Experiment Design & Operation

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Experimental Planning

Design Types

Design Types

- In this lecture we will consider design for:
  - One factor with two treatments
  - One factor with more than two treatments
  - Two factors with two treatments
  - More than two factors each with two treatments
- Note: There are many more designs, if you are truly interested in experimentation:
  - Read: "Design and Analysis of Experiments" by Douglas Montgomery
  - Take MATH 4458/5558 - Experimental Design
- **Notation**
  - μ_i - the mean of the dependent variable for treatment i
  - y_{ij} - the jth measure of the dependent variable for treatment i

Design Types

One Factor with Two Treatments

Completely Randomized Design

- Compares treatment means
- Same objects for both treatments
- Subjects randomly assigned to treatments
- Each subject uses one Treatment on one object
- Hypotheses:
  - H_0: $\mu_1 = \mu_2$
  - H_A: $\mu_1 \neq \mu_2, \mu_1 < \mu_2, \mu_1 > \mu_2$
- Analyses:
  - t-test
  - Mann-Whitney

EX: Assigning Subjects to Treatments

Subjects	Treatment 1	Treatment 2
1	X	
2		X
3		X
4	X	
5		X
6	X	

Paired Comparison Design

- Makes comparisons on paired data
- Each subject uses both treatments on some object
- Compares difference to zero
- Hypotheses
  - $d_j = y_{1j} - y_{2j}$
  - μ_d is mean of diff
  - H_0: $\mu_d = 0$
  - H_A: $\mu_d \neq 0$, $\mu_d < 0$, $\mu_d > 0$

EX: Assigning Subjects to Treatments

Subjects	Treatment 1	Treatment 2
1	2	1
2	1	2
3	2	1
4	2	1
5	1	2
6	1	2

- Analyses
  - Paired t-test
  - Sign Test
  - Wilcoxson

Design Types

One Factor with more than Two Treatments

Completely Randomized Design

- Random order of tests
- Uniform experiment environment
- One object to all treatments
- Subjects assigned randomly to treatments
- Hypotheses:
  - H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_A$
  - H_A: $\mu_i \neq \mu_j$ for at least one pair (i, j)

Example Assingment

Subjects	Treatment 1	Treatment 2	Treatment 3
1		X	
2			X
3	X		
4	X		
5		X	
6			X

- Analyses:
  - ANOVA
  - Kruskal-Wallis

Randomized Complete Block

- useful when variability between subjects is large
- each subject (block) uses all treatments and subjects form a homogeneous experiment unit
- one object to all treatments
- subjects order to treatments is random
- Hypotheses:
  - H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_A$
  - H_A: $\mu_i \neq \mu_j$ for at least one pair (i, j)

Example Assingment

Subjects	Treatment 1 |	Treatment 2 | *	*Treatment 3**
1	1	3	2
2	3	1	2
3	2	3	1
4	2	1	3
5	3	2	1
6	1	2	3

- Analyses:
  - ANOVA
  - Kruskal-Wallis

Design Types

Two Factor with Two Treatments

Two Factors

- A bit more complex
- Splits the single hypothesis into 3 separate hypotheses (each factor and the interaction)
- **Notation**
  - τ_i - effect of treatment i on factor A
  - β_j - effect of treatment j on factor B
  - $(\tau\beta)_{ij}$ effect of the interaction between τ_i and β_j

2x2 Factorial

- 2 Factors each with 2 Treatments
- Random assignment of subjects to treatment combos
- Analysis: ANOVA

- Hypotheses
  - $H_{1,0}$: $\tau_1 = \tau_2 = 0$
  - $H_{1,A}$: at least one $\tau_i \neq 0$
  - $H_{2,0}$: $\beta_1 = \beta_2 = 0$
  - $H_{2,A}$: at least one $\beta_j \neq 0$
  - $H_{3,0}$: $(\tau\beta)_{ij} = 0$ for all i, j
  - $H_{3,A}$: at least one $(\tau\beta)ij \neq 0$

Example Assignment

		Factor A	
		Treatment A1	Treatment A2
Factor B	Treatment B1	Subject 4, 6	Subject 1, 7
	Treatment B2	Subject 2, 3	Subject 5,8

Two Stage Nested

- two factors, each with two or more treatments
- when one factor is similar, but not identical for different treatments of the other factor then the design is hierarchical
- Hypotheses and analyses are same as 2x2 factorial

Example Assignment

Factor A			
Treatment A1		Treatment A2	
Factor B		**Factor B**	
Treatment B1’	Treatment B2’	Treatment B1”	Treatment B2”
Subject 1, 3	Subject 6, 2	Subject 7, 8	Subject 5, 4

Design Types

Two Factor with more than Two Treatments

2K Factorial

- 2^k combinations, all are tested
- k factors where each has 2 treatments
- Subjects randomly assigned to treatment combinations
- Hypotheses and Analyses same as for 2x2 factorial

Factor A	Factor B	Factor C	Subjects
A1	B1	C1	2, 3
A2	B1	C1	1, 13
A1	B2	C1	5, 6
A2	B2	C1	10, 16
A1	B1	C2	7, 15
A2	B1	C2	8, 11
A1	B2	C2	4, 9
A2	B2	C2	12, 14

2K Fractional Factorial

- As k increases the number of factor combos exponentially increases
- Often higher-order interactions can be assumed to be negligible
- Thus, main effects and low-order interactions can be evaluated using only a fraction of the combos
- Based on 3 ideas:
  - **Sparsity of effect principle**: it is likely that the system is primarily driven by main and low-order interaction effects
  - **Projection property**: a stronger design can be obtained by taking a subset of significant factors from the fractional factorial design
  - **Sequential experimentation**: a stronger design can be obtained by combining sequential runs of two or more fractional factorial design

Instrumentation

- Experimental Instruments are of 3 types
  - Objects (i.e., specification or code documents)
  - Guidelines (i.e., process descriptions or checklists) - guide the participants
  - Measurement Instruments (i.e., questionnaires or metrics) - data collection
- In planning, instruments are selected
- In execution, instruments are developed
- **Overall goal**: provide means for performing and monitoring the experiment without affecting experimental control.

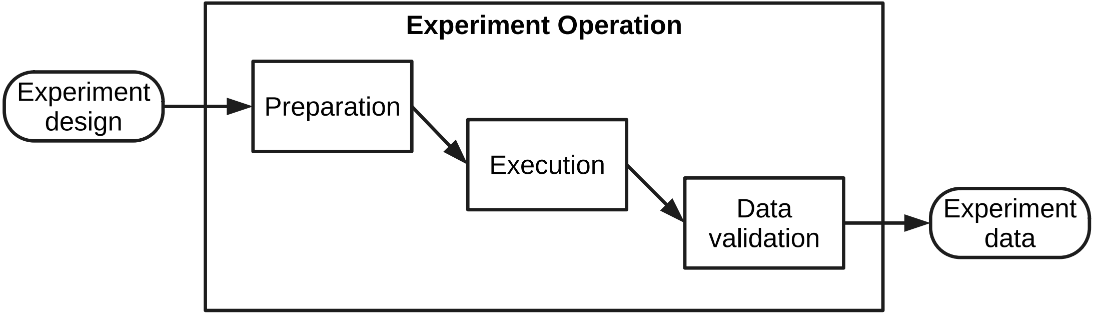
Experimental Operation

Operation

There are three steps to experimental operation:

1. **Preparation** - where subjects are choose and forms are prepared
2. **Execution** - where subjects perform their tasks according to different treatments and data is collected
3. **Data Validation** - where the collected data is validated

Operation



Experiment Operation
Experiment design
Preparation
Execution
Data validation
Experiment data

Preparation

- Better preparation -> Easier experiment execution
- Two important aspects of preparation
  1. Select and inform participants
  2. Prepare materials such as forms and tools

Commit Participants

- Find people whose normal work tasks are similar to the experiment's tasks
- Ensure the participants are representative of the population to which you want to generalize
  - Reduces threats to external validity
- **Goal**: convince the right people to participate

Instrumentation Concerns

- Before execution, all instruments must be ready, including:
  - Objects
  - Guidelines
  - Measurement forms
    - Must be handed out to participants
    - Anonymous?
  - Measurement tools
- In order to facilitate random order of trials
  - provide a personal set of instruments to each participant
- Additionally, interview questionnaires should be created prior to execution

Execution

- Experiments may be executed in many ways:
  - Simple experiments may be carried out at one occasion within a single large meeting of participants
    - Limits number of communications with participants
    - Data can be collected directly
    - Can resolve questions immediately and completely
  - More complex experiments will require a longer time span
    - Experimenter cannot participate in every detail of data collection

Data Collection

- Data Collection Approaches
  - Manual - via participants filling out forms
    - Reduces experimenter effort
    - Increases inconsistencies, uncertainties and flaws
  - Manual - via supported tools
  - Interviews
    - Improves communication with participants
    - Requires more effort from experimenter
  - Automatically - via tools

Experimental Environment

- Experiments should not affect projects more than necessary
  - This allows effects of treatments to be readily observed
  - Too many changes reduce this visibility
- Interaction with projects is necessary to ensure the protocols are being followed

Data Validation

- All data collected must be checked for
  - reasonableness
  - correctness
- Did participants fill in the forms correctly?
- Did participants take the experiment seriously?
  - If not their data should be removed.
- Was the experiment conducted as intended?
  - Validate via seminar with participants reviewing the data collected.
    - helps build trust

Are there any questions?