Basics of testing hypothesis

Null Hypothesis (H_0)

What is a Hypothesis?

- In statistics, a hypothesis is an assumption or a claim about a population parameter.
- For example, you might assume that the average height of adult women in a city is 160 cm.
- This assumption can be tested using data.

What is the Null Hypothesis?

- The null hypothesis, often written as **H_0**, is a starting assumption in a statistical test.
- It says that there is **no effect, no difference, or nothing has changed.**
- It acts like the **"default" position** or the idea that **"nothing interesting is going on."**

Example:

- Imagine a company claims that their battery lasts 10 hours on average. A researcher wants to test if this claim is true. So they collect data on 100 batteries.
- **Null hypothesis (H_0):** The average battery life is 10 hours.
- **Mathematically:** H_0: $\mu = 10$
- The null hypothesis is what the researcher tries to test against.
- If the data provides strong evidence that the average battery life is not 10 hours, the researcher may decide to reject the null hypothesis.

Important Notes:

- You do not try to prove the null hypothesis. You only test whether it should be rejected.
- If you don't find strong evidence against it, you fail to reject the null hypothesis (not the same as accepting it as true).
- Null hypotheses can be about means, proportions, differences between groups, etc.

Level of Significance (α)

What is the Level of Significance?

- The level of significance is a threshold that helps you decide whether to reject the null hypothesis.
- It is usually written as the Greek letter alpha **(α)** and is chosen before the test is performed.
- It tells you how much risk of making a mistake **(rejecting H_0 when it is actually true)** you are willing to accept.

Common Values of α:

- **0.05 (5%)** – most common
- **0.01 (1%)** – stricter, used when stronger evidence is needed
- **0.10 (10%)** – used sometimes for more lenient tests

What Does It Mean?

- If you choose **α = 0.05**, you are saying:
  - "I am okay with a 5% chance of wrongly rejecting the null hypothesis (false alarm)."
- This 5% is called the Type I error rate.

Example:

- Using the battery example again:
  - **H_0:** Battery life = **10 hours**
  - The researcher uses **α = 0.05**
- This means that if the probability of seeing the data **(assuming H_0 is true)** is less than 5%, then the researcher rejects the null hypothesis and says the average battery life is probably not 10 hours.

Important Notes:

- The lower the α, the less likely you are to reject H_0.
- But a lower α also means you need stronger evidence (data) to make a conclusion.
- Choosing α is a trade-off between detecting real effects and avoiding false positives.

Power of Test

What is the Power of a Statistical Test?

- The power of a test tells us how good a test is at detecting a real effect or difference when one actually exists.
- **In simple words:**
  - Power = Chance of correctly rejecting the null hypothesis when it is false.
- It is usually written as a percentage or a decimal between 0 and 1.

Mathematical Definition:

- Power = 1 − β
- Where β (beta) is the probability of a Type II error (failing to reject the null hypothesis when it is actually false).
- **So:**

- A power of 0.80 (or 80%) means there's an 80% chance the test will detect a real effect if it exists.
- A power of 0.50 (or 50%) means the test is weak and may miss real differences.

Why is Power Important?

- Imagine you're testing a new medicine that might reduce blood pressure.
- If the test has low power, it might fail to detect the medicine's real effect, and you might wrongly say it doesn't work. That's risky.
- A high-power test reduces the chance of missing true effects.

What Affects the Power of a Test?

- **Sample size –** Bigger samples give more power.
- **Effect size –** Larger differences are easier to detect.
- **Significance level (α) –** If you allow more chance of Type I error (higher α), power increases.
- **Data variability –** Less variability (more consistent data) gives more power.

Example:

- Suppose you're testing whether a new teaching method improves test scores.
  - If the test has high power, it will likely detect the improvement.
  - If it has low power, it might not see the improvement even if it's really there.
- Researchers often aim for 80% power or more in their studies.

P-Value

What is the P-Value?

- The p-value tells us how likely it is to get our observed data (or more extreme) if the null hypothesis were true.
- It does not tell you the probability that the null hypothesis is true. Instead, it measures how surprising your data is under the assumption that the null hypothesis is correct.

Simple Explanation:

- **A small p-value means:** "Wow, this data is unusual if H_0 is true!"
- **A large p-value means:** "This data is pretty normal if H_0 is true."

Common Interpretation:

- If p-value ≤ α (e.g., 0.05) → You reject the null hypothesis.
- If p-value > α → You do not reject the null hypothesis.

Example:

- Let's go back to the battery example.
  - H_0: Battery lasts 10 hours.
- After testing 100 batteries, you calculate a p-value of 0.02.
- If your $\alpha = 0.05$:
  - Since $0.02 < 0.05$, you reject H_0.
- This means: "There's strong evidence the average battery life is not 10 hours."

Important Notes:

- A very small p-value (like 0.001) means very strong evidence against H_0.
- A large p-value (like 0.6) means the data is not surprising under H_0 – so you don't reject it.
- A p-value is not a proof. It's just a way to measure evidence against H_0.
- P-value is affected by sample size: in large samples, even tiny effects can produce small p-values.

Statistical Estimation of Confidence Intervals

What Is a Confidence Interval?

- A confidence interval (CI) is a range of values that we believe is likely to contain the true value of a population parameter (like the average or proportion).
- Instead of giving just a single number (called a point estimate), a confidence interval gives you a range of possible values, along with a confidence level that tells you how sure you can be about that range.
- It's like saying: "I don't know the exact answer, but I'm pretty sure it's between this number and that number."

Confidence Level – What Does It Mean?

- **The most common confidence levels are:**
  - 90%
  - 95% (most commonly used)
  - 99%
- **A 95% confidence interval means:**
  - "If we repeated the same process many times, about 95% of those intervals would contain the true population value."
- It does not mean that there is a 95% chance that this one specific interval contains the true value. The confidence is about the method, not any one result.

Example:

- Suppose you want to estimate the average height of adult women in a city.
- **You take a sample of 100 women and calculate:**
  - Sample mean = 160 cm
  - Confidence interval = [158 cm, 162 cm] at 95% confidence level
- **This means:**
  - "Based on my sample, I am 95% confident that the true average height of all adult women in the city is between 158 cm and 162 cm."
- You are not claiming the exact value is 160. Instead, you're giving a range of likely values.

How Is a Confidence Interval Calculated?

- For a population mean, the general formula is:
  - Confidence Interval = Sample Mean ± Margin of Error
- **The margin of error depends on:**
  - Standard deviation or standard error of your data
  - Sample size – larger samples give smaller margins of error
  - Confidence level – higher confidence means wider intervals
- For example, a 99% confidence interval will be wider than a 95% one because you're trying to be more certain.

Factors That Affect the Width of Confidence Intervals:

A. Sample size:

- Bigger sample → narrower interval (more precise)

B. Confidence level:

- Higher confidence → wider interval (you need a bigger range to be more sure)

C. Data variability:

- More variation in data → wider interval (less precise)

Uses of Confidence Intervals:

- Estimating population averages, proportions, or differences
- Giving a range for survey results (e.g., election polls)
- Indicating the precision of your estimate
- Comparing groups in experiments

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