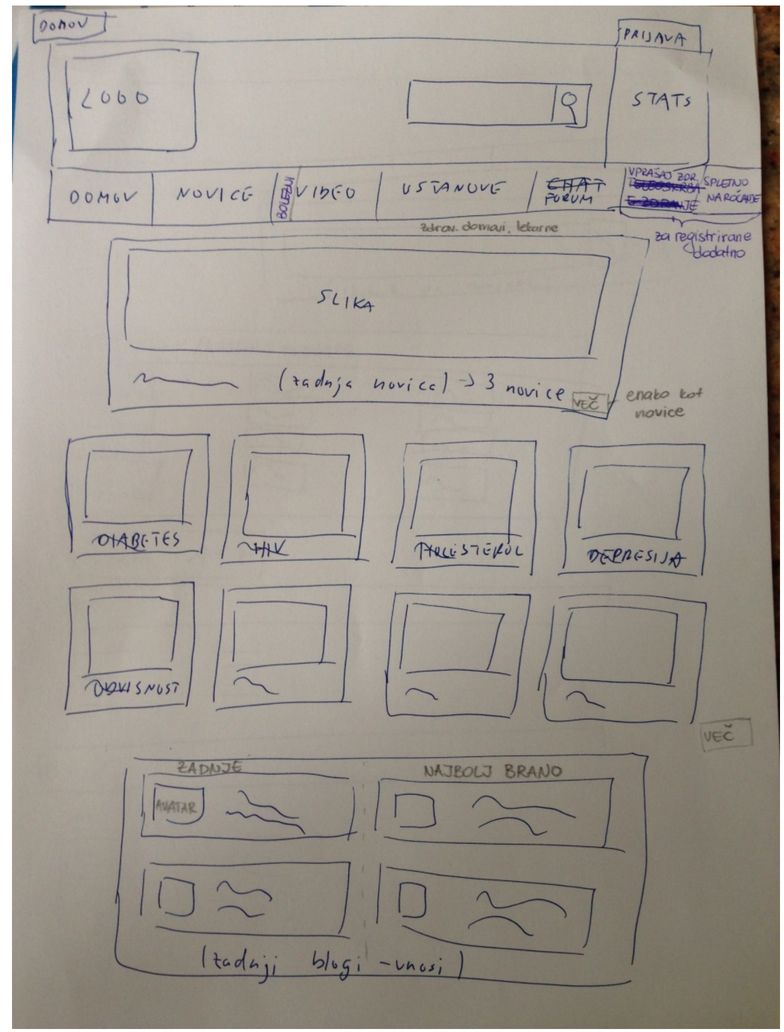
User-Centered Design

- Rapid prototyping
  - PROS
    - Developed very quickly
    - Covers more ideas and alternatives
    - Concrete baseline for communication between all parties
    - Encourages early user participation and involvement
    - „Rapidity“ depends on the context of the project and design stage
  - CONS
    - Needs cooperation of many people
    - Programmers may lose discipline
    - Lack of abstractive thinking (managers, some users)
    - Can be overworked
    - Over-promising prototypes

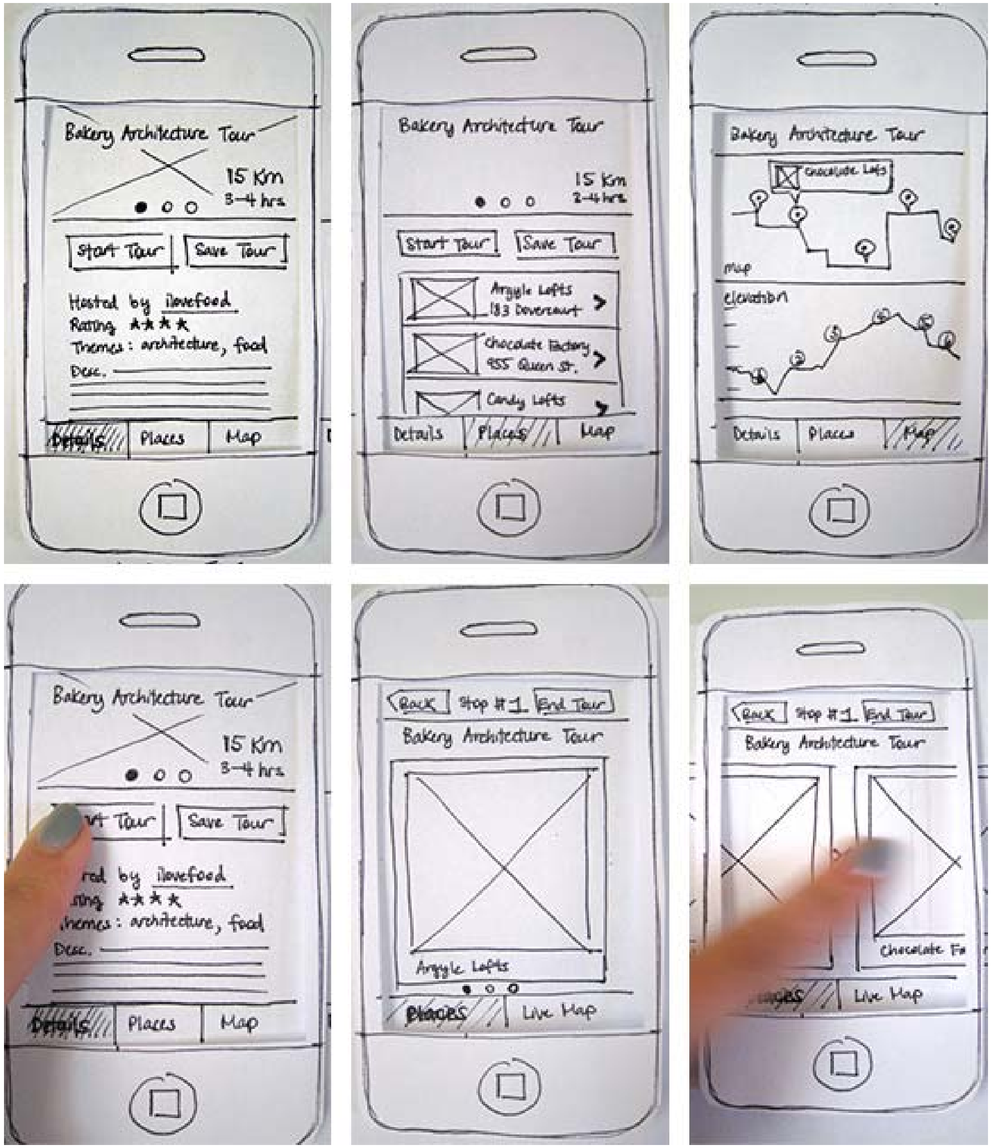
User-Centered Design

- Rapid prototyping
  - Paper and pencil
    - Quick sketches on the paper
    - Consequential set of interface pictures
    - Reusable components (buttons, menus, sliders, etc.)
    - Verbal description (imagination) of difficult elements (progress indicators, right mouse menus, hyperlinks, etc.)
    - Background poster board
      - Board for desktop computer
      - Physical mockup for tablet or mobile phone
    - Familiar operating system elements

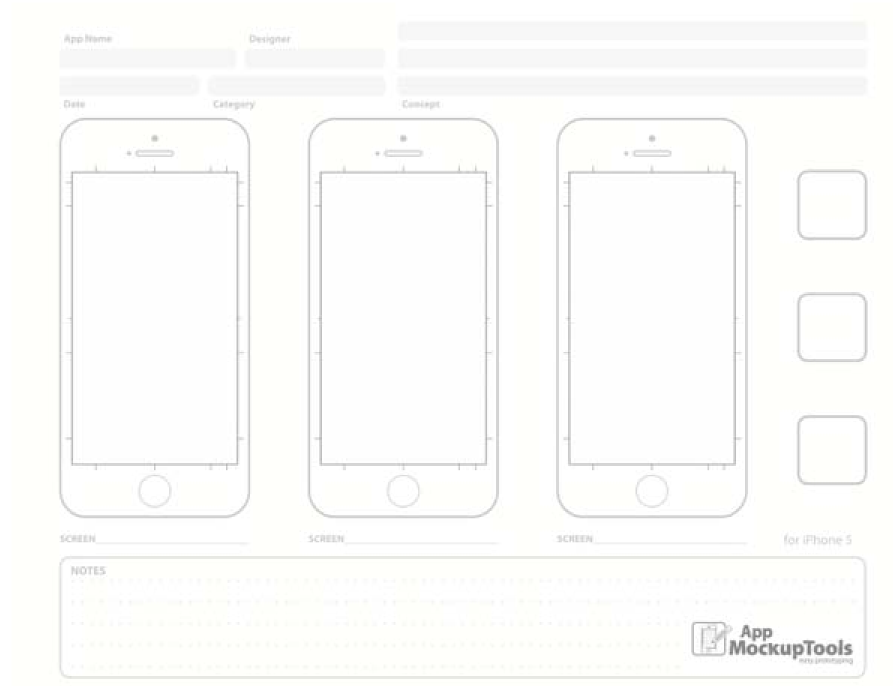
User-Centered Design



User-Centered Design



User-Centered Design



www.uistencils.com
https://www.graffletopia.com/stencils/413
http://www.appmockuptools.com/

User-Centered Design

User-Centered Design

- Rapid prototyping
  - Digital mock-up
    - Power Point presentation with screenshots
    - Wireframing
    - Static HTML pages
    - Mockup tools
      - Balsamiq (http://www.balsamiq.com/products/mockups#)
      - Lucidchart (https://www.lucidchart.com/pages/examples/android_mockup_tool)
      - Mockup Builder (http://mockupbuilder.com/)
      - Wireframesketcher (http://wireframesketcher.com/)
      - Mockingbird (http://gomockingbird.com/)
      - Yeblon (http://yeblon.com/androidmockup/)
    - Mobile device apps
      - AppCooker (http://www.appcooker.com/)
      - POP – Prototyping on Paper (https://popapp.in/)

User-Centered Design

- Rapid prototyping
  - Faking it
    - Video prototyping
      - Cheap and fast
      - Great communication tool
      - Self-explanatory
      - Connects designs and tasks
        - Makes sure all interface elements are present
      - Informal or formal prototypes (changing fidelity)
        - Just and idea or effective marketing tool
      - Steps
        - Outline or storyboard
        - Equipment (camera, interactive devices, people, realistic locations)
        - Interfaces can be paper, digital mock-ups, invisible, etc.

User-Centered Design

- Rapid prototyping
  - Faking it
    - Wizard of Oz
      - Just user interface (front end)
      - Interactive application with fake response
        - Sophisticated and even future technology
      - Less effort than real code
        - Easy to make multiple variations
      - Hi-fidelity or low-fidelity interface
      - Best examples: speech interfaces, search algorithms, etc.
      - Fake response can be eventually be replaced by real responses
      - Running the test with Wizard interface
        - Facilitator
        - Wizard
        - User feedback (think aloud, retrospective, heuristic evaluation)

User-Centered Design

- Rapid prototyping
  - Quality vs. quantity
    - Producing one „fancy“ prototype or multiple low-fidelity prototypes
    - Separating ego from the artifact
    - Parallel enables comparison and transfer
    - Benefits of comparing multiple ideas
      - More individual exploration
      - Better in-group communication
      - Alternatives provide a vocabulary

Evaluation

Expert analysis

Evaluation

- Evaluation
  - Should occur throughout the design life cycle
  - The goal is to assess
    - Extent and accessibility of the system’s functionality
    - Users’ experience of the interaction
    - Identify any specific problems with the system
  - Formal
    - Models and formulas to measure success and accuracy
  - Automated
    - Automatic measurement
  - Empirical
    - Tests with real users

Evaluation

- Evaluation
  - Evaluation through expert analysis
    - Performed on any type of interface
      - Design specification, storyboards and prototypes or full implementations
    - Before user testing
    - Before redesigning
      - To get evidence on problems you‘re aware of
    - Before release
  - Two techniques
    - Cognitive walkthrough
      - Task-specific
    - Expertise and heuristic feedback
      - Holistic view to catch potential problems

Evaluation

- Cognitive walkthrough
  - Proposed by Peter Polson and his colleagues
    - Based on the process of code walkthrough in software engineering
  - Detailed review of a sequence of actions
    - Focus is on learning through exploration
    - Steps required by the interface to accomplish a task
    - Evaluators go through every step and provide a feedback about why that step is good or not
  - Input for evaluators
    - Specification or prototype
    - Description of task(s)
    - Information about the users (experience, knowledge)
    - Complete, written list of actions needed to complete the task (exploration ???)

Evaluation

- Cognitive walkthrough
  - Evaluators answer the following four questions for each step
    - Is the effect of the action the same as the user’s goal at this point?
      - Each action will have a specific effect
    - Will users see that the action is available?
      - Example: Is the button visible when it is needed?
    - Once users have found the correct action, will they know it is the one they need?
      - Example: The button is visible, will they users know this is “the one”?
    - After the action is taken, will users understand the feedback they got?
      - Is feedback ok?
  - Standard evaluation forms
  - Negative answers should be documented on a separate usability list?

Evaluation

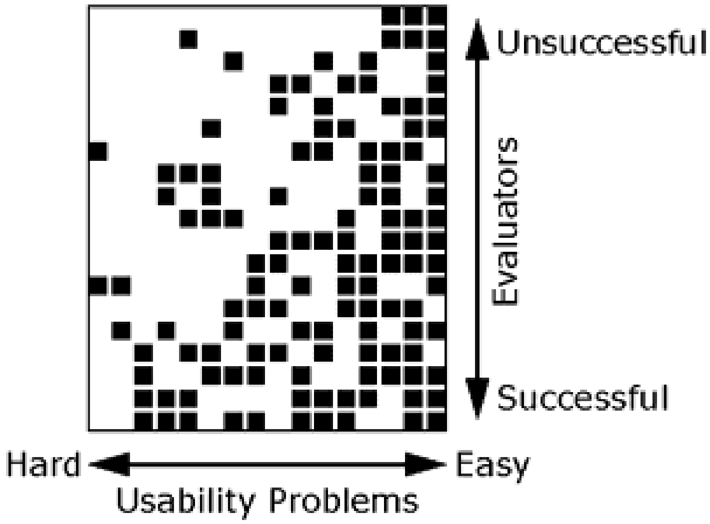
- Heuristic Evaluation
  - Developed by Jakob Nielsen
  - Identification of usability problems in design
  - Small set of expert evaluators (3-5)
    - Independent check-ups based on heuristic principles
    - 1-2 hours for each evaluator
    - Exchange of experiences and aggregation of findings
  - Can be performed on real software or prototypes
  - Results are pre-interpreted

Evaluation

- Heuristic Evaluation
  - Nielsen‘s ten heuristics
    1. Visibility of system status
    2. Match between system and the real world
    3. User control and freedom
    4. Consistency and standards
    5. Error prevention
    6. Recognition rather than recall
    7. Flexibility and efficiency of use
    8. Aesthetic and minimalist design
    9. Help users recognize, diagnose and recover from errors
    10. Help and documentation

Evaluation

- Heuristic Evaluation
  - Process
    - Step through UI several times
      - Flow, architecture, details
      - Pre-evaluation training
      - Evaluation
      - Severity rating
      - Debriefing
    - Different aspects should be evaluated
      - Based on heuristics
      - Additional domain-specific rules and requirements
      - Category-specific heuristics
    - Violations are info for improvement
    - Different evaluators find different problems
    - No evaluator could find all problems
      - Single evaluator (35% of usability problems)
      - Some find more than others
      - Serious (critical problems) are found more often



Evaluation

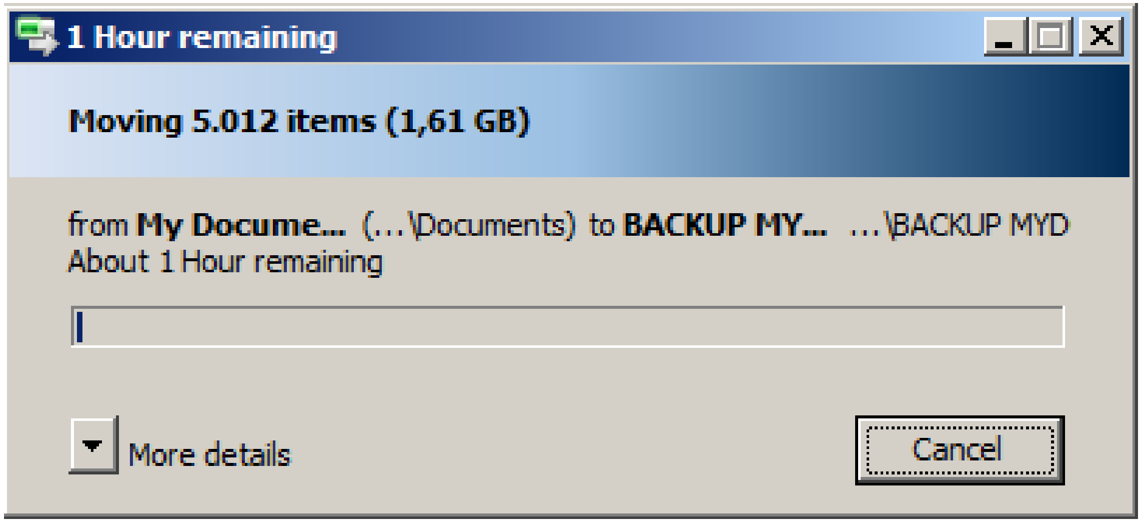
- Heuristic Evaluation
  - Two or more passes for each evaluator
    - First pass to get feel and learn the flow
    - Second pass to pay attention to details
  - Evaluators should be supplied with scenarios and instructions (when needed)
  - Each evaluator produces list of problems
    - References to concrete heuristic principles
    - Separate spec for each problem (violation)
      - To avoid duplications and to identify non-fixable problems
    - Different types of problems
      - Wrong or strange names, wrong flow or architecture, something is missing, etc.

- Heuristic Evaluation
  - Severity rating
    - 0: Don't agree that this is a problem
    - 1: Cosmetic problem
    - 2: Minor usability problem
    - 3: Major usability problem (important to fix)
    - 4: Usability catastrophe (urgent to fix)
  - Example
    - Issue: Unable to edit info on age
    - Description: When you enter the app for the first time, you enter info on your date of birth (to calculate your age). You can not change that afterwards.
    - Severity: ?
    - Heuristics violated: ?

- Heuristic Evaluation
  - Debriefing
    - Between evaluators, observers, designers (and development team)
    - Discussion on general and specific problems and properties of UI
    - Suggestions for potential improvements
    - Assessment of effort to fix problems
      - Ignore “kayak“ problems
      - Adding new elements rarely solves the problem
      - “Low-hanging fruit“
      - “Don‘t throw the baby out with the dishes“
    - Brainstorm solutions

User-Centered Design

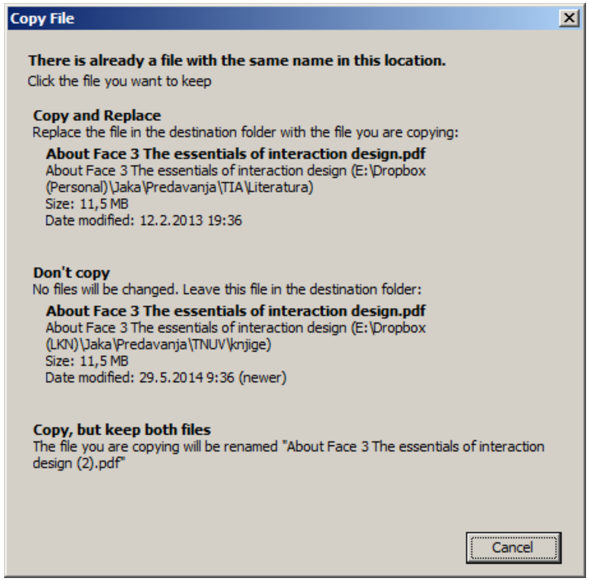
- Nielsen‘s design heuristics
  1. Visibility of system status
     - Time
       - < 1s: show outcome
       - ~ 1s: just info about ongoing activity
       - >> 1s: fractional progress or remaining time



Evaluation

- Nielsen‘s design heuristics
  1. Visibility of system status
     - Space

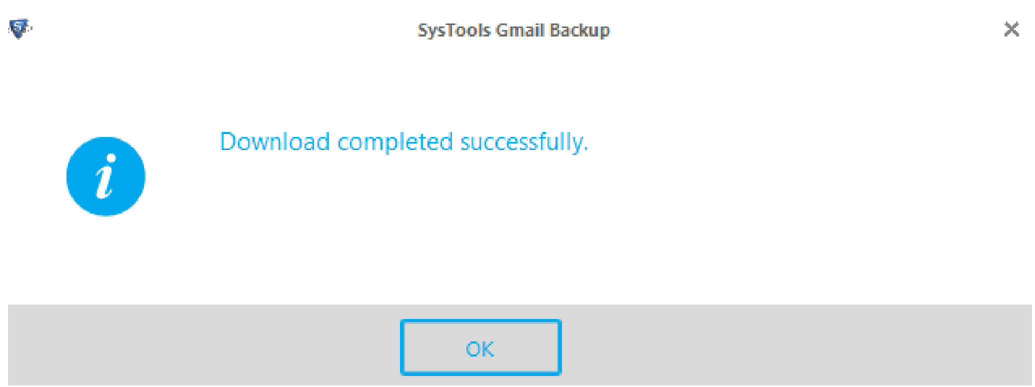
     - Change



Evaluation

- Nielsen‘s design heuristics
  1. Visibility of system status
     - Next steps

     - Completion



Evaluation

- Nielsen's design heuristics
  2. Match between system and the real world
     - Use of familiar metaphors and language (from the real world)
       - Language of users vs. language of developers
     - Use of conventions

4	Zap.št	Identifikacijska številka posamezne enote	Številka stanovanja ali poslovnega prostora	Ime in priimek etažnega lastnika	Površina posamezne enote v m² - BRUTO površina	Solastniški delež BRUTO - neto tlorisna površina v %	Solastniški delež BRUTO - neto tlorisna površina v % - samo SD	Površina posamezne enote v m² - NETO površina	Ogrevalna površina v m²	Solastniški delež OGREVALNA POVRŠINA v %
5	1.	2083-920-1	1	[redacted]	62,21	2,062	2,856	52,44	52,44	2,10
6	2.	2083-920-2	2		76,68	2,542	3,520	61,92	61,92	2,48
7	3.	2083-920-3	3		73,06	2,422	3,354	63,61	63,61	2,55
8	4.	2083-920-4	4		68,16	2,260	3,129	52,44	52,44	2,10
9	5.	2083-920-5	5		77,64	2,574	3,564	61,92	61,92	2,48
10	6.	2083-920-6	6		65,48	2,171	3,006	56,03	56,03	2,25
11	7.	2083-920-7	7		46,85	1,553	2,151	37,40	37,40	1,50
12	8.	2083-920-8	8		85,01	2,818	3,902	57,77	57,77	2,32
13	9.	2083-920-9	9		143,47	4,756	6,586	69,19	69,19	2,78
14	10.	2083-920-10	10		65,11	2,158	2,989	54,38	54,38	2,18
15	11.	2083-920-11	11		47,86	1,587	2,197	38,41	38,41	1,54
16	12.	2083-920-12	12		49,53	1,642	2,274	40,08	40,08	1,61
17	13.	2083-920-13	13		65,17	2,160	2,992	54,44	54,44	2,18
18	14.	2083-920-14	14		143,64	4,762	6,594	68,78	68,78	2,76
19	15.	2083-920-15	15		83,95	2,783	3,854	57,77	57,77	2,32
20	16.	2083-920-16	16		174,05	5,770	7,990	137,82	137,82	5,53
21	17.	2083-920-17	17		103,38	3,427	4,746	85,87	85,87	3,44
22	18.	2083-920-18	18		44,65	1,480	2,050	35,98	35,98	1,44
23	19.	2083-920-19	19		112,32	3,723	5,156	95,36	95,36	3,82
24	20.	2083-920-20	20		114,54	3,797	5,258	94,42	94,42	3,79
25	21.	2083-920-21	21		136,54	4,526	6,268	102,45	102,45	4,11
26	22.	2083-920-22	22		88,59	2,937	4,067	72,45	72,45	2,91
27	23.	2083-920-23	23		57,28	1,899	2,629	41,78	41,78	1,68
28	24.	2083-920-24	24		132,82	4,403	6,097	110,53	110,53	4,43
29	25.	2083-920-25	25		60,43	2,003	2,774	51,94	51,94	2,08

DOM SISTEMI, d.o.o., Ulica Lojzeta Hrovata 3a, 4000 KRANJ
Objekt: PSO Breška pot 2a in 2b, Preddvor
Površine delov stavbe bruto, neto, ogrevalna površina

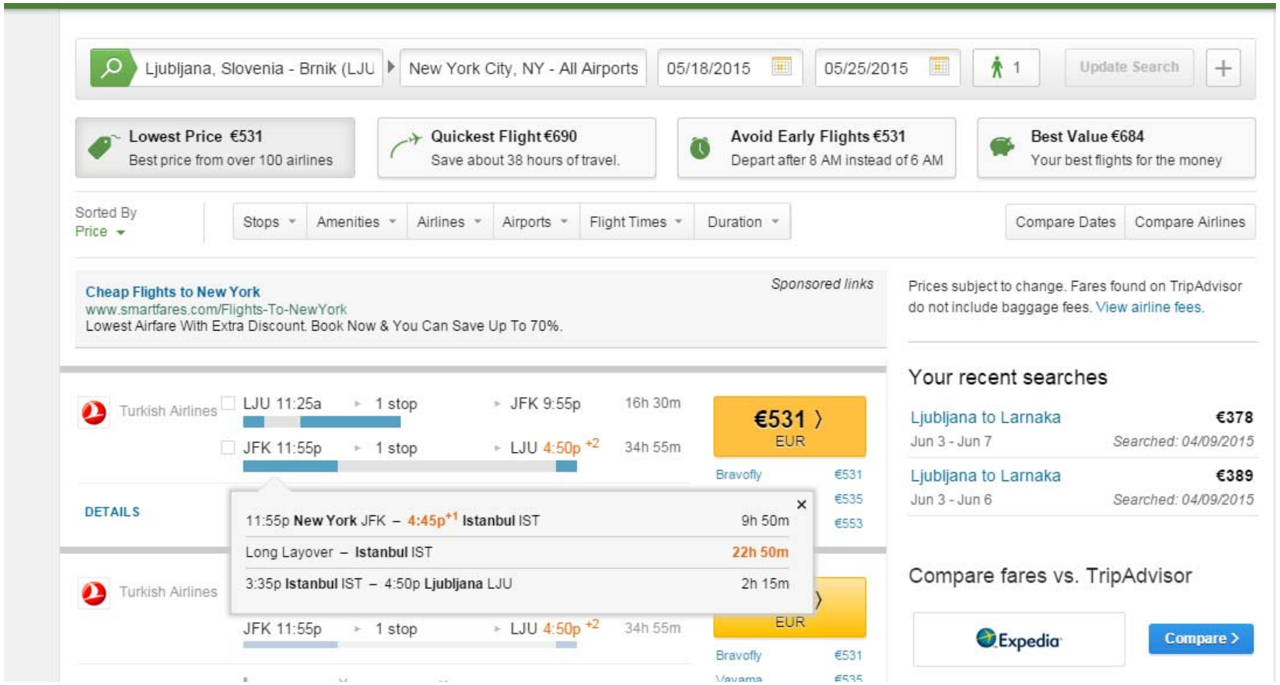
Zap.št	Identifikacijska številka posamezne enote	Številka stanovanja ali poslovnega prostora	Ime in priimek etažnega lastnika	Površina posamezne enote v m² - BRUTO površina	Solastniški delež BRUTO - neto tlorisna površina v %
1.	2083-920-1	1	[redacted]	62,21	2,062
2.	2083-920-2	2		76,68	2,542
3.	2083-920-3	3		73,06	2,422
4.	2083-920-4	4		68,16	2,260
5.	2083-920-5	5		77,64	2,574
6.	2083-920-6	6		65,48	2,171
7.	2083-920-7	7		46,85	1,553
8.	2083-920-8	8		85,01	2,818
9.	2083-920-9	9		143,47	4,756
10.	2083-920-10	10		65,11	2,158
11.	2083-920-11	11		47,86	1,587
12.	2083-920-12	12		49,53	1,642
13.	2083-920-13	13		65,17	2,160
14.	2083-920-14	14		143,64	4,762
15.	2083-920-15	15		83,95	2,783
16.	2083-920-16	16		174,05	5,770
17.	2083-920-17	17		103,38	3,427
18.	2083-920-18	18		44,65	1,480
19.	2083-920-19	19		112,32	3,723
20.	2083-920-20	20		114,54	3,797
21.	2083-920-21	21		136,54	4,526
22.	2083-920-22	22		88,59	2,937
23.	2083-920-23	23		57,28	1,899
24.	2083-920-24	24		132,82	4,403
25.	2083-920-25	25		60,43	2,003
26.	2083-920-26	26		763,44	25,308
27.	2083-920-27	27		5,25	0,174
28.	2083-920-28	28		69,46	2,303
				3016,57	100,000

Stanovanjski del	2178,42	
TRIS COOP, d.o.o.		
Mercator		

Evaluation

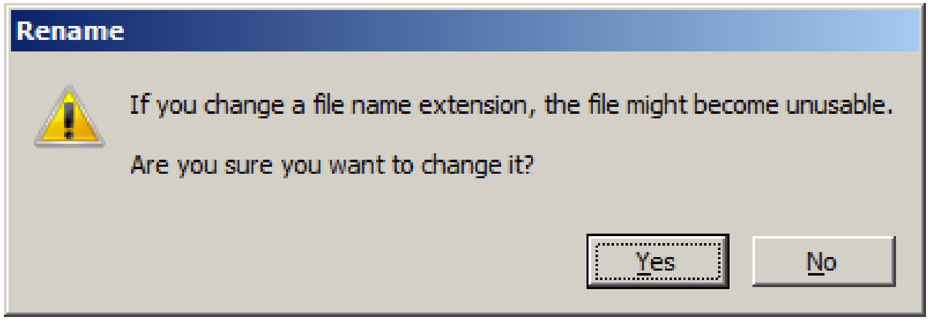
- Nielsen's design heuristics
  3. User control and freedom
     - Exits from mistaken choices, ability to undo and redo, not forcing people to predefined paths and procedures, etc.
     - First time users vs. experts
     - Freedom to explore

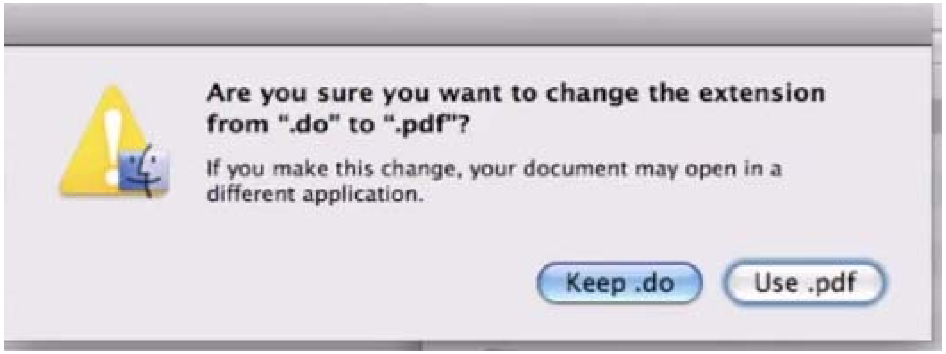
Domov / Avto-moto / Dodatna oprema / Oprema za motorna kolesa

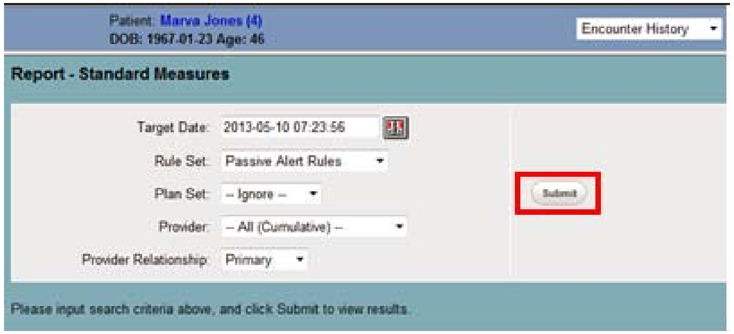


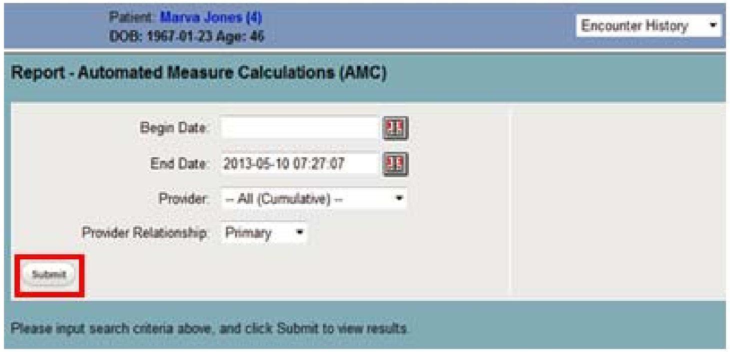
Evaluation

- Nielsen's design heuristics
  4. Consistency and standards
     - Consistent layout (MS Office)
     - Consistent names
     - Clear choices

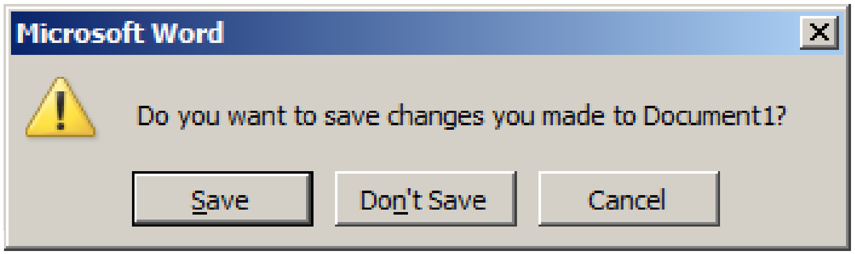


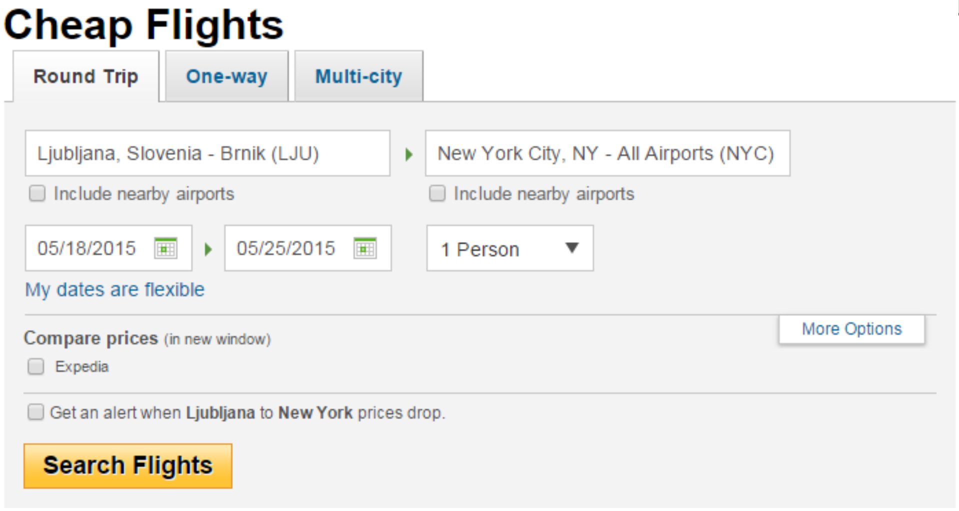






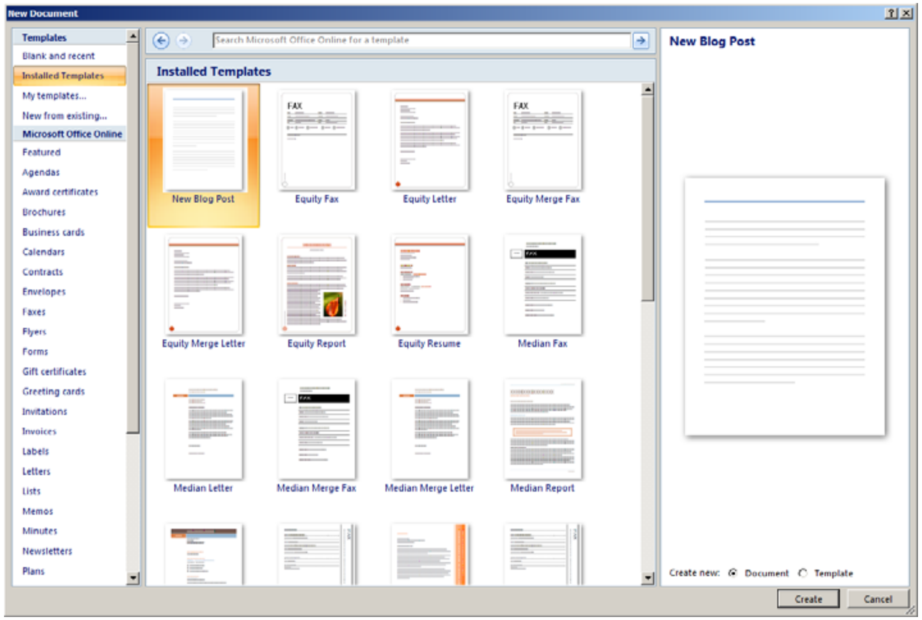
- Nielsen‘s design heuristics
  5. Error prevention
     - Data loss
     - Data clutter
     - Confusing flow
     - Well formed input





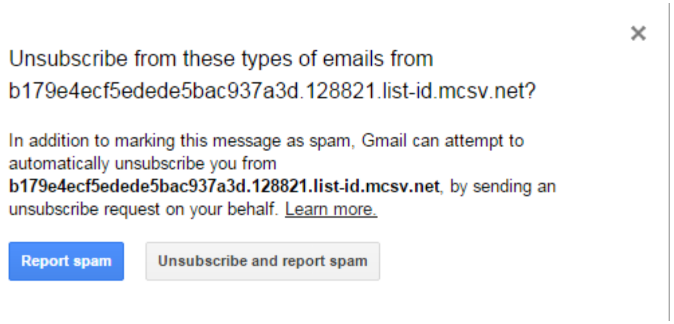
Evaluation

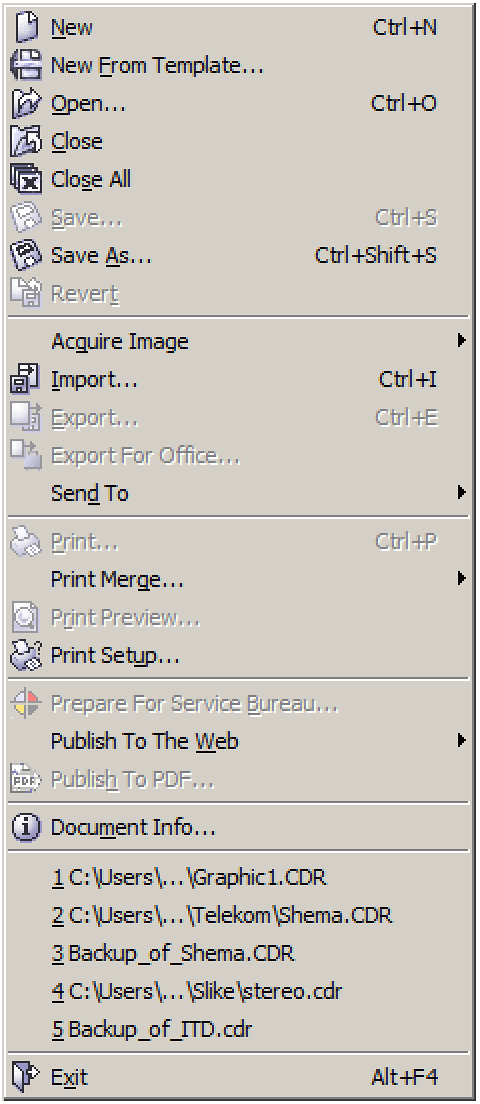
- Nielsen‘s design heuristics
  6. Recognition rather than recall
     - Objects, options, actions and directions should be visible and easy to reach
     - Avoid codes
     - Avoid extra options and hurdles
     - Use of previews



Evaluation

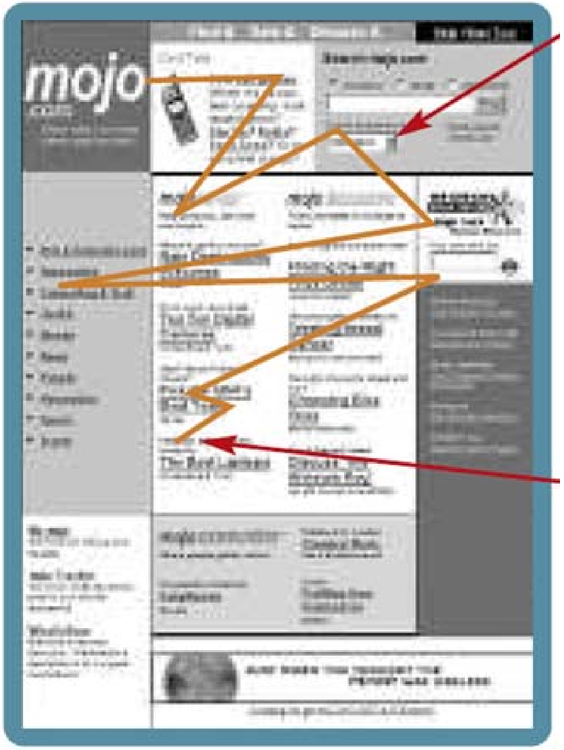
- Nielsen's design heuristics
  7. Flexibility and efficiency of use
     - Shortcuts for expert users
     - Ambient information
     - Flexible proactivity
     - Recommendations
       - Should be relevant





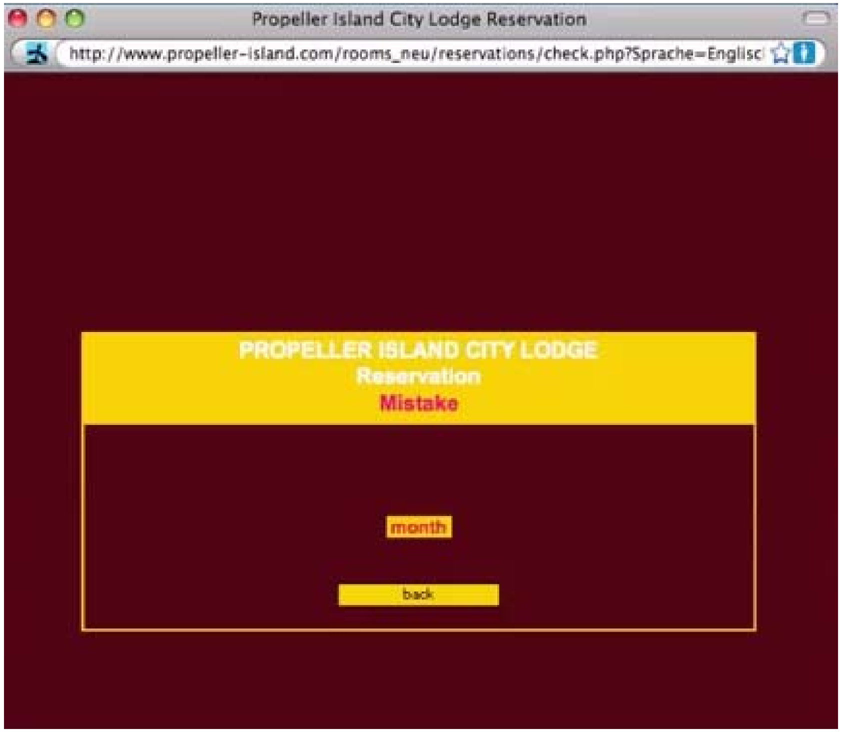
Evaluation

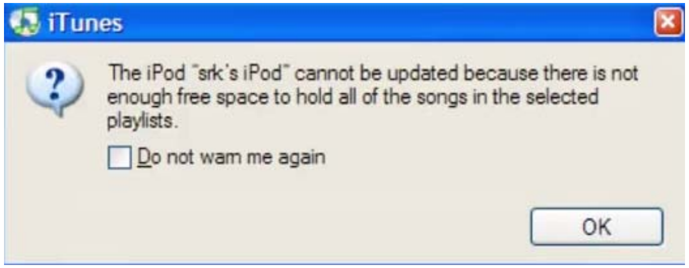
- Nielsen's design heuristics
  8. Aesthetic and minimalist design
     - Placement of relevant information
     - Signal-to-noise ratio
     - Redundancy

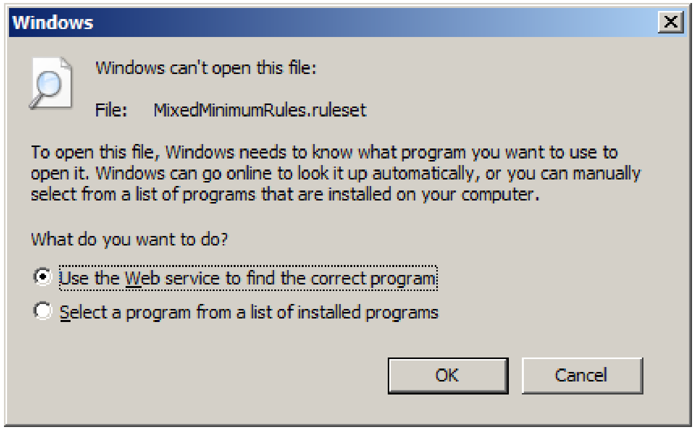


Evaluation

- Nielsen's design heuristics
  9. Help users recognize, diagnose and recover from errors
     - Problems when filling in the forms
     - Indicate the correct path (step forward)

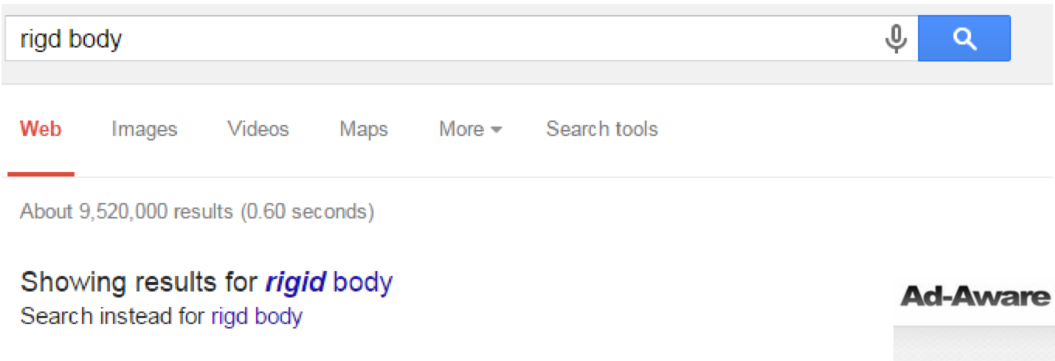


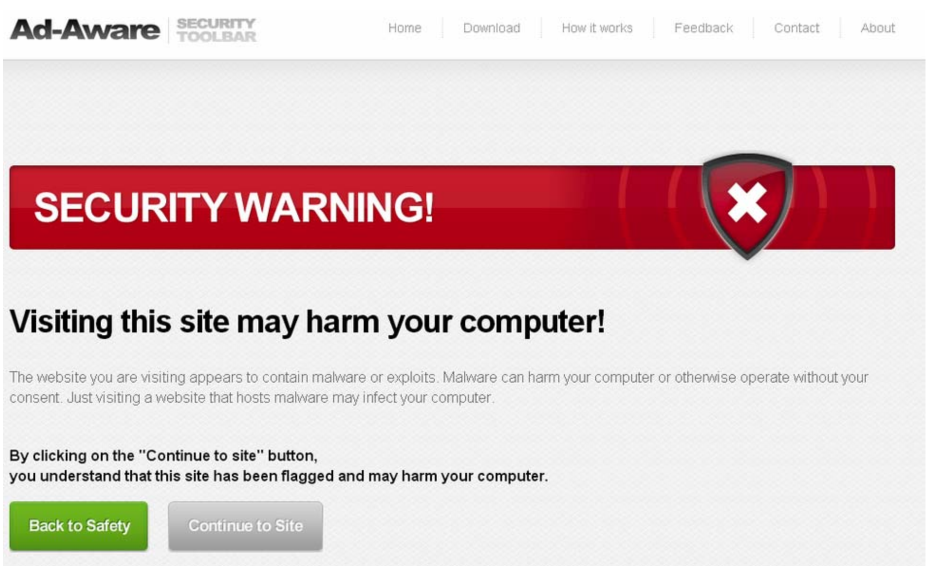




Evaluation

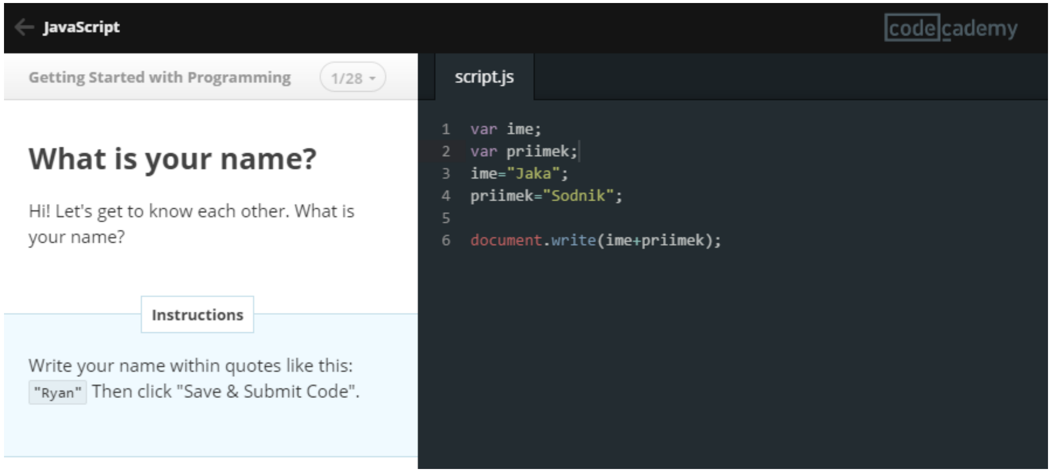
- Nielsen's design heuristics
  9. Help users recognize, diagnose and recover from errors
     - Propose an alternative
     - Recognize and warn about errors

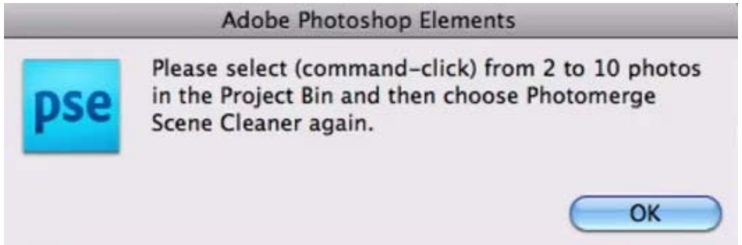


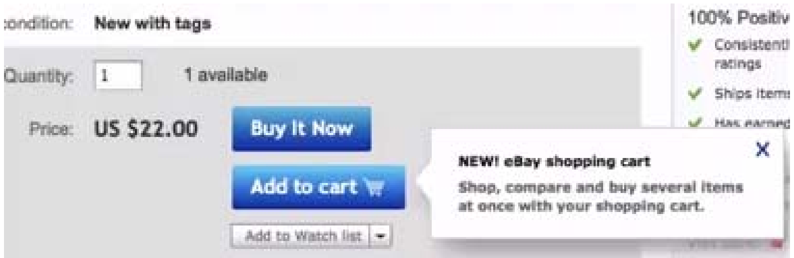


Evaluation

- Nielsen‘s design heuristics
  9. Help and documentation
     - Learning with examples
     - Help choices with examples
     - Show the steps
     - Indicate changes and new features
     - Clear help
     - “Funny” elements







Evaluation

User studies

Evaluation

- Usability testing
  - Evaluate a product by testing it on users
  - Comparing new approach to some industry standard
    - Controlled comparison
- “Do you like my interface?“
  - Please the experimenter bias
  - The need for some kind of comparison
  - Measurements
    - Frequency of events, duration (“How often does X occur?“)
    - Correlations (“Do X and Y co-vary?“)
    - Causes (“Is Y caused by X?“)
  - Independent variables (manipulations)
    - Experiment conditions
  - Dependent variables (measures)
    - Task completion time, accuracy, recall, etc.
  - Internal validity (precision)

Evaluation

- Usability testing: iPhone example

Friday, August 17, 2007 11:03 AM PT Posted by Harry McCracken

A Not-Very-Useful iPhone Keyboard Study

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SLASHDOT IT DIGG THIS DEL.ICIO.US NEWSVINE

Research firm User Centric has released a study that tries to gauge how effective the iPhone's unusual on-screen keyboard is. The goal is certainly a noble one, but I can't say that the survey's approach results in data that makes much sense.

User Centric brought in twenty owners of other phones--half who had ones with QWERTY keyboards, and half who had ordinary numeric phone keypads. None were familiar with the iPhone. The research involved having the test subjects enter six sample text messages with the phones they already had, and six with an iPhone.

Logical end result: These iPhone newbies took twice as long to enter text with an iPhone as they did with their own phones, and made lots more typos.

Evaluation

- Usability testing: iPhone example
  - Independent variable: input style
  - Dependent variable: typing speed (words per minute)
  - Test subjects: 20 people (10 with QUERTY keyboards and 10 with numeric keyboards)
    - No experience with iPhone
  - Six messages in each condition
  - Results
    - iPhone was two-times slower than the older device
  - Problems
    - Unfair comparison (experts vs. novice users)
    - Good info on the effect of practice
    - Significant difference?

Evaluation

- Usability testing: iPhone – new experiment
  - Three conditions
    - New group with expert iPhone users
  - Dependent variables
    - Speed
    - Accuracy
  - Results
    - iPhone users and QUERTY users were equally fast
    - Numeric users were much slower
    - iPhone users make much more errors
  - Potential problems
    - Who were the users?
    - Problems of groups selections?

Evaluation

- Assigning participants to conditions
  - Between subject design
    - Test subjects are assigned to one of the conditions
    - Control group
    - Individual differences (bad testing population)
    - We need a lot of test subjects
  - Within subject design
    - All test subjects test participate in all conditions
      - We easily identify “bad subjects“
    - Ordering, learning effect
    - We need less test subjects
  - Counterbalancing
    - Changing the order of conditions
    - Changing tasks to eliminate order effect
  - Individual differences
    - Random assignment

Evaluation

- Assigning participants to conditions
  - Three or more conditions
  - Latin Square
    - Each condition appears precisely once in each row and each condition
    - The number of participants should be a multiple of the number of conditions

A	B	C
B	C	A
C	A	B

A	B	C	D	E
B	C	D	E	A
C	D	E	A	B
D	E	A	B	C
E	A	B	C	D

Evaluation

- Assigning participants to conditions
  - Balanced Latin Square
    - Possible to construct for any even number of conditions

A	B	C	D
B	C	D	A
C	D	A	B
D	A	B	C

A	B	D	C
B	C	A	D
C	D	B	A
D	A	C	B

    - Procedure
      - 1st line: A, B, n, C, n-1, D, n-2, etc.
      - Entries in 2nd and subsequent columns are in order (following first line)
    - Example: 6x6 Latin Square

- Assigning participants to conditions
  - Example: 6x6 Latin Square

A	B	F	C	E	D
B	C	A	D	F	E
C	D	B	E	A	F
D	E	C	F	B	A
E	F	D	A	C	B
F	A	E	B	D	C

Evaluation

- Assigning participants to conditions
  - Importance of random assignment (examples)
    - Morning vs. afternoon typing
    - Manipulation of lighting level in the room
  - Each participant should have equal chance to end up in any condition
  - Pre-tests to get info on pre-knowledge and expertise
    - Offline or online tests
  - Regression
    - Initial observations change over time
    - Example: coins with tendency

Evaluation

- Web studies
  - Multiple version of web pages
  - The traffic get distributed between different versions
  - Compare the “performance“
    - Effectiveness of web advertising
  - Design differences
    - Position and color of controls, white space in the page, the number of columns, etc.
  - Metrics
    - Increase in web traffic, length of visit, page views, clicks, as views, etc.
  - Website tracking software
  - Small change makes big difference

Evaluation

- “Live“ studies
  - Two experiment leaders
    - Facilitator and observer (taking notes)
  - Ethical consideration
    - Voluntary participation and quit
    - The system is tested not users
  - Hypothesis
  - Experiment procedure
    - Order of tasks (from simple to hard, random?)
    - Training
    - What to do if somebody doesn‘t finish
    - Pilot study
  - Capturing results
    - Objective and subjective variables
    - Audio, video material

Evaluation

- “Live“ studies
  - Collecting data
    - Process data: qualitative data
      - Observations of what users are doing and thinking
      - General questions
      - “Think aloud“ method
      - Data based on self-evaluation
        - Quantitative data extracted from subjective measurements
        - NASA TLX, User Experience Questionnaire (UEQ)
    - Bottom-line data: quantitative data
      - Task completion times
      - Number of successfully completed tasks
      - Number of errors
      - etc.
  - Debriefing

Evaluation

- "Live" studies
  - NASA TLX test

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Mental Demand – How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)?

Physical Demand – How much physical activity was required (e.g.. pushing, pulling, turning, controlling, activating, etc.)?

Temporal Demand – How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?

Performance – How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)?

Effort – How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration – How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Evaluation

- User Experience Questionnaire (UEQ)
  - 26 bipolar items, rated on a seven-point Lickert scale

annoying	1	2	3	4	5	6	7	enjoyable
attractive	1	2	3	4	5	6	7	unattractive
efficient	1	2	3	4	5	6	7	inefficient

  - 6 different aspects
    - Attractiveness, perspicuity, efficiency, dependability, stimulation, novelty

Evaluation

- Customized questions about the experiment
  - Seven point Lickert scale

I found the driving simulator realistic.
I found the tasks realistic.
Tasks could be performed in a straightforward manner.
I found it easy to learn to navigate the system.
I could clearly read all menu items.
I found the playback of the menu distracting.

I found the scrolling wheel attached to the steering wheel easy to use.
I found the buttons (up and down) attached to the steering wheel confusing.

Using the simulator made me feel sick.

Evaluation

- Data analysis
  - Backup of original data and material
  - What are the mean values?
    - Aggregation of all numbers
      - Lists, tables, sheets
    - Mean values and standard deviations
  - What does the data look like?
    - Graphical exploration of data
    - Observation of different patterns
  - Are the observed differences significant?
    - Comparative tests (alpha and p value)

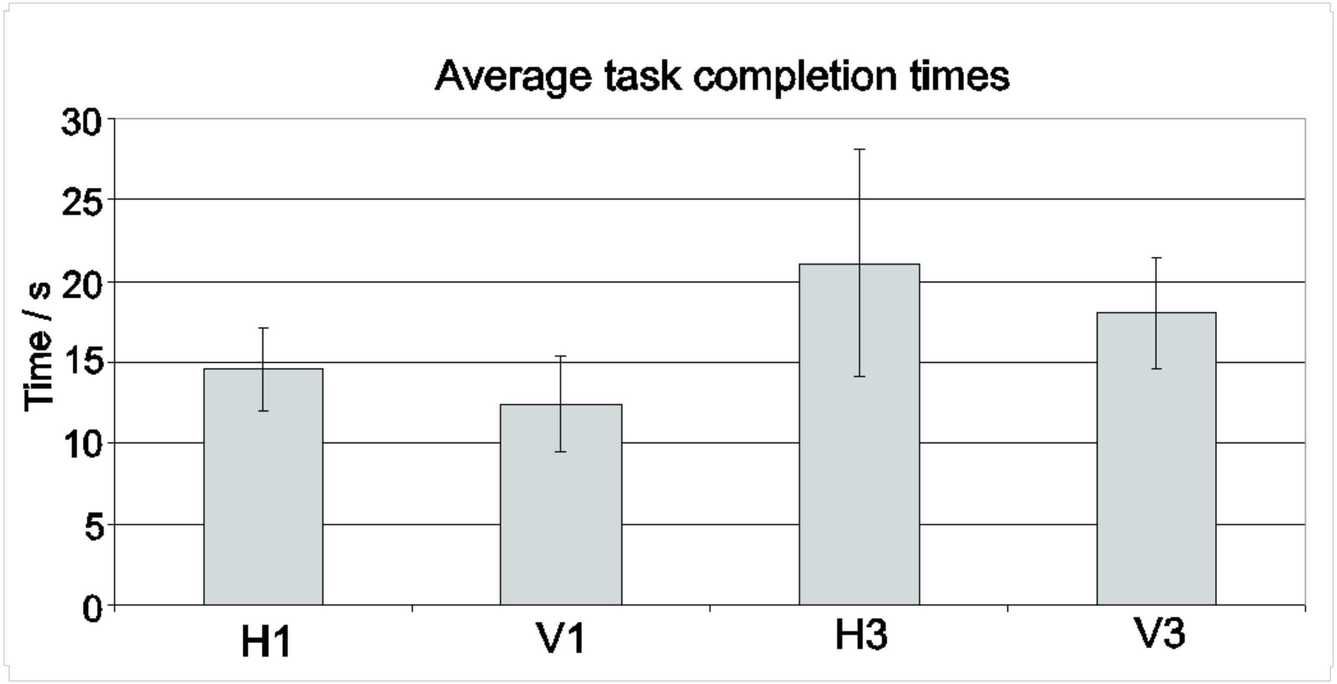
Evaluation

- Data analysis
  - Mean value (arithmetic mean)
  - Median
  - Variance and standard deviation

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$\sigma^2 = \frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}$$

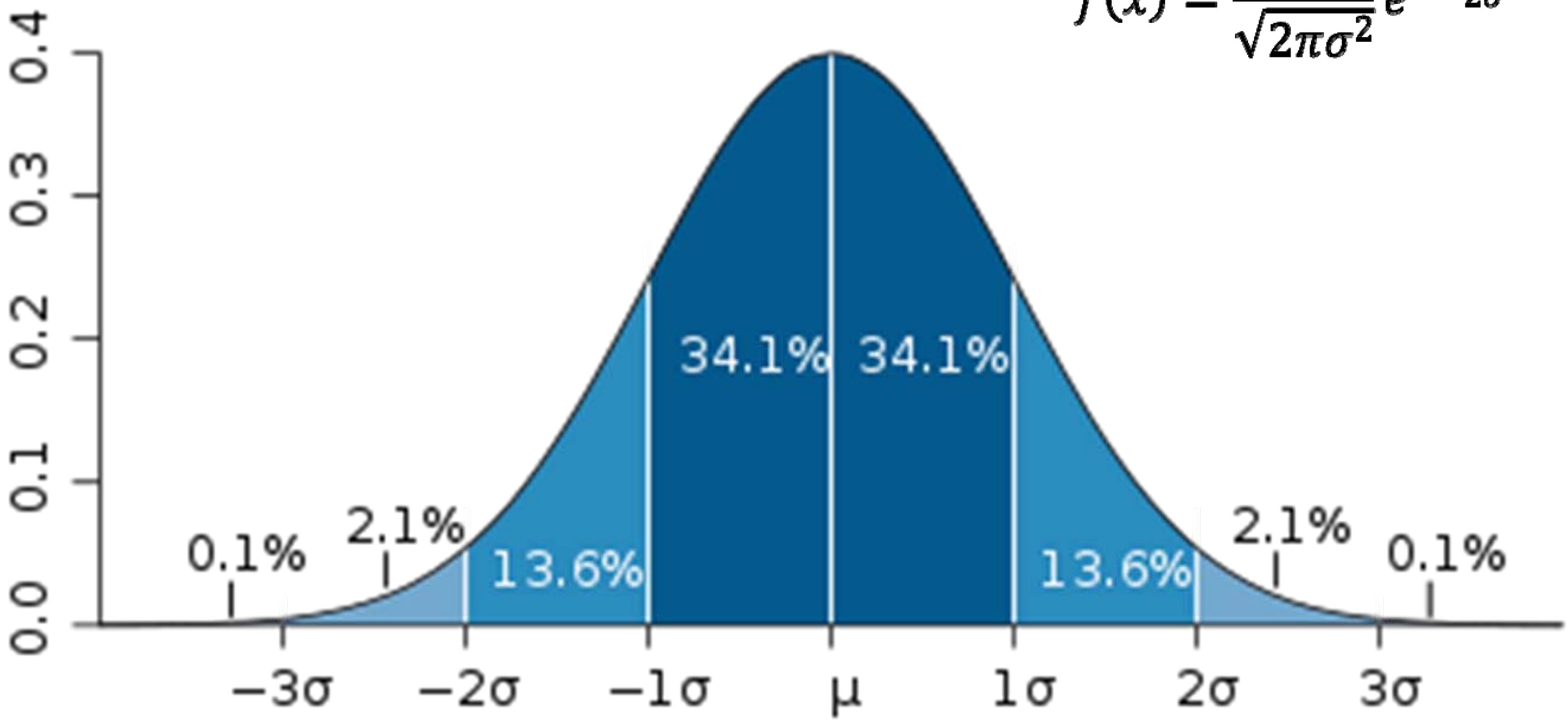
$$\sigma$$



Evaluation

- Data analysis
  - Normal or Gaussian distribution

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$



Evaluation

- Data analysis
  - alpha – the level of significance
    - Probability of a "type I" error
    - Confidence level of our trust
      - 90% : 1 – 0.90 = 0.10
      - **95%: 1 – 0.95 = 0.05**
      - 99%: 1 – 0.05 = 0.01
  - p value
    - Probability that the observed statistics occurred by chance alone
  - Statistical significance
    - We compare p and alpha
    - p <= alpha (reject the null hypothesis):
    - p > alpha (fail to reject the null hypothesis)

Evaluation

- Data analysis
  - Pearson‘s chi-squared test (X^2)
    - How likely it is that any observed difference between the sets arose by chance?
    - Null hypothesis
      - Frequency distribution of certain events observed in a sample is consistent with a theoretical distribution
      - The hypothesis is there is no difference
    - Critical values for chi-squared
      - Observed values, expected value
      - Degrees of freedom (df)

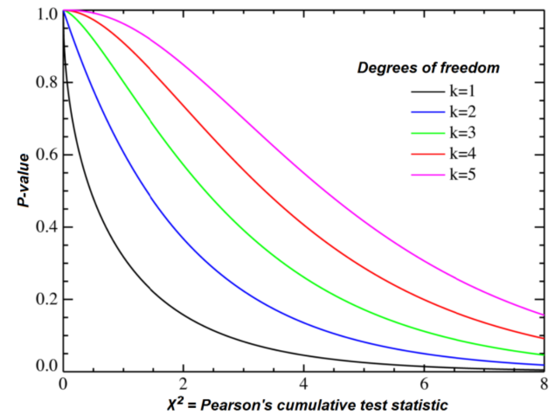
$$X^2 = \sum \frac{(Observed\ value - Expected\ value)^2}{Expected\ value}$$

$$df = sample\ size - 1$$

Evaluation

- Data analysis
  - Chi-square probabilities

df	0,99	0,975	0,95	0,9	0,1	0,05	0,025	0,01
1		0,001	0,004	0,016	2,706	3,841	5,024	6,635
2	0,02	0,051	0,103	0,211	4,605	5,991	7,378	9,21
3	0,115	0,216	0,352	0,584	6,251	7,815	9,348	11,345
4	0,297	0,484	0,711	1,064	7,779	9,488	11,143	13,277
5	0,554	0,831	1,145	1,61	9,236	11,071	12,833	15,086



$$f(x;k) = \begin{cases} \frac{x^{(k/2-1)}e^{-x/2}}{2^{k/2}\Gamma\left(\frac{k}{2}\right)}, & x \geq 0; \\ 0, & \text{otherwise.} \end{cases}$$

  - Example #1:
    - Coin tosses
  - Example #2:
    - New stylus device with a mobile phone

Evaluation

- Data analysis
  - Continuous data (with normal distribution)
    - Statistical software (SPSS, R)
    - T-test (comparing 2 conditions)
      - Comparing the means of two groups
      - Paired vs. unpaired
    - F-test (comparing 2 conditions)
      - Comparing the variance of two groups
      - Very sensitive to non-normality
      - Separate tests for checking of the homogeneity of variances
    - ANOVA (comparing > 2 conditions)
      - Analysis of Variance
      - Testing difference in means among more than 2 groups
      - Finds differences among groups, T-test shows where these differences are

Evaluation

- Data analysis
  - T-test
    - Test statistics follows Student's t distribution
    - Whether a difference between two groups' averages is unlikely to have occurred because of random chance in sample selection
    - Unpaired (independent) two-sample test
      - Between subject
    - Paired samples test
      - Within subject

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{{S_1}^2}{N_1} + \frac{{S_2}^2}{N_2}}}$$

Evaluation

- Data analysis
  - T-test: Example
  - Task completion times for two interfaces

A	B
3,12	4,01
3,45	3,32
2,30	4,12
4,15	4,55
3,30	4,82
2,49	3,12
3,99	5,22
4,42	4,69
1,90	4,11
3,00	3,05

Null Hypothesis: $\overline{x_1} = \overline{x_2}$

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{SD_1{}^2}{N_1} + \frac{SD_2{}^2}{N_2}}}$$

Evaluation

- Data analysis
  - ANOVA (Analysis of variance)
    - Analyze the differences between group means and their associated procedures
    - “One-way“ ANOVA
      - One dependent and one independent variable
    - Generalization of t-test for more than two groups
    - The variance calculated between the group means should be lower than the variance within the samples
    - Assumptions
      - Normal distribution
      - Samples are independent
      - Variances of populations are equal

Evaluation

- Data analysis
  - ANOVA (F statistics)
    - Sum of squared deviations between the groups, multiplied by number of samples (SSB)
    - Squared deviations within the groups (GSS)
      - SSW: Sum of GGS
    - Degrees of freedom (df)
    - F ratio: Mean square between and mean square within

$$MSB = \frac{SSB}{dfB} \qquad MSW = \frac{SSW}{dfW}$$

$$F\ statistics = \frac{mean\ square\ between}{mean\ square\ within} = \frac{MSB}{MSW}$$

Numerator: $dfB = (number\ of\ groups) - 1$

Denumerator: $dfW = (number\ of\ cases) - (number\ of\ groups)$

Evaluation

- Data analysis
  - ANOVA: Example (4 interfaces, error rate)
    - Is there significant difference between interfaces

(a = 0.05)

A	B	C	D
12	13	14	12
18	12	15	11
16	10	12	9
16	14	16	15
22	15	18	17
14	9	12	12
16	13	16	10
19	12	10	10
17	11	11	9
15	13	14	14

Evaluation

A	B	C	D
12	13	14	12
18	12	15	11
16	10	12	9
16	14	16	15
22	15	18	17
14	9	12	12
16	13	16	10
19	12	10	10
17	11	11	9
15	13	14	14

$\bar{X}$	**16,5**	**12,2**	**13,8**	**11,9**
SD	2,76	1,81	2,53	2,69

$\bar{X}_n = 13,6$

SSB

A	$10(16,5-13,6)^2 = 84,1$
B	$10(12,2-13,6)^2 = 19,6$
C	$10(13,8-13,6)^2 = 0,4$
D	$10(11,9-13,6)^2 = 28,9$

SSB = **133**

Evaluation

A	B	C	D
12	13	14	12
18	12	15	11
16	10	12	9
16	14	16	15
22	15	18	17
14	9	12	12
16	13	16	10
19	12	10	10
17	11	11	9
15	13	14	14

$\bar{X}$	**16,5**	**12,2**	**13,8**	**11,9**
SD	2,76	1,81	2,53	2,69

GSS

A	B	C	D
$=(12-16{,}5)^2$	$=(13-12{,}2)^2$	...	...
$=(18-16{,}5)^2$	$=(12-12{,}2)^2$	...	...
$=(16-16{,}5)^2$	$=(10-12{,}2)^2$	...	...
$=(16-16{,}5)^2$	$=(14-12{,}2)^2$	...	...
$=(22-16{,}5)^2$	$=(15-12{,}2)^2$	...	...
$=(14-16{,}5)^2$	$=(9-12{,}2)^2$	...	...
$=(16-16{,}5)^2$	$=(13-12{,}2)^2$	...	...
$=(19-16{,}5)^2$	$=(12-12{,}2)^2$	...	...
$=(17-16{,}5)^2$	$=(11-12{,}2)^2$	...	...
$=(15-16{,}5)^2$	$=(13-12{,}2)^2$	...	...
68,5	**29,6**	**57,6**	**64,9**

SSW $= \sum$ GSS = **220,6**

Evaluation

$$F\ statistics = \frac{mean\ square\ between}{mean\ square\ within} = \frac{MSB}{MSW}$$

$$MSB = \frac{SSB}{dfB} \qquad MSW = \frac{SSW}{dfW}$$

Numerator: $dfB = (number\ of\ groups) - 1$

Denumerator: $dfW = (number\ of\ cases) - (number\ of\ groups)$

Evaluation

$$dfB = 4 - 1 = 3$$

$$dfW = 4\,x\,10 \; - 4 = 36$$

$$MSB = \frac{133}{3} = 44{,}33 \qquad MSW = \frac{220{,}6}{36} = 6{,}13$$

$$F\ statistics = \frac{44{,}33}{6{,}13} = \mathbf{7{,}23}$$

Evaluation

v_2 \ v_1	1	2	3	4	5
1	16210.72	19999.50	21614.74	22499.58	23055.80
2	198.50	199.00	199.17	199.25	199.30
3	55.55	49.80	47.47	46.19	45.39
4	31.33	26.28	24.26	23.15	22.46
5	22.78	18.31	16.53	15.56	14.94
6	18.63	14.54	12.92	12.03	11.46
7	16.24	12.40	10.88	10.05	9.52
8	14.69	11.04	9.60	8.81	8.30
9	13.61	10.11	8.72	7.96	7.47
10	12.83	9.43	8.08	7.34	6.87
11	12.23	8.91	7.60	6.88	6.42
12	11.75	8.51	7.23	6.52	6.07
13	11.37	8.19	6.93	6.23	5.79
14	11.06	7.92	6.68	6.00	5.56
15	10.80	7.70	6.48	5.80	5.37
16	10.58	7.51	6.30	5.64	5.21
17	10.38	7.35	6.16	5.50	5.07
18	10.22	7.21	6.03	5.37	4.96
19	10.07	7.09	5.92	5.27	4.85
20	9.94	6.99	5.82	5.17	4.76
21	9.83	6.89	5.73	5.09	4.68
22	9.73	6.81	5.65	5.02	4.61
23	9.63	6.73	5.58	4.95	4.54
24	9.55	6.66	5.52	4.89	4.49
25	9.48	6.60	5.46	4.84	4.43
26	9.41	6.54	5.41	4.79	4.38
27	9.34	6.49	5.36	4.74	4.34
28	9.28	6.44	5.32	4.70	4.30
29	9.23	6.40	5.28	4.66	4.26
30	9.18	6.35	$\boxed{5.24}$	4.62	4.23
40	8.83	6.07	$\boxed{4.98}$	4.37	3.99

Numerator Degree; Denominator Degrees of Freedom

$$F\ statistics = \frac{44{,}33}{6{,}13} = 7{,}23$$

p value calculator:

http://graphpad.com/quickcalcs/PValue1.cfm

F = 7,23 Dfn=3 Dfd = 36

P = 0,0006

Report on ANOVA results:

F(3,36) = 7,23, p < 0.05

Evaluation

- Data analysis
  - Non-normal data
    - Test for normality
    - Different comparative tests
      - Mann-Whitney, Wilcoxon, Kruskal-Wallis, etc.
  - Statistical testing
    - Confirms observed differences (they are important or significant differences)
    - Generalization from small samples

Spatial auditory interface for an embedded communication device in a car

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Christina Dicke[2] and Mark Billinghurst[2]

University of Ljubljana, Slovenia[1]
HIT Lab, New Zealand[2]

Agenda

- Introduction and motivation
- Experiment design and conditions
- Results
- Video recordings
- Conclusions

Introduction

- Car – an office on the go
- Decreased safety of drivers
- Prototype of an auditory interface as a substitute for a visual interface
- Evaluation experiment
  - Two different auditory menus are compared with a classic visual interface (three experiment conditions)
- Observation parameters:
  - Time efficiency
  - Safety of the driver
  - Subjective evaluations of the interfaces (made by test subjects)

Experiment design and conditions

- Simple in-vehicle communication device
  - Simplified menu of NOKIA mobile phone (series 60)
  - Making phone calls, sending text messages, playing audio and video clips, etc.
  - Three different interfaces – same menu structure
  - Common interaction device
  - Car simulator

Experiment design and conditions

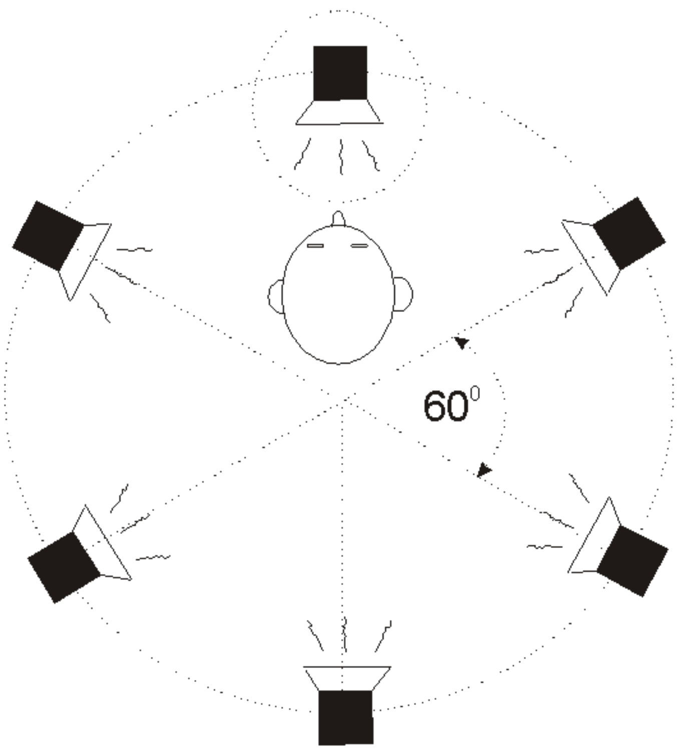
- Car simulator
  - Visualization room with large projection screen (2.4 x 1.8 meter)
  - Sound system
    - 7.1 surround sound system
    - Creative Sound Blaster X-Fi Extreme Music + OpenAL
    - CMSS-3D technology
  - Logitech MOMO steering wheel

Experiment design and conditions

- Visual interface
  - LCD screen on the dashboard
  - Simple tree menu structure (based on NOKIA mobile phone)
  - Phone-like keyboard

Experiment design and conditions

- Auditory interface
  - “Sonification” of the hierarchical menu
  - Played through 7.1 surround system
  - Two auditory conditions: A, A1
  - Background music with changing pitch



Experiment design and conditions

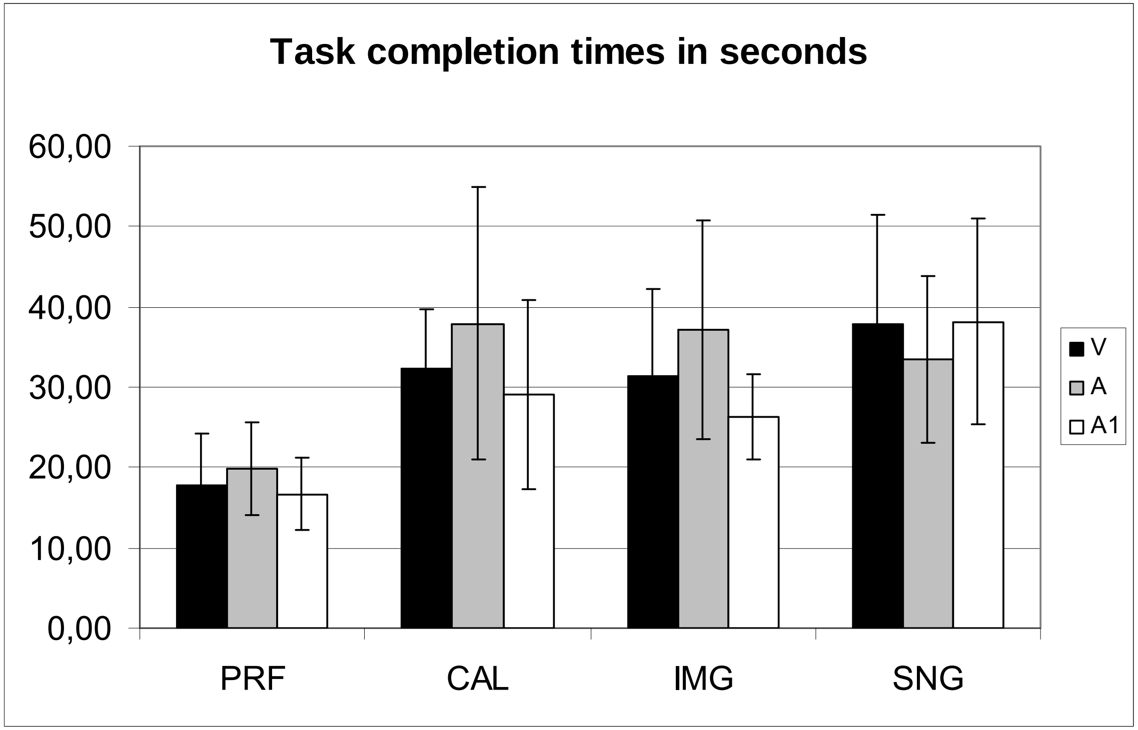
- Interaction device

Experiment design and conditions

- Experiment procedure
  - 18 test subjects (in average: 8.7 years of driving experience)
  - Warm-up drive (5 minutes)
  - 3 groups using three different interfaces in different sequential order
  - 5 tasks (15 minutes of break between two tasks):
    - Changing the active profile of the device - PRF
    - Making a call to specific person - CAL
    - Deleting a specific image from the device - IMG
    - Playing a specific song – SNG
- Variables
  - Automatic time measurement (task completion times)
  - Video recordings and post-processing (driving anomalies)
  - NASA TLX workload test
  - Questionnaire for User Interface Satisfaction - QUIS

Results

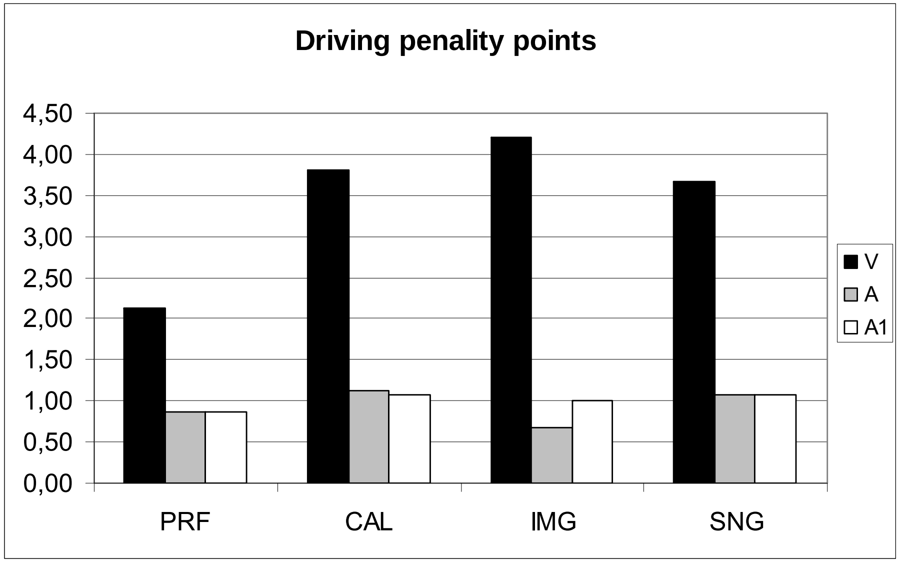
- Task completion times



$F_{PRF}(2, 51) = 0.358$, $p = 0.701$; $F_{CAL}(2, 50) = 0.550$, $p = 0.581$;
$F_{IMG}(2, 51) = 1.213$, $p = 0.306$; $F_{SNG}(2, 50) = 0.211$, $p = 0.811$;

Results

- Driving anomalies (penalty points)
  - 1: unsafe driving (slight winding on the road or slowing down unexpectedly and unnecessarily)
  - 2: extreme winding on the road and driving on the road shoulders
  - 5: causing an accident or crashing the car
- Average speeds of the three conditions:
  - V: 32 km/h
  - A: 59 km/h
  - A1: 55 km/h

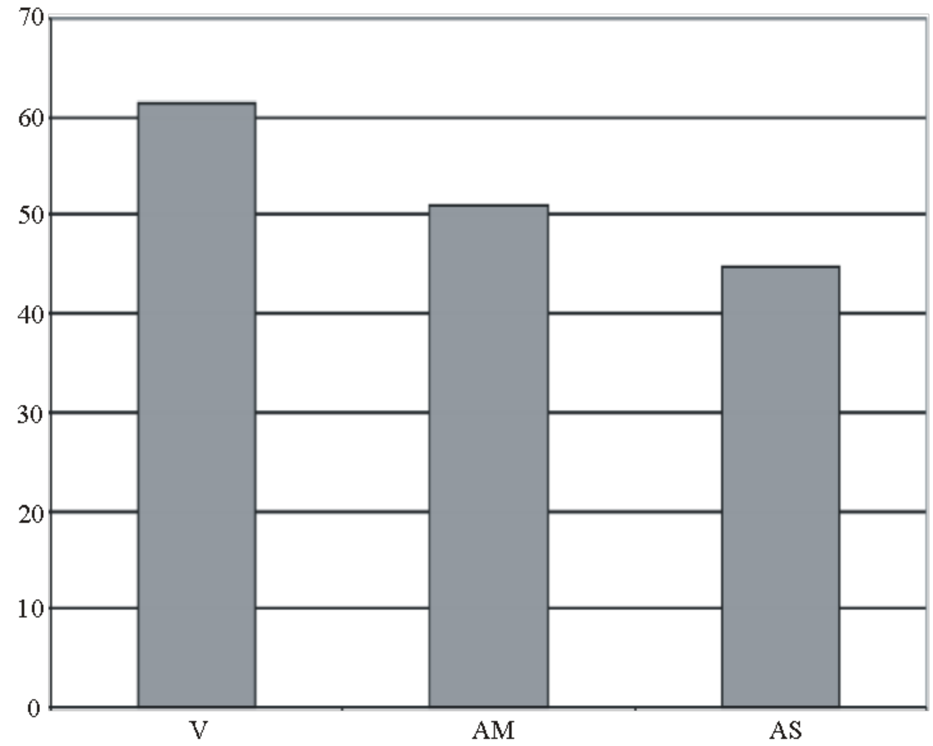


$F_{PRF}(2, 41) = 2.795$, $p = 0.073$;
$F_{CAL}(2, 41) = 6.493$, $p = 0.004$;
$F_{IMG}(2, 41) = 5.479$, $p = 0.008$;
$F_{SNG}(2, 41) = 4.395$, $p = 0.019$;

Results

- NASA workload test (overall workload perceived by the test subjects under different conditions)
  - Mental demand
  - Physical demand
  - Temporal demand
  - Performance
  - Effort level
  - Frustration level

Final NASA TLX scores



ANOVA test
$F(2, 321) = 15.386$, $p < 0.001$

physical demand: $F(2,51) = 4.090$, $p = 0.023$;
temporal demand: $F(2,51) = 4.648$, $p = 0.014$;
performance: $F(2,51) = 4.237$, $p = 0.020$;
frustration: $F(2,51) = 3.188$, $p = 0.049$;

Results

- QUIS test
  - Measures the reaction of the users to the software used in the experiment
  - Ranking the individual interfaces on a scale 0 to 9 (0 being entirely false and 9 being entirely true), based on the following statements:
    - The interface was more wonderful than terrible
    - The interface was more easy than difficult
    - The interface was more satisfying than frustrating
    - The interface was more adequate than inadequate
    - The interface was more stimulating than dull
    - The interface was more flexible than rigid
    - It was easy to learn how to operate the system
    - It was easy to explore the new features by trial and error
    - It was easy to remember names and use commands

Conclusions

- Evaluation of an acoustic interface as a substitute for the traditional visual interface in cars
- No significant difference in the task completion times
- Increased safety and a significant reduction in the distraction of the driver when using auditory interface
  - 60% less penalty points and in 25 km/h higher average speed
- Users felt less physical and temporal demand when using auditory interface
- Spatial auditory interface did not prove to have any advantages when compared to single sound interface