A Beautiful Science

Scientific Method For an idea to be scientific, it must be falsifiable.

falsifiable = testable

For information to be scientific, it must be empirical.

empirical = gathered through methodical observation

The Basics of Study Design

1) There must be a fully formed, clearly stated research question.

   (What do we wish to learn? Why are we conducting this research?)

2) Focus is critical. There must be a clear goal in mind. Otherwise, time, energy, and money will be invested only to find that nothing has been accomplished.
3) A useful approach is to ask early on if, at the end of the project, only one question could be answered, what would that question be?

Make sure the project is feasible.

- Can we define and measure everything that needs to be defined and measured?
- If the study involves some condition, can we define it? Can we be sure we'll recognize it when we see it? (What is improved nutritional status? What is an unhealthy eating behavior? What is crop yield--what gets harvested or what makes it to market, or both? What are sales--what gets manufactured or what gets into the hands of the consumer? What's the difference between a cold and the flu? How do you measure usual dietary intake? Does it matter how lean body mass is measured? What do we mean by *family income* or *improved nutritional status*?)

Measurement

- How accurate are the measurements?
- How accurate do they need to be?
- How should we choose among different measurement techniques?
- Are we measuring what we think we're measuring?
- Can measurements be made consistently, that is, if a measurement is made twice will we get the same number? Can others get the same value (inter-laboratory, inter-technician variability)? What happens if different measurement techniques are used within a particular study?

Data Collection

- Every data item and every facet of the protocol must be carefully considered.
- All of the relevant data must be collected. If a critical piece of data cannot be obtained, perhaps the study should not be undertaken.
- It is equally important to guard against collecting data unrelated to the research question. It is very easy to overlook how quickly data can multiply and bog down a study, if not destroy it. Be sure the cost in time and effort of each data item is clearly understood.

Treatments

- Treatments must be clearly identified
- Anything that is done to subjects may be responsible for any observed effects, and something must be done to rule out those possibilities that aren't of interest (for example, socialization and good feelings or heightened sensitivity to the issue being studied that come from participation).
- Things aren't always what they appear to be.

Types of Studies

- Descriptive: To observe and describe the world around us. E.g., the Origin of the Species
- Relational: Designed to examine the relationship between two or more variables. E.g., relating age to hair color
- Causal: Designed to determine whether one of more variables causes or affects one or more outcomes.

Types of Studies

- The typical study can be classified into one of two types:
- observational studies and
- intervention trials.
- The distinction is based on whether an intervention is involved, that is, whether the investigator changes some aspect of subjects' behavior.

Types of Studies

- A *cross-sectional study* involves a group of people observed at a single point in time. (Imagine a lot of lines on a plot with time as the horizontal axis and taking a slice or *cross-section* out of it at a particular point in time.)
- A *longitudinal study* involves the same individuals measured over time (or a*long* the time line).
- It is often tempting to interpret the results of a cross-sectional study as though they came from a longitudinal study. Cross-sectional studies are faster and cheaper than longitudinal studies, so there's little wonder that this approach is attractive.
- Sometimes it works; sometimes it doesn't. But, there's no way to know whether it will work simply by looking at the data.

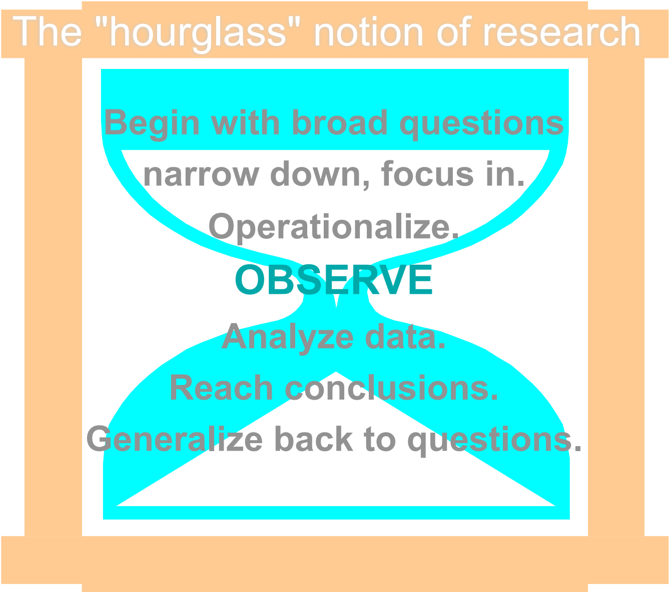
The Structure of Research

Causal Hypotheses

Causal Hypotheses

- Statement of relationship between an independent and dependent variable
- Describes a cause and effect
- Usually stated in two forms
  - The null hypothesis
  - The alternative hypothesis
- The two forms are
  - Mutually exclusive
  - Exhaustive

The Structure of Research



The Scientific Method

- **The scientific method has four steps**
  - 1. Observation and description of a phenomenon or group of phenomena.
  - 2. Formulation of an hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.
  - 3. Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.
  - 4. Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments.
- If the experiments bear out the hypothesis it may come to be regarded as a theory or law of nature

Common Mistakes

- The most fundamental error is to mistake the hypothesis for an explanation of a phenomenon, without performing experimental tests. Sometimes "common sense" and "logic" tempt us into believing that no test is needed.
- Another common mistake is to ignore or rule out data which do not support the hypothesis. Ideally, the experimenter is open to the possibility that the hypothesis is correct or incorrect. Sometimes, however, a scientist may have a strong belief that the hypothesis is true (or false), or feels internal or external pressure to get a specific result. In that case, there may be a psychological tendency to find "something wrong", such as systematic effects, with data which do not support the scientist's expectations, while data which do agree with those expectations may not be checked as carefully. The lesson is that all data must be handled in the same way.
- Another common mistake arises from the failure to estimate quantitatively systematic errors (and all errors).
- In a field where there is active experimentation and open communication among members of the scientific community, the biases of individuals or groups may cancel out, because experimental tests are repeated by different scientists who may have different biases. In addition, different types of experimental setups have different sources of systematic errors. Over a period spanning a variety of experimental tests (usually at least several years), a consensus develops in the community as to which experimental results have stood the test of time.

“Hypothesis," "model," "theory" and "law"

- An hypothesis is a limited statement regarding cause and effect in specific situations; it also refers to our state of knowledge before experimental work has been performed and perhaps even before new phenomena have been predicted.
- The word model is reserved for situations when it is known that the hypothesis has at least limited validity.
- A scientific theory or law represents an hypothesis, or a group of related hypotheses, which has been confirmed through repeated experimental tests. Accepted scientific theories and laws become part of our understanding of the universe and the basis for exploring less well-understood areas of knowledge. Theories are not easily discarded; new discoveries are first assumed to fit into the existing theoretical framework. It is only when, after repeated experimental tests, the new phenomenon cannot be accommodated that scientists seriously question the theory and attempt to modify it.

The Art of Logical Reasoning

- An argument is any piece of discourse that gives reasons to support some statement.
- For example:
  - Socrates is a man, and all men are mortal, so Socrates is mortal
  - Because standard IQ tests are culturally biased, they are discriminatory. That makes it unconstitutional to use them in public schools.

The same topic continued

- Conclusion: This is the statement the argument is designed to support or defend
- Premises: In most arguments, at least one statement is affirmed without any defense. It is one of the ultimate reasons given by the argument to support its conclusion:
  - Premises may be explicit or implicit (tacit)
- Intermediate Steps: Assertions designed to bring out the connection between premises and conclusions.

Evaluation

- Deductive validity: If the premises are true, the conclusion <u>must</u> also be true.
- Inductive validity: if the premises are true, the conclusion might follow.
- Truth of premises/ plausibility of premises/ evidence of validity
  - The strength of an argument depends upon the truth of the premises
  - If an argument is validly made from premises that we agree to be true, then we must accept the conclusion.

Steps in evaluating arguments

- 1. Reconstruct
- 2. Standardize
- 3. Test for validity
- 4. Supply validating premises if possible
- 5. Evaluate the truth of the premises
- Note: You don’t care about alternative arguments

Explanations

- Explanations and arguments are much alike. The purpose of an explanation is not to support the conclusion, but rather to explain why it is true
  - Conclusion of an argument is something we do not agree upon;
  - Conclusion of an explanation is something we all observe
- Premises in explanations are statements that we do not agree upon; statements about things we do not (and can not) observe.

Evaluating Explanations

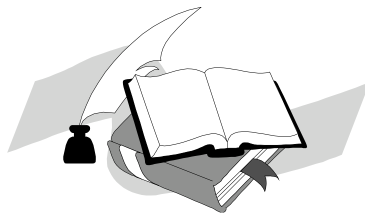
- Is the Conclusion true?
- Does the conclusion follow as a consequence of the premises? (Deductive validity
- Are the premises plausible?
- Comparative economy: we prefer simpler to more complicated explanations
- Comparative generality: we prefer general to special explanations

Validity

- Validity is the quality of the conclusions you might reach based on your research.
  - The best available approximation to the truth of a given proposition, inference or conclusion.
- 4 types of validity: Conclusion; internal; construct; external.

What is Validity?

- The best available approximation to the truth or falsity of a given inference, proposition, or conclusion
- A set of standards by which research can be judged



The Causal Context

Theory

Observation

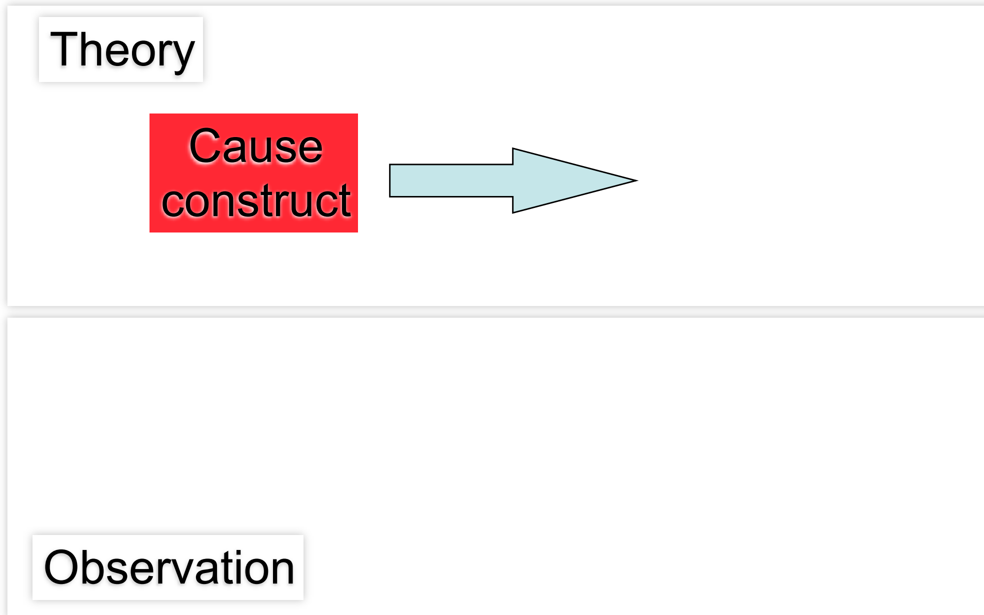
The Causal Context

Theory

Cause construct

Observation

The Causal Context



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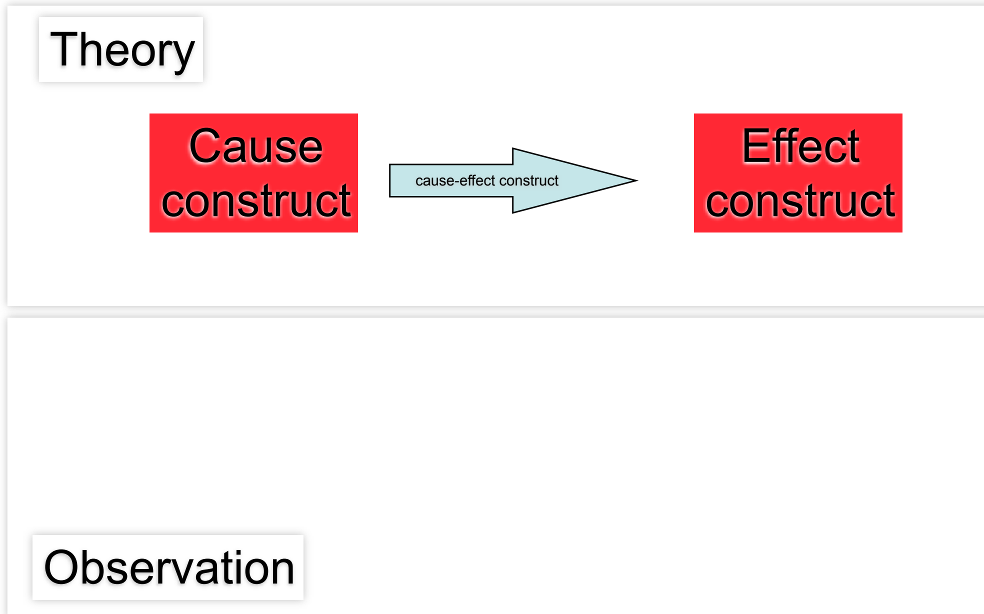

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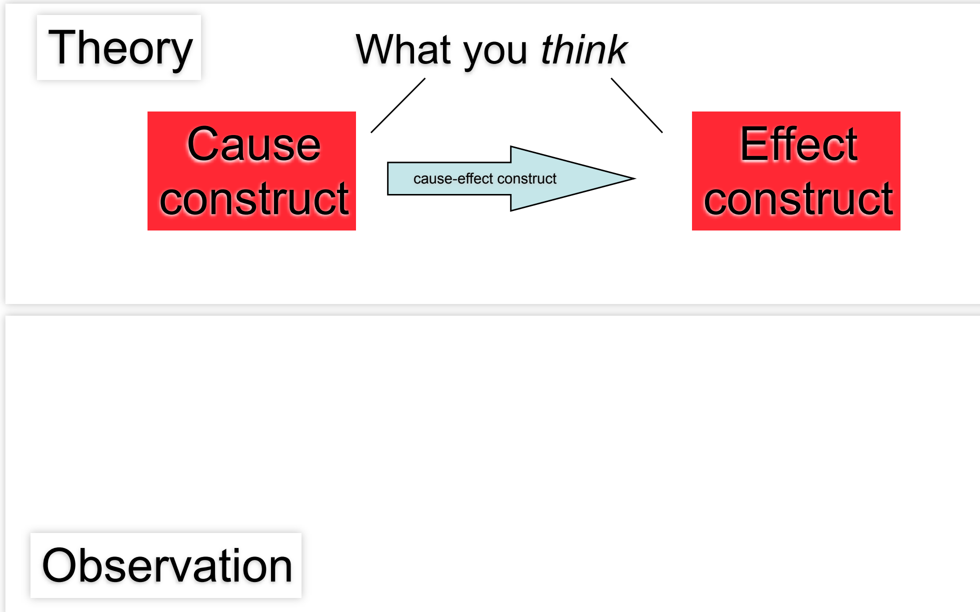

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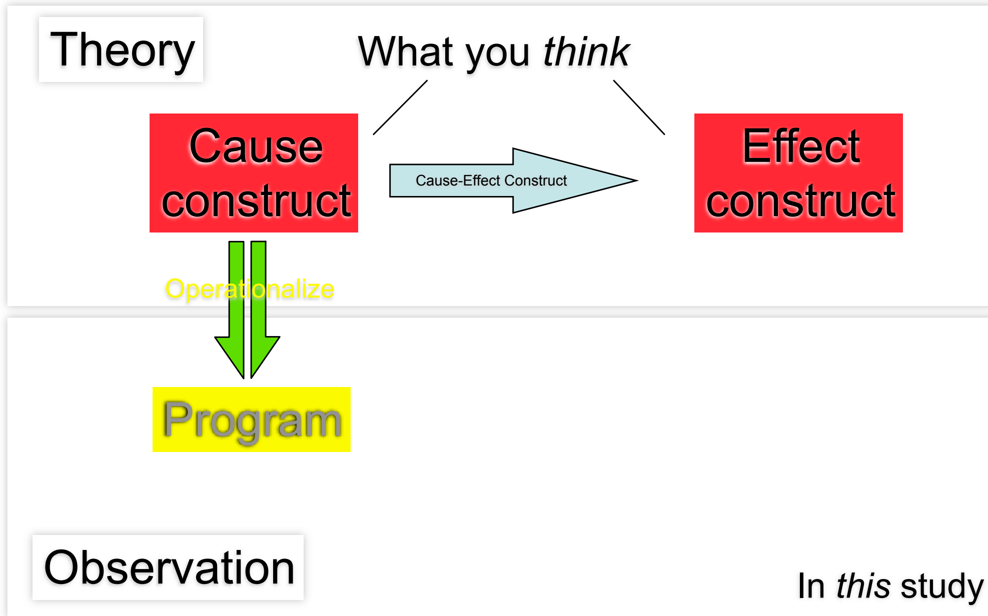

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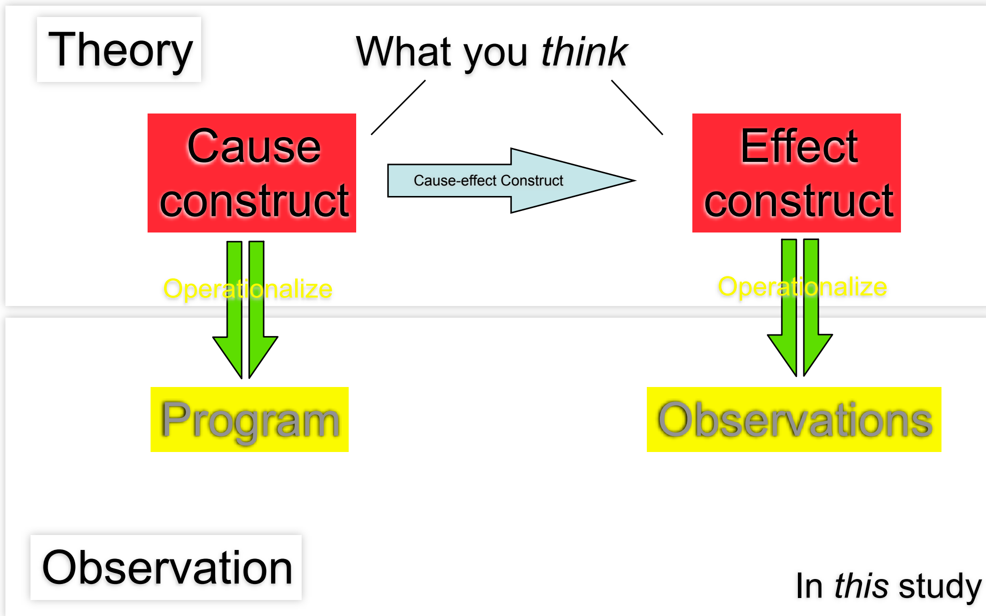

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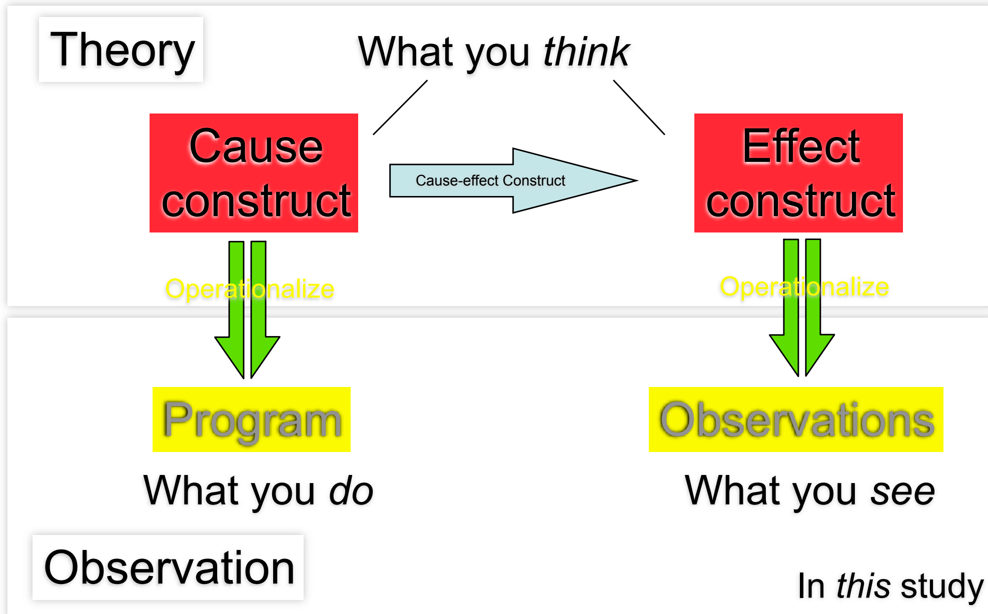

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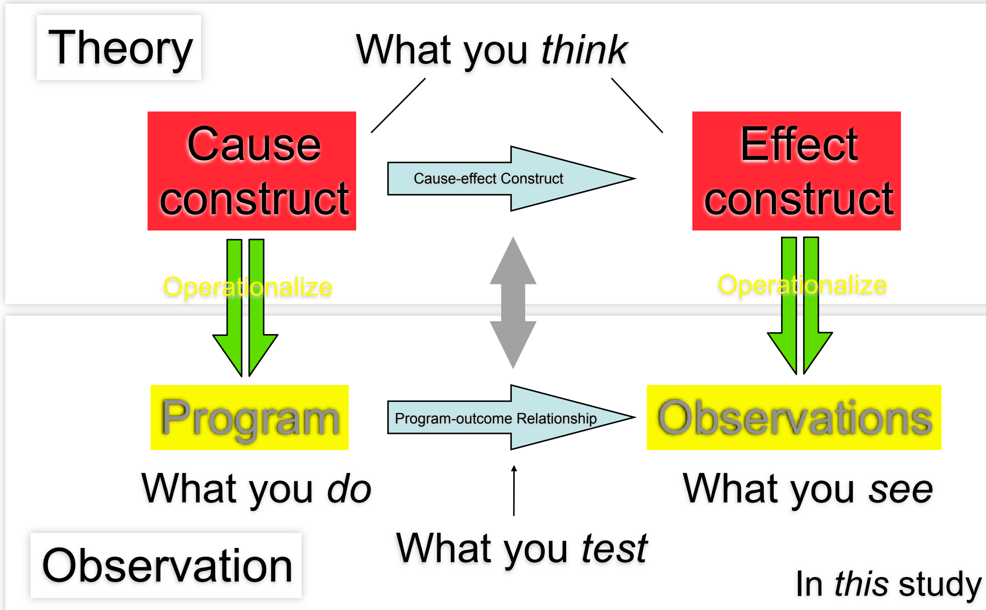
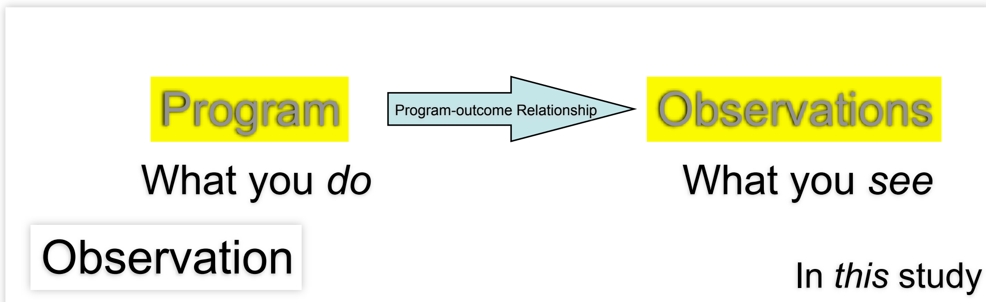


Conclusion Validity

Is there a *relationship* between...

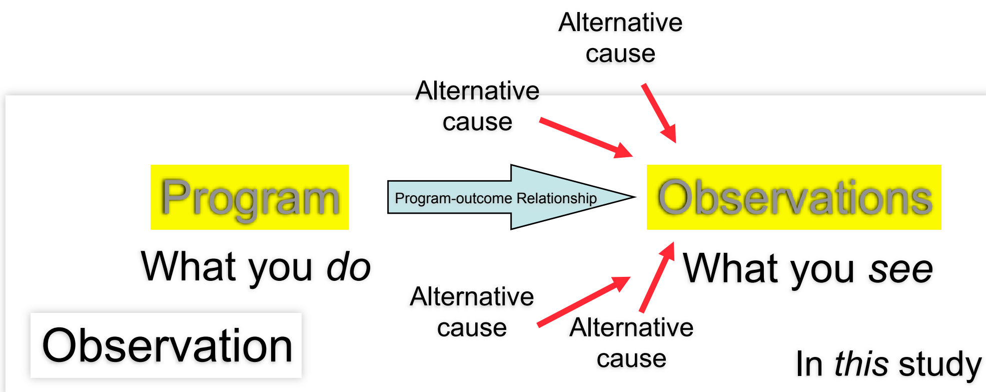
- What you did and what you saw?
- Your program and your observations?



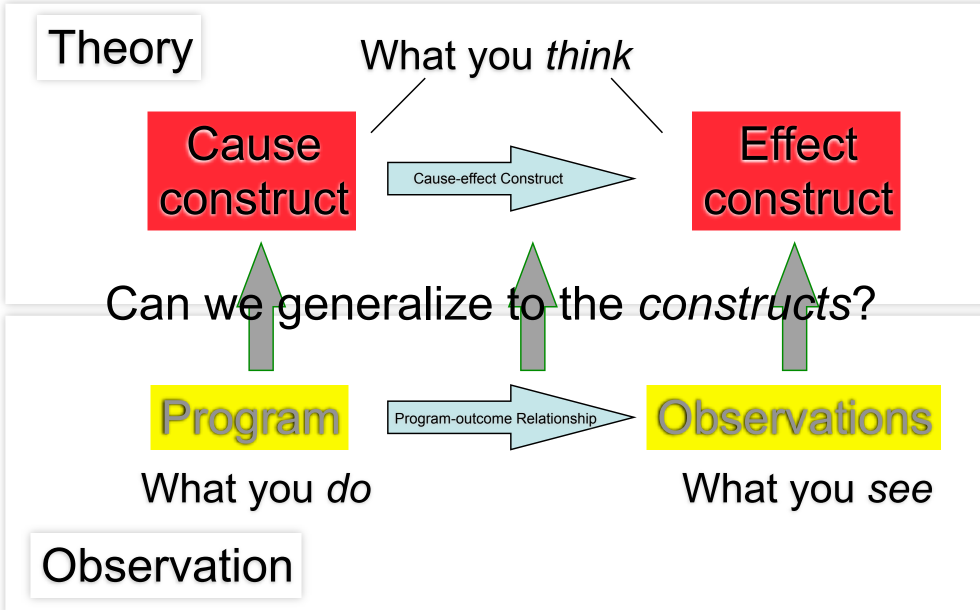
Internal Validity

Is the relationship *causal* between...

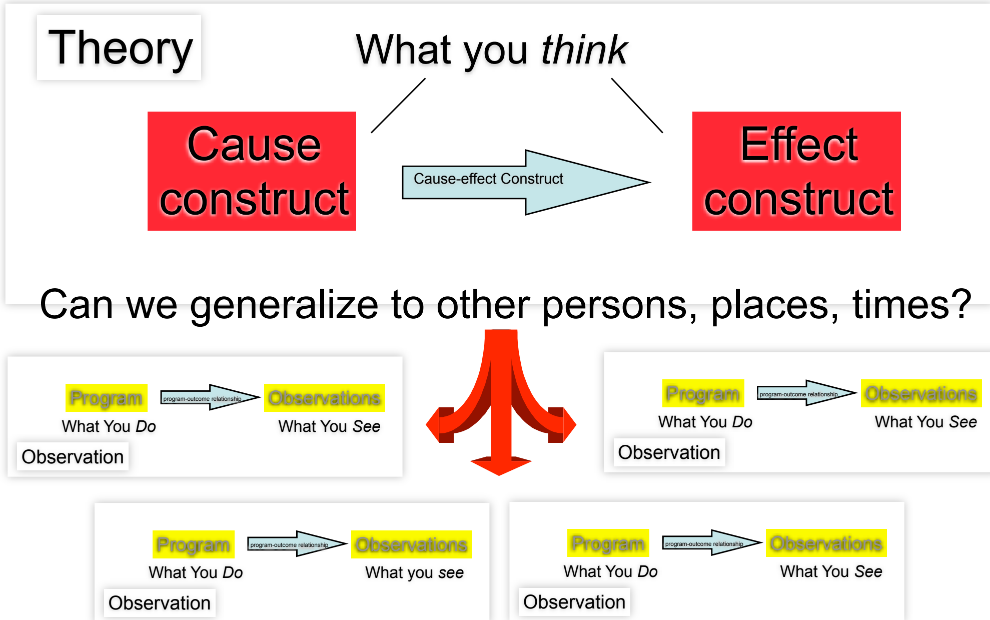
- What you did and what you saw?
- Your program and your observations?



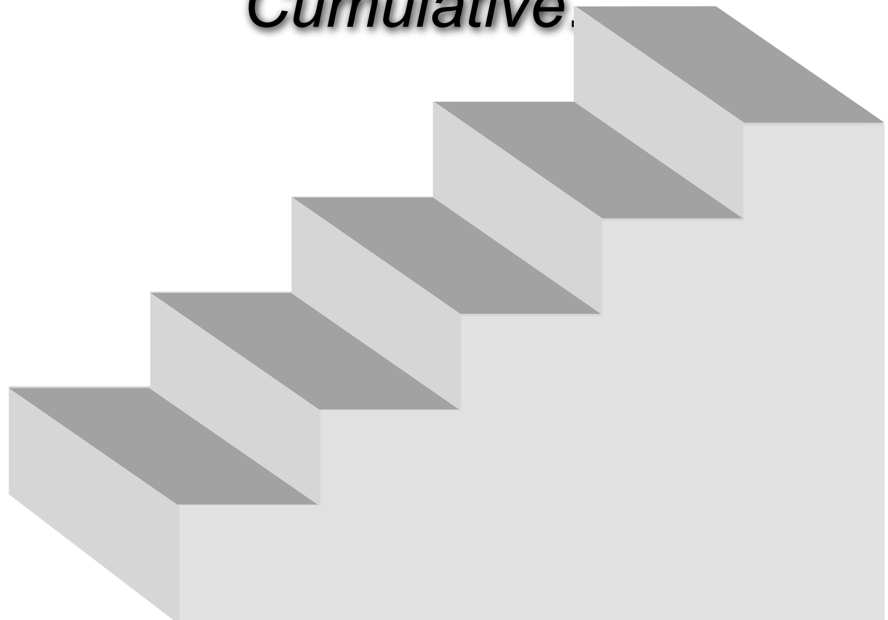
Construct Validity



External Validity



The Validity Questions Are *Cumulative*.



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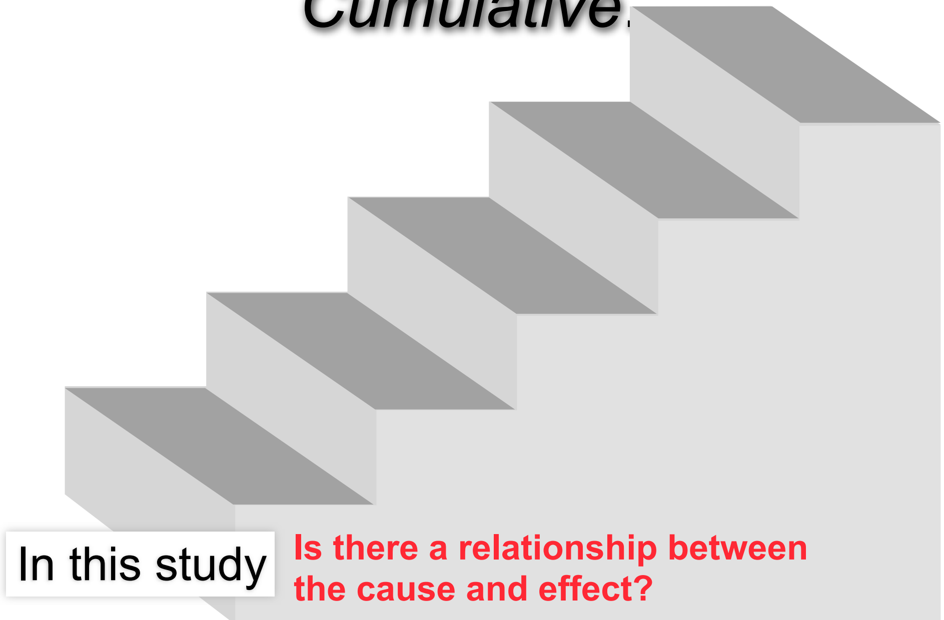

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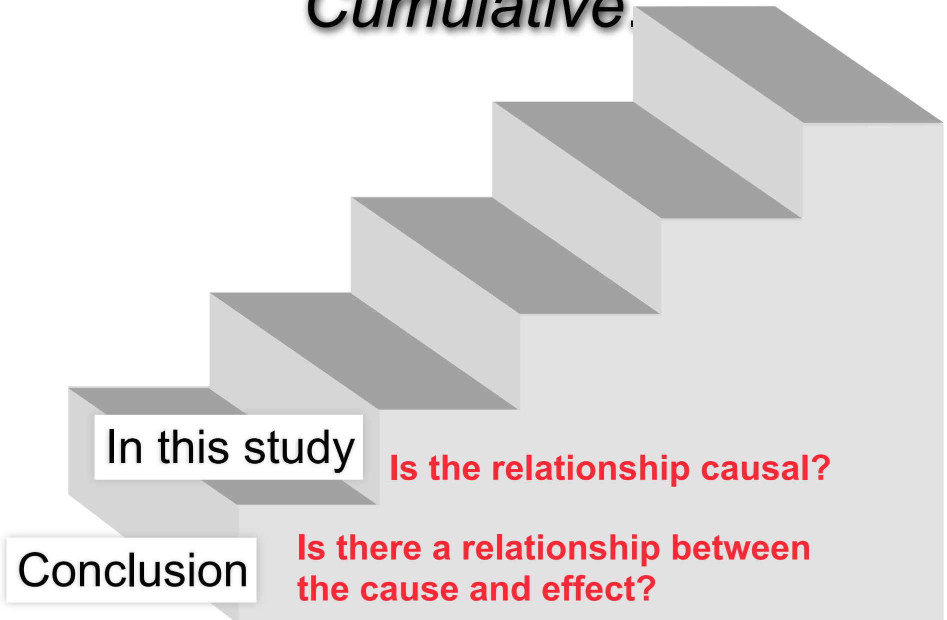

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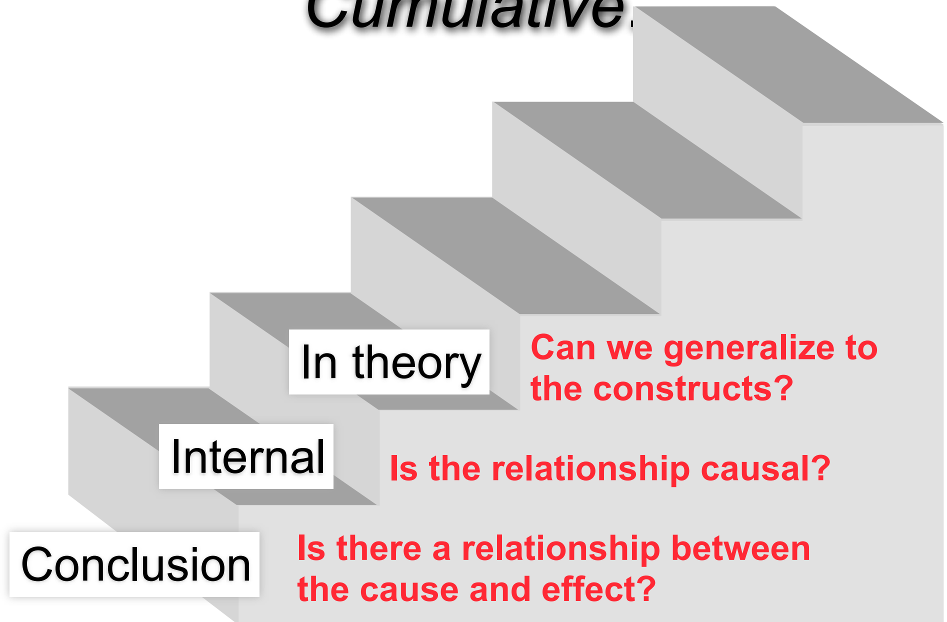

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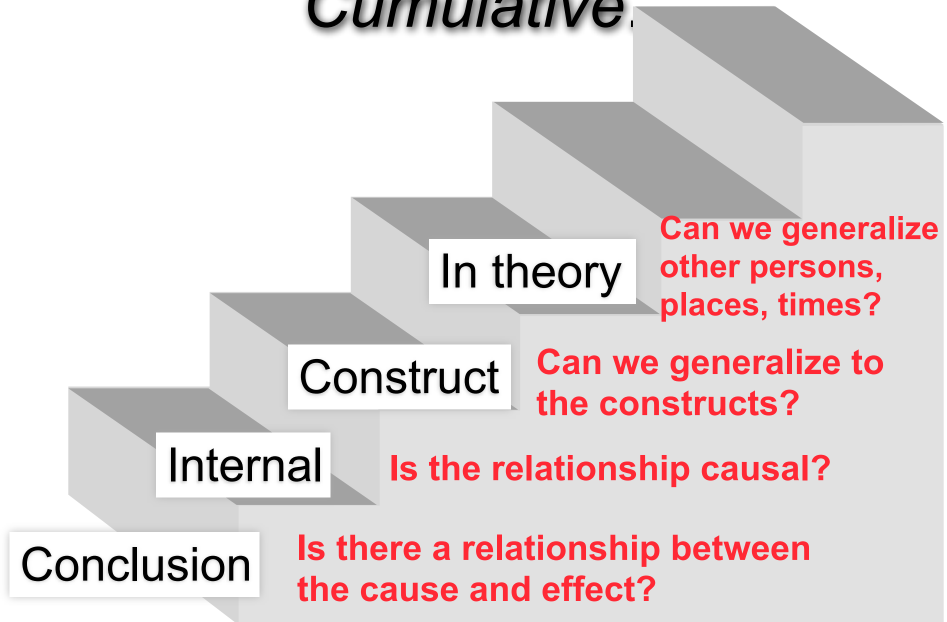

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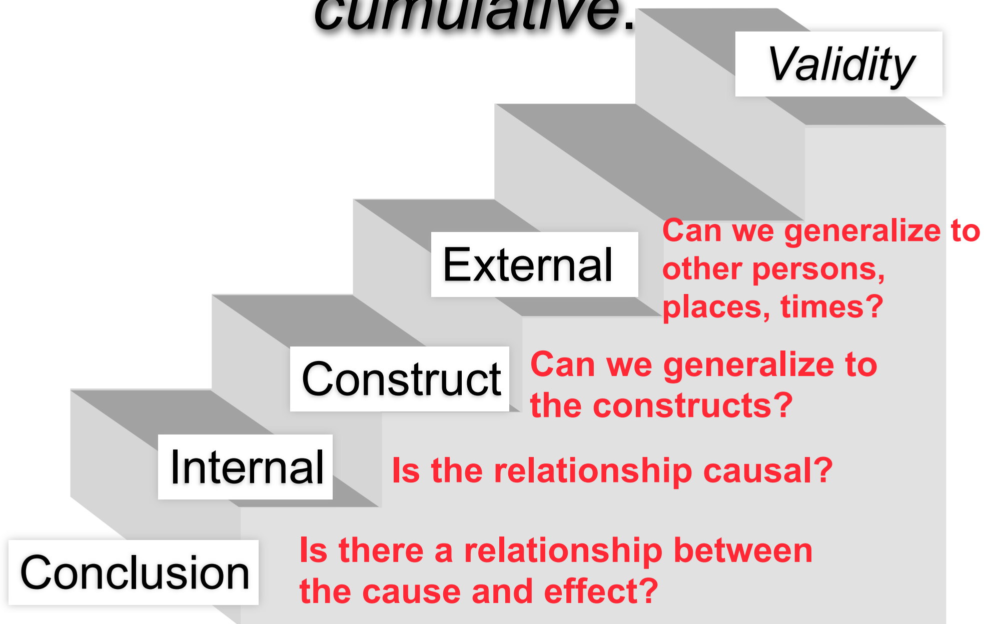
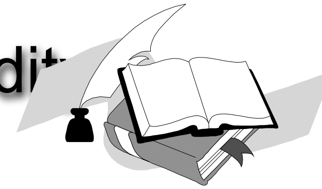


Threats to Validit



You Want to Make an Inference...

- There *is* a relationship between the cause and effect.
- The relationship *is* causal.
- You *can* generalize to the constructs.
- You *can* generalize to other persons, places, and times.

Threats to Validity

How could you be *wrong* in the inference?

Conclusion Validity

- There is a relationship, but you don't *see* it.
- There is no relationship, but you *do* see one.

Threats to Validity

How could you be *wrong* in the inference?

Internal Validity

- There is a causal relationship, but you don't *see* it.
- There is no causal relationship, but you *do* see one.

Threats to Validity

How could you be *wrong* in the inference?

Construct Validity

- You can generalize to constructs, but you *conclude you can't.*
- You can't generalize to constructs, but you *conclude you can.*

Threats to Validity

How could you be *wrong* in the inference?

External Validity

- You can generalize to other contexts, but you *conclude you can't*
- You can't generalize to contexts, but you *conclude you can*

Threats to Validity

- How you can be wrong in making your inference
- Specific factors that can bias or distort your conclusions
- A list of common threats to the quality of your study
- A “checklist” you can use in planning your study