Chapter 11: Experimental Designs

"It is a capital mistake to theorize before one has data." --Sir Arthur Conan Doyle

Learning Objectives

Upon completion of this chapter, students should know

- How to generate, define, and identify null and research hypotheses.
- How to define and differentiate between the three major classifications of variables.
- The purpose and fundamental elements of true experiments.
- The impact of experimenter bias and demand characteristics to experimental findings.
- To define and distinguish among between-subjects, within-subjects, and mixed designs.
- To identify, the purpose of, and to distinguish between one-tailed and two-tailed hypothesis.
- The conceptual meaning of statistical significance.
- To define and differentiate between Type I and Type II errors in statistical decisions.
- The concept of, factors that influence, and impact of statistical power in analyses.

Key Terms

Hypothesis is a specific research prediction concerning the behavior being studied. A scientific hypothesis is a prediction based predominantly on a scientific theory or body of knowledge.

Independent variables are those variables that are manipulated by the experimenter in order to determine what effect they may have on behavior. The experimenter varies the independent variable(s) from one condition to another condition in the experiment. By applying this factor(s) to one condition and not another, the experimenter compares the effect of the independent variable on the behavior of interest.

Dependent variables are measurements of the effect(s) of the independent variable on the behavior being studied in an experiment.

Subject variables are variables that describe the characteristics or attributes of participants in the study that cannot be attributed to the manipulation of the independent variable. Examples of subject variables are gender, age, year in school, marital status, etc.

Between-subjects design is sometimes called an independent-group design. In this design, each level of each independent variable has different participants. Thus, there is a distinction *between* each level of the experiment because each participant participants only in one level.

Within-subjects design is also called a repeated-measures design. In this design, each participant participants in all levels of all independent variables. Each participant stays *within* the experiment for its entire run.

Mixed design occurs most often when there are at least two independent variables and each person participates in all levels of one variable but not all levels of at least one of the other variables.

One-group experimental design is a design in which a single sample mean is compared to the mean of a known population.

Completely randomized experimental design is a design with at least one independent variable with at least two levels and participants are both randomly selected to participate in the study and randomly assigned to one of the groups in a completely random fashion.

Completely randomized factorial experimental design is a completely randomized experimental design, except there are at least two independent variables, each having at least two levels.

Experimental control is a scientific technique to help rule out alternative explanations for the experimental findings. Experimenters attempt to ensure that all conditions of the experiment are identical except for the manipulated independent variable.

Extraneous variables are variables that may vary in an experiment and affect participants' behavior. An experimenter tries to control extraneous variables. If an extra variable(s) varies between the conditions, then experimenter cannot be sure whether it was the independent variable or the extra variable that caused any detected differences in participants' behavior between conditions.

Experimenter bias can take place when experimenters, knowing the research hypothesis, unknowingly behave in ways that can influence the results of the study in favor of the predicted research hypothesis. The experimenter's behavior may differ in many ways including facial expression, verbal instructions, or body language.

Demand characteristics are changes in participants' behavior or responses based on their knowledge of the research hypothesis. When the research hypothesis is transparent or the participants think they know it, then their behavior may be changed to either support or not support the research hypothesis.

Null hypothesis (H_0) is one of two mutually exclusive hypotheses in a research study. It is a prediction or explanation that there is no difference or relationship between sample means. It is the hypothesis that is tested in statistics.

Research hypothesis (H_1) is one of two mutually exclusive hypotheses in a research study. It is a prediction or explanation that there is a difference or relationship between sample means.

Type I error is one of two incorrect decisions possible in statistics. This error takes place when researchers reject the null hypothesis and the null hypothesis is actually true.

Type II error is one of two incorrect decisions possible in statistics. This error takes place when researchers fail to reject the null hypothesis and the null hypothesis is actually false.

One-tailed test is a test for significance of a hypothesis that specifies the direction of the experimental effect.

Two-tailed test is a test for significance of a hypothesis that does not specify the direction of the experimental effect.

Power is the probability that a statistical test will correctly reject the null hypothesis when the null hypothesis is false. Several factors can affect the power of statistical test, such as the size of alpha, sample size, the difference between the means of two populations that the samples come from, and the type of statistical test used in the analysis.

Lecture and Demonstration Aids

The methodology in this chapter may seem like a foreign language to students. A lot of new terms and concepts are introduced. Use Transparency 11-1 to review the process and terminology of experimental methods.

Research Design. Use Transparencies 11-2 to 11-5 to discuss research design, assignment to conditions, and multi-level experiments. The research scenario used in these examples is a hypothetical study examining different types of music on student concentration while studying. The scenario is expanded to include volume of the music in the factorial design.

Type I and Type II Errors. After discussing the two types of decision errors, use Transparency 11-6 as an incorporation activity and ask students to identify the type of error in each example. This may help students bridge this concept to personal experiences and enhance their understanding.

Instructional Video. *Against All Odds: Inside Statistics.* Program Twelve, "Experimental Design" discusses the topics of observation, producing data, placebo, randomization, random selection, random assignment, and controlled experiments. The entire 30 minutes relates to the course material. This video is produced by the Consortium for Mathematics and Its Applications and Chedd-Angier (1989). Available through Annenberg/CPB.

Active-Learning Activities

Generating Experimental Scenarios. Separate the class into small groups and ask them to generate several research proposals. At least two proposals, one one-tailed and one two-tailed, should be developed. Have students identify the independent and dependent variables, discuss experimenter bias, demand characteristics, and the various methods of assignment to condition. It is a good idea to ask students to include the number of participants needed also. When the number of participants does not match the design, it signals confusion. Afterwards, ask students to share their proposals with the class and allow others practice differentiating between the different designs.

Additional Assignments

Test Questions. Have students develop 10 exam review questions. Questions should be specific and include complete answers. This assignment helps misunderstandings rise to the surface and gives you an opportunity to clarify these points.

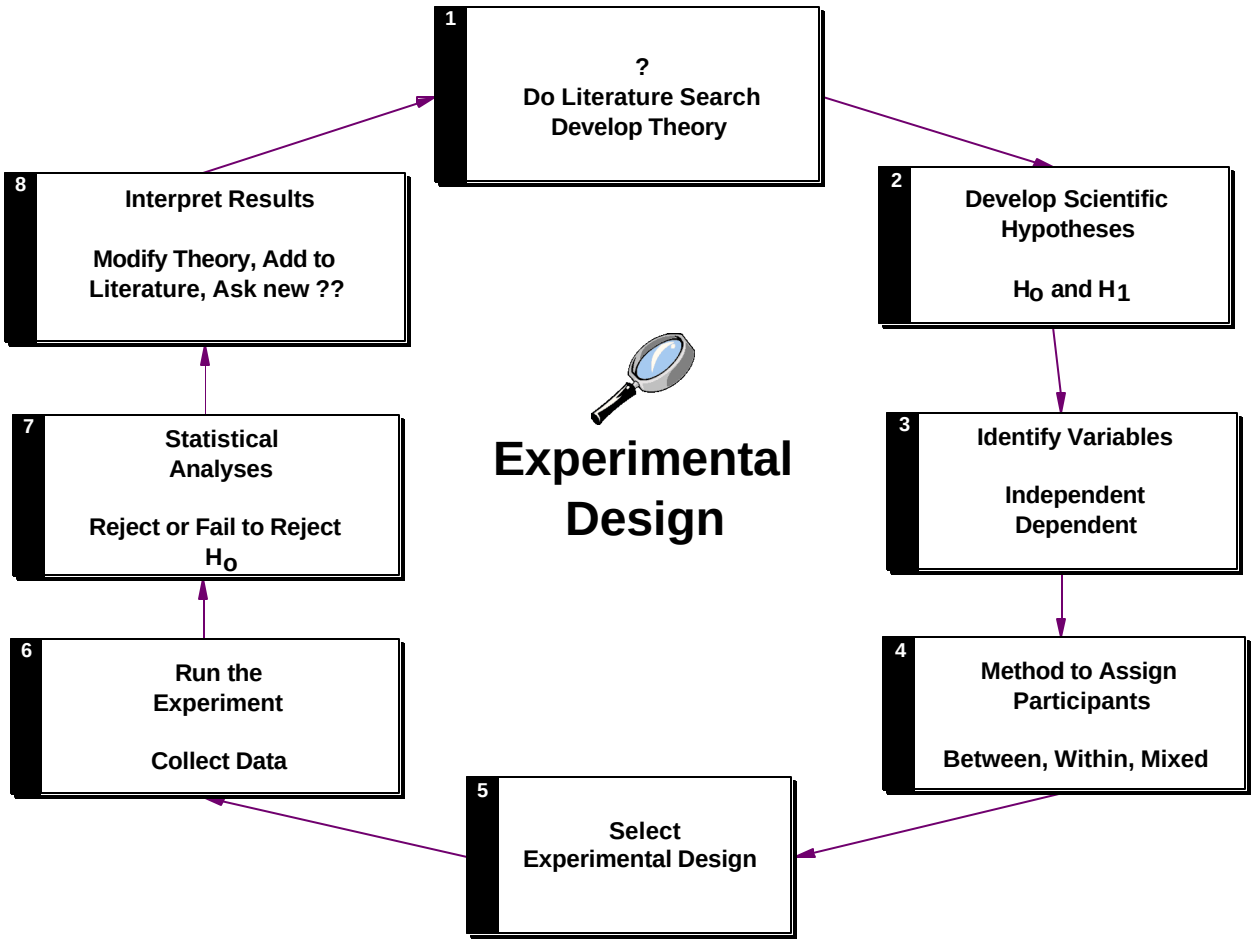
Web Quest. Ask students to visit the following websites and write a two-page reaction paper sharing this learning experience.

(1) Troffer, S. & Tart, C. (1964). Experimenter bias in hypnotist performance. *Science, 145* (3638), 1330-1331. URL: http://www.paradigm-sys.com/cttart/sci-docs/ctt64-ebihp.html

(2) Beyerstein, B. *Why Bogus Therapies Seem to Work*. URL: http://www.csicop.org/si/9709/beyer.html

(3) Green, G. *Facilitated Communication: Mental Miracle or Sleight of Hand?*
URL: http://www.skeptic.com/02.3.green-fc.html

Transparency 11-1.



Transparency 11-2.

One Independent Variable = Type of Music
Two Levels: Jazz, Blues

Between-Subjects Design

TYPE OF MUSIC

JAZZ (Level 1)		BLUES (Level 2)	
P_1	P_4	P_7	P_{10}
P_2	P_5	P_8	P_{11}
P_3	P_6	P_9	P_{12}

Within-Subjects Design

TYPE OF MUSIC

JAZZ (Level 1)		BLUES (Level 2)	
P_1	P_4	P_1	P_4
P_2	P_5	P_2	P_5
P_3	P_6	P_3	P_6

Transparency 11-3.

Two Independent Variables

(1) Type of Music with Two Levels: Jazz, Blues

(2) Volume of Music with Two Levels: Soft, Loud

Between-Subjects Design

		TYPE OF MUSIC			
		JAZZ		BLUES	
VOLUME OF MUSIC	SOFT	P_1	P_4	P_7	P_{10}
		P_2	P_5	P_8	P_{11}
		P_3	P_6	P_9	P_{12}
	LOUD	P_{13}	P_{16}	P_{19}	P_{22}
		P_{14}	P_{17}	P_{20}	P_{23}
		P_{15}	P_{18}	P_{21}	P_{24}

Transparency 11-4.

Two Independent Variables

(1) Type of Music with Two Levels: Jazz, Blues

(2) Volume of Music with Two Levels: Soft, Loud

Within-Subjects Design

		TYPE OF MUSIC			
		JAZZ		BLUES	
VOLUME OF MUSIC	SOFT	P_1	P_4	P_1	P_4
		P_2	P_5	P_2	P_5
		P_3	P_6	P_3	P_6
	LOUD	P_1	P_4	P_1	P_4
		P_2	P_5	P_2	P_5
		P_3	P_6	P_3	P_6

Transparency 11-5.

Two Independent Variables

(1) Type of Music with Two Levels: Jazz, Blues

(2) Volume of Music with Two Levels: Soft, Loud

Mixed Design

		TYPE OF MUSIC			
		JAZZ		BLUES	
VOLUME OF MUSIC	SOFT	P_1	P_4	P_1	P_4
		P_2	P_5	P_2	P_5
		P_3	P_6	P_3	P_6
	LOUD	P_7	P_{10}	P_7	P_{10}
		P_8	P_{11}	P_8	P_{11}
		P_9	P_{12}	P_9	P_{12}

Transparency 11-6.

TRUE SITUATION

DECISION	Null Hypothesis True	Null Hypothesis False
Reject Null Hypothesis	Type I Error a	Correct
Fail to Reject Null Hypothesis	Correct	Type II Error b

Name the type of error:

1. **The dentist says you do not have any cavities and you do have cavities.**

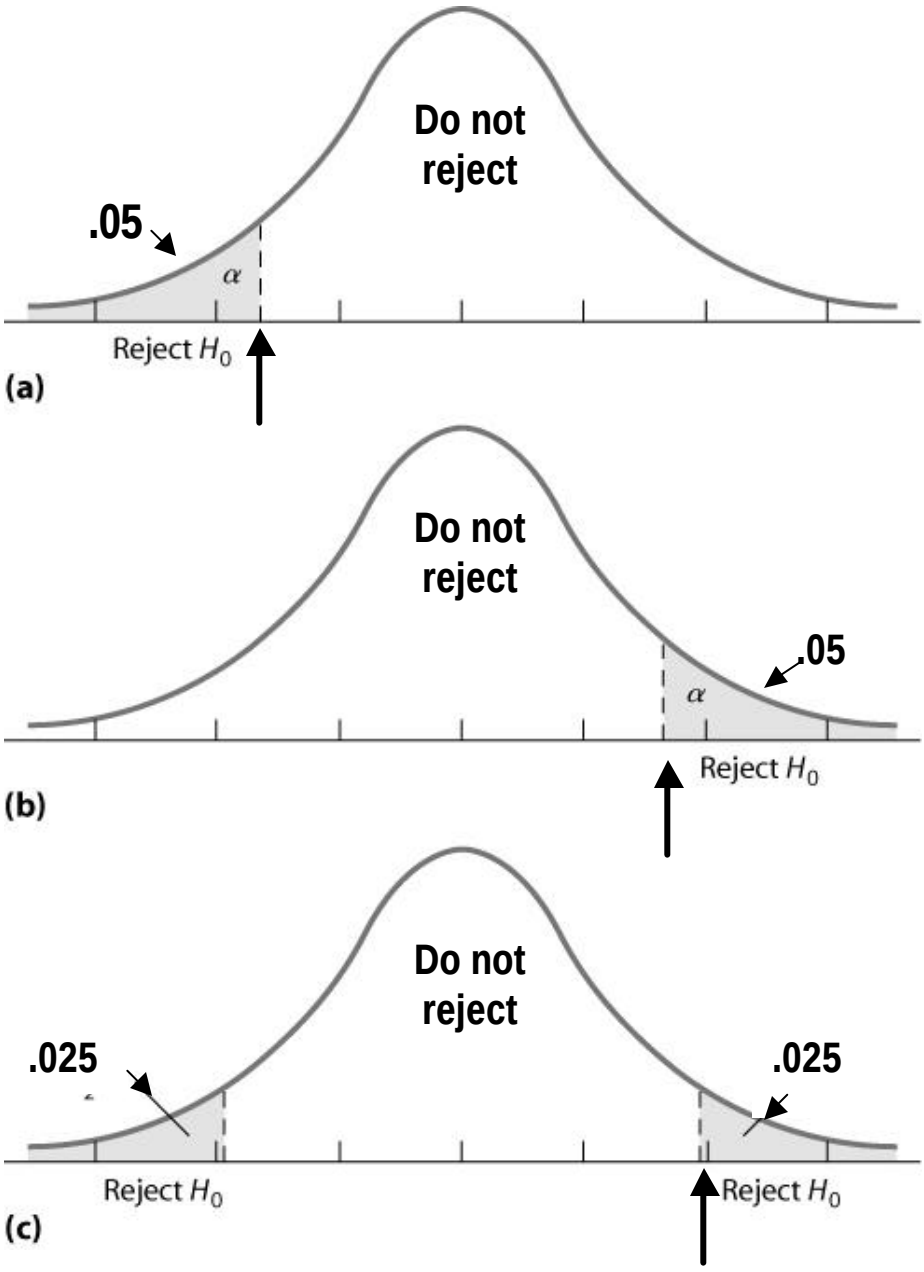
2. **The mechanic says you need a new battery and the battery is fine.**

3. **The smoke detector goes off and there is no fire.**

4. **The gas gauge says empty and the tank is empty.**

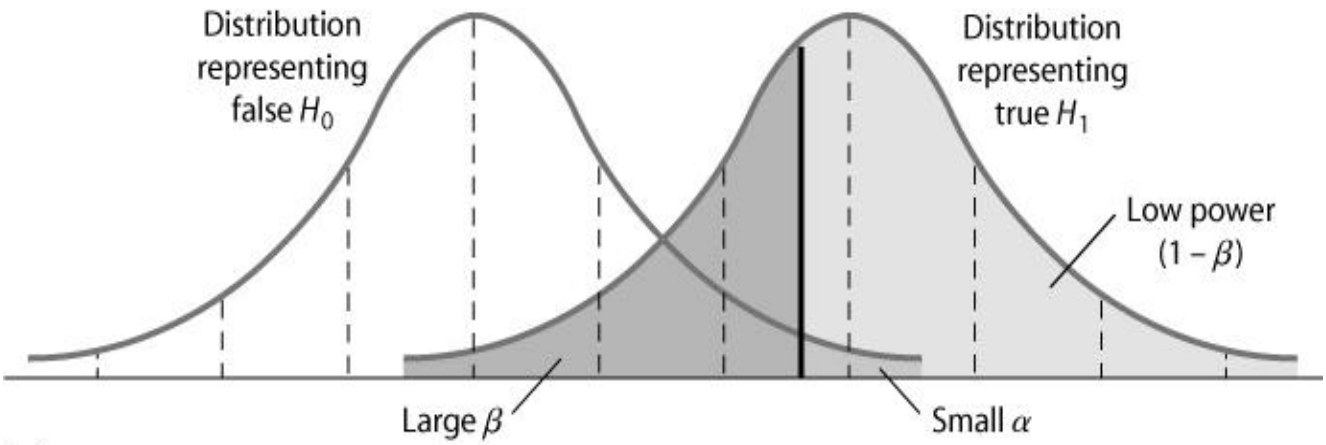
Transparency 11-7.

One –Tailed and Two-Tailed Statistical Tests

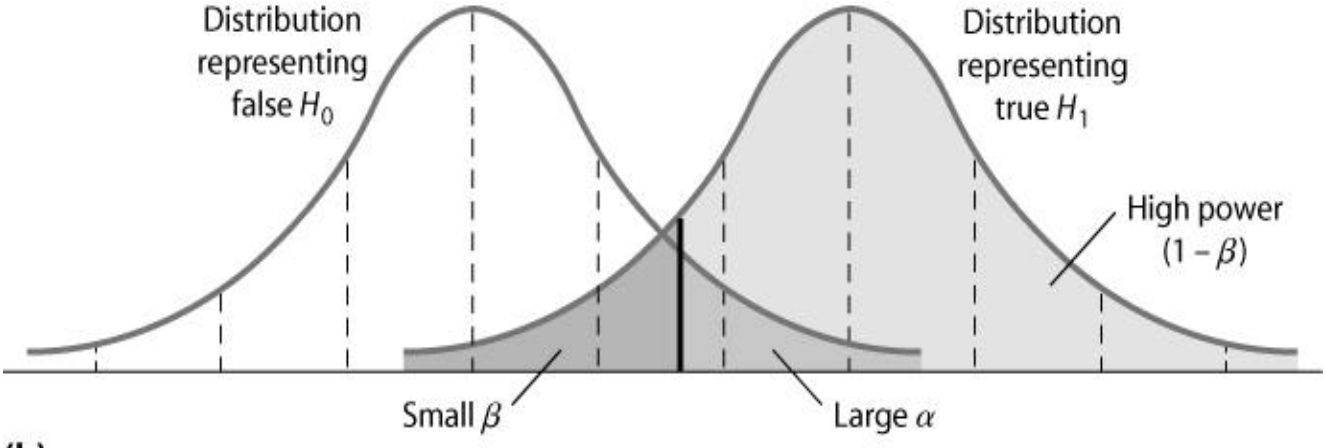


Transparency 11-8.

Statistical Power



(a)



(b)