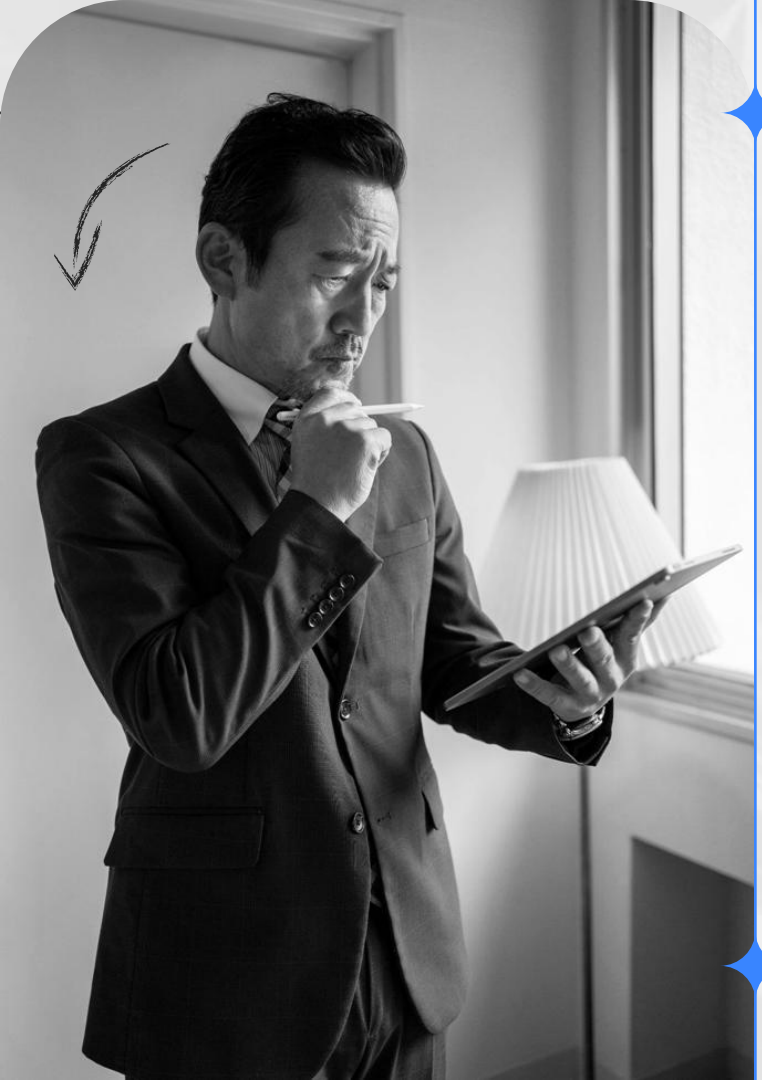
WRITING A SCIENTIFIC EXPERIMENT

INTRODUCTION

Companies often need to conduct experiments to test new products and try new practices. These experiments can help improve a company's products and services and provide valuable research results. To better understand how companies use this research method, it can be helpful to know how to design an experiment.



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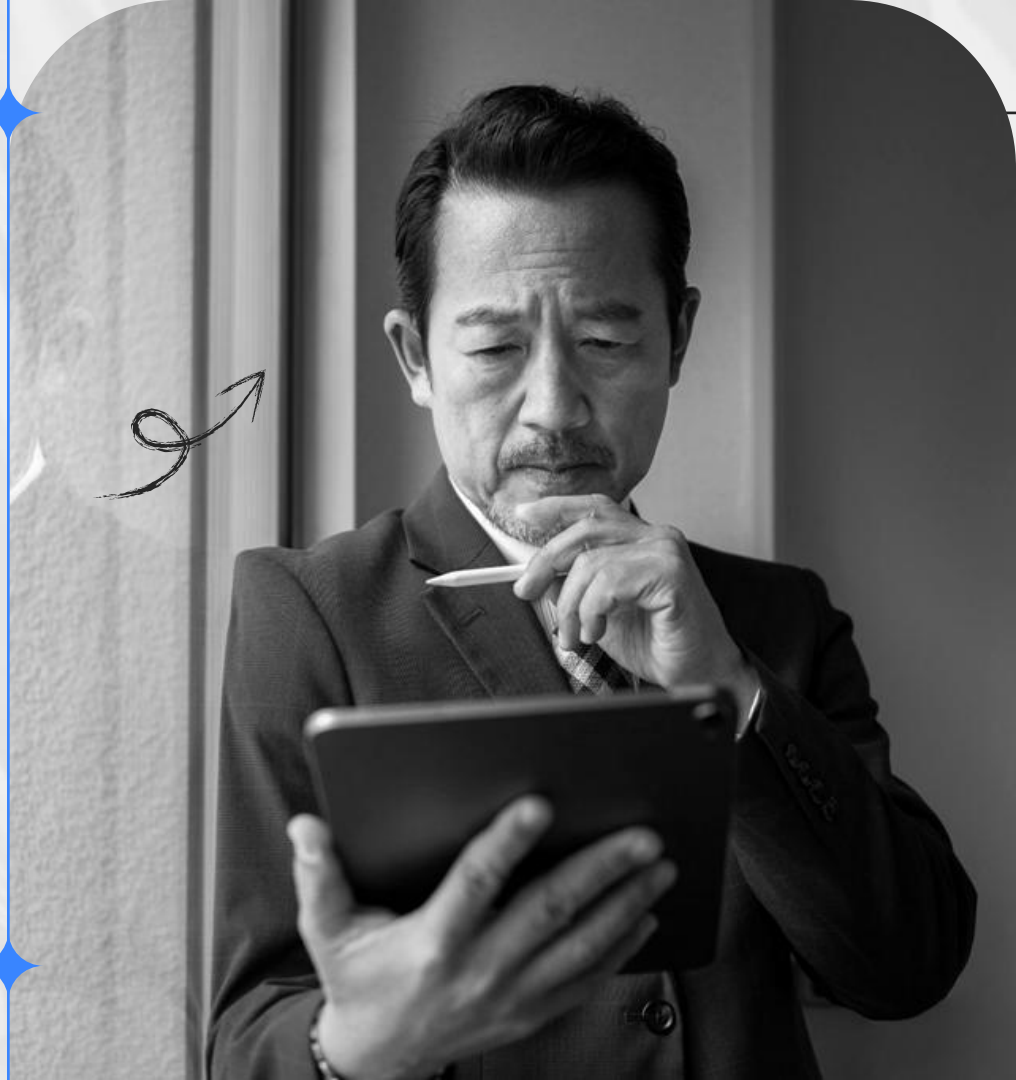
EXPERIMENTS

EXPERIMENTS DEFINITION

are used to study causal relationships. You manipulate one or more independent variables and measure their effect on one or more dependent variables.



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EXPERIMENTAL DESIGN

THE EXPERIMENTAL DESIGN DEFINITION

create a set of procedures to systematically test a hypothesis. A good experimental design requires a strong understanding of the system you are studying.

TYPES OF EXPERIMENTAL DESIGN

Researchers usually separate these types by comparing aspects of control groups, such as their size or sorting method.

Independent measures	use different participants to be in different test groups. This means the professionals who supervises the experiment separates participants into two or more groups and treat each group differently. However, each participant is only used to test one variable, and the researchers sort these participants randomly into the focus groups.
Repeated measures	use the same participants throughout the experiment. This means the control test group and variable groups consist of the same participants, but the researchers test them at different times. Repeated measures experiments can save time by using the same participants throughout the study. It also requires fewer people to take part in the experiment.
Matched pairs	When practicing an experiment designed with matched pairs, the professionals who are conducting the experiment assign each participant to another, making a matched pair. This can allow researchers to test how their product or practice may appeal to different demographics and notice any trends in participant responses. To do this, the professionals may interview each participant and make a note of those with similar values, or they may match participants based on their demographics.

HOW TO DESIGN AN EXPERIMENT

01

Consider your **variables** and how they are related

02

Write a specific, testable **hypothesis**

03

Design experimental treatments to manipulate the **independent variable**

04

Assign subjects to groups, either **between-subjects** or **within-subjects**

05

Plan how you will measure your **dependent variable**

For valid conclusions, you also need to select a representative sample and control any extraneous variables that might influence your results. If random assignment of participants to control and treatment groups is impossible, unethical, or highly difficult, consider an observational study instead. This minimizes several types of research bias, particularly sampling bias, survivorship bias, and attrition bias as time passes.

STEP I: DEFINE YOUR VARIABLES

- You should begin with a specific research question. We will work with one research question example, from health sciences

Example question : Phone use and sleep
You want to know how phone use before bedtime affects sleep patterns. Specifically, you ask how the number of minutes a person uses their phone before sleep affects the number of hours they sleep.

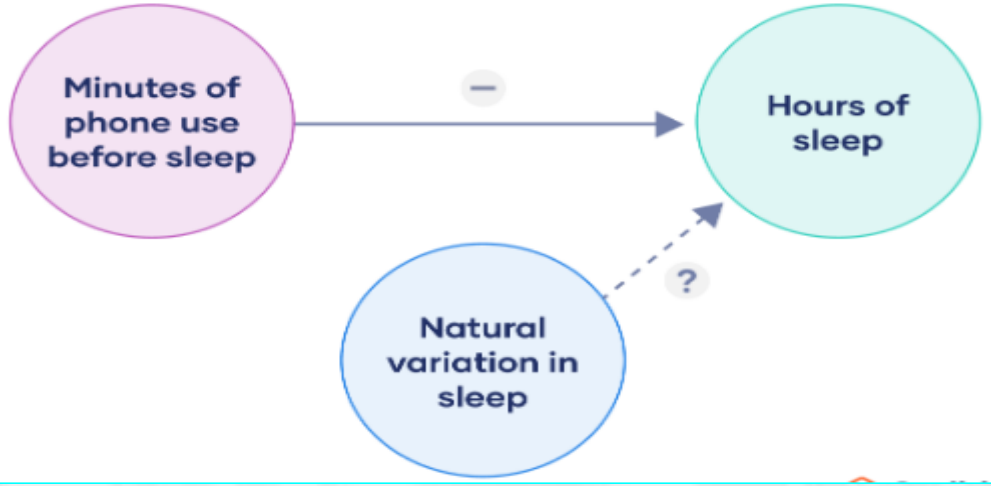
To translate your research question into an experimental hypothesis, you need to define the main variables and make predictions about how they are related.
Start by simply listing the independent and dependent variables.

Research question	Independent variable	Dependent variable
Phone use and sleep	Minutes of phone use before sleep	Hours of sleep per night

Then you need to think about possible extraneous and confounding variables and consider how you might control them in your experiment.

	Extraneous variable	**How to control**
Phone use and sleep	**Natural variation** in sleep patterns among individuals.	**Control statistically:** measure the average difference between sleep with phone use and sleep without phone use rather than the average amount of sleep per treatment group.

Finally, you can put these variables together into a diagram. Use arrows to show the possible relationships between variables and include signs to show the expected direction of the relationships.



Here we predict that the amount of phone use will have a negative effect on hours of sleep, and predict an unknown influence of natural variation on hours of sleep.

STEP 2: WRITE YOUR HYPOTHESIS

- Now that you have a strong conceptual understanding of the system you are studying, you should be able to write a specific, testable hypothesis that addresses your research question.

Example question : the same .

	Null hypothesis (H_0)	**Alternate hypothesis (H_1)**
Phone use and sleep	Phone use before sleep does not correlate with the amount of sleep a person gets.	Increasing phone use before sleep leads to a decrease in sleep.

The next steps will describe how to design a **controlled experiment**. In a controlled experiment, you must be able to:

✓Systematically and precisely manipulate the independent variable(s).

✓Precisely measure the dependent variable(s).

✓Control any potential confounding variables.

If your study system doesn't match these criteria, there are other types of research you can use to answer your research question

STEP 3: DESIGN YOUR EXPERIMENTAL TREATMENTS

- How you manipulate the independent variable can affect the experiment's external validity – that is, the extent to which the results can be generalized and applied to the broader world.

  First, you may need to decide how **widely** to vary your independent variable

  Second, you may need to choose how **finely** to vary your independent variable. Sometimes this choice is made for you by your experimental system, but often you will need to decide, and this will affect how much you can infer from your results.

Phone-use experiment : You can choose to treat phone use as:

- ❖ a categorical variable: either as binary (yes/no) or as levels of a factor (no phone use, low phone use, high phone use).
- ❖ a continuous variable (minutes of phone use measured every night).

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STEP 4: ASSIGN YOUR SUBJECTS TO TREATMENT GROUPS

- How you apply your experimental treatments to your test subjects is crucial for obtaining valid and reliable results.

First, you need to consider the **study size**: how many individuals will be included in the experiment? In general, the more subjects you include, the greater your experiment's statistical power, which determines how much confidence you can have in your results.

Then you need to randomly assign your subjects to **treatment groups**. Each group receives a different level of the treatment (e.g. no phone use, low phone use, high phone use).

You should also include a **control group**, which receives no treatment. The control group tells us what would have happened to your test subjects without any experimental intervention.

When assigning your subjects to groups, there are two main choices you need to make:

- A **completely randomized design** vs a **randomized block design**.
- A **between-subjects design** vs a **within-subjects design**.

Randomization

An experiment can be completely randomized or randomized within blocks (aka strata):

- In a **completely randomized design**, every subject is assigned to a treatment group at random.
- In a **randomized block design** (aka stratified random design), subjects are first grouped according to a characteristic they share, and then randomly assigned to treatments within those groups.

	Completely randomized design	**Randomized block design**
Phone use and sleep	Subjects are all randomly assigned a level of phone use using a random number generator.	Subjects are first grouped by age, and then phone use treatments are randomly assigned within these groups.

Between-subjects vs. within-subjects

- In a **between-subjects design** (also known as an independent measures design or classic ANOVA design), individuals receive only one of the possible levels of an experimental treatment.
- . In a **within-subjects design** (also known as a repeated measures design), every individual receives each of the experimental treatments consecutively, and their responses to each treatment are measured.

Counterbalancing (randomizing or reversing the order of treatments among subjects) is often used in within-subjects designs to ensure that the order of treatment application doesn't influence the results of the experiment.

	Between-subjects (independent measures) design	**Within-subjects (repeated measures) design**
Phone use and sleep	Subjects are randomly assigned a level of phone use (none, low, or high) and follow that level of phone use throughout the experiment.	Subjects are assigned consecutively to zero, low, and high levels of phone use throughout the experiment, and the order in which they follow these treatments is randomized.

STEP 5: MEASURE YOUR DEPENDENT VARIABLE

Finally, you need to decide how you'll collect data on your dependent variable outcomes. You should aim for reliable and valid measurements that minimize research bias or error.

Some variables, like temperature, can be objectively measured with scientific instruments. Others may need to be operationalized to turn them into measurable observations.

Phone use experiment : In your experiment about phone use and sleep, you could measure your dependent variable in one of two ways:

- Ask participants to record what time they go to sleep and get up each day.
- Ask participants to wear a sleep tracker.

HOW PRECISELY YOU MEASURE YOUR DEPENDENT VARIABLE ALSO AFFECTS THE KINDS OF STATISTICAL ANALYSIS YOU CAN USE ON YOUR DATA.

EXPERIMENTS ARE ALWAYS CONTEXT-DEPENDENT, AND A GOOD EXPERIMENTAL DESIGN WILL TAKE INTO ACCOUNT ALL OF THE UNIQUE CONSIDERATIONS OF YOUR STUDY SYSTEM TO PRODUCE INFORMATION THAT IS BOTH VALID AND RELEVANT TO YOUR RESEARCH QUESTION.