

Elementary Statistical Concepts and the  
Logic of the Scientific Method

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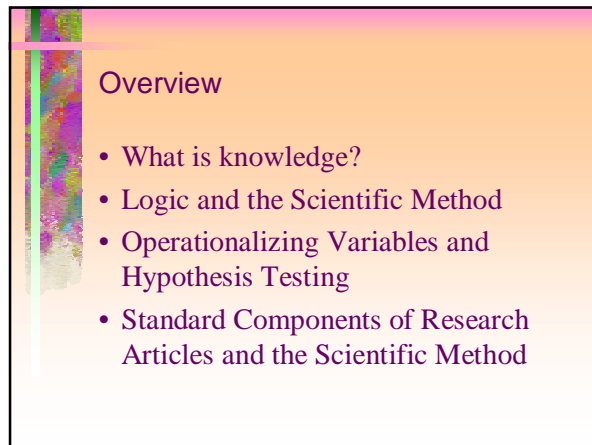
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Overview

- What is knowledge?
- Logic and the Scientific Method
- Operationalizing Variables and Hypothesis Testing
- Standard Components of Research Articles and the Scientific Method

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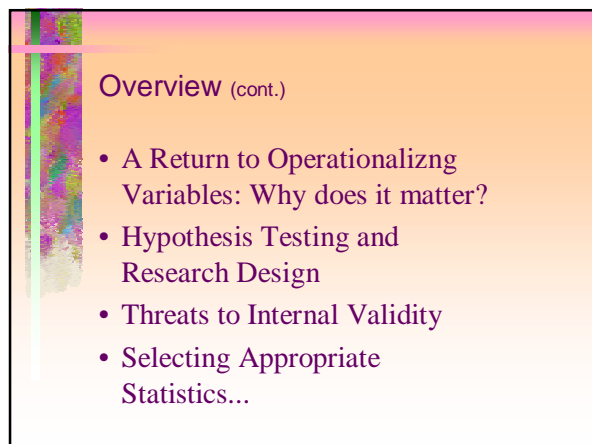
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Overview (cont.)

- A Return to Operationalizing Variables: Why does it matter?
- Hypothesis Testing and Research Design
- Threats to Internal Validity
- Selecting Appropriate Statistics...

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**A Body of Knowledge**  
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An organized system of concepts,  
rules, and processes

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**Creating a Body of Knowledge**  
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**Many sources of knowledge:**

- Authority - religious or political;
- Tradition;
- Invention
- Expert opinion;
- The scientific method

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**Creating a Body of Knowledge:  
Knowledge Systems**  
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Natural Systems	Man-made Systems
• “Educated guess”	• Specified/Invented
• Evolving	• Static
• Theory-building	• Theory-driven
• Scientific Method	• Acquire/learn
– Discovery	– Acquisition

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Creating a Body of Knowledge:  
The Scientific Method  
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Why Scientific Method?  
Powerful means to reduce error involved  
in the process of building knowledge  
about the world - particularly  
understanding “**natural systems.**”  
Allows us to predict, control, explain,  
and describe how the world operates.

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Natural Systems:  
**Concepts**, Theory, and Hypotheses  
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Abstract Concepts are NOT constrained by  
specific time or place.  
Concrete Concepts ARE constrained to a  
specific time or place.

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Natural Systems:  
**Concepts**, Theory, and Hypotheses  
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Abstract:                      Concrete:  
• Temperature              • Temp. of the sun  
• Three days                 • Dec. 4-6, 1967  
• Attitude                    • What Harry thinks of  
   the president  
• Social System              • General Motors  
• Identity status             • A score on an  
   “identity status” scale

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Natural Systems:  
Concepts, **Theory, and Hypothesis**

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- **Theory:** A set of theoretical statements about the world
- **Theoretical statement:** Use of abstract (versus concrete) concepts to describe the relationship between two or more variables.
- **Hypothesis:** An assertion of a relationship between two or more concepts/variables, using concrete concepts, subject to verification, and based on theory.

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Building Blocks of Logic and Reasoning:  
The Syllogism

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- The syllogism is the primary building block of all reasoning/logic
- Three components of a syllogism: premise(s), inference and conclusion
- Example:  
All cats are animals, Toby is a cat,  
therefore, Toby is an animal.

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Building Blocks of Logic and Reasoning:  
Deduction and Induction

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- **Deduction:** To reach a conclusion by reasoning. To infer from a general principle to a particular instance; reason deductively.
- **Induction:** A principle of reasoning to a conclusion about all the members of a class from examination of only a few members of the class; to infer general principles from examination of a particular.

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Building Blocks of Logic and Reasoning:  
Deduction and Induction

- If premises are true and the inference is valid, then, the conclusion must be true.
- All squirrels eat peanuts; my pet is a squirrel.

Therefore.....

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The Scientific Method as an Instance  
of Deductive Reasoning

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Theory  
    Deduction  
    ↓  
Hypothesis

Theory is related to hypothesis via deductive logic. We deduce hypotheses from theory. If the theoretical statements are true, the hypothesis must be true.

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The Scientific Method:  
Operational Definitions of Concepts

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- Goal: Measuring abstract concepts

Making an abstract concept into a concrete concept (for the purpose of hypothesis testing) is to “operationalize” the concept.

- Measurement Options for a concept:  
Four levels of measurement

- Nominal
- Ordinal
- Interval
- Ratio

**NOIR**  
(see Table 1)

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The Scientific Method:  
**Operational Definitions of Concepts**  
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- To operationalize a concept is to make it available to “sense data” (i.e., something we can see, hear, touch, smell, or taste)
- The scientific method is, thus, the marriage of logic and “empiricism” = logical empiricism

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The Scientific Method as an Instance  
of Deductive Reasoning  
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- **Hypothesis:** An assertion of an expected relationship between two or more variables (concepts), subject to verification, and based on theory.
- When testing a hypothesis, if the “null hypothesis” is rejected, then, these results serve as a “confirmatory instance” of theoretical rational used to deduce hypothesis; **giving ONLY inductive support for the theory. NOT proving the theory.**

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Standard Components of a Research  
Article and the 7 Components of the  
Scientific Method  
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**Introduction:**

- 1) Recognize a problem
- 2) Define the problem in clear specific language
- 3) Develop hypotheses

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Standard Components of a Research Article and the 7 Components of the Scientific Method  
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**Methods:**  
4) Develop techniques or instruments to obtain information related to the problem and hypotheses  
5) Collect data or information

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Standard Components of a Research Article and the 7 Components of the Scientific Method  
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**Results:**  
6) Analyze the data or information  
  
**Discussion:**  
7) Generate conclusions based upon data related to the hypotheses

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Standard Components of a Research Article  
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**Introduction:**  
• Research Problem: What are the abstract concepts (variables) we believe are operating in the world and what are the affects of these on other concepts (variables) and with what population?  
• Hypothesis: In a concrete setting, what do we expect to see if the above situation is true?  
• Necessary to operationalize concepts and produce hypotheses about what we expect to actually see/find in the world (in "Methods" section, next section).

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**Standard Components of a Research Article**  
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**Methods:**

- Who are the subjects (“Subjects” section)?
- How are we testing the hypotheses (“Procedure” section)?
- How did we operationalize the concepts/variables (“Instrumentation”)? What is the level of measurement of each variable measured?

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**Standard Components of a Research Article**  
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**Results:**

- Does the data indicate “real” differences or is error or chance a possible explanation of our data?
- Is our obtained data rare enough to possibly be from a different population?

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**Standard Components of a Research Article**  
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**Discussion:**

- What does our data mean? What does it imply regarding our theories about the world? (Refers back to the problem defined in the Introduction.)

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**A Return to Operationalizing Variables**

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**Qualitative Data:**

- **Nominal:** Types of cars, gender, race, hair color
- **Ordinal:** Most popular car in America, finishing rank in a race

**Quantitative Data:**

- **Interval:** Time, Likert-scale
- **Ratio:** Temperature,

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**A Return to Operationalizing Variables:  
Why does it matter?**

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- Provides us an avenue for testing theory
- Ability to manipulate the data - summarize, divide, multiply, etc. - is dependent on level of measurement
- Selecting appropriate statistic ("Results" section) is dependent on:
  - Research design
  - Level of measurement

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**Hypothesis Testing and Research Design**

- **Independent and Dependent Variables**
  - Changes in independent variable(s) "cause" changes in the dependent variable(s)
- **Criterion for arguing causation:**
  - Correlation
  - Changes in IV precede changes in DV
  - No "third" variables explain the correlation

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Hypothesis Testing and Research Design: Design Examples

- Single Group Designs
  - Administer treatment --> Measure outcomes
  - Test --> Retest
- True Experimental Designs
  - Treatment and non-treatment (control) groups; compare group outcomes
  - Random assignment to groups

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Hypothesis Testing and Research Design: Examples (cont.)

- Quasi-Experimental Designs
  - “Control group(s)” outcomes compared to treatment group(s)
  - No random assignment (non-equivalent control group”)
- Non-Experimental Designs
  - No control group
  - No random assignment

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Hypothesis Testing and Research Design: Statistical Assumptions for Parametric Tests

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- **Independence of Observations**
- **Sampling Normality.** Observations must be drawn from a normally distributed population (Tests for Kurtosis)
- **Homogeneity of Variance** (F-Max test)
- **Linear Relationship** between IV and DV (Examine scatterplots)
- **DV is Measured on Interval or Ratio Scale**

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Activity:  
Read Article, *When Trying to Win:  
Competition and Intrinsic Motivation*

- Research Problem
- Hypotheses
- Indep. and Dependent Variables and Level of Measurement of Each
- Appropriate Statistical Test(s) Used?
- “Checklist” Issues?

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Session 2 (1:00-3:00 Friday):

- Before next session:
  - Working alone or with 1-2 other people, obtain and read another research article
  - Prepare a single page handout and provide:
    - complete reference to article
    - Research Problem
    - Hypotheses
    - Indep. and Dependent Variables and Level of Measurement of Each
    - Appropriate Statistical Test(s) Used
    - “Checklist” Issues?

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Session 2 (1:00-3:00 Friday) - cont.:

- We’ll recap Monday’s session
- We’ll go over any questions that come up with your individual articles
- We’ll apply the “Decision Tree for Parametric and Non-Parametric Statistics” to one or more articles

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Hypothesis Testing and Research Design:  
**Threats to Internal Validity in Single  
Group Designs**  
(page 3; Girden, E.R. *Evaluating Research Articles*)

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- History
- Maturation
- Testing
- Instrumentation
- Mortality
- Regression

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Hypothesis Testing and Research Design:  
**Threats to Internal Validity in  
All Designs**  
(page 3-4; Girden)

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- Selection Bias
- “Social Threats”
  - Interaction Effects
  - Diffusion or Imitation of Treatment
  - Compensatory Rivalry
  - Resentful Demoralization
  - “Instructor” Bias (compensatory or not)

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Hypothesis Testing and Research Design:  
**Threats to Statistical Validity**  
(page 4-6; Girden)

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- Insufficient power of statistical test
- Unreliable instrument(s)
- Varied test conditions
- Varied participant characteristics
- **Violation of statistical assumptions**

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Hypothesis Testing and Research Design: Threats to External Validity

- How generalizable are your results?
  - Place
  - People
  - Setting
  - Time

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Elementary Statistical Concepts and the Logic of the Scientific Method:  
**Useful URLs**  
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- This handout: (available August 1, 2000)  
[www.studyskillsweb.org](http://www.studyskillsweb.org)
- <http://www.statsoft.com/textbook/stathome.html>
- <http://trochim.human.cornell.edu/>

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