Notes

Causality

* Causality refers to a cause-and-effect relationship between two variables, where one variable directly influences the other.
* Unlike association, which only shows a relationship, causality means changing one variable leads to a change in another.

Definition

* Causality occurs when a change in one variable (Cause) directly produces a change in another variable (effect).

Key Feature

* One event must happen before the other, and there must be no other explanation for the effect.

Causality vs. Association

|  |  |  |
| --- | --- | --- |
| Concept | Definition | Example |
| Association | Two variables are related, but one does not necessarily cause the other. | More firefighters are found at big fires, but firefighters do not cause the fires. |
| Causality | One variable directly causes the other to change. | Lightning a match causes a fire. |

Causality always implies association.

Association does NOT always imply causality.

Conditions for Causality

* Temporal Precedence (Cause happens first)
  + The cause must happen before the effect.
  + Example: You take a painkiller before your headache goes away.
  + If the effect happens first, it’s not causal.
* Covariation (Two variables must move together)
  + When the cause changes, the effect must also change.
  + Example: If you increase exercise, you should see a decrease in weight.
* No Confounding Variables (No other explanations)
  + There should be no third factor explaining the relationship.
  + Example: Ice cream sales and drowning deaths are associated, but the real cause is hot weather (Not Ice cream).

Types of Causality

* Direct Causality (A🡪B)
  + One event directly causes another.
  + Example: Smoking🡪Lung Cancer.
* Indirect Causality (A🡪B🡪C)
  + The cause leads to an intermediate step before the effect.
  + Example: Exercise -> Faster Metabolism -> Weight loss
* Reverse Causality (B🡪A)
  + The effect actually causes the supposed cause.
  + Example:
    - More hospitals are found in cities with high illness rates.
    - But hospitals don’t cause illness; they are just built where people need them.
* Bidirectional Causality (A 🡨🡪 B)
  + Both variables influence each other.
  + Example: Stress 🡨🡪 Poor Sleep
  + Stress causes poor sleep, and poor sleep causes more stress.

How to prove Causality:

* Randomized Controlled Trials (RCT’s):
  + The gold standard for proving causation.
  + Example: A new medicine is tested on one group (treatment) and compared to another group (placebo).
  + If the treatment group improves significantly, we conclude the medicine causes improvement.
* Controlled Experiments:
  + All variables except the one being tested are kept constant.
  + Example: Testing whether the fertilizer increases crop yield by applying it to some plants but not the others.
* Longitudinal Studies:
  + Observing changes in a population over time.
  + Example: Tracking smokers for 20 years to see if they develop lung cancer.
* Causal Inference in Statistics:
  + Using statistical techniques like:
    - Regression Analysis
    - Instrumental Variables
    - Granger Causality test

Causality means one variable directly influences another.

Association does not mean causality – just because two things are related doesn’t mean one causes the other.

Causality is proven by RCT’s and other statistical methods.

Understanding causality helps in real-world decision-making across all fields.

Example:

* Conducted a causal analysis to determine if increasing study hours leads to higher exam scores and a higher probability of passing using regression analysis and probability modeling.
* Key Findings:
  + Dependent Variable – Exam Score
  + Independent Variable – Study Hours
  + R-Squared – 0.921 (92.1% of the variation in exam scores is explained by study hours)
  + P-value for Study Hours - <0.0001 (Highly Statistically Significant)
  + Coefficient of Study Hours – 5.74 (Each additional hour of study increases the expected score by ~ 5.74 points)
  + Coefficient of Study Hours – 5.74 (Each additional hour of study increases the expected score by ~ 5.74 points)