What is Hardcore Science?

- intro in applied statistics -

Matthias Rauterberg

Eindhoven University of Technology

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A deep insight…

Arthur Schopenhauer [1788 – 1860]

“The task is not so much *to see* what no one yet has seen, but to *think what nobody* yet has *thought* about that which *everybody sees*…

But life is short, and truth works far and lives long: let us speak the truth."
(1818)

La Vérité ("Truth")
Jules Joseph Lefebvre, 1870

So, what is TRUTH?

The meaning of the word **truth** extends from honesty, good faith, and sincerity in general, to agreement with fact or reality in particular.

The term has no single definition about which a majority of professional philosophers and scholars agree, and various theories of truth continue to be debated.

There are differing claims on such questions as what constitutes truth; how to define and identify truth; the roles that revealed and acquired knowledge play; and whether truth is subjective, relative, objective, or absolute.

From Wikipedia, the free encyclopedia

“But life is short, and truth works far and lives long…” Schopenhauer

“Time Saving Truth from Falsehood and Envy”
François Lemoyne, 1737

	Ontological Reference		
	Real Being	**Formal Being**	**Ideal Being**
Epistemo-logical Method	Observation of Reality	Formal proof	Belief based on intuition
Inference Concept	Inductive logic	Deductive logic	Value system
Academic Paradigm	Natural Sciences	Mathe-matics	Humane Sciences

Causation, science and common sense

- We have a somewhat problem free handle on talk about causes, effects and causal explanations.

- Example: The beer got me so drunk that I fell down the stairs causing a fracture in my leg.

  That explains why I am moving around using these crutches.

- In science, acknowledging causes and effects is **central**

The regularity view of causation

- *c* causes *e* iff

  (I) *c* is spatiotemporally contiguous to *e*

  (II) *e* succeeds *c* in time, and

  (III) all events of type *C* (i.e., events that are like *c*) are regularly followed by or constantly conjoined with events of type *E* (i.e. events like *e*)

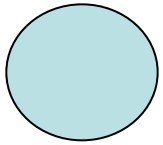
  (This formulation can be found in Psillos, 2002, p.19)

- Our ‘received view’ of causation tells us that causation happens in virtue of ‘something else’.

- If *c* causes *e*, it is because there is some real connection between *c* and *e* (that necessitates *e* happening when *c* happens).

What are causes and effects?

A



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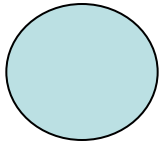

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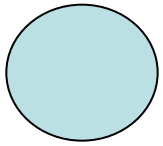
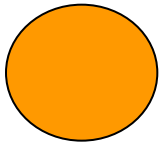
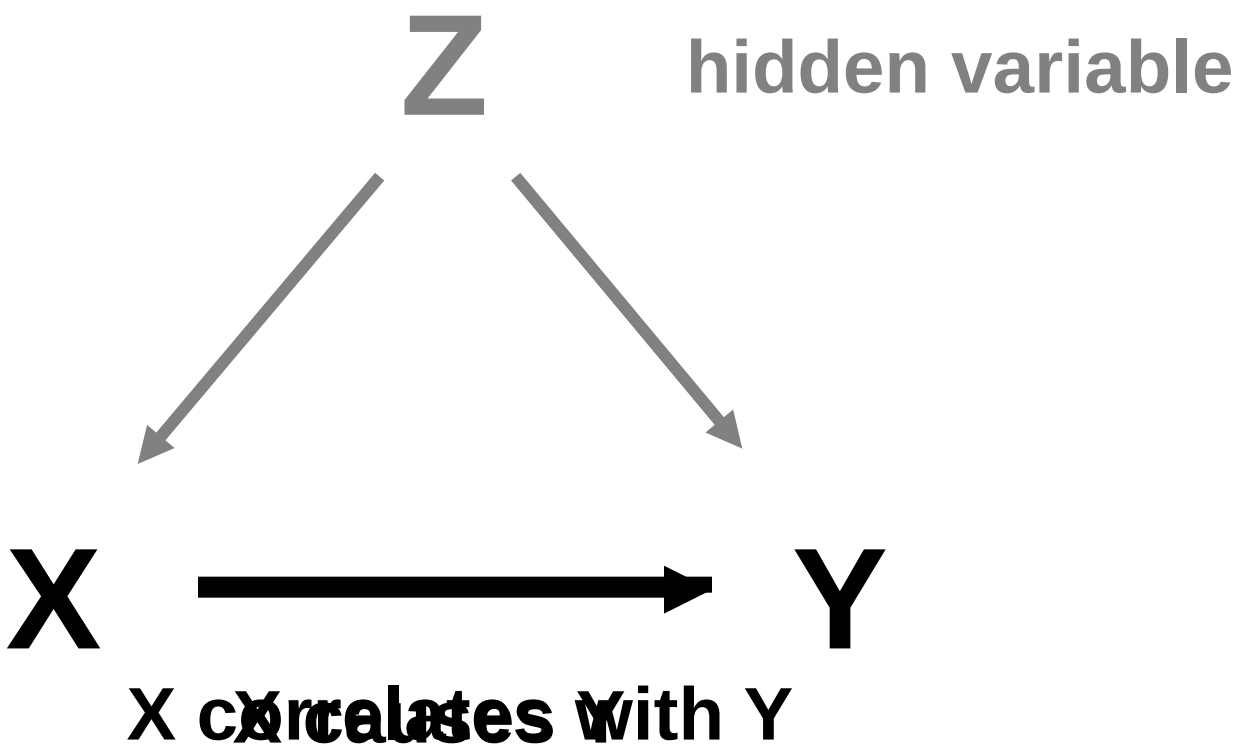




To explain the world, we need to know…

- The cause(s) -- effect(s) relationship(s)
- Factors altering functional relationships
- Systematic context for that information

The basic idea in explaining the world…



REF: Robert Mauro, Understanding L.O.V.E. (Left Out Variables Error): A Method for Estimating the Effects of Omitted Variables. *Psychological Bulletin*, Volume 108, Issue 2, September 1990, Pages 314-329

Principles for Positivistic sciences

- ***Causality:*** An assumption of linear causality; there are no effects without causes and no causes without effects.
- ***Reductionism:*** A single, tangible reality "out there" that can be broken apart into pieces capable of being studied independently.
- ***Objectivity:*** The separation of the observer from the observed.
  - So that the results of an inquiry are essentially free from beliefs, interpretations, etc.
- ***Universality:*** What is true at one time and place will also be true at another time and place.

General Principle of the minimum

"Ockham's razor":

- Elimination of superfluous concepts

  (*pluralitas non est podenda sine necessitate*)

- Scepticism
- Omnipotence principle

William of Ockham
(c.1280 - c.1348)

Criteria for scientific theories

Agreement with data

- Falsifiability (hypothetico-deductive method)
- Repeatability and reproducibility

Coherence or unity

- Internal and external coherence
  (deductive structure)

Generality

- Parsimony or economy
  (Occam's razor to find the simplest theory)

Fertility

- New implied discoveries

A scientific method is…

"a method of research, in which a problem is identified, relevant data are gathered, a hypothesis is formulated [= discovery], and the hypothesis is empirically tested [= verification]" [Random House 1999]

- *Problem* is a question proposed for solution or discussion.

- *Hypothesis* is a provisional theory suggested as a solution to the problem: either a causal or a non-causal correlation between variables.

Now the big question is…

How to distinguish between
a *causal* correlation
and
a *non-causal* correlation?

Answer: the controlled experiment !

Experimental settings

Laboratory experiment

Experiments conducted in a controlled setting.

Field experiment

Tests conducted outside the laboratory in an actual environment, such as a marketplace.

Experiments have to demonstrate validity

Internal validity

The extent to which competing explanations for the results observed can be ruled-out.

External validity

The extent to which causal correlations measured can be generalized to outside persons, settings, and times.

What is an experiment?

An experiment:

A research approach in which one [or more] variable[s] are manipulated and the effect[s] on other variable[s] are observed.

Key variables:

Independent (IV): variables one controls directly such as price, packaging, distribution, product features, etc.;

Treatment (T): the independent variable manipulated during an experiment to measure its effect on the dependent variable;

Dependent (DV): variables one does not directly control such as sales or customer satisfaction - *(might control them by manipulating the independent variable);*

Extraneous (EF): factors one does not control but has to live with such as the weather.

Extraneous variables

History:

Intervention, between the beginning and end of an experiment, of outside variables that might change the dependent variable.

Maturation:

Changes in subjects occurring during the experiment that are not related to the experiment but which might affect subjects' response to the treatment factor.

Instrument variation:

Changes in measurement instruments *(e.g., interviews or observers)* that might affect measurements.

Selections bias:

Systematic differences between the test group and the control group due to a biased selection process.

Extraneous variables (cont'd)

Mortality:

Loss of test units or subjects during the course of an experiment - which might result in a nonrepresentativeness.

Testing effect:

An effect that is a by-product of the research process itself (e.g. 'Hawthorne effect').

Regression to the mean:

Tendency of subjects with extreme behavior to move towards the average for that behavior during the course of the experiment.

Controlling extraneous variables

Randomization:

The random assignment of subjects to treatment conditions to ensure equal representation of subject characteristics.

Physical control:

Holding constant the value or level of extraneous variables throughout the course of an experiment.

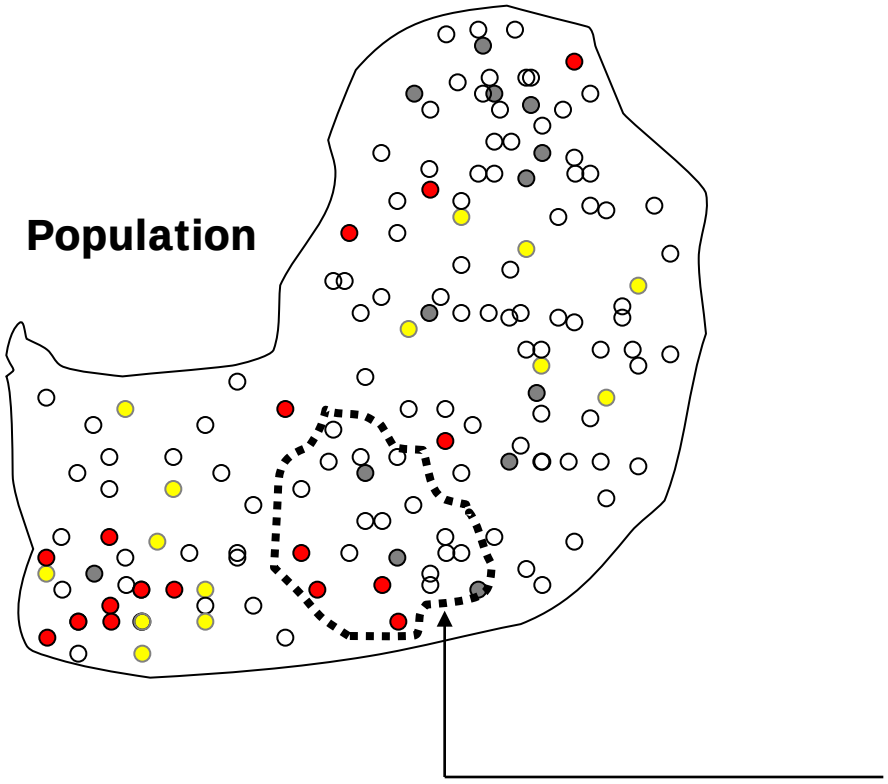
Test-design control:

Use of experimental design to control extraneous causal factors.

Statistical control:

Adjusting for the effects of extraneous variables by statistically adjusting the value or the dependant variable for each treatment condition.

Population



Definition

A ***population*** consists of all elements – individuals, items, or objects – whose characteristics are being studied.

The population that is being studied is also called the ***target population***.

A portion of the population selected for study is referred to as a ***sample***.

The random sample

Definition

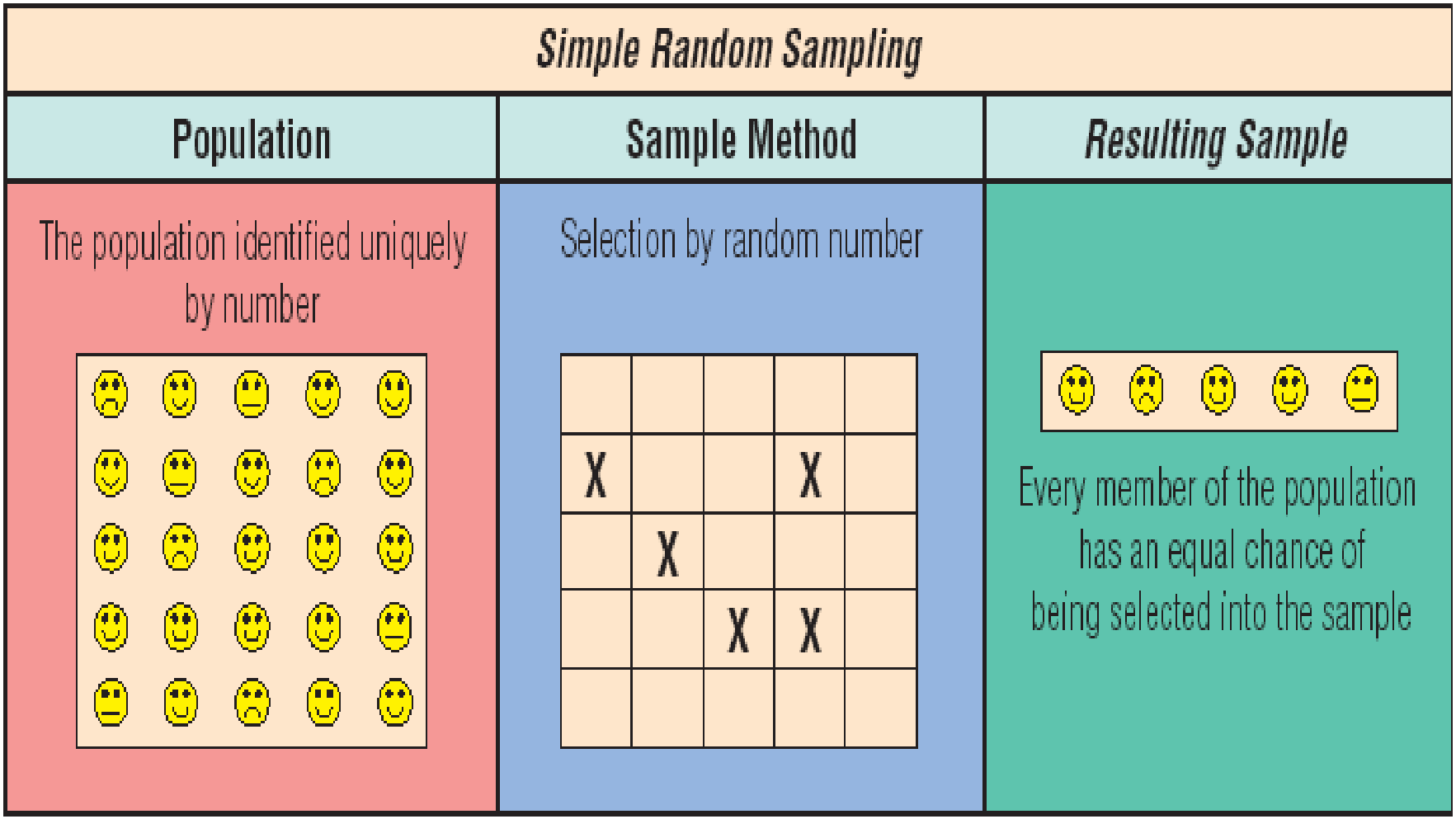
A sample drawn in such a way that each element of the population has a chance of being selected is called a ***random sample***. If the chance of being selected is the same for each element of the population, it is called a ***simple random sample***.

An ***element*** or ***member*** of a sample or population is a specific subject or object (for example, a person, firm, item, state, or country) about which the information is collected.

A ***variable*** is a characteristic under study that assumes different values for different elements. In contrast to a variable, the value of a ***constant*** is fixed.

The value of a variable for an element is called an ***observation*** or ***measurement***.

Random sampling method

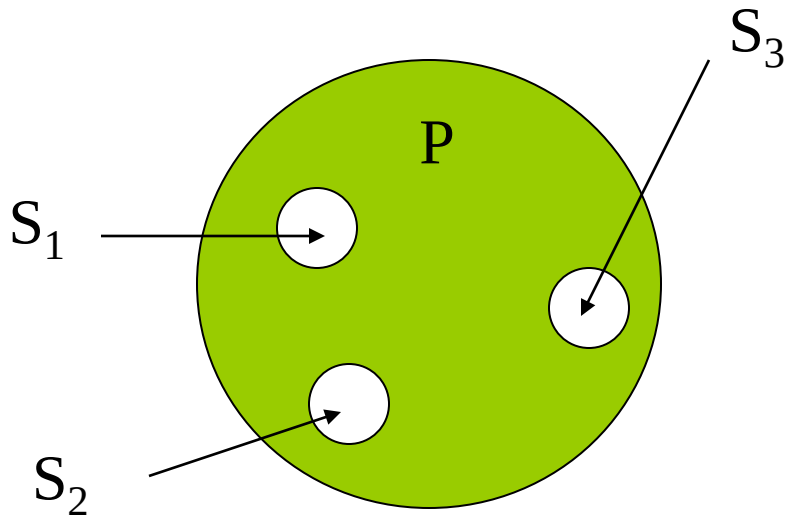


From sample to population

- Here is the problem: different samples (S_x) drawn from the same population (P) can have different properties.

- When you take a sample from a population, you only have a subset of the population--a piece of what you're trying to understand.

The **solution** to this problem is called *statistics*, in particular *inferential statistics*!



What is statistics?

Definition

Statistics is a group of methods used to collect, analyze, present, and interpret data and to make decisions.

Types of Statistics:

Descriptive Statistics consists of methods for organizing, displaying, and describing data by using tables, graphs, and summary measures.

Inferential Statistics consists of methods that use sample results to help make decisions or predictions about a population.

What is a hypothesis?

We like to think of statistical hypothesis testing as the data analysis stage of an **experiment,** in which the scientist is interested, for example, in comparing the means of a population to a specified value (e.g. mean ‘usability’).

A **statistical hypothesis** is a statement about the parameters of one or more populations.

One-sided and two-sided hypotheses

Two-Sided Test:

$$H_0: \mu = \mu_0$$
$$H_1: \mu \neq \mu_0$$

One-Sided Tests:

$$H_0: \mu = \mu_0 \quad H_1: \mu > \mu_0 \qquad \text{or} \qquad H_0: \mu = \mu_0 \quad H_1: \mu < \mu_0$$

Outcomes of a statistical analysis

	H_0 True (no correlation)	H_1 True (correlation)
Do not reject H_0 (not stat. sig.)	Correct decision	Type II (beta error)
Reject H_0 (stat. sig.)	Type I (alpha error)	Correct decision

How to measure?

N_x^c **N**ominal scale: **= , ≠**

O_x **O**rdinal scale: **= , ≠ , > , <**

I_x **I**nterval scale: **= , ≠ , > , < , – , +**

R_x **R**ational scale: **= , ≠ , > , < , – , + , × , ÷**

See further at ftp://ftp.sas.com/pub/neural/measurement.html

Measures of central tendency

- A way of summarising the data using a single value that is in some way representative of the entire data set
  - It is not always possible to follow the same procedure in producing a central representative value: this changes with the shape of the distribution

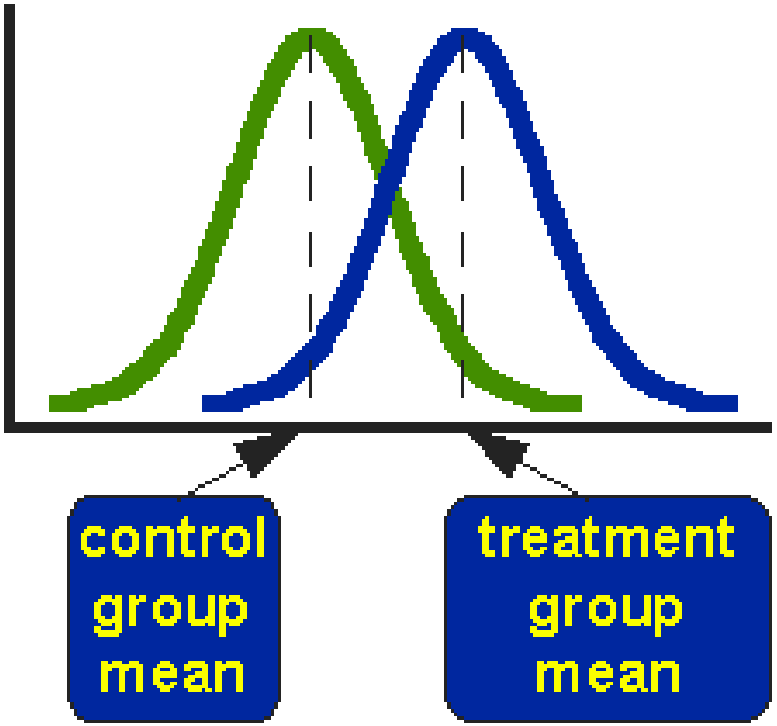
- **Mode** [recommended for N-scale]
  - Most frequent value
  - Does not take into account exact scores
  - Unaffected by extreme scores
  - Not useful when there are several values that occur equally often in a set

Measures of central tendency (cont'd)

- **Median** [recommended for O-scale]
  - The values that falls exactly in the midpoint of a ranked distribution
  - Does not take into account exact scores
  - Unaffected by extreme scores
  - In a small set it can be unrepresentative

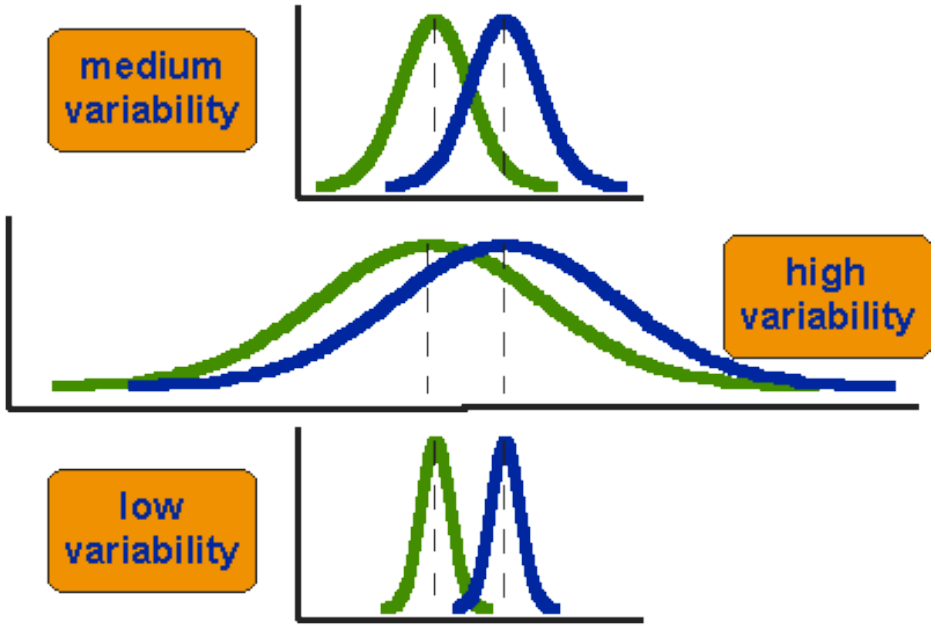
- **Mean** (Arithmetic average) [recommended for I-scale]
  - Sample mean: $M = \frac{\Sigma X}{n}$ Population mean: $\mu = \frac{\Sigma X}{N}$
  - Takes into account all values
  - Easily distorted by extreme values

[N^2 * I] Differences in means



- In order to know whether a difference between two means is important, we need to know how much the scores vary around the means.

[N^2 * I] Differences in means (cont'd)



- Holding the difference between the means constant
- With high variability the two groups nearly overlap
- With low variability the two groups show very little overlap

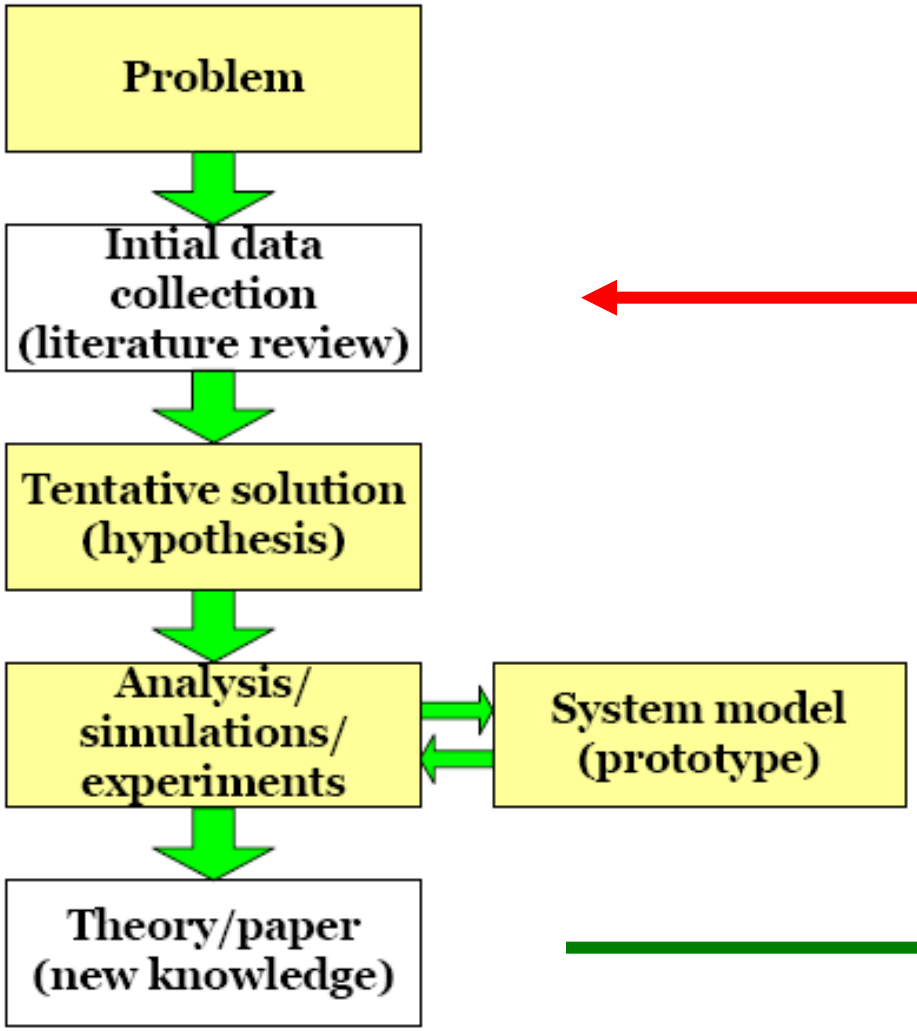
Choosing a significance level

- In general
  - Pilot program and intervention evaluations use liberal significance levels (.2 - .1) to avoid discarding effective interventions.
  - Pure research uses conservative significance levels (.01-.001) to avoid wide dissemination of erroneous results.

Overview over inference tests

$N^2 * N^2$	Fisher's exact test; Odds Ratio
$N^x * N^y$	CHI^2 (with x>2 and/or y>2)
$N^2 * O$	Mann-Whitney-U-test
$N^2 * I$	T-test
$N_x{}^y * I$	[M]Anova (with x>1 and/or y>2)
$I_x * N$	Discriminant analysis (with x>1)
$O * O$	Spearman's rank correlation
$I * I$	Pearson correlation
N_x	Cluster analysis (with x>2)
O_x	Multidimensional scaling (with x>2)
I_x	Factor analysis (with x>2)

Overview over the scientific approach



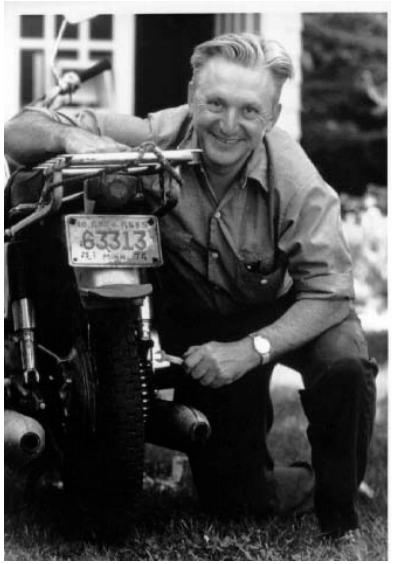
Google scholar, Digital libraries, etc.

Your own conference or journal publication!

Thank you for your attention…

"Traditional scientific method has always been at the very best 20-20 hindsight.
It's good for seeing where you've been.
It's good for testing the truth of what you think you know, **but**
it can't tell you where you ought to go."

Robert Pirsig, 1974
"Zen and the art of motorcycle maintenance"



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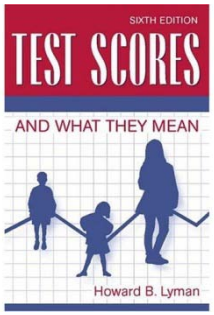

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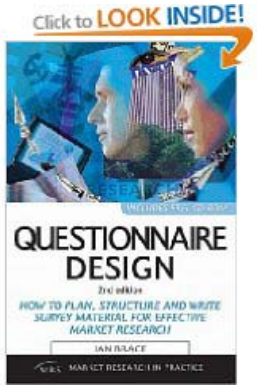

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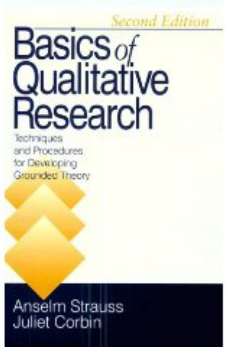

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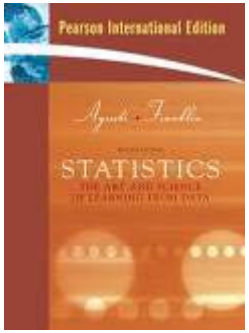

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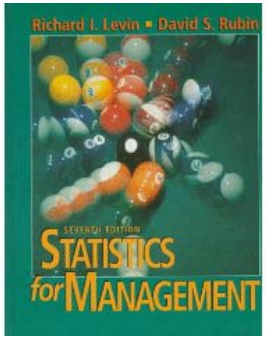

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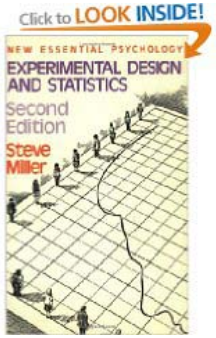

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