Lecture 4: Human factors
Research methodologies
ENVD 5380 Human Factors/Ergonomics in ENVD
(ENVD 5311-001 Design & Ergonomics)
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Types of HF research

- Descriptive studies
  - Characterize a population in terms of certain attributes
  - Examples:
    - Survey of the dimensions of people’s bodies.
    - Survey of operators to gather their opinions about design deficiencies and problems.

- Experimental research
  - The purpose is to test the effects of some variable on behavior.
  - Examples:
    - Comparing how well people can edit manuscripts with computer displays.
    - Assessing the effect of seat belts and shoulder harnesses on functional arm reach.
    - Relative difference in performance between conditions (e.g., light).

- Evaluation research
  - The purpose is to assess the effect of “something”
  - It seeks to describe the performance and behaviors of the people using the system or product.
  - Assess the “goodness” of designs, theirs and others, and recommendations for improvement based on the information collected.
  - Example:
    - Benefit and cost analysis
    - Evaluating a new training program, a new software package for word processing, ergonomic products or spaces.

Choosing a research settings

- Descriptive studies
  - Actual data collection can be done in lab.

- Experimental research
  - Field studies
    - Observing people in their natural environments.
    - Cost effective.
    - Data collected is more meaningful and consistent.
  - Laboratory setting
    - Controlling the environment.
    - Limited control over the environment.
  - Simulations
    - Looking like, feeling like, or acting like.

- Evaluation research
  - The best should be conducted under controlled environment.
Selecting variables

Criterion variables:
- Physical characteristics
  - Arm reach, stomach girth, and body weight, etc.
- Performance data
  - Reaction time, visual acuity, hand grip strength, etc.
- Subjective data
  - Preferences, opinions, and ratings.
- Physiological indices
  - Heart rate, body temperature, and pupil dilation.
- Stratiﬁcation variables
  - Age, sex, gender, etc.

Descriptive studies

Independent variables

Environmental variables

Experimental variables

Subject related variables

Performance, subjective, or physiological variables

Dependent variables

Experimental research

Evaluation Research

Selecting variables for evaluation research requires the researcher to translate the goals and objectives of the system or device into specific criterion variables that can be measured.

Choosing Subjects

Descriptive studies

- Representative samples of a population
- It should be relevant samples.
- It should not be biased.

Random sampling
- Random selection from the population.
- Sample size
  - The larger the sample size
  - The more conﬁdence one has in the results,
  - The more degree of accuracy desired,
  - The greater the degree of variability in the population
  - The statistic being estimated, e.g. mean, 5th percentile.

Evaluation Research

- The same consideration as descriptive studies and experimental research.

Choosing Subjects

Experimental Research

- Select subjects representative of those people to whom the results will be generalized.
- Do not have to be representative of the target population.
- The question is whether the subjects will be affected by the independent variables (e.g., illumination).
- Example: When we consider an experiment to investigate the effects of room illumination (high vs. low) on reading text.
- Sample size is to collect enough data to reliably assess the effects of the Independent Variables.
- Less than 9 ~11 subjects.

Collecting the Data

Data

- Measurements
  - Example: Energy expenditure of performing work
  - Example: Measuring Zone of Convenient Reach (ZCR)
  - Measure:
    - \( a \) = shoulder (acromion) - grip (center of hand) length.
    - \( d \) = horizontal distance from shoulder to surface.
    - \( r = \sqrt{a^2 - d^2} \)
    - \( r \) = radius of ZCR
    - ZCR defines the maximum working area.
    - Zones of Convenient Reach + Optimal Visual Zones.
  - Surveys and Interviews
Analyzing the data

**Descriptive studies**
- Frequency distributions
- Mean, median, mode
- Standard Deviation (e.g. reaction time)
- Correlation Coefficient
- Percentiles

**Experimental Research**
- Analysis of Variance (ANOVA)
- Multivariate analysis of variance (MANOVA)

**Distributions**

- Distribution of measurements
  - Any distribution (set of measurements) can be represented by three statistics:
    - Mean (the average)
    - Median (midpoint at which 50% >, 50% < than value)
    - Mode (most frequently occurring number)

**Normal Distribution**

- Normal distribution
  - In a normal distribution all three statistics, the mean, median, and mode are the same. 68% of values in a normal distribution are within a standard deviation (SD) of either side of the mean (SD= \( \sqrt{\sum (X-Mean)^2/n-1} \)).
  - Example: Mean=60", SD= 4"
    - \( \pm 1SD = 56-64" \) covers 68% of sample

**Non-Normal Distribution**

- Kurtosis
  - Relates to the shape of the distribution.
  - It’s important to plot the data, as it’s crucial to know it’s shape for analysis.
  - A type of distribution shapes:
    - Bell curve, Gaussian curve (named after Gauss, a physicist), normal distribution.
- Skewed distributions
  - Skewed occurs when one tail of a distribution is disproportionate to the other tail:
    - Positive skew
    - Negative skew

**Coefficient of Variation**

- Coefficient of Variation (CV)
  - Useful index of variability of a dimension (CV=sd/mean).
  - A low value means that the data are normally distributed (<10).
  - A high value indicates increasing skewness of data.
  - Typical values are
    - Stature 3-4%
    - Body heights (sitting height etc.) 3-5%
    - Body breadths 5-9%
    - Dynamic reach 4-11%
    - Weight 10-21%
    - Joint ranges 7-28%
    - Muscle strength (static) 13-45%

**Calculating percentiles**

- Z scores (standard scores)
  \[ Z = (Value-Mean)/SD \]
- For any percentile:
  \[ X_p = mean + (SD * Z) \]
  - Example for US adults:
    - Mean stature 1755 mm
    - SD=71 mm
    - Z (for 90th percentile)=1.28
    - 90%ile stature =1755 + (71*1.28)=1755+90.88
    - 90%ile stature =1845.88 mm (~72.6")
Kinetosphere

- **Kinetosphere**
  - The dynamic reach envelope
  - Describes where the user is able to reach
  - Examples: Grip strength and reach
  - Volumetric reach envelope
  - Used to model optimal workspace layout (e.g. SAMMIE CAD).

- **Read related article of Kinetosphere:**
  http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1579192

Criterion Measures in Research

- **System**
- **Task**
- **Human**

**Criterion Measures in Research**

- **System-descriptive criteria**
  - Equipment reliability
  - Resistance to wear
  - Cost of operation
  - Maintainability

- **Task performance criteria (The outcome)**
  - Quantity of output
  - Number of decoded, number of shots fired.
  - Quality of output
  - Accidents, number of errors, accuracy of drilling.
  - Performance time

**Criterion Measures in Research**

- **Physiological indices**
  - Measure strain in humans resulting from physical or mental work and from environmental influences
  - E.g. heat, vibration, noise, and acceleration.
  - Indices can be classified by the major biological systems of the body
  - Cardiovascular (e.g. heart rate or blood pressure)
  - Respiratory (e.g. respiration rate or oxygen consumption)
  - Nervous (e.g. electric brain potentials or muscle activity)
  - Sensory (e.g. visual acuity, blink rate, or hearing acuity)
  - Blood chemistry

**Criterion Measures in Research**

- **Human criteria**
  - Performance measures
  - Frequency measures
  - (e.g. number of targets detected, number of keystrokes made, etc.)
  - Intensity measures
  - (e.g. torque produced on a steering wheel)
  - Latency measures
  - (e.g. reaction time or delay in switching from one activity to another)
  - Duration measures
  - (e.g. time to log on or time on target in a tracking task)
  - Reliability (the probability of errorless performance)

**Criterion Measures in Research**

- **Subjective responses**
  - Subjects’ opinions, ratings, or judgments to measure criteria.
  - Criteria such as comfort of a seat
  - Ease of use of a computer system
  - Preferences for various lengths of tool handle.
  - Used to measure perceived mental and physical workload.
  - Likes, dislikes, and feelings.
Practical requirements a criterion measure should be:

- Objective
- Quantitative
- Unobtrusive
- Easy to collect
- Require no special data collection techniques
- Cost as little as possible.

Requirements for research criteria

<table>
<thead>
<tr>
<th>Reliability</th>
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<tbody>
<tr>
<td>• Free from error</td>
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<table>
<thead>
<tr>
<th>Validity (types)</th>
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<tbody>
<tr>
<td>• Face validity</td>
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<tr>
<td>• Looks</td>
</tr>
<tr>
<td>• Content validity</td>
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<tr>
<td>• Extent to which a measure of some variable samples a domain, such as a field of knowledge or a set of job behaviors. (e.g. air traffic controllers)</td>
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<tr>
<td>• Construct validity (construct of interest)</td>
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<td>• Based on judgmental assessment</td>
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Requirements for research criteria

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<thead>
<tr>
<th>Freedom from contamination</th>
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<td>• Should not be influenced by variables.</td>
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<th>Sensitivity</th>
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<td>• Should be measured in units or scale.</td>
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<td>• e.g. 3 point rating scale (uncomfortable- neutral- comfortable) to measure various chairs.</td>
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Human reliability

<table>
<thead>
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<th>Human reliability (human error)</th>
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<tr>
<td>• Human reliability is a procedure for conducting a quantitative analysis to predict the likelihood of human error.</td>
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<td>• .992, then out of 1000 readings 992 to be correct.</td>
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<td>• Database</td>
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<td>• In1962, the first prototype human reliability data bank (Database, Data store)</td>
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<td>• Methodologies for determining human reliability</td>
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<td>• THERP (the technique for human error rate prediction)</td>
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<tr>
<td>• Probabilities, diagrams.</td>
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<td>• Simulation models</td>
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Discussion