Summary cognitive psychology

Cognitive Psychology and its Applications (Vrije Universiteit Amsterdam)

Summary cognitive psychology and its applications

Lecture 1: introduction to human factors engineering

Cognitive psychology

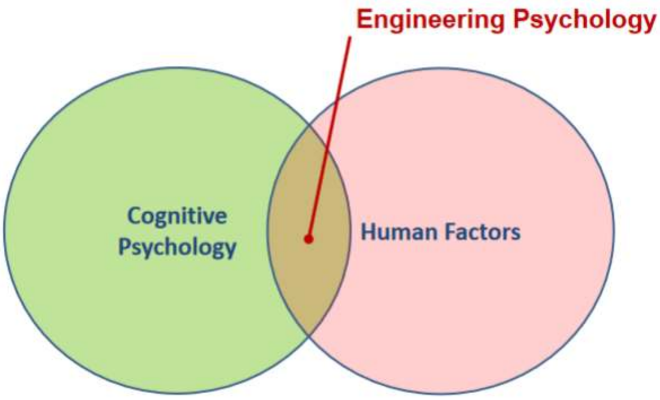
- To uncover the laws of information processing and behaviour through experiments
- Fundamental questions
- No requirement for application

Human factors

- To apply knowledge by designing systems that work
- To accommodate the limits of human performance
- Directly applied problems
- The study of interaction between humans and systems in order to improve performance, safety, health and usability

Related disciplines

- Ergonomics: more focus on physical aspects
- Cognitive engineering (AI): machine



Poulton, 1966: "The aim of engineering psychology is not simply to compare two possible designs for a piece of equipment [human factors], but to specify the capacities and limitations of the human [generate experimental database] from which the choice of a better design should be directly deducible".

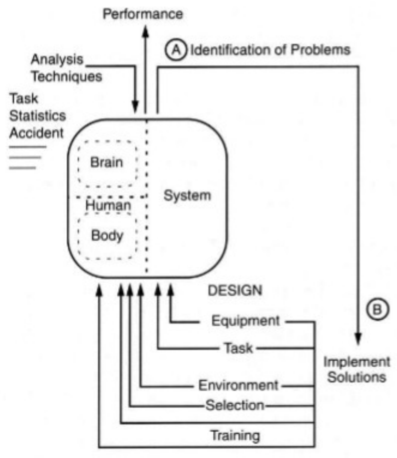
Goals of human factors

- Development of generic knowledge
- Enhance efficiency (productivity)
- Ensure safety, reduce error
- Assure tasks are within human capability
- Increase user satisfaction, comfort
- Improve human performance
- Gain market acceptance
- Reduce costs (economic, legal, social)
- Development of tools and equipment

History of human factors

- WWII: designing a human to fit the machine
  - Aviation and weapons
- Technology advancements
  - Increased logical complexity
  - Increased physical complexity
- Human information processing theory
  - Improves H-M dialog

The human factor cycle



Costs of human factor design
- Can be low
  - Consultancy
  - Expert review
  - Tests
- Can be high
  - User-centred design
    - Early focus on user and tasks
    - Empirical, quantitative approach
      - Studies, tests, surveys
    - Iterative design using prototypes
  - Complete task analysis
  - Surveys
  - Experimental research

Benefits of human factors
- Prevention of accidents
- Prevent compensation payments
- Less support for customers
- Less sick leave, higher job satisfaction
- Higher productivity, more efficiency
- Lower costs for training and instruction

Front end analyses
- User analysis
  - Who are the users
- Environment analysis
- Determine goals, functions, tasks
  - Goal: highest level (e.g. mobile phone: communication)
    - Important because it may be reached with a completely different system
  - Functions: functionalities (e.g. making a call or sending a text)
  - Tasks: actions of the user(s) (e.g. selecting number, starting call)

Task analysis
- Physical
  - Use of tools, instruments
- Cognitive
  - Decision making, problem solving is complex
  - Large amounts of knowledge are needed
  - There are complex rule structures

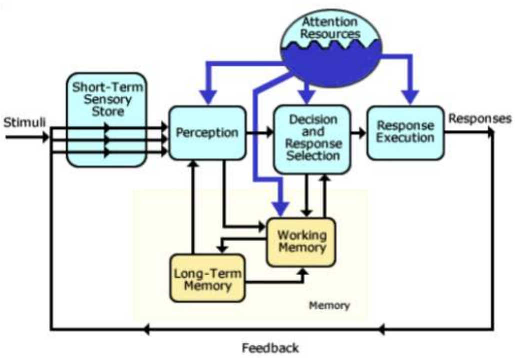
Steps of task analysis

- Define purpose
- Collect data
  - Think aloud
  - Interviews
  - Literature
  - Incident / accident analysis (less/not controlled)
  - Surveys (less/not controlled)
  - Observations (less/not controlled)
    - Problems surveys and observations:
      - No causal relationship
      - "Suitable" answers
      - Interpretation of questions
      - Preferred solution is not always optimal
      - Population may not be representative
  - Experiments (controlled)
    - Types:
      - Lab study
      - Field study
    - Problems:
      - Subjects are not representative
      - Confounding variables
      - Power too low
- Summarize task data
- Iterative design & testing
  - Usability testing
    - Learnability
    - Efficiency
    - Memorability
    - Errors
    - Satisfaction

Lecture 2: human information processing

What is human information processing?

- Sensory systems (vision, audition, tactile etc.)
- Cognitive systems (perception, attention, memory, language, decision-making etc.)
- Understanding HIF helps build better systems



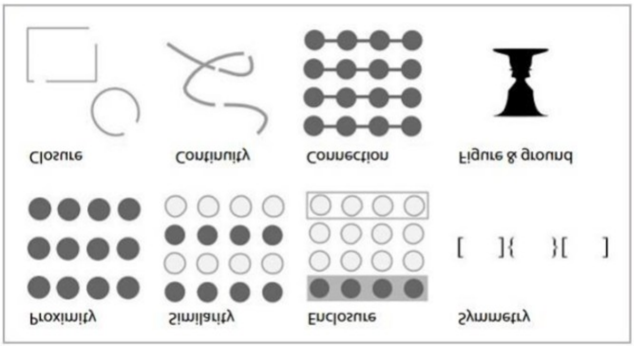
Sensation

- Colour
  - Location on the retina (fovea, non-fovea)
  - Acuity
    - Cones high, rods low
  - Sensitivity

        - Scotopic vision (only rods, at night)
        - Photopic vision (rods and cones)
    - Low light: adaption of rods, hypersensitivity of cones
    - Different wavelength sensitivity (S, L, M cones)
    - Colour mixing
        - Additive colour mixing
            - Red, green and blue
        - Subtractive colour mixing
            - Cyan, magenta and yellow

Perception

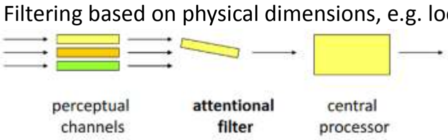
- The role of previous experience
- Gestalt laws



- Solving “inverse” problem: the process of calculating from a set of observations the causal factors that produced them
    - Accommodation
    - Convergence
    - Binocular disparity
- Depth cues
    - Linear perspective
    - Relative size
    - Interposition
    - Light and shading
    - Textural gradients

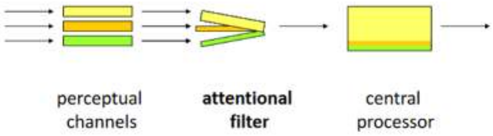
Attention

- You are functionally blind without attention
- Attention determines which information is processed and which information is ignored
- Competition among current goals, physical salience and selection history
- Additive attention
    - Dichotic listening technique
        - Cherry (1953): shadowing- pay attention to the message in one ear
            - Shadowed ear: cat, large, day, apple, friend, every, select
            - Unattended ear: table, book, chair, sample, always, pretty
            - Conclusion: Detailed aspects such as language, individual words and semantic content are unnoticed
    - Early selection
        - Broadbent (1958)
            - Filter theory
            - Bottleneck at stimulus-identification
            - Filtering based on physical dimensions, e.g. location, loudness

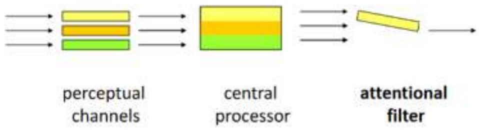


    - Is it really early?

- Treisman (1960): filter attenuation theory
  - Message: In a picnic basket, she had peanut butter sandwiches and chocolate brownies
  - Shadowed ear: Is the picnic basket she had peanut butter, books, leaf, roof, sample
  - Unattended ear: table, book, chair, sample, always, pretty, sandwiches, and cholate brownies
  - Cocktail party effect
  - Relevant information passes the filter



- Late selection
  - Deutsch & Deutsch (1963)
    - Bottleneck occurs after stimulus-identification

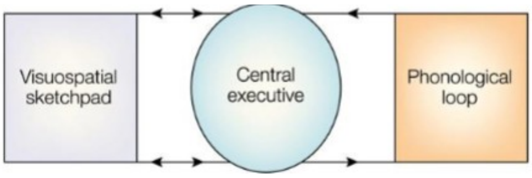


- Visual attention
  - Mechanism by which we select relevant and ignore irrelevant visual information
  - Spatial
    - Selectivity of location
  - Feature-based
    - Colour
    - Orientation
    - Size
  - Attentional control
    - Top-down
      - Voluntary, goal-driven
        - A butterfly in a field of red tulips and one yellow tulip
    - Bottom-up
      - Automatic, stimulus-driven
        - One yellow tulip in a field of red tulips
  - Eye movements
    - Covert attention = eyes are still
    - Overt attentions = eyes move

Memory

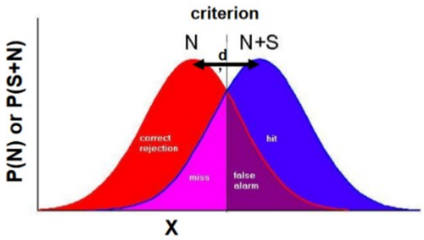
- Visual memory
  - Iconic memory: 0 – 250 ms
    - Sperling (1960)
      - If participants were shown 3x4 letters, they could on average only remember 4 letters
      - If participants were shown 3x4 letters and were asked to recall the first row, they could remember all the letters
      - This suggests that sensory memory is rather large but has a short duration
      - Perceptual representations:
        - Are aesily overwritten by new stimuli
        - Decay quickly
  - Visual short-term: 250 ms – seconds
    - VSTM is a memory system that stores visual information for a few seconds so that it can be used in the service of ongoing cognitive tasks
    - VSTM representation can survive eye movements, eye blink and other visual interruptions
    - A limited amount of information to be maintained in an "on-line" or readily accessible state
  - Long term: hours – days – years
- Working memory
  - Baddely and Hitch model of working memory

        - Visuospatial sketchpad
            - Spatial working memory
            - Visual working memory
                - Mechanism by which we actively retain relevant visual information and prevent interference from irrelevant visual information
        - Phonological loop
            - Verbal (speech-based) working memory
                - Memory span is larger for items that are easy to rehearse
                    - Fifth avenue VS van der Boechorststraat



Signal detection theory

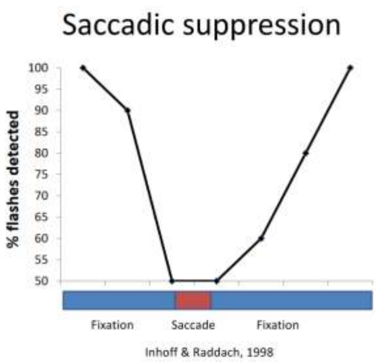
- Separation discrimination and decision in detection, recognition and matters of life and death
    - N = Noise
    - N + S = Noise + Signal
    - X = Decision dimension
    - d' (criterion) = distance in z-space (normal distribution)
        - d' = z[p(hits)] – z[p(false alarms)]
    - Sensitivity is independent of criterion setting (or bias)
    - The criterion is neutral: in between the N and N + S distributions
    - If the criterion is not neutral, it is lenient (or liberal) towards the left or conservative towards the right.



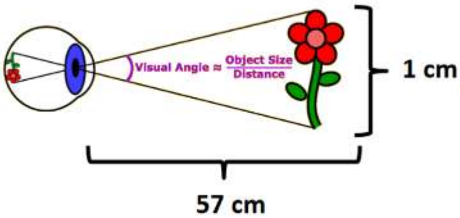
Lecture 3: eye-tracking

Eye movements

- Saccades: jerky movements that occur 3-4 times a second and you have 230.000 saccades a day
    - We do not use saccades to paint a complete internal representation of a visual scene
    - Saccades constitute in a way to select relevant information
- Temor (90 Hz): physiological nystagmus, noise in muscle control
- Drift: slow movements taking the eye away from fixation
- Vergence eye movement: binocular focus, dominant eye, both eyes typically move together
- Vestibular-ocular reflex: correct for head movements by producing eye movements in the direction opposite to head movement, preserving the image on the center of the visual field
- Optokinetic reflex: smooth pursuit + saccade
- Smooth pursuit eye movement: moving object
- Microsaccades: small eye movements at fixation



Degrees of visual angle

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Arctan(1 cm / 57 cm) = arctan(0.017541) = 1 degree
1 radian = 360 / 2pi = 180 / pi
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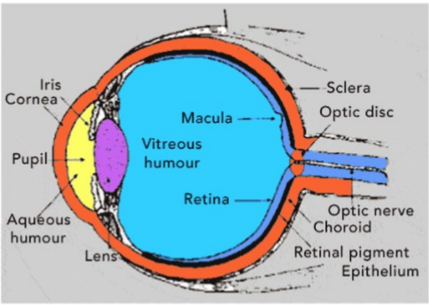
The eye

- Inhomogeneity of the visual system
    - Cones: almost exclusively in the fovea
    - Rods: more or less equally distributed in the periphery



Vision

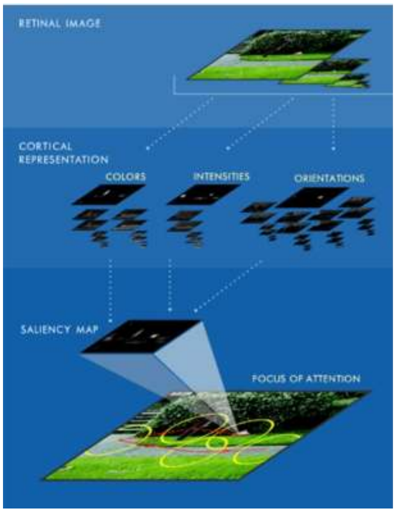
- Vision is not passive
- Movement is essential for vision
    - Not fixated = missed (almost always)
    - Covert attention is active (microsaccades)
    - Stable image = vision fades
        - This shows that eye movements are intrinsically linked with information processing

Salience map

- Fast parallel input stage for many feature maps
- Slow and sequential focal attention stage

What drives information processing?

- Target features (top-down)
- Visual salience (bottom-up)
- Scene context (learned expectations)
    - Information processing during reading
        - 'Content' words are fixated more often than 'function' words
        - Distribution of attention is asymmetrical
            - 3-4 letters to the left, 14-15 to the right of fixation
        - 10-15% of the time readers move their eyes (regress) back to previously read material in the text
        - Saccade size and fixation duration are both modulated by text difficulty
            - As the text becomes more difficult, saccade size decreases, fixation duration increases and regressions increase



Eye-tracking

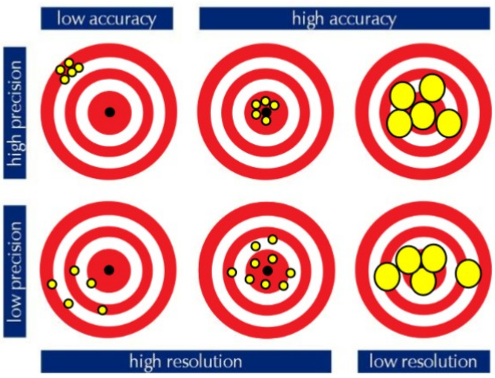
- Eye-tracking is a complex physiological measure of information processing with a long history and many applications in research.

Eye movement recording history

- Mechanical (Huey, 1898)
- Photograph of reflection of light source (Dodge & Cline, 1901)
- Suction cup with a mirror (Yarbus, 1960s) – high accuracy
- Electromagnetic coils (Collewijn, 1998) – high accuracy
- Electrooculography (EOG) – low accuracy
- Video-based: desktop or head mounted

Properties of an eye tracker

- Temporal resolution / sampling rate
  - Wide range available (25 Hz – 2000 Hz)
  - Faster is not necessarily better
    - Depends on experimental purpose
    - Can constrain participant configuration
  - Affects what measures can be calculated
    - E.g. saccadic peak velocity can be estimated with 60 Hz data, but only for saccades > 10°
      - Saccades during reading typically < 10°
- Spatial resolution
  - The smallest distance between eye positions that can be detected
- Spatial accuracy
  - Average angular offset (distance in degrees of visual angle) between n fixations locations and corresponding location of fixation targets
- Spatial precision
  - Root Mean Square (RMS) of angular distance (in degrees of visual angle) between successive samples



Calibration
- Gaze determined by changes between centre of pupil and corneal reflection
- Mapping of ocular changes to measured parameters required

Eye movement analysis
- Latency
- Direction
- Duration
  - Fixation duration
    - The length of time the eyes remain (more or less) stationary in a given location
      - Exploration: Large amplitude saccades, shorter fixations
      - Exploitation: Smaller amplitude saccades, longer fixations
    - Typically around 200-250 ms, longer in viewing scenes than in reading
    - Typically associated with the depth of processing
- Amplitude
- Trajectory
- Velocity and acceleration, deceleration

Higher order measures (applications)
- Areas of interest
  - A priory defined areas over which experimental hypotheses are tested (e.g. lung defined area in lung pictures)
  - Cannot be modified post-hoc
  - Challenges
    - Overlapping areas of interest
    - Size of the area of interest
    - Data samples or fixations?
      - With high sampling rate this makes no difference
      - With low sampling rate use fixations
    - Inaccurate data
      - Perform an offset correct at your own risk
- Scan paths
  - A viewing pattern
  - Different across people
  - Different across tasks
  - Sequence of vectors, saccade amplitude and direction based strings
  - Similarity between scan paths can be computed (e.g. Levenshtein distance)
    - 'Decode' the task from the scan paths

Lecture 4: transportation, distraction and multitasking: driving

Transportation
- Millions of people travel every day
- Tracking and manual control at high speeds
- Rapidly changing environments
- Safety concerns
- Costs of life, material costs

Driving
- Driving safety is of world importance
- >90% of the accidents in traffic are due to human error

How can we improve the safety?
What are the main tasks during driving?
- Task analysis
  - Strategic
    - Choice of route
    - Choice of travel time

    - Tactical
        - Choice of speed
        - Lane choice, overtaking
        - Taking turns
    - Control
        - Longitudinal (speed, distance from other cars)
        - Lateral (position on road)
    - Assessment of driving performance based on:
        - Strategic
        - Tactical
        - Control
- Primary tasks
    - Lane keeping
    - Hazard monitoring
- Secondary tasks
    - Navigation
    - Scanning for signs
    - Radio
    - Cell phone

What are the critical issues that can be improved by human factors?

- Visibility of PVAL (primary visual attention lobe)
    - Anthropometry
        - Reachability (no one size fits all approach)
        - Visibility of instruments and roadway
    - Illumination
        - Driving at night is 10 times more dangerous than driving during day
        - Illumination reduces accidents in two
    - Road signs
        - Readability
        - Consistency
        - Clutter
        - Redundancy
    - Resource competition
        - Dashboard, telephone, radio, advertisement
            - Effect can be (partly) quantified by glance time / duration
                - Glances should be shorter than 0.8 s
                - There should be more than 3 s between glances
            - Head-up displays
            - Hands-free cell phones
            - Audio / speech warnings
                - Speech controls
- Hazards and collisions
    - Control loss
        - Lateral of longitudinal
        - Because of fatigue
            - Most important cause of accidents during night
            - Vigilance
                - Almost 50% of the truck drivers has fallen asleep behind wheel
        - Because of speed
            - Underestimating dangers
            - Overestimating driving skills
            - Inadequate mental model for hazards
            - Not detecting hazard / obstruction
            - More distance travelled before manoeuvre is made
            - Greater damage at impact
        - Alcohol
            - Causes 50% of fatal accidents in US

            - Poorer RTs, tracking, information processing
            - Speed limits, fines, social pressure
        - Age
            - Much greater risk for young (male) drivers
                - Inexperience, overconfidence, risk taking
                - Alcohol, fatigue, driving at night
                - Distraction
        - Overcorrection (dangerous at high speeds)
        - Most casualties (40%) when driving off the road
        - Countermeasure: rumble strips
    - Hazard response time
        - Most important cause of dangerous situations
        - RT for braking on average 1.5 s
        - Even slower for unexpected events
        - Recommended 2 s
        - Collision from behind occurs most often (30%)
- Impaired drivers

Countermeasures
- Driving safety improvements
    - Use of seat belts
    - Airbag
    - Emergency call
    - Better roadway designs
    - Etc.
- Automation
    - Vehicle control
        - Lane departure warning
        - Collision avoidance (intelligent cruise control)
    - Navigation
        - Trip planning, route information
        - Up-to-date information (traffic jams, weather, services)
    - Semi of full self-driving mode
    - Risks
        - Overconfidence system
        - Less attention for driving task
        - Trade safety against efficiency

Principles of attention
1. Legible / audible
    - Lighting, size, contrast, noise
2. Absolute judgment
    - "If the light is amber, proceed with caution"
3. Top-down processing
    - Checklist
4. Redundancy gain
    - Position and hue are redundant
5. Similarity
    - Confusion
6. Pictorial realism
    - E.g. display high / low
7. Consistency of movement
    - Altimeter that moves up when plane goes up
8. Accessibility of information
    - "Somewhere in the manual"
9. Proximity compatibility principle
    - Integration of compatible information
        - E.g. spatial proximity, same color, …

        - However: prevent clutter
10. Multiple resources
    - Use of multiple modalities
11. Support with visual information
    - E.g. a flowchart
12. Predictive aiding
    - In particular when system behaviour is complex
13. Consistency
    - E.g. of layout

Lecture 5: automation, control and stress/workload

Why are tasks automated?

- 3Ds: dull, dirty, dangerous
    - Repetitive tasks, working with explosives or radioactive material
- For multi-tasking, difficult or unpleasant tasks
    - Process control, welding, autopilot
- Extension of human capability
    - Decision support
- Because the technology makes it possible
    - Telephone services using speech recognition
    - Chatbots

Stages and levels of automation

- Information acquisition, selection and filtering
    - Spelling checkers
- Data integration
    - Pattern recognition; complex (prioritized) warning systems
- Advisory systems
    - Collision avoidance systems
- Control, execution of actions
    - Industrial robots

Levels in terms of control

1. The human is in control
2. The system suggests different alternatives
3. The system selects a single alternative
4. The system acts after approval by the human
5. The system provides limited time to stop the action
6. The system acts and informs afterwards
7. The system acts and informs when asked
8. The system is in control

(Un)reliability

- Causes of unreliability
    - Errors, e.g. because of complexity
    - Use outside the operating range
    - Wrong settings are entered
    - Logic of system is not understood by user
        - Automation induced surprises
- In most cases the user-system combination is unreliable, or the system is imperfect (not unreliable)

Trust

- Perceived reliability
- Critical for acceptance of automated systems
- Trust is often not well calibrated
- Which is better, mistrust or over trust?
    - Mistrust

        - What is mistrust?
            - High false alarm rate
            - Failure to understand (limitations) of system
        - Consequences
            - Inefficient, slow
            - Errors (e.g. because warnings are not taken seriously)
    - Over trust
        - Over trust or complacency
            - Actual reliability is difficult to judge when few errors occur
        - Consequences
            - Slow detection for failures (c.f. vigilance)
            - Poor situation awareness because user is not actively involved

Other aspects

- Automation should be tuned to keep workload within right bandwidth
    - "Clumsy automation" makes easy tasks easier and hard tasks harder
- Training should be adapted to level of automation
- Human-system communication is less "rich" than human-human communication
    - E.g. tone of voice
- Job satisfaction

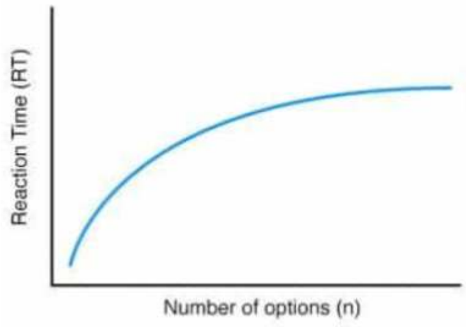
Design of automation

- Task and function analysis
- Allocation of tasks and functions to humans and systems
    - Use strong points of humans and systems
        - Humans
            - Perceiving patterns
            - Detection of noise
            - Generalization
            - Improvisation
            - Inductive reasoning
        - System
            - Working with details
            - Computations
            - Deductive reasoning
            - Repetitive work
            - Monitoring
            - Using (large) databases
- "Human-centred automation"
    - Keeping the human informed
    - Keeping the human trained
    - Keeping the human in the loop
    - Selecting appropriate stages and levels when automation is imperfect
    - Using flexible/adaptive automation
    - Managing the introduction and use of automation

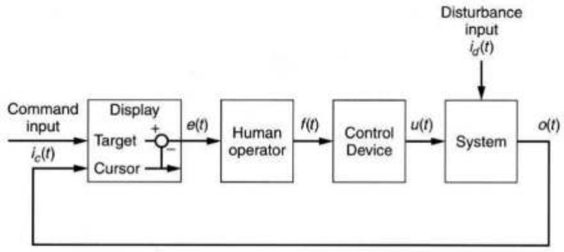
Control

- Principles of response selection
    - Decision complexity
        - Complexity as the number of possible alternatives
            - Simple decisions
            - Complex decisions
        - Hick – Hyman law / Hick's law
            - $RT = a + b \log_2 (n)$
                - RT: reaction time
                - n: number of stimuli
                - a and b: constants

        - Information transfer is greater with a small number of complex decisions: decision complexity advantage
            - Keyboard is faster than Morse code, while Morse code is a simple decision and keyboard typing a complex decision



    - Response expectancy
    - Compatibility
        - Stimulus-response (or display-control) compatibility
            - Of location, of movement (Simon effect)
    - The speed-accuracy trade-off
        - When we try to do things quicker, we become less accurate
        - In many cases speed and accuracy are positively correlated
            - Both correlate with task difficulty
            - Trade-off can occur as a result of user strategy
    - Feedback
- Positioning systems
    - Controls require movement
    - Hand/foot movements to reach controls
    - Controlling the device (steering wheel)
        - Direct control of position (e.g. touch screen)
            - Mouse and direct control best for pointing and dragging
            - Tablet and direct control best for drawing
        - Indirect control of position (e.g. mouse, trackball)
        - Indirect control of speed (e.g. joystick)
            - Spring brings stick back to resting position
            - Sometimes no movement (pressure sensitive stick)
        - Voice control
            - Voice input
                - Hands and eyes are free
                - Large number of response alternatives are possible
                - Recently improved:
                    - Limited vocabulary
                    - Errors because of small acoustic differences
                    - Effect of noise
                    - Effect of accent, stress
                    - Improvements in deep RNNs
    - Fitt's law
        - Used to model the act of pointing, either by physically touching an object with a hand or finger, or virtually, by pointing to an object on a computer monitor using a pointing device.
- Control of continuous processes
    - Closed loop control
        - Negative feedback: operator tries to minimize error (e(t))
        - Problems:
            - Too large input bandwidth
            - Time delay
                - Causes similar anticipation problems and 2^{nd} order system
            - High gain
                - Overcorrections and instability



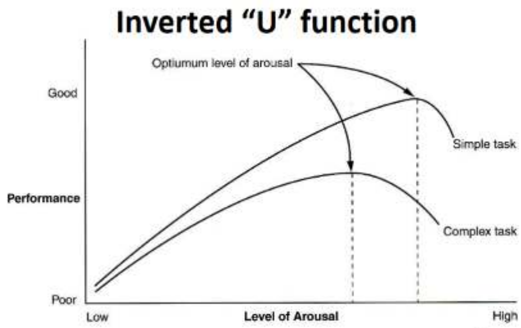
- Open loop control
  - Operator does not correct based on the error
  - Advanced knowledge and experience with the system
  - Experienced pilot does not constantly check the instruments during landing
- Control order
  - Change in position of control device:
    - 0^{th} order: position (mouse)
    - 1^{st} order: speed (e.g. gas pedal, joystick)
    - 2^{nd} order: acceleration (e.g. controlling spacecraft)
      - Very difficult, oscillations typically occur

- Remote control

Stress and workload

- Types of stressors
  - Environmental factors
    - Noise
    - Lighting
    - Motion
      - High-frequency vibration – disrupts tool use, readability
      - Low-frequency vibration – causes motion sickness
    - Air quality (ships, mines)
    - Thermal stress
  - Psychological factors
    - Life stress: job, personal life
    - When someone fears
      - Loss of esteem
      - Loss of something valuable
      - Danger
    - Depends on cognitive appraisal
      - Difference novice / expert
      - Over(confidence)
      - Feeling of being in control
  - Fatigue, sleep disruption
    - Causes
      - Long working period
        - Due to prolonged action
        - Under arousal
      - Working at night
        - Sleep deprivation
        - Circadian rhythm
          - Working at low point of rhythm (early morning)
          - Disruption (jet lag or night shifts)
    - Effects of sleep disruption
      - Higher order cognition on less demanding tasks such as monitoring
      - Various cognitive effects
        - Decision making
        - Creativity
        - Maintaining situation awareness
        - Learning
- Effects

- Experience
    - Frustration, arousal
        - Performance changes
            - Tunnelling
                - Visual, e.g. when using display
                - Cognitive e.g. use of single hypothesis
            - Working memory deficits
                - In particular short-term
            - Tendency to take most common action (heuristic)
                - Escaping through a building through the entrance
                - Emergency procedures should be overtrained
            - Desire to take immediate action
        - Remediation
            - Simpler procedures
            - Limit u se of working memory (e.g. checklist)
            - Actions should be compatible with well-known courses of action
            - Easy-to-use displays and controls
            - Warning signals should be disruptive
            - Training
        - Measuring arousal
            - Yerkes-Dodson law



- Physiological
    - Heart rate, hormones
- Information processing often impaired
- Long term health consequences

Workload & overload

- How to measure and predict workload
    - Timeline model: time required for task / time available
        - Problems:
            - Determination of task time
                - Also for cognitive tasks (planning, diagnosis, monitoring)
            - Prioritization
                - Tasks with low priority can be postponed
            - Task demands
                - Can be quantified (weights for each task)
            - Task switch costs
    - Task performance
    - Secondary task performance
        - E.g. memory tasks, mental arithmetic, RT task
    - Physiological
        - Heart rate (variability)
        - Eye movements, eye blinks
        - P300 (EEG)
    - Subjective
        - Mostly: one dimensional scale
            - "How mentally demanding was the task?" [very low – very high]

- Consequences of overload
  - Selective attention impairments
  - More important information receives more weight
  - Reduced accuracy
  - Use of simple / single strategy
- Remediation
  - Task redesign, automation
  - Redesign environment, displays
  - Training

Lecture 6: thinking and deciding

Models of thinking

- Normative: the ideal standard to reach goals
- Descriptive: how people normally think
- Prescriptive: how we should improve our thinking

Rational thinking

- The kind of thinking that helps people the best in achieving their goals
- Rational thinking is considered to be the best kind of thinking
- There is not one best way of rational thinking
- Rational thinking ≠ good outcomes
- Irrational thinking ≠ bad outcomes
- Rational = invariance

- We do not always think rationally, because of:
    - Recent experiences
    - The way information is presented
    - Intuition
    - Comparison with others

Dual-process thinking

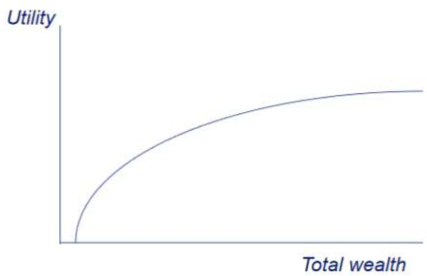
- Several dual process theories
- Two different reasoning systems:
    - Heuristic system
        - Properties
            - Unconscious
            - Implicit
            - Automatic
            - Effortless
            - Rapid
            - Holistic
            - Old (evolution)
            - Does not use WM
            - Not distractible
        - Biases
            - A cognitive bias is a systematic error in judgement
                - Systematic deviation from a normative model
            - A very large number of cognitive biases have been identified
                - Representativeness bias
                    - Considering how much the hypothesis resembles available data as opposed to estimating the probability
                    - The subjective probability of an event is determined by the degree to which it:
                        - Is similar in essential characteristics to its population
                        - Reflects the salient features
                    - A: Linda is a bank teller, B: Linda is a bank teller and is active in the feminist movement. A is more likely than B, but 65% chooses option B
                - Availability bias
                    - The probability of an event is evaluated by the ease with which it come to mind
                        - Frequent events
                        - Recent experiences
                        - Remarkable events
                    - Is K more likely to appear in the first position of a word or in the third position of a word? 105 out of 152 judged the first position to be more likely. It is easier to think of words starting with a K than of words where K is in the third position.
                - Confirmation bias
    - Analytical system
        - Properties
        - Conscious
        - Explicit
        - Controlled
        - Effortful
        - Slow
        - Analytic
        - New (evolution)
        - Uses WM
        - Distractible

Decision making

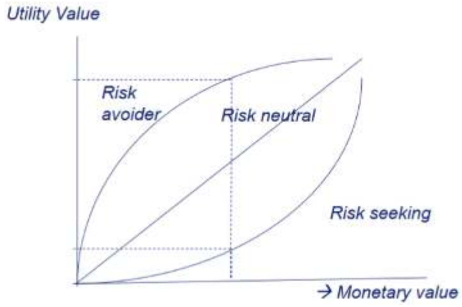
- Decision making under certainty
    - The decision maker knows with certainty the consequences of every alternative
- Decision making under uncertainty
    - The decision maker knows the probabilities of the various outcomes (risk)
    - The decision maker does not know the probabilities of the various outcomes
    - How to make the best decision in order to get the preferred outcome (e.g. gambling)
        - Expected value (EV) = value of payoff * probability
        - The option with the higher EV is the preferred option, example:
            - The probability of getting 100,- is 1 in 80 (EV = 1,25)
            - Guaranteed payment of 1,- (EV = 1)
            - Based on the expected value you choose the first one
            - Works not always as expected
                - If you get 1 million euro's or you have 50% chance of 3 million euro's, you will choose 1 million euro's
                - 3 million euro's is not three times as desirable as 1 million euro's
                    - Utility theory

Expected utility theory

- Bernoulli (1738) explains why poor people bought insurance and rich people sold insurance
- People's value of money is not linear; the value increases at a decreasing rate



- Expected utility theory (Von Neumann and Morgenstern (1947))
- We do not make decisions based on monetary values, but based on utility values
- Utility = usefulness



- Criticism
    - Entire risk profile cannot be captured with a single number (expected utility)
    - Utility has no meaning to most people
    - Famous alternative theory: the prospect theory

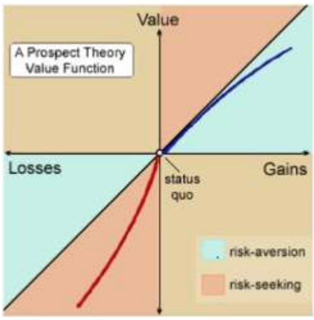
Prospect theory

- Kahneman and Tversky (1979)
- The preferences do not depend on overall wealth and attitudes only
- Preferences are reference dependent (gains and losses), just like perception
- Bernoulli's error: his model is reference independent
- As in perception, the carriers of utility are likely to be gains and loses rather than state of wealth
- We have an irrational tendency to be less willing to gamble with profits than with losses
    - Choices are always made by considering gains and losses
        - Framing
            - Loss aversion

- If the question is asked in 'gains', people choose 200 people saved over 1/3 chance that 600 people will be saved and 2/3 chance no one will be saved.
- If the question is asked in 'loss', people choose 2/3 chance that 600 people will die and 1/3 chance that no one will die, over 400 people dying.

- Loss versus costs
  - Framing negative outcomes as costs rather than losses improves subjective feelings
  - Continuing a project that has already cost a lot without any results, rather than starting a new one, although the previous costs are sunk costs

- Risky prospects can be framed in different ways- as gains or as losses
- Changing the description of a prospect should not change decisions, but it does, in a way predicted by prospect theory



Two main theories of decisions under certainty:
- Expected utility theory: decisions not on monetary values but also incorporates our attitude towards risk
- Prospect theory: preferences are reference dependent
  - Decisions influenced by e.g. framing

Bayes theorem
- Theory of probability by Thomas Bayes
- Provides the probability that a hypothesis is true given certain observations: conditional probability
- P(H|E) = p(E|H) / P(E) * P(H)
- Taking prior probabilities into account

Applications to medicine

Patient safety, medical error
- Very frequent (5%-10% of hospital admissions)
- Can have severe consequences (disability/death)
- Variety of causes:
  - Cognitive errors
  - System related errors

Eye-tracking study on diagnosing X-rays
- Diagnostic errors can be severe
- In radiology, diagnostic errors are not uncommon
  - Despite improved technology, the error rate has remained stable
- Different types of errors:
  - Search
  - Recognition
  - Decision errors

Research among 25 radiologists:
- Large effect of condition (match-mismatch)
- Recognition errors were most prevalent
  - More decision errors in the two abnormality cases
- A mismatching patient description
  - More recognition errors in the mismatching condition
  - More decision errors in the mismatching condition
- Inattentional blindness?
  - Yes, sometimes
  - Other times they don't believe their eyes

Stress measurement
- Stress influences our performance

- In other industries you can train to handle stressful situations
- Physicians often deny that stress affects their performance
- Stress can be objective as well as subjectively experienced

Lecture 6: neuromarketing

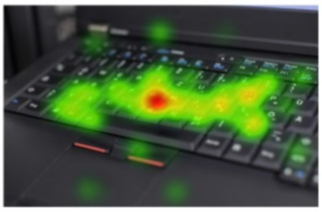
Our world

- Everything around us is constantly competing four our attention
- Attention has become the world's most valuable commodity
- Information overload
    - Classic marketing tactics are frequently experiences as 'unpleasant' by their target audiences
    - And their effectiveness is decreasing
- Transition to an experience economy
    - Many companies no longer have the goal to sell as much as possible in a short time, but rather make customers 'loyal' to their brand

How to optimize experience?

- Measuring human behaviour and experiences
    - 10% conscious
    - 90% non-conscious
- Arousal
    - Heart rate (HR)
    - Blood pressure (BP)
    - Skin conductance (Galvanic Skin Response (GSR))
        - Sweat secretion and the associated changes in sin conductance are unconscious processes that reflect changes in arousal
- Facial expression analysis
    - Eye tracking indicates:
        - Which elements attract immediate attention
        - Which elements attract above-average attention
        - If some elements are being ignored or overlooked
        - In which order the elements are noticed

Gaze maps



Heatmaps

    - Lab VS outside world
        - Pros outside world:
            - Lab settings are/can be synthetically and look not real
            - Results obtained in a lab do not always translate well to the real world (e.g. can have low validity)
            - Lab setting is less immersive: experience is probably completely different, so it is hard to tell in the 'real' experience is being measured
            - Let people experience dangerous situations in a safe way
        - Cons outside world:
            - Less control of environmental variables than in a lab:
                - Weather
                - Traffic density
                - Time of day
                - Solution:
                    - Eye tracking in VR or AR
            - Hard to keep the environment constant
            - Many sensors are not there yet for full ambulant research

- Takes longer to set up and get a session going