Experimental Design and Statistical Analysis Seminar

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Review of Last Week: STUDY DESIGNS

1. Classification of Study Designs
2. Essential Design Features of a Controlled Clinical Trial
3. Quality Assurance
4. Computer Facility
5. Data Security Precautions
6. Preparation of Analysis Files
7. Activities By Stage of Clinical Trial

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EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS SEMINAR: Chapter 2: Experimental Design (2 Weeks)

1. **Main Principles of Experimental Design**
2. **Selecting an appropriate Design**
3. **Criteria for Evaluating An Experimental Design**
4. **Threats to Valid Inference-Making**
5. **Overview of Experimental Designs Types:**
   i. Completely Randomized design (CR)
   ii. Randomized Block Design (RB)
   iii. Latin Square Design (LS-p)
   iv. Completely Randomized Factorial Design
   v. Split-Plot Factorial Design

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Experimental Design: 1: Main Principles of Experimental Design

1. **MAX**imize Systematic Variation.
2. **CON**trol Extraneous Variation: These are the other sources of variation that are known to affect the dependent variables. The extraneous variation increases the chance of variation -> more difficult to reject the null Hypothesis.
   a) Eliminate the Extraneous Variable
   b) Include it as an Independent Variable
   c) Use the variable as a blocking factor
   d) Randomization (sample size ≥ 50)
   e) Use the Analysis of Covariance.

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Experimental Design: 1: Main Principles of Experimental Design

1. **MAX**imize Systematic Variation.
2. **CON**trol Extraneous Variation:
3. **MIN**imize Sample Variation: This will reduce the chance variation and the experimental error.
   a) Development of controlled, repeatable condition for study (SOP)
   b) Use reliable instruments
   c) Use a powerful design for the study.

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EXPERIMENTAL DESIGN :
2: Selecting an Appropriate Design:

- **Research:** Research is the empirical investigation of the relationship between or among several variables.
- There are three basic goals in any research:
  1. To collect data that are free of bias.
  2. To draw valid conclusions concerning the effects of an independent variable.
  3. To make valid generalizations to populations and settings of interest.

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EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS SEMINAR:

- Research begins with a substantive question that is converted to a statistical question.
- Statistical question is then converted to a hypothesis about a parameter of the population (e.g., mean).
- A statistical question can be answered by collecting data.
- There will be variability in collected data.

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EXPERIMENTAL DESIGN :
2: Selecting an Appropriate Design:

1) What kind of research is being done?
2) Is it Hypothesis Testing or Estimation?
3) What kind of data is required?
4) How many times does data need to be collected?
5) What kind of sample and how large a sample do you need to have?
6) What type of power would be adequate to test the statistical hypotheses?
7) How to improve the efficiency of the Design?

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2: Selecting an Appropriate Design:
1. What kind of research is being done?

1. Study Type
   - i. Observational studies:
     - a) Case Series
     - b) Case-Control (Retrospective Studies)
     - c) Cross-Sectional (Prevalence Studies)
     - d) Cohort (Prospective Studies)
   - ii. Experimental studies:
     - a) Uncontrolled trials
     - b) Controlled trials:
       1. Trials With Independent Concurrent Controls
       2. Trials with Self-Controls
       3. Crossover Studies
       4. Trials with External Controls
2. Main Objectives
   - i. Feasibility
   - ii. Efficacy
   - iii. Effectiveness

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3: Broader classification of study designs

1. Randomized Controlled Trial (RCT)
2. Factorial Design
3. Single-Arm Trial
4. Block Design
5. Basket design clinical trial
6. Umbrella Study Design
7. Platform Study Design
8. Adaptive Randomization Design
9. Parallel-Group
10. Pragmatic Trial (Effectiveness)
11. Decentralized/ Remote Trials
12. Cluster Randomized Trial
13. Community trial (cluster-randomized)
14. Field trial (preventive or prophylactic
15. Dose Escalation Design
16. Non-Inferiority Trial
17. Matched Design / Matched Pair Design
18. 3+3 Design
19. Enriched Design
20. N-of-1 trial
21. Waitlist Control Group

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2: Selecting an Appropriate Design:
2: What kind of hypothesis will be tested?

A. Hypothesis Testing

1. It is a statement about the value of certain population parameters.
2. Is it about association among variables, prediction, or group differences?
3. What are the probabilities of a Type I & II errors?
4. Is it directional (one-tailed) or non-directional (two-tailed)?
5. If it is a group difference: Is it about a Single Mean or Two or More Means (Independent, Dependent Means)?

B. Estimation

1. It is an estimation of certain population parameters.
2. What is the population value?

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2: Selecting an Appropriate Design:
3: What kind of data is required?

a) What type of data is required?
b) How many treatment levels should be used?
c) Should the treatment levels used in the experiment be selected on an a priori basis or by random sampling from a population of treatment levels?
d) Are all treatments and all treatment levels of equal interest to the experimenter?
e) Should a factorial experiment be used so that interaction effects can be evaluated?

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2: Selecting an Appropriate Design:
3: What kind of data is required?

1. Data can be a collection of information and/or scores obtained when a subject's behavior or characteristic is measured.
2. Data Type:
   a) Qualitative data is information that is based on exploring the meaning, not the frequency, of beliefs, attitudes, and perceptions of people's lived experiences that shape their interactions.
   b) Quantitative data are measures of values or counts and are expressed as numbers.

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2: Selecting an Appropriate Design:
3: What kind of data is required?

- Quantitative Data is a collection of scores obtained when a subject's behavior/characteristic is measured.
- Data may be a Constant or a Variable.
- A Constant is a characteristic that cannot have other than a single value (i.e., Group membership).
- A Variable is a characteristic that may take on different values (i.e. Depression, Pain Scores). It may be:
  1. Categorical: It is measured by categorizing the subjects. It is always Discrete.
  2. Continuous: It is measured by Ranking or Scoring.

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2: Selecting an Appropriate Design:
3: What kind of data is required?

- Categorical: It is measured by categorizing the subjects. It is always Discrete.
- Categorical/Discrete Variable can take only certain values, and none in between (i.e., number of diagnoses), and produce a Nominal Scale.
- Nominal Scale is a classification system
  - Places items, objects, characteristics, or individuals into categories.
  - These categories are mutually exclusive.
  - These categories differ from one another only in a qualitative sense (i.e., hair color, political affiliation, and marital status).

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2: Selecting an Appropriate Design:
3: What kind of data is required?

- Variables: Quantitative (Categorical, Continuous):
- Continuous Variable is a variable that may take on any of an infinite number of values (i.e., weight).
- It may be Discrete or Continuous.
- A continuous one can be reduced to a discrete one.
- It can be measured by Ranking or Scoring.
- Ranking:
  - Observations are ranked in order of magnitude,
  - Ranks express a "greater than" relationship,
  - No implication about how much greater.
  - produces the Ordinal Scale.

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2: Selecting an Appropriate Design:
3: What kind of data is required?

- Variables: Quantitative (Categorical, Continuous):
- Continuous Variable can also be measured by Scoring.
- It can produce an Interval Scale or a Ratio Scale.
- Interval Scale
  - Observations are ranked in order of magnitude,
  - Relative distances between points are meaningful,
  - Intervals between measures are equal.
- Ratio Scale
  - This Scale has all the properties of an interval scale,
  - Also includes an absolute zero point,
  - Ratio between measures becomes meaningful.

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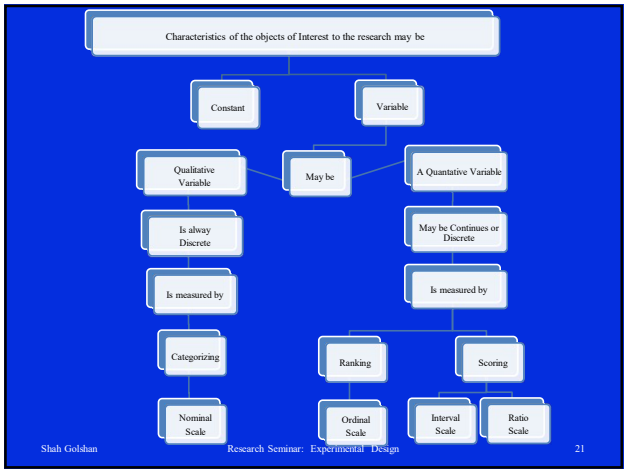

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2: Selecting an Appropriate Design:
4: What kind of sample is needed?
5: How many times data needs to be collected?

a) Should subjects' selection in one group effect the subjects' selection in the other group?
b) Should subjects be observed under more than one treatment level? (cross-over)
c) How many times should a subject be measured?
d) Should subjects be stratified into homogeneous blocks?
e) Do the available subjects represent a random sample from the population of interest to the experimenter?
f) Will the treatment(s) produce physical or psychological injury to the subjects?

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2: Selecting an Appropriate Design:

6) What type of power would be adequate to test the statistical hypotheses?

a) What size treatment effect does the experimenter consider to be of practical interest?
b) What statistical effect size does the treatment effect convert to?
c) Is the sample size large enough to provide adequate precision in testing the statistical hypotheses (Is the power of the proposed experimental design adequate to test the statistical hypotheses)?
d) What are the consequences of committing Type I and Type II errors?

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2: Selecting an Appropriate Design:

7: How to improve the efficiency of the Design?

1. Which experimental design provides maximum efficiency in testing the statistical hypotheses?
2. Would efficiency be improved more by :
   a) Using a large number of randomly assigned subjects or using blocks of homogeneous subjects or controlling additional nuisance variables?
   a) Using a simple design with a large sample size or using a complex experimental design (Time to plan and analyze)?
   a) Measuring one or more characteristics related to the DV in order to use regression techniques?

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EXPERIMENTAL DESIGN:
3: Criteria for Evaluating An Experimental Design:

1. Does the design permit an experimenter to calculate a valid estimate of the experimental effects and error effects?
2. Does the data collection procedure produce reliable results?
3. Does the design provide maximum efficiency within the constraints imposed by the experimental situation?
4. Does the design possess sufficient power to permit an adequate test of the statistical hypotheses?
5. Does the experimental procedure conform to accepted practices and procedures used in the research area?

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EXPERIMENTAL DESIGN :
4: Threats to Valid Inference-Making :

- Three basic goals of research:
  1. To collect data that are free of bias, especially treatment-related bias.
  2. To draw conclusions concerning the effects of an Independent Variable
  3. To make valid generalizations to populations and settings of interest.

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EXPERIMENTAL DESIGN : 4: Threats to Valid Inference-Making :

- Cook and Campbell (1979) have identified four categories of threats to our basic goals of research:
  1. Statistical Conclusion Validity
  2. Internal Validity
  3. Construct Validity
  4. External Validity
  5. Content Validity

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EXPERIMENTAL DESIGN : 4: Threats to Valid Inference-Making :

I. Statistical Conclusion Validity

is concerned with threats to valid inference making that result from random error and the ill-advised selection of statistical procedures.

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EXPERIMENTAL DESIGN : 4: Threats to Valid Inference-Making :

I. Statistical Conclusion Validity:

1. Low statistical power.
2. Violated assumptions of statistical tests.
3. Fishing and the error rate problem.
4. Low reliability of measures (↑ Type II error; F-).
5. Low treatment fidelity (↑ Type II error; F-).
6. Lack of SOP=Random irrelevancies in the experimental setting.
7. Random heterogeneity of respondents.

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EXPERIMENTAL DESIGN : 4: Threats to Valid Inference-Making :

II. Internal Validity:

- It studies whether the variable that the researcher had varied (Treatment/Independent Variable) caused the Outcome (DV) to co-vary.
- The independent variable is responsible for variation in the Dependent Variable (DV).
- Need to rule out all systematic blunders as an alternative explanation for the changes in the Dependent Variables.
- Errors or chance variation are not systematic variation.

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4: Threats to Valid Inference-Making :

II: Internal Validity (11 items)

1. History.
2. Maturation.
3. Testing: Repeated testing of experimental units
4. Instrumentation: Calibration.
5. Statistical Regression: The amount of statistical regression is inversely related to the reliability of the test.
   a) increase the scores of experimental units originally found to score high on a test
   b) not affect the scores of experimental units found to score at the mean of the test

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4: Threats to Valid Inference-Making :

II: Internal Validity

6. Selection: Differences among the Groups.
7. Mortality.
8. Diffusion or Imitation of Treatment: Communication among treatment groups.
9. Compensatory Equalization of Treatment: Providing compensatory goods or services to units not scheduled to receive them.
10. Compensatory rivalry by respondents receiving less desirable treatments, "John Henry" effect.
11. Resentful Demoralization of respondents receiving less desirable treatments.

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4: Threats to Valid Inference-Making :

III. Construct Validity is concerned with the possibility that operations that are meant to represent the manipulation of a particular independent variable or the measurement of a particular dependent variable can be constructed in terms of other variables

1. Hypothesis guessing by subjects.
2. Experimenter expectancies (personal bias).
3. Interaction of different treatments (carry over).
4. Inadequate pre-operational definition of construct.
5. Mono-operation bias.

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4: Threats to Valid Inference-Making :

IV. External Validity is concerned with the ability to generalize the findings. It asks: Can I generalize my findings beyond the population used in this study?

1. Interaction of selection and treatment; i.e., use of volunteers vs. systematic recruitment.
2. Interaction of setting and treatment; i.e., use of small groups or specialized settings.
3. Interaction of history and treatment; i.e., taking place on a "special day".

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5: Threats to Content Validity:

V. Content Validity is the degree to which the items on a tool adequately represent the universe of content.

- The extent to which the items included in an instrument adequately represent the content domain of the concept of interest.
- Using established Scale vs. self developed one
- Using shorter, unstandardized version of scale.
- Not following the scale SOP.
- Same as Face validity.

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