Summary

Human - Millieu system

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<th>Human Physical features</th>
<th>Millieu Material environment</th>
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<td>- Anatomy</td>
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Ergonomics

- Ergonomics is the science of improving employee performance and well-being in relation to the
  - job tasks
  - equipment,
  - the environment.

- Ergonomics is a continuous improvement effort to design the workplace for what people do well, and design against what people don’t do well.

The division of ergonomics

- Physical ergonomics - human anatomical, anthropometric, physiological and bio mechanical characteristics as they relate to physical activity
- Cognitive ergonomics - mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system
- Organizational ergonomics - optimization of socio technical systems, including their organizational structures, policies, and processes

The division of ergonomics

- Corrective ergonomics - the improvement of the existing state
- Conceptive ergonomics - proper design
**Stages of ergonomic design**

1. Body measures
2. Biomechanical activity
3. User - workstation relations

**Height Probability Distribution for US men and women**

- Centile models
- Simplex limitations
  - Minimal - reach
  - Maximal
    - Heights (headroom)
    - Safety measures

**Duplex limitations**

- User population
- Adjustment

**Biomechanical and physiological features**

- Physiological features
  - Senses activity
  - Fatigue
- Biomechanical agility
  - Permissible spread of joint mobility
  - Prompted forces and torques

*National Health Statistics Reports, Anthropometric Reference Data for Children and Adults: United States, 2003-2006*
Visual field

1. Often vision without head and torso movements
2. Observation and manipulation with bend head
3. Rare observations
4. Rare observations with head and torso leaned back

Arm and forearm surface area

3. Relation analysis
- Analysis of all activities
  - Equipment choice
  - Working posture choice
- Bondable points

Equipment choice
- Task
- Layout criteria by McCormick
  - Importance
  - Frequency of use
  - Sequence of use
  - Similar functionality

Factors influencing working height
- Worker’s measures
- Task features
  - Precision
  - Used force
  - Object size

Working height for standing posture
Basic rules of sitting at a computer

- Obtuse angles instead of right angles
- Fitting to a desktop height
- MOVE!!

The Comfortable Computing Top 10

1. Avoid twisting
2. Position the top of your monitor screen at eye level
3. Tilt your monitor back 10° to 20° to keep the same focal length as your eyes scan from the top to bottom of screen
4. Position your monitor no closer than 20" (50 cm) from your eyes. A good rule of thumb is an arm’s length distance. The larger a screen, the more distance you’ll want
5. The top of your keyboard should be level with the height of your elbow
6. Tilt your keyboard back slightly so that your wrists remain flat
7. Use a wrist rest so your hands and wrists remain relaxed
8. Rest your eyes periodically by focusing on an object 6+ m away
9. Stand and stretch your back and arms from time to time
10. Use an easily adjusted chair, display mount and keyboard tray. Change the position of your display and keyboard to accommodate reflexive changes in your posture

Work environment

Microclimate

How do humans adjust their thermal comfort?

Thermal regulation

- chemical: Alternation of heat produced
- physical: Alternation of heat exchanged with environment

- active: Sweating and evaporation
- passive: Radiation, Convection, Conduction
**Physical thermal regulation**

- **conduction**
  - energy is transferred by a direct contact of molecules, not by a movement of the material
  - depends on a joint surface area and how conductive the material is
- **convection**
  - heat transfer by motions of a medium such as air or water when the heated medium particles are caused to move away from the source of heat, carrying energy with themselves

**Heat balance**

\[
\Delta Q = M \pm C \pm R - E
\]

- \(\Delta Q\) - heat alternation (increase / decrease)
- \(M\) - metabolic heat
- \(C\) - convection or conduction heat (supplied or lost)
- \(R\) - radiation heat (supplied or lost)
- \(E\) - lost evaporation heat

**Responses to a hot microclimate**

- Vasodilation: the blood supply to the periphery is increased
- Increasing skin temperature
- Sweating increase
- Quickened pulse

**Psychological responses to a hot microclimate**

- Sleepness
- Work capacity decrease
- Longer reaction time
- Lower perception
- Increase of error and accidents number

**Responses to a cool microclimate**

- Vasoconstriction decreasing the heat loss from the skin surface
- Cessation of sweating
- Shivering increasing heat production in muscles.
- Goose pimples
- Skin temperature decrease
Psychological responses to a cool microclimate

- Nervousness
- Lower concentration
- Work capacity decrease

Thermal comfort

- Thermal neutrality, where an individual desires neither a warmer nor a colder environment, is a necessary condition for thermal comfort.
- The sensation of complete physical and mental well being
  /ISO 7730/

Thermal comfort

- Zero heat balance
- Optimal body temperature
- Optimal skin temperature
- No sweat secretion
- No discomfort feeling

Comfort assessment according to ISO 7730

- PMV (Predicted Mean Vote) - from -0.5 to +0.5
  \[ PMV = \frac{0.303e^{0.028}}{(M-W) - 3.05 \cdot 10^{-5}(5733 - 6.98(M-W) - p) - 0.42(M-W) - 5.17 \cdot 10^{-3}(M(9867 - p) - 0.0014(M(34 - t_c) - 3.95 \cdot 10^{-8}(t_c + 273)^2 - t(t_c - t) - f_h(t_c - t))} \]
- PPD (Predicted Percentage of Dissatisfied) - below 10%
  \[ PPD = 100 - 95e^{-0.00333 \cdot (M - W) - 0.3179 \cdot 35.77} \]

PMV & PPD relation

[Graph showing PMV & PPD relation]
PMV factors
- Personal factors
  - Insulative clothing (Clo Value)
  - Activity levels (Met Rate)
- General Factors (microclimate elements)
- Localized factors
  - Air movement/velocity
  - Radiant asymmetry
  - Floor surface temperatures
  - Air temperature stratification

Wind Chill Index
\[
t_{\text{wC}} = 13.12 + 0.6215 t_a - 11.37 v^{0.16} + 0.3965 t_a v^{0.16}
\]
where
- \( t_{\text{wC}} \) = effective “wind” temperature (°C)
- \( t_a \) = air temperature (°C)
- \( v \) = wind velocity (km/h)
**Sound**

A pressure wave traveling through air, water or other media that the human ear can detect.

Normal Atmospheric Pressure

**Sound characteristics**

- **Frequency**
  - Number of times per second a vibrating body traces one complete cycle of motion
  - Cycles/second = Hertz (Hz) = f

- **Wavelength (λ)**
  - Distance measured between two analogous points on two successive parts of a wave
  - Distance a sound wave travels in one cycle

**Distance Vs Loudness (db)**

- 90
- 85
- 80
- 75
- 70
- 65
- 60
- 0 1 2 3 4 5 6 7 8 9 10

**The Hearing mechanism**

1. Collection and concentration of sound waves by ear lobes and pinna
2. Vibration of tympanic membrane (ear drum) in harmony with the frequency of sound source
3. Movement of three ossicles as lever system
4. In and out movement of the footplate of stapes at the oval window of cochlea - pressing on the fluid in the cochlear
Noise influence on human organismus

- Impact on hearing organ
  - Adaptation
  - Fatigue
  - Acoustic trauma
- Physiological impact
  - Psychological - anxiety disorders, deconcentration, longer reaction time
  - Hormonal
  - Equilibrium disorders

Noise Exposure Factors

- Intensity → Loudness
- Frequency
- Duration → Length of exposure
- Distance from the source

Noise reduction methods

- Technical
  - Emission reduction → silent devices, automatization, maintenance
  - Transmission reduction → housings, screens, traps
  - Immission reduction → personal hearing protection
- Administrative
  - Law regulations
  - Organizational → work time, breaks, workstation layout

Fill in the sentences below with the words: increases, decreases, does not change, no data

1. If the temperature increases and other thermal comfort factors do not change, PMV (Predicted Mean Vote) value ...
2. If the physical activity level decreases and other thermal comfort factors do not change, PPD (Percent of Dissatisfied) value ...
3. If the sound frequency decreases, the sound tone ...
4. With increasing age, the threshold of audibility...
5. If the sound frequency decreases, the sound pressure ...

Vision
Eye anatomy

Retina anatomy
- Rods → contours and motions
  - Low resolution
  - ~7 mln
- Cones → 100,000 colours
  - High resolution
  - ~120 mln

Rods → contours and motions
- Rods: Low resolution
- ~7 mln
- Cones: High resolution
- ~120 mln

Directional sensitivity

Main vision mechanisms
- Adaptation
- Accommodation
- Convergention

Adaptation - good vision at changing lighting levels
- Alternations of an iris diameter
  - 2 - 8 mm
- Light intensity alternations 1:20
- Photochemical adaptation of cones and rods
  A. Cones
  B. Rods
**Accommodation - good vision at changing distances**

- Muscles relax, long focal length
- Muscles tense, short focal length

**Convergence - 3D vision**

- A single target observed by two eyes
- Very fast mechanism (<~0.5s)
- Better in good lighting conditions

**Lighting**

**Light**

- energy radiated over wavelengths sensitive to the human eye, from about 330 nm to 780 nm

**Basic measures**

- Luminous flux $\Phi$ [lm],
- Intensity $I$ [cd],
- Illuminance $E$ [lx],
- Luminance $L$ [cd/m²].

**Basic photometric measures**
EN 12464 Standard “The Lighting of Workplaces”
(Polish Standard: PN-EN 12464-1: 2011
Światło i oświetlenie. Oświetlenie miejsc pracy.
- Valid from 11.2004
- Obligatory for employers
- Lighting parameters for different workstations

Visual task
- Visual elements of work
- Factors influencing on difficulty level
  - Work object measures
  - Luminance of object
  - Contrast between the object and background
  - Time

Visual task area- area for visual tasks performance
Surrounding area - area encompassing task area with minimal width 0.5 m

Main lighting criteria
- Illuminance
- Luminance (glares)
- Colour aspects
- Day light

Illuminance
- Appropriate for photopic vision
- Suitable contrast and detail recognition
- Fitted to
  - User age
  - Vision task
  - Object of work

Luminance and glare assessment
- To high luminance → risk of glares
- Measuring:
  - Simple: Illuminance + Reflectance factor - measure of the extent to which a surface reflects incident light; expressed as the ratio of incident flux to reflected flux
  - Complex: UGR (Unified Glare Rating) - The lower the UGR value, the lower the glare.
Typical relative illuminance values together with suggested reflectance values

Maximal contrasts in vision field
- Contrast - a measure of the difference of luminance levels between two areas

Direct and indirect glare

CRI (Ra) Colour Rendering Index
- A measure of the quality of color light
- Quantitative measure of the ability of a light source to reproduce the colours of various objects faithfully in comparison with an ideal or natural light source

Colour temperature of a light source [K]
- defined in comparison with a “black body radiator” and plotted on what is known as the “Planckian curve”

Colour temperature differences
- Higher colour temperature → colder colour of light
- Influence on thermal comfort
Workload

Cumulative effect of daily causes of fatigue (Grandjean, 1968)

Biomechanical workload

Factors influencing on body posture
- Body dimensions of worker
- Working pace dimensions
- Layout of work elements
- Working task
  - Accuracy
  - Force
  - Working object dimensions
- Worker’s preferences and habits

Neutral position
- Ideal working posture
- Straight back
- Elbows at the side of the torso
- Wrists neutral

Awkward position
- Any fixed or constrained body position that overloads muscles and tendons or loads joints in an uneven or asymmetrical manner
- Deviation from the ideal working posture
- Any position of the body while performing work activities that is associated with an increased risk for injury
  - reaching behind,
  - twisting
  - Forward or backward bending
  - Squatting
Dynamic and static work of muscles

Dynamic work:
- isotonic meaning 'same tension')
- rhythmical contraction and relaxation of a muscle which does result in movement
- less tiring and more efficient than static work.
- Muscles act like a pump allowing the blood to supply more oxygen and take away more lactic acid.

Static work:
- Muscles act like a pump allowing the blood to supply more oxygen and take away more lactic acid.
- very tiring as muscles don't get time to relax.
- A muscle which is heavily contracted

Biomechanical workload assessment

- Objective
  - Analysis of body segments torques
  - Analysis of body reaches and vision field of a worker
- Subjective
  - Pain questionnaire
  - SOWA (Subjective Overall Work Analysis)

Energy expenditure assessment

- Calorymetry
  - Direct
  - Indirect
- Günter Lehmann’s chart (1966)
  - Posture
  - Muscles load
  - Work time

<table>
<thead>
<tr>
<th>Workload</th>
<th>Heart rate [per min]</th>
<th>Lung ventilation [l/min]</th>
<th>Oxygen flow [l/min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>&lt;75</td>
<td>8-10</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Light</td>
<td>75-100</td>
<td>10-20</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Medium</td>
<td>100-125</td>
<td>20-35</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Hard</td>
<td>125-150</td>
<td>35-50</td>
<td>1.5-2.0</td>
</tr>
<tr>
<td>Very hard</td>
<td>150-175</td>
<td>50-65</td>
<td>2.0-2.5</td>
</tr>
<tr>
<td>Extremely hard</td>
<td>&gt;175</td>
<td>&gt;65</td>
<td>&gt;2.5</td>
</tr>
</tbody>
</table>

Lehmann chart

<table>
<thead>
<tr>
<th>Body Position (A)</th>
<th>Energic expenditure kcal/min</th>
<th>Energic expenditure kJ/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting</td>
<td>0.3</td>
<td>1.26</td>
</tr>
<tr>
<td>On knees, squating</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Standing</td>
<td>0.6</td>
<td>2.51</td>
</tr>
<tr>
<td>Standing bended</td>
<td>0.8</td>
<td>3.35</td>
</tr>
<tr>
<td>Walking</td>
<td>2.6</td>
<td>10.89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload of Muscles (B)</th>
<th>Energic expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work of fingers, palms, forearm</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Work of one forearm</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>Work of both forearms</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>Work of whole body (muscles of torso and limbs)</td>
<td>3.0-10.0</td>
</tr>
</tbody>
</table>

Energic expenditure = (A+B) x time of work [min]
Ovako Working Posture Analysis (OWAS)

1. Find a code of position
2. Find a static workload category
3. Correct a workstation (if necessary)

Code of position

1. Back (1-4)
2. Upper limbs (1-3)
3. Lower limbs (1-7)
4. Load
   1. below 10 kg
   2. 10-20 kg
   3. Above 20 kg

Static workload category

<table>
<thead>
<tr>
<th>Category</th>
<th>Interpretation</th>
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<tr>
<td>1</td>
<td>Natural, neutral work positions</td>
</tr>
<tr>
<td></td>
<td>Acceptable workload</td>
</tr>
<tr>
<td></td>
<td>No need of changes</td>
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<tr>
<td>2</td>
<td>Potentially negative workpositions</td>
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<td></td>
<td>Almost acceptable workload</td>
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<td></td>
<td>No need of immediate changes</td>
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<tr>
<td>3</td>
<td>Workpositions impact on musculoskeletal system</td>
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<tr>
<td></td>
<td>High workload</td>
</tr>
<tr>
<td></td>
<td>Need of fast changes</td>
</tr>
<tr>
<td>4</td>
<td>Workpositions impact very negatively on musculoskeletal system</td>
</tr>
<tr>
<td></td>
<td>Extremely high workload</td>
</tr>
<tr>
<td></td>
<td>Need of immediate changes</td>
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Mental workload
Mental workload assessment

1. Primary Task Performance - measure the influence of mental workload
2. Secondary Task Techniques - measure the reserve capacity
3. Subjective Response
4. Physiological Assessment (Central and Peripheral) allow non-intrusive measures

Subjective Responses

- Different questionnaires i.e. SOWA and NASA-TLX
- The advantage: easy to do and high face validity
- The disadvantage: often performance and perception deviate

NASA-TLX (Task Load Index)

- Data easily available, future failure unpredictable
- Intrusive diagnostic and administration
- High face validity, often dissociate
- Unobtrusive, expensive data (but getting cheaper)

Usability

- Definition
- Basic principles
- Testing
Usability
- Result - ergonomic product
- Creating process (UCD - User Centered Design)
- Set of testing technics
- 5 E (efficient, effective, engaging, error tolerant, easy to learn)

ISO 9241

ISO 9241
- Effectiveness: Accuracy and completeness with which users achieve specified goals
- Efficiency: Resources expended in relation to the accuracy and completeness with which users achieve goals
- Satisfaction: Freedom from discomfort, and positive attitudes towards the use of the product

Usability Heuristics - from Nielsen
1. Simple and natural dialogue
2. Speak the user’s language
3. Minimize the user’s memory load
4. Consistency
5. Feedback
6. Clearly marked exits
7. Shortcuts
8. Good error messages
9. Prevent errors
10. Help and Documentation

(Nielsen & Molich, 1990)