Experimental Design

Chapter 1 (Keppel and Wickens)

ERSH 8310

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Today's Lecture

- Experimental design:
  - Variables in experimental design.
  - Control in experimentation.
  - Populations and generalizing.
  - Basic experimental designs.

Experimental Design

Experimental Design

- A well-designed experiment permits the inference of causation.
  - An experimental manipulation is said to have caused the difference in groups that are randomly assigned.

- An experiment consists of a carefully worked-out and executed plan for data collection and analysis.

Experimental Design

- Treatment conditions are chosen to focus on particular features of the testing environment.

- These conditions are administered to subjects in such a way that observed differences in behavior can be unambiguously attributed to critical differences among various treatment conditions.

Components of Experimentation

Components of Experimentation

- Four key components of experimentation are:

1. Experimentation begins by formulating a number of research hypotheses.
   - Research hypotheses are the questions you hope to answer by means of experiment (but stated as declarative sentences).

2. The next stage in experimentation is the translation of the different research hypotheses into a set of treatment conditions and the selection of an appropriate experimental design within which to embody the different treatment conditions.

Components of Experimentation

3. The experiment is conducted, and the data are collected.
   - We then summarize the outcome of the experiment by means of statistical indices and procedures and evaluate the status of the research hypotheses.
   - The statistical analysis provides a way of determining the repeatability of any differences observed in an experiment.

4. The final stage of experimentation involves the assimilation of the outcomes of the statistical tests of the research hypotheses into the theory that generated the hypotheses originally (or the creation of a theoretical explanation if none is available in the literature).

Variables in Experimental Design

Variables in Experimental Design

- The basic requirements of an experiment are simple:
  - Differential treatments are administered to different groups of subjects (or to the same subjects in different orders), and performance on some response measure is observed and recorded following the administration of the treatments.
- Of interest are three types of variables: independent, dependent, and nuisance.

The Independent Variable

- The independent variable implies several meanings in the context of experimental design.
  1. First, the administration of the independent variable is under the direct control of the researcher.
  2. Second, the independent variable is independent from all other potential variables that can affect the dependent variable.
  3. Third, two or more independent variables can be manipulated simultaneously in the same experiment (e.g., a factorial design).

- An independent variable is also called a manipulated variable, a treatment variable, or a factor. The independent variable is usually defined by the nature of the critical differences systematically varied among the treatment conditions.

Types of Independent Variables

- Most experiments consist of more than two (i.e., multiple) treatment conditions.
  - Qualitative independent variables or categorical independent variables represent variation in kind or in type rather than in amount.
  - Quantitative independent variables or continuous independent variables are variables that represent variation in amount.

Types of Independent Variables

- Experiments are frequently encountered that include the systematic variation of characteristics that are intrinsic to the subjects (e.g., intelligence).
- Variables of this sort are variously referred to as classification variables, subject variables, organismic variables, and individual difference variables.
- Note that a classification variable can be either categorical or continuous.
- We may perform a correlational study, in which the classification variable is simply another dimension that is observed and recorded in addition to the dependent variable.

The Dependent Variable

- Each investigator will select measures (i.e., dependent variables) that seem to capture the phenomenon being studied most accurately.
  - Note that there is no simple rule to govern the actual selection of response measures.

- It is possibly economical to attempt to include in an experiment a sufficient variety of response measures to ensure as complete a description as possible of the phenomenon under study.

Nuisance Variables

- Nuisance variables are potential independent variables, which if left uncontrolled, could exert a systematic influence on the different treatment conditions.
- The nuisance variables should be controlled or randomized.
- A confounding of the independent variable with some other features of the experimental situation may occur and it will be a threat to internal validity of experiments.

Control in Experimentation

Control in Experimentation

- It is impossible to conduct an experiment in which the only difference among treatment groups is the experimental manipulation.
- Nonetheless, we are still able to conduct experiments and to draw meaningful conclusions.
- For example, certain features can be held constant across the levels of the experiment, and control of other features of the experiment is sufficiently close to be considered essentially constant.

Control by Design

- Note that many variables that might influence the behavior we are studying remain uncontrolled.
- One obvious way to hold subject differences constant is to use the same subject in each treatment condition.
- Unfortunately, even the same subject is not the same person each time he or she is tested due to carryover effects and maturation.

Control by Design

- We could try to match sets of subjects on important characteristics and then assign one member of each matched set to a different treatment, but matching would never be exact.

- It is nevertheless possible to make the groups more comparable by grouping the subjects into sets based on some nuisance variable (i.e., blocks) and then assign an equal number of members from each set to each of the experimental groups.

- We may also use analysis of covariance designs in Chapter 15.

Control by Randomization

- The elimination of systematic differences among the treatment conditions is possible by means of randomization.
- Treatment conditions in the experiment, after all the subjects are assigned to the groups, can be randomly determined.
- Random assignment of subjects to treatments will ensure in the long run that there will be an equivalence of subjects across the different treatments.
- Hence, subject differences are controlled by randomization.

Populations and Generalizing

Populations and Generalizing

- Our goal in research is to extend a set of findings beyond the sample that is tested in any actual experiment to the entire population.
- Random sampling requires the specification of a population of subjects and then the assurance that each member of the population has an equally likely chance of being selected for the experiment.
- Random assignment indicates that a randomization procedure is used to assign treatments to subjects and to testing sessions.
- A statistical generalization depends on random sampling, whereas a nonstatistical generalization (e.g., use of samples of convenience) depends on knowledge of a particular research area.

Basic Experimental Designs

The Basic Experimental Designs

- Note that the between-subjects design and the within-subject design are the single-factor (i.e., one independent variable) designs.

- The between-subjects design is characterized by the fact that subjects are randomly assigned to only one of the different treatment conditions (i.e., the completely randomized design).
  - It is simpler to understand conceptually. It is easier to design and analyze.
  - It is relatively free from restrictive statistical assumptions.
  - But, it requires a large number of subjects.

Within Subjects Design

- In the within-subject design each subject serves in all treatment conditions.
  - It is also known as a repeated measures design.
  - It requires fewer subjects and is more sensitive than a corresponding between-subjects design.
  - Relative restrictive statistical assumptions are required for the within-subjects design.

Factorial Designs

- Factorial designs permit the manipulation of more than one independent variable in the same experiment.

- The arrangement of the treatment conditions is such that information can be obtained about the influence of each of the independent variables considered separately and about how the variables combine to influence behavior.

- For the factorial designs, we may use the between-subjects factorial design, the within-subject factorial design, or a mixed factorial design.

For More Information

- Kirk (1995) provides a useful classification scheme that describes a great number of experimental designs and the building blocks used in their construction.

- Kirk, R. E. (1995). *Experimental design: Procedures for the behavioral sciences* (3rd ed.). Pacific Grove, CA: Brooks/Cole.

Final Thought

- Experimental design is the foundation for the application of analysis of variance statistical techniques.

- Knowledge of the basics of experimental design will help to understand the types of ANOVA techniques that exist.
- The congruence of the design of an experiment and the selection of the proper analysis technique will lead to better inference.

Next Class

- Chapter 2 of Keppel:
  - Sources of Variability and Sums of Squares.