Basic Principles of Experimental Design

Cause and Effect: the cause must precede the effect in time.

X ⟶ Y (Sufficient)

No X ⟶ No Y (Necessary)

Treatment and Control Conditions

Basic Principles

Z → Y ← X

We must control Z or include it.

In a experiment we must control (hold constant) other possible causes of X.

Control

- Experimental
  - Blocking
  - Matching
  - Randomization
- Statistical
  - ANCOVA
  - Multiple Regression
  - Structural Equations

Theory and Scientific Judgment

- Simon: If relevant causes are NOT included in the study/experiment, the study will yield biased results. All relevant causes must be included in the study. (Relevant causes are finite.)
- Isolation or identification of relevant causes: the problem with confounded variables.
  - Cow manure on the soil makes plants grow, thus cow manure is responsible for plant growth. However, it would be difficult to find out specifically which of one ingredient (Nitrogen, phosphorus, ash, or organic matter) is (are) responsible for the growth.

Not Identifying the “Real” Cause

- I had my favor baseball cap on today and I won the game. Wearing my favor cap helps me win the game. I will wear my favorite cap every time I play. (Self-efficacy at work?)
- In elementary school, children’s reading ability is related to shoe size.

Positivism

- Logical Positivism–
  - a proposition is meaningful only if it can be empirically verified. We must seek explanations away from supernatural phenomena.
  - All logical propositions are deducible from a very small number of logical principles

Heisenberg's Uncertainty Principle

- There is a limit *in principle* as to how accurately one can simultaneously measure the **position** and **momentum** of a particle - if one tries to measure the position more accurately by using light of a shorter wavelength, then the uncertainty in momentum grows, whereas if one uses light of a longer wavelength in order to reduce the uncertainty in momentum, then the uncertainty in position grows. One cannot reduce both down to zero simultaneously - this is a direct consequence of the wave-particle duality of nature.

Heisenberg declared

Because one cannot know the precise position and momentum of a particle at a given instant, so its future cannot be determined. One can't calculate the precise future motion of a particle, but only a range of possibilities.

Heisenberg

- Light has a dual nature; in some cases it behaves as a wave, and in other cases it behaves as a photon. It depends how you look at it.

Godel's Theorem

- In 1931, the Czech-born mathematician Kurt Gödel demonstrated that within any given branch of mathematics, there would always be some propositions that couldn't be proven either true or false using the rules and axioms ... of that mathematical branch itself. You might be able to prove every conceivable statement about numbers within a system by going *outside* the system in order to come up with new rules an axioms, but by doing so you'll only create a larger system with its own unprovable statements. **The implication is that *all* logical system of any complexity are, by definition, incomplete; each of them contains, at any given time, more true statements than it can possibly prove according to its own defining set of rules.**

Popper's Falsification

- We can reject a theory, but not prove it correct.
- Progress in Science in made by rejecting Theories

Kuhn's Paradigms

- Paradigms– Recognized scientific ideas that for a time provide models and solutions to a community of scientists.
- Normal Science *then can create*
- Anomalities *which lead to*
- New Paradigms

Related Points of View

- Realism– scientific propositions are true or false by virtue of their correspondence or lack of with the way of the world.
- Instrumental– Scientific theories are not intended to be literally true but simply convenient summaries.

Practical Applications

- The practical problem for scientists is how to eliminate explanations other than the theory of interest.

Internal Validity

- Internal validity– How we designed the study carefully so that we can make causal inferences between X and Y?
- Intact groups
- Selection
- Missing data
- Maturation

External Validity

- External validity– Can I generalize my findings and conclusion to other settings/
- Statistical argument – random sample
- Logical/theoretical argument

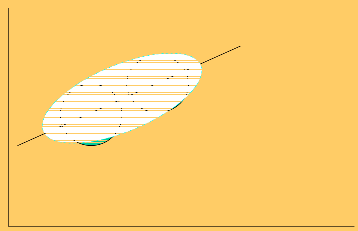
Examples Dealing with Statistical Control

Home Computer	Average Test Score
Yes	82
No	74

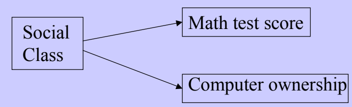
Adjusting for Social Class

Social Class	Home computer	Average Test Score
Lower	Yes	69.5
Lower	No	68.7
Middle	Yes	80.7
Middle	No	79.3
Upper	Yes	87.5
Upper	No	86.8

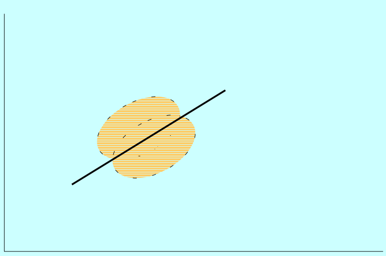
Combined Groups

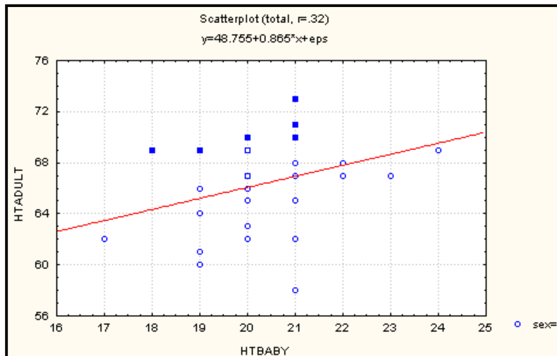


Structural Model
A single Cause

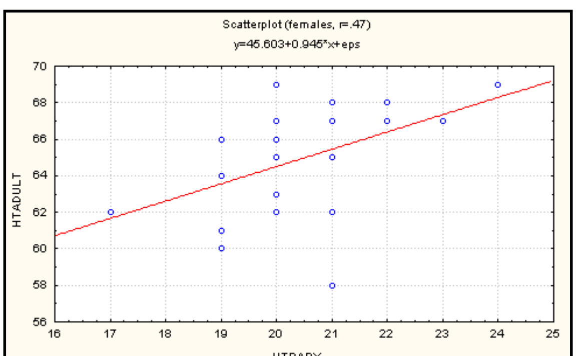


Combined Groups
Suppresor Variable

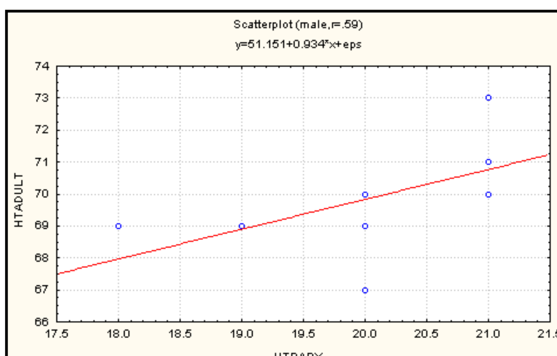




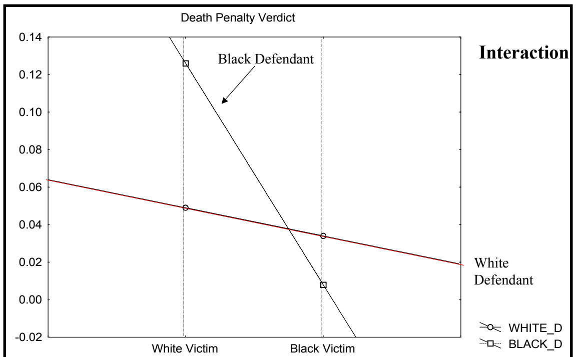
r=.32



r=.47, n=27.



r=.59, *n=11*



Proportion of defendants receiving the death penalty

Death Penalty by Race
Simpson's Paradox

White Defendant	.048
Black Defendant	.025

Explanation

Victim

Defendant		White		Black			
		Yes	No	Yes	No	Yes	No
	W	227	4418	9	255	236	4673
	B	92	639	36	4392	128	5031

Statistical Issues in Experimental Design

- Sample size Affects
  - Precision in estimation
  - Power
- Effect size (Meaningful results)
- Power
  - Experimental design (isolation of important variables)
  - alpha
  - Sample size
  - Measurement error
- Probability of type one error

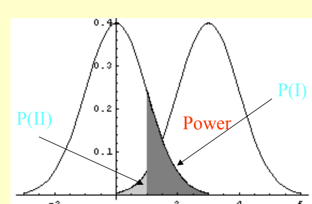
Fundamentals of Hypothesis Testing

State of the World

Your Decision		**Ho is true**	**Ha is true**
	Decide to Retain Ho	Correct Decision P(retaining Ho|Ho)=1-α	Mistake Type II Error P(II)=β
	Decide to Reject Ho	Mistake Type I Error P(I)=α	Correct Decision P(rejecting Ho|Ha)=1-β (Power)

Either Ho Or Ha is true

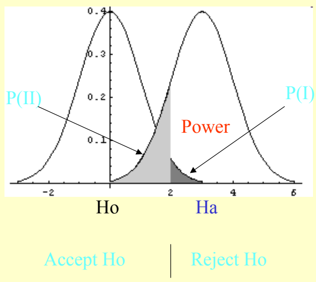
One-tailed test

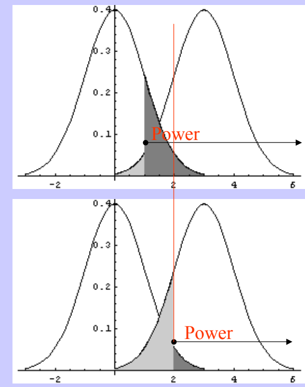


Ho Ha

Accept Ho | Reject Ho

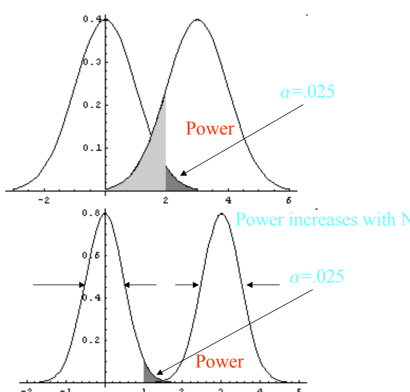
Decreasing α Increases β





By decreasing Alpha, we have decreased power.

N=50,
σ^2=50,
σ^2/N=1



N=100,
σ^2=50
σ^2/N=.5

Power and Sample Size

- Power increases as sample size increases. By increasing the sample size, we can detect smaller and smaller differences between populations.
- Thus we must be careful evaluating statistical significance.
- Statistical significance does not always implies that important differences have been found.