Experiments!

March 25, 2026

Experiments

Experiments are a scientific study where treatments are randomly *assigned* to experimental units

- Latin root: "test" or "try"
- An **Experimental Unit** is the object *a* treatment is applied to
  - Eg a farmer's field that recieves soybean hybrid A
  - Note singular: one experimental unit can have only one treatment
  - Often we can physcially touch it (safety check)
  - It's NOT the variable we are maniupulating (seed variety)
- ASSIGNED is the critical word with respect to experiments
  - Without assignment it's observational

Factors, Levels, and Treatments

A **factor** is a categorical input variable (eg fertilizer type). **Levels** of a factor are the categories the variable can take.

- Eg Varieties A, B, and C would be the three levels of a trinary variable Seed Type

A **treatment** (trt) is a combination of (all of the) input variables

- Eg (seed variety A) + (fertilizer type 2)
- If there is only one input the treatment and the variable are the same

	Fertilizer 1	Fertilizer 2
Corn (mono crop)	Corn + Fert 1	Corn + Fert 2
Corn-Soybean rotation	Corn/Soy + Fert 1	
Corn-Soy-Alfalfa rotation		
Corn-Soy-Winter Oats rotation		

Experimental Units (EUs)

Experimental units are what we randomly (ideally) *assign* treatments to

- Without *assignment* it's an observational study
- Without *random assignment* it's a biased study

Observational Units is the thing we observe/measure and write down in our spreadsheets

- Common for EU's and OU's to be the same but not always
  - Eg applied seed variety A to the *entire* field at once so the entire field is the experimental unit
  - Any given soybean plant in the field is an observational unit
- The confusion is often the impetus of *pseudo – replication*

Exp. Unit Helpful Advice

THE EASIEST WAY TO IDENTIFY THE EXPERIMENTAL UNIT IS TO THINK ABOUT WHAT THE TREATMENT IS BEING ASSIGNED TO!!

Experiments: Example

There is a field split in 64 sections outside of Ames, IA owned and operated by Iowa State University. In one study, crops of different types (corn, soybean, white oats, alfalfa) were planted and, in early spring of the following year, a sample was taken of biomass from each section of the field.

- Treatment?
- Experimental Unit?
- Observational Unit?

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- Treatment? The seed varieties
- Experimental Unit? The $1/64^{th}$ section of the field
- Observational Unit? The same as the experimental unit

Experiments: Example

ISU also does research in wine making (just a more interesting crop study....). 12 rows of grape vines were in the experiment. Each row was assigned one of four fertilizers and was either aggressively trimmed or was only mildly trimmed.

At the end of the season ten bottles of wine were made from each row of grapes. Then, each bottle underwent a chemical analysis and the results (nutrition content, polyphenals, etc...) were recorded.

- Variables we are controlling? What are their levels?
- Treatment?
- Experimental Unit?
- Observational Unit?

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- Variables we are controlling? What are their levels?
  - Trimming: Aggressively trimmed or mildly trimmed
  - Fertilizer: 1 of 4 types
- Treatment? A combination of trimming and fertilizer (eg Aggressively trimmed with fertilizer number 2)
- Experimental Unit? An entire row of grape vines
- Observational Unit? A single bottle of wine

Observation vs Experimental Units: Who Cares

The reason observational and experimental units need to be kept seperated is because an experimental unit is considered the foundational piece of information.

The total number of experimental units presents the upper limit of your information

At the end of the day we had 12 grape vines where each vine got a treatment. We didn't have 120 grape vines (120 = 10 bottles x 12 vines)

The ten bottles of wine give us a better understanding of that experimental unit and variability in the system

Experiments: Causality?

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No, no, no No No NO NO no NOO no a thousand times NO!

Experiments: No Causality

Claim: Experiments cannot prove causation.

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Arguments:

1. The analysis depends on our assumptions
   - True independence between exp units?
   - "identically distributed" There is no reason any exp unit will be different? No lurking variables leading to different means?
   - Sample Distribution $\approx$ Population Distribution?
   - Ability to generalize from our *very* restrictive experimental conditions

Experiments: No Causality

Claim: Experiments cannot prove causation.

Arguments:

1. The analysis depends on our assumptions
2. Our models are a simplification
   - Central limit theorem gets us *close* to normality
   - Measurement error, hand waving away lurking variables
   - Difference between a "straight" line and a 17^{th} order polynomial that is extremely flat?
   - Eg Did we account for relativity?

Experiments: No Causality

Claim: Experiments cannot prove causation.

Arguments:

1. The analysis depends on our assumptions
2. Our models are a simplification
3. Our estimates are wrong
   - No one truly believes there sample's estimates are population's parameter (ie the true value)
   - Sample Distribution $\approx$ Population Distribution isn't good enough, we need equality (w/ probability 1)
   - Confidence intervals wouldn't exist for experiments if we could prove causality.....

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In conclusion: Using estimates we expect to be wrong and assumptions we don't trust we build an overly simplified model.....and then claim to have proven causality?

Basically, Plato's Allegory of the Cave

What do you study Professor?

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Good question! I study experimental design....

Experimental Design

We help people pick which treatments should be picked and how many replicates of each treatment should be picked.

For example imagine a situation where we apply Chemical X in differing amounts to a jungle foilage. The question is how much foilage would be destroyed given various amounts of Chemical X. We have ten simulated jungle patches we are allowed to spray.

Choices...

Two different possible experiments are below.

Trial ID	Exp 1	Exp 2
1	0	.05
2	0	.15
3	0	.25
4	0	.35
5	.5	.45
6	.5	.55
7	1	.65
8	1	.75
9	1	.85
10	1	.95

Why/when would we choose Experiment 1 vs Experiment 2?