

Making Claims & Arguments with Statistics

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Rival Explanations Proposed During Hypothesis Testing

- ☞ All variation is systematic variation
 - ◆ Predicts differences in group means
 - ◆ Predicts no variability in observations within groups
 - ◆ Validity of this explanation for observations in biology, chemistry, and physics
- ☞ All variation is random variation
 - ◆ Predicts variability in observations within groups
 - ◆ Predicts no differences between group means
- ☞ Variation is a mixture of random and systematic variation

Importance of Explicit Comparisons

- ☞ Isolated data are difficult to interpret
- ☞ Explicit comparisons create a context in which to interpret data
- ☞ Effects of one's choice of comparison
 - ◆ Directs attention to specific types of explanation
 - ◆ What is the appropriate comparison to evaluate the observation of a long life expectancy for conductors?
 - Adults?
 - Adults who have lived to at least age 30?
 - Adults who are musicians?
 - Adults who have lead active lives?

Problems in Statistical Decision Making

- ☞ Explanation based on random variation alone is almost never (technically) true
 - ◆ The means of any two groups are almost never exactly identical
 - ◆ How large must the differences between means be to be considered different?
- ☞ Burden of proof that the difference is “large enough” to discredit the “randomness alone” explanation falls on the researcher
- ☞ Statistical analysis supports arguments that are essentially logical and rhetorical in nature

Cognitive Biases in Interpretation of Findings

- ☞ Underestimate the amount of variability created by random variation
 - ◆ Bias to discover ordered patterns
 - ◆ Exaggerated perception of systematic effects
 - ◆ Overconfidence in our ability to predict future outcomes
- ☞ Failure to appreciate the increased variability of findings based on small samples
 - ◆ False belief in the “law of small numbers”

Statistical Decisions are Ambiguous

- ☞ No decision is guaranteed to be true
- ☞ Decision to reject the explanation based on random variation alone can be made in error
 - ◆ Type I Error
 - ◆ Estimated by level of significance (α) or the p value of the test
- ☞ Decision to *not* reject the explanation based on random variation alone can be made in error
 - ◆ Type II Error
 - ◆ Estimated by β

Limited Value of an Isolated Finding

- ☞ *One swallow does not make a summer.*
- ☞ One statistically significant finding is not enough to build a persuasive argument
 - ◆ *Doubters can attack the methodology*
 - ◆ *Doubters can suggest other sources of systematic variation to explain the finding*
- ☞ Abelson's MAGIC criteria for strong arguments
 - ◆ *Magnitude*
 - ◆ *Articulation*
 - ◆ *Generality*
 - ◆ *Interestingness*
 - ◆ *Credibility & Coherence*

Biases in Thinking about Random Generation Processes

- ☞ Gambler's fallacy
 - ◆ *Assumes that random processes are self-correcting*
 - ◆ *Error is that processes have no "memory" for prior trials*
 - ◆ *Trials are independent*
- ☞ Representativeness Heuristic
 - H H T H T T H T
 - H H H H T T T T
 - ◆ *Long runs of identical outcomes violate our stereotype of a "typical" random process*
 - ◆ *Random processes are lumpy and create long runs*
 - ◆ *These are mistakenly attributed to systematic patterns*

Explanations Based on Randomness

- ☞ Random Generation of Data
- ☞ Random Sampling of Data from a Distribution
- ☞ Random Assignment of Sampled Individuals to Groups
 - ◆ *Relevant when the individuals have not been randomly sampled*

Random Processes for Sampling from a Distribution (Population)

- ☞ Need for a representative sample from a population
- ☞ Characteristics of Random Samples
 - ◆ *Each element has an equal probability of being selected*
 - ◆ *All samples of a given size are equally likely to be selected*
- ☞ People underestimate the variability of populations and of samples
- ☞ People are overconfident in the representativeness of small samples

Random Processes for Data Generation

- ☞ Binomial process
 - ◆ *2 outcomes*
 - *Success*
 - *Failure*
 - ◆ *Each outcome has a constant probability*
 - ◆ *Trials are independent*
- ☞ Patterns of outcomes of a binomial process
 - ◆ *P(success) for a large set of trials equals P(success) for a single trial*
 - ◆ *Independent trials allow us to estimate the probability of runs of various lengths for a given outcome*

Effect of Sample Size on Variability of the Sample Mean

	A			B	
A	A			B	B
A	A			B	B
1	2	3	4	5	6

- ☞ Samples of size 5
- ☞ Mean for Sample A = 1.6
- ☞ Mean for Sample B = 5.4

Samples of Size 10

		A	B		
	A	A	B	B	
A	A	A	B	B	B
A	A	AB	AB	B	B
1	2	3	4	5	6

- ☞ Mean of Sample A = 2.4
- ☞ Mean of Sample B = 4.6

Non-Random Selection of Samples

- ☞ Group might not be representative of the population sampled
- ☞ Random assignment to groups enables tests of random versus systematic explanations for differences between the groups
 - ♦ *Random assignment to groups*
 - ♦ *Differences explained by random assignment process*
 - ♦ *Differences explained by systematic differences in treatment of the groups created*

Samples of Size 10

		AB	AB		
	A	AB	AB		
A	AB	AB	AB	AB	B
A	AB	AB	AB	AB	B
1	2	3	4	5	6

- ☞ Mean for Sample A = 3.07
- ☞ Mean for Sample B = 3.90

Dealing with Ambiguous Data

- ☞ What happens when groups differ but the statistical test has a p value > .05?
- ☞ Consider the sensitivity of your experiment to detection of effects (power)
 - ♦ *Could this be a Type II Error?*
- ☞ Acknowledge that the effect, if it exists at all, is a weak effect
 - ♦ *Is this effect worth pursuing with additional research?*
- ☞ Delay publication until additional research that resolves the ambiguity can be completed

Explaining Differences between Sampled Groups

- ☞ Explanation based on random error
 - ♦ *Sampling error*
 - ♦ *Random processes can generate non-representative samples (especially when sample size is small)*
- ☞ Explanations based on systematic error
 - ♦ *Sampling bias*
 - ♦ *Non-random processes in selection*
 - *Attrition, non-volunteers, different parts of the population are available for sampling at different times, etc.*
- ☞ Explanations based on systematic manipulation of variables