3- Between-Subjects Factorial Design

FACTORIAL DESIGNS ALLOW RESEARCHERS TO STUDY MULTIPLE INDEPENDENT VARIABLES SIMULTANEOUSLY. THIS ENABLES MORE SOPHISTICATED RESEARCH QUESTIONS AND THE EXAMINATION OF INTERACTIONS BETWEEN VARIABLES.

Objectives

- Understand Factorial Designs
- Set Up Factorial Experiments
- Analyze Main and Interaction Effects
- Conduct and Interpret Factorial ANOVA

Factorial Designs

Factorial Design Basics

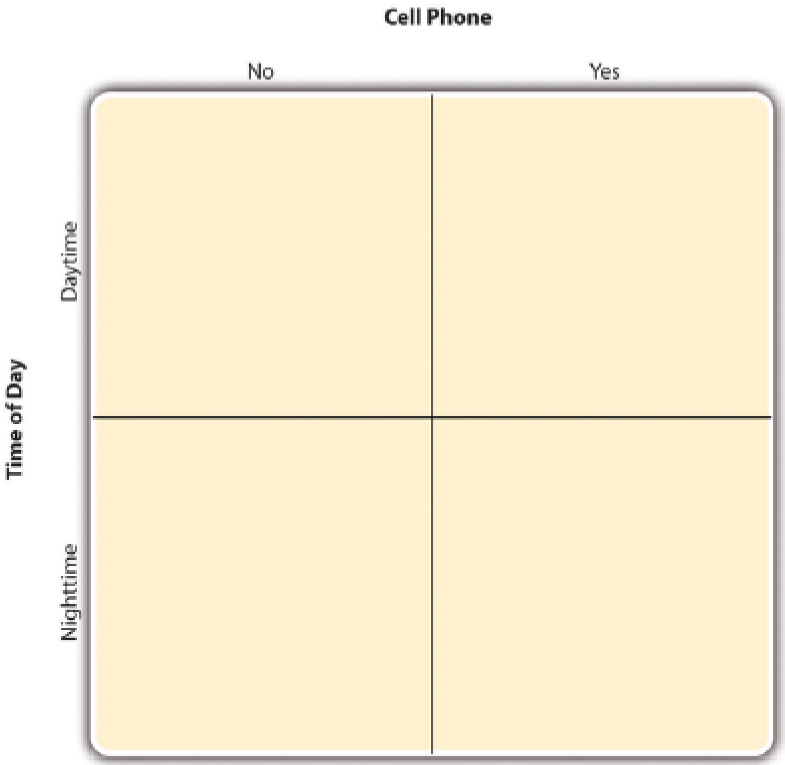


Figure 3.1.1 : Factorial Design Table Representing a 2 × 2 Factorial Design

- A factorial design involves more than one independent variable.
- This allows researchers to examine complex interactions between variables.
- Example: A 2x2 design combines two independent variables, each with two levels.
  - Cell phone use (yes/no) and time of day (day/night) affecting driving performance.

Multiple Factors

Combines levels of multiple independent variables.

Notation

2x2, 3x2 etc. indicate number of variables and levels.

Conditions

Each combination becomes an experimental condition.

More Complex Designs

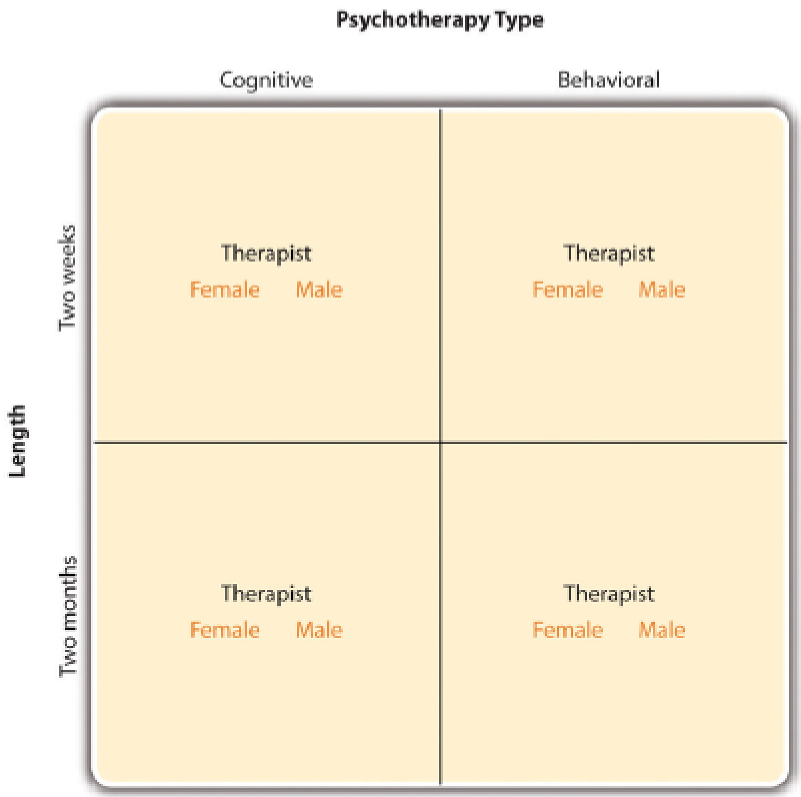


Figure 3.1.2: Factorial Design Table Representing a 2 × 2 × 2 Factorial Design

- Factorial designs can have more than two variables or levels.
- Example: A 3x2 design has three levels of one variable and two levels of another.
- The number of conditions increases as variables and levels increase
- Example: Experiment with the type of psychotherapy (cognitive vs. behavioral), the length of the psychotherapy (2 weeks vs. 2 months), and the sex of the psychotherapist (female vs. male).
  - This would be a 2 × 2 × 2 factorial design and would have eight conditions.

Types of Factorial Designs

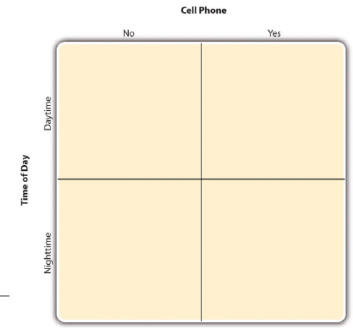


Figure 3.1.1: Factorial Design Table Representing a 2 × 2 Factorial Design

- **In a Between-Subjects Design**, participants are assigned to only one condition.
  - Example: Participants experience either the cell phone or no cell phone condition, during either the day or night.
- **Mixed Factorial Design**: one independent variable is manipulated between subjects, while another is within subjects.
  - Example: Testing participants both with and without a cell phone, but only during one time of day.
- **Non-Manipulated Independent Variables**: Some independent variables may not be manipulated by the researcher.
- These variables are usually participant background variables.
  - Example: Self-esteem (high/low) can be measured but not controlled.

- **Non-Experimental Studies With Factorial Designs:** include only non-manipulated independent variables,
- In which case they are no longer experiment designs, but are instead non-experimental in nature.
  - Example: Hypothetical study in which a researcher simply measures both the moods (positive or negative) and the self-esteem (low or high) of several participantsand outcome= willingness to have unprotected sex.
  - This is 2 × 2 factorial non- manipulated between-subjects factors.

Factorial ANOVA

Graphing Factorial Results

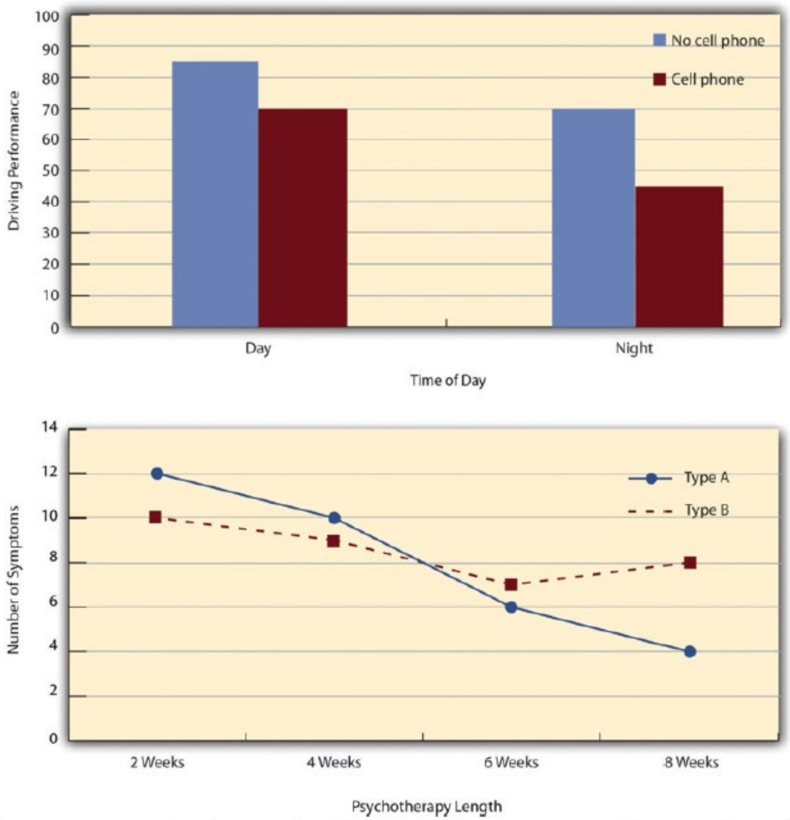


Figure 3.2.1: Two Ways to Plot the Results of a Factorial Experiment With Two Independent Variables

1 **Bar Graphs**

Use for categorical independent variables.

2 **Line Graphs**

Use for quantitative independent variables or time intervals.

3 **X-Axis**

Represents one independent variable.

4 **Colors/Lines**

Represent levels of second independent variable.

Analyzing Factorial Designs

1. **Main Effects**

   Examine overall effects of each independent variable.

2. **Interactions**

   Look for interdependence between variables.

3. **Simple Effects**

   Break down interactions if present.

Factorial ANOVA: Main Effects

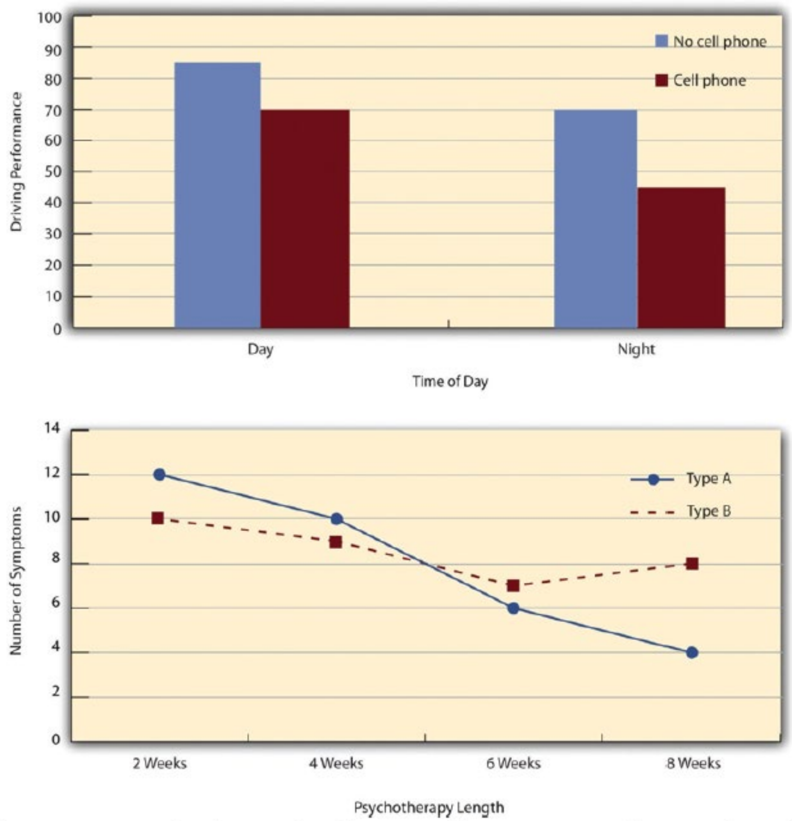


Figure 3.2.1: Two Ways to Plot the Results of a Factorial Experiment With Two Independent Variables

- Factorial ANOVA is used to analyze the effects of multiple independent variables.
- It helps identify **main effects**, **interaction effects**, and **simple effects**.

Main Effects

1. **Definition**

   Effect of one independent variable, averaging across others.

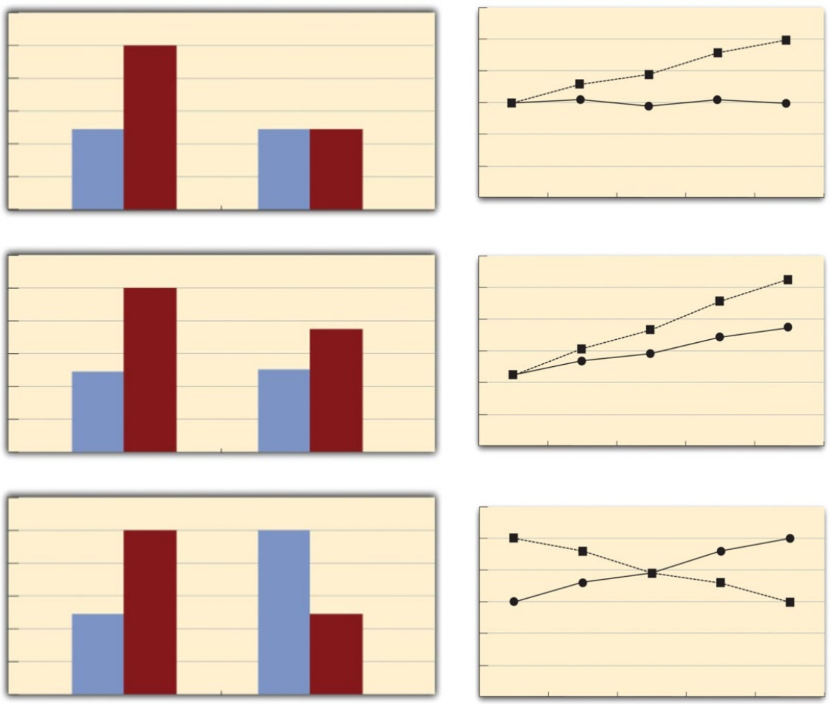
2. **Analysis**

   Examine each independent variable separately.

3. **Interpretation**

   Consider overall trends for each variable.

Factorial ANOVA: Interaction Effects



Bar and Line Graphs Showing Three Types of Interactions. In the top panel, one independent variable has an effect at one level of the second independent variable but not at the other. In the middle panel, one independent variable has a stronger effect at one level of the second independent variable than at the other. In the bottom panel, one independent variable has the opposite effect at one level of the second independent variable than at the other.

- An interaction occurs when the effect of one independent variable depends on the level of another.
  - Example: The effect of cell phone use on driving performance change depending on the time of day.
  - Brown and her colleagues were inspired by the idea that people with hypochondriasis are especially attentive to any negative health-related information. Led to Hypothesis: People high in hypochondriasis would recall negative health-related words more accurately than people low in hypochondriasis but recall non-health-related words about the same as people low in hypochondriasis.
- In many studies, the primary research question is about an interaction.
- Types of Interaction:
  - Spreading (Effect present at one level, weak/absent at another)
  - Crossover (Effects in opposite directions at different levels.

Factorial ANOVA: Simple Effects

- Simple effects are used to break down interactions and analyze specific conditions.
  - **Example Gilliland's study (1980)** : The effect of caffeine on introverts vs. extroverts.
  - Introverts were found to perform better on a test of verbal test performance than extraverts when they had not ingested any caffeine, but extraverts were found to perform better than introverts when they had ingested 4 mg of caffeine per kilogram of body weight.
  - To examine the main effect of caffeine consumption, the researchers would have averaged across introversion and extraversion and simply looked at whether overall those who ingested caffeine had better or worse verbal memory test performance.
    - Because the positive effect of caffeine on extraverts would be wiped out by the negative effects of caffeine on the introverts, no main effect of caffeine consumption would have been found.
  - Similarly, to examine the main effect of personality, the researchers would have averaged across the levels of the caffeine variable to look at the effects of personality (introversion vs. extraversion) independent of caffeine.
    - In this case, the positive effects extraversion in the caffeine condition would be wiped out by the negative effects of extraversion in the no caffeine condition.
  - Does the absence of any main effects mean that there is no effect of caffeine and no effect of personality? No of course not.
- The presence of the interaction indicates that the story is more complicated, that the effects of caffeine on verbal test performance depend on personality

Factorial ANOVA: Simple Effects

- **Simple effects** are a way of breaking down the interaction to figure out precisely what is going on.
- An interaction simply informs us that the effects of at least one independent variable depend on the level of another independent variable.
- Whenever an interaction is detected, researchers need to conduct additional analyses to determine where that interaction is coming from. When there is no interaction then the main effects will tell the complete and accurate story.
- Specifically, a simple effects analysis allows researchers to determine the effects of each independent variable at each level of the other independent variable.
- For a 2 x 2 design like in our example, there will be two main effects the researchers can explore and four simple effect
- A researcher using a 2×2 design with four conditions would need to look at 2 main effects and 4 simple effects.
- While the number of main effects depends simply on the number of independent variables included (one main effect can be explored for each independent variable), the number of simple effects analyses depends on the **number of levels of the independent variables** (because a separate analysis of each independent variable is conducted at each level of the other independent variable).
  - A researcher using a 2×3 design with six conditions would need to look at 2 main effects and 5 simple effects
  - A researcher using a 3×3 design with nine conditions would need to look at 2 main effects and 6 simple effects.

Interpreting Results

1 **Consider All Effects**

Examine main effects, interactions, and simple effects together.

2 **Context Matters**

Interpret results in light of research questions and hypotheses.

3 **Caution with Non-Manipulated Variables**

Be careful about causal conclusions with measured variables.

Partitioning Sum of Squares in Factorial ANOVA

Factorial ANOVA partitions the total sum of squares into components for main effects, interactions, and error. This allows researchers to analyze the unique contributions of multiple independent variables and their interactions.

The Logic of Partitioning

Total Sum of Squares

The total variance in the data, represented by SS Total.

Main Effects

Variance explained by each independent variable separately.

Interaction Effects

Variance explained by the interaction between independent variables.

Error

Unexplained variance remaining after accounting for main and interaction effects.

$$SS_{\text{TOTAL}} = SS_{\text{Effect}} + SS_{\text{Error}}$$

$$SS_{\text{Total}} = SS_{\text{Effect IV1}} + SS_{\text{Effect IV2}} + SS_{\text{Effect IV1xIV2}} + SS_{\text{Error}}$$

Formula for Partitioning

1. **SS Total**
   The total sum of squares across all conditions.
2. **SS Effect IV1**
   Sum of squares for the first independent variable.
3. **SS Effect IV2**
   Sum of squares for the second independent variable.
4. **SS Effect IV1xIV2**
   Sum of squares for the interaction effect.
5. **SS Error**
   Remaining unexplained sum of squares.

$$\boxed{SS_{\text{Total}} = SS_{\text{Effect IV1}} + SS_{\text{Effect IV2}} + SS_{\text{Effect IV1xIV2}} + SS_{\text{Error}}}$$

Calculating SS Total

1

Calculate Grand Mean

Find the mean of all scores across conditions.

2

Calculate Differences

Subtract grand mean from each score.

3

Square Differences

Square each difference score.

4

Sum Squares

Add up all squared differences to get SS Total.

Calculating SS for Main Effects

IV1 (e.g. Cell Phone Use)

1. Calculate grand mean
2. Calculate means for each IV1 condition
3. Find differences between condition means and grand mean
4. Square and sum differences

IV2 (e.g. Time of Day)

1. Calculate grand mean
2. Calculate means for each IV2 condition
3. Find differences between condition means and grand mean
4. Square and sum differences

Calculating SS for Interaction Effects

1 **Step 1**

Calculate the four condition means (e.g. cell phone yes/no x day/night).

2 **Step 2**

For each score, subtract IV1 mean, IV2 mean, and add grand mean.

3 **Step 3**

Square the resulting differences.

4 **Step 4**

Sum the squared differences to get SS Interaction.

Formula for Interaction Effect

$\bar{X}_{\text{condition}}$	Condition mean
$\bar{X}_{\text{IV1}}$	Mean for IV1 group
$\bar{X}_{\text{IV2}}$	Mean for IV2 group
$\bar{X}_{\text{Grand Mean}}$	Overall grand mean

$$\boxed{\bar{X}_{\text{condition}} - \bar{X}_{\text{IV1}} - \bar{X}_{\text{IV2}} + \bar{X}_{\text{Grand Mean}}}$$

Calculating SS Error

1

Step 1

Calculate mean for each condition group.

2

Step 2

Subtract condition mean from each score in that condition.

3

Step 3

Square the differences.

4

Step 4

Sum squared differences across all conditions to get SS Error.

$$SS_{\text{Total}} = SS_{\text{Effect IV1}} + SS_{\text{Effect IV2}} + SS_{\text{Effect IV1xIV2}} + SS_{\text{Error}}$$