

Introduction to Experimental Design

Introduction to Experimental Design

Key concepts, terminology, and steps for planning and conducting rigorous experiments.

1. What Is Experimental Design?

- **Definition** – A systematic plan for collecting data that allows researchers to test hypotheses and draw valid conclusions about cause and effect relationships.
- **Purpose** – Minimize bias, control variability, and maximize the amount of information obtained from each experimental unit.
- **Scope** – Used in biology, psychology, engineering, social sciences, marketing, agriculture, and many other fields.

2. Core Terminology

Term	Meaning	Example
Population	The complete set of items or subjects of interest.	All adult patients with hypertension in a city.
Sample	Subset of the population actually studied.	200 patients randomly selected from the city.
Experimental Unit	The smallest entity to which a treatment is applied.	One mouse, one plot of land, one classroom.
Treatment	A specific condition or intervention applied to experimental units.	Drug A, fertilizer dose, teaching method.
Control	Baseline condition against which treatments are compared (often “no treatment”).	Placebo pill, untreated plot.
Factor	A variable whose effect is being studied; can have multiple levels.	Temperature (low, medium, high).
Level	A specific value or category of a factor.	15°C, 20°C, 25°C.
Replication	Repeating the same treatment on multiple experimental units.	5 mice receive the same dose of drug.

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Randomization	Random assignment of treatments to experimental units to avoid systematic bias.	Using a random number generator to allocate plots to fertilizer levels.
Blocking	Grouping similar experimental units together and randomizing within each block to reduce known sources of variability.	Blocking by gender in a clinical trial.
Confounding	When the effect of one factor cannot be separated from another because they vary together.	Giving a new drug only to older patients.
Interaction	When the effect of one factor depends on the level of another factor.	Drug efficacy differs between males and females.
Statistical Power	Probability of detecting a true effect if it exists (influenced by sample size, effect size, variability, α level).	Power = 0.80 is a common target.

3. Steps in Designing an Experiment

1. Define the Research Question & Hypotheses

- Formulate a *null hypothesis* (H_0) and an *alternative hypothesis* (H_a).
- Example: H_0 : "Fertilizer X does not increase crop yield."
- H_a : "Fertilizer X increases crop yield by at least 10%."

2. Identify Variables

- **Independent variable(s)** (factors) – what you manipulate.
- **Dependent variable(s)** – what you measure.
- **Control variables** – conditions kept constant.

3. Choose an Experimental Design Type

- **Completely Randomized Design (CRD)** – simplest; random allocation of treatments.
- **Randomized Complete Block Design (RCBD)** – blocks to control known variability.
- **Factorial Design** – multiple factors simultaneously, allows interaction assessment.

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- Split?Plot, Latin Square, Repeated Measures, etc., for more complex situations.

4. Determine Sample Size & Replication

- Conduct a *power analysis* (software: G