

# FOUNDATIONS OF STATISTICAL DECISION MAKING

Measuring Uncertainty

June 18, 2019

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PHTH 7147: Critical Inquiry I



**PREVIEW**

# Preview

## 1. June 18, 2019

- *Fundamentals of Statistical Inference: Measuring Uncertainty*

## 2. July 02, 2019

- *Fundamentals of Statistical Decision Making: Comparing Multiple Groups*

## 3. July 09, 2019

- *Fundamentals of Statistical Decision Making: Relationships and Prediction*

# OUTLINE

# Outline

- Descriptive vs. inferential statistics
- The normal distribution
- Comparing groups
- Statistical/practical significance

# Resources

- Slides, data, and handouts available at:

[bit.ly/umhb\\_dpt](https://bit.ly/umhb_dpt)

# STATISTICS

- Experimentation and observation:
  1. Measurement of uncertainty
  2. Examination of the consequences of that uncertainty



- Two fundamental branches
  1. Descriptive statistics
    - Summarize data
    - Condense larger themes
  2. Inferential statistics
    - Infer meaning
    - Test predictions

**EXAMPLE**

# Low Birth Weight Study

- Baystate Medical Center, Springfield, MA.
- Sample of 189 births in 1986
- Risk factors in low birth weight babies

# Low Birth Weight Study

Age	Weight	Race	Smoking Status	Birth Weight
19	182	Black	Non-Smoker	5.56
33	155	Other	Non-Smoker	5.62
20	105	White	Smoker	5.64
21	108	White	Smoker	5.72
18	107	White	Smoker	5.73
21	124	Other	Non-Smoker	5.78

# DESCRIPTIVE STATISTICS

# Descriptive Statistics

- How many babies were born at low birth weight ( $< 5.5$  lbs.)?
- How many mothers smoked during pregnancy?
- How much did the average baby weigh?
  - Given mothers' smoking status
  - Given mothers' race

# Descriptive Statistics

## Question:

*Do babies born to mothers who smoked during pregnancy weigh less than those born to mothers who did not?*

# Descriptive Statistics

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*Do babies born to mothers who smoked during pregnancy weigh less than those born to mothers who did not?*

- How should we answer this question?



# Descriptive Statistics

## Question:

*[ON AVERAGE], do babies born to mothers who smoked during pregnancy weigh less than those born to mothers who did not?*

Smoking Status	<i>n</i>	Min.	Max.	<i>M</i>	<i>SD</i>
Non-Smoker	115	2.25	11.00	6.74	1.66
Smoker	74	1.56	9.34	6.11	1.46

# Descriptive Statistics

## Question:

1. Based on our sample, what are we left to assume about the weights of babies *in the population* born to smoking and non-smoking mothers?

# Descriptive Statistics

## Question:

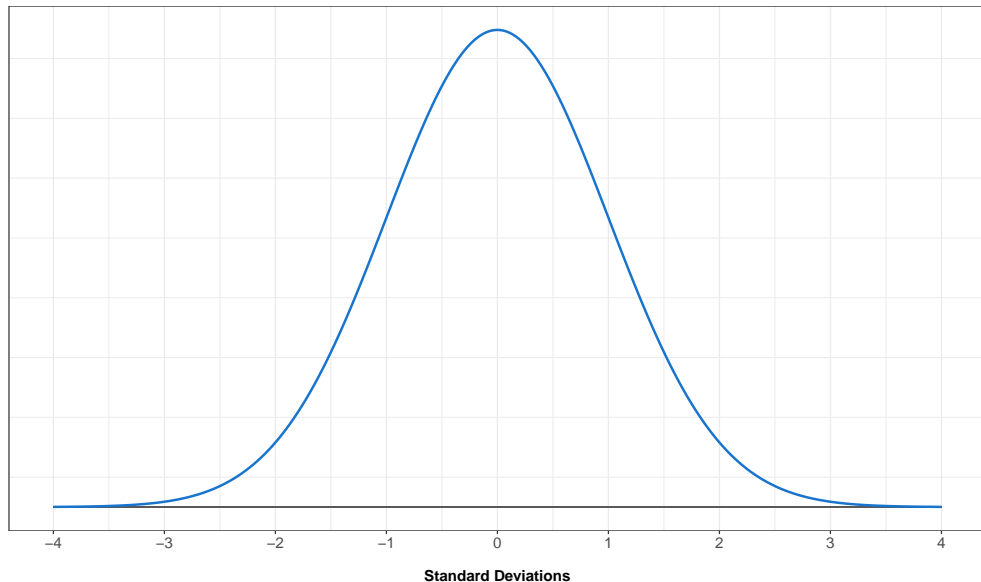
1. Based on our sample, what are we left to assume about the weights of babies *in the population* born to smoking and non-smoking mothers?
  - That the sample estimates represent the population parameters

Smoking Status	$n$	Min.	Max.	$M$	$SD$
Non-Smoker	115	2.25	11.00	6.74	1.66
Smoker	74	1.56	9.34	6.11	1.46

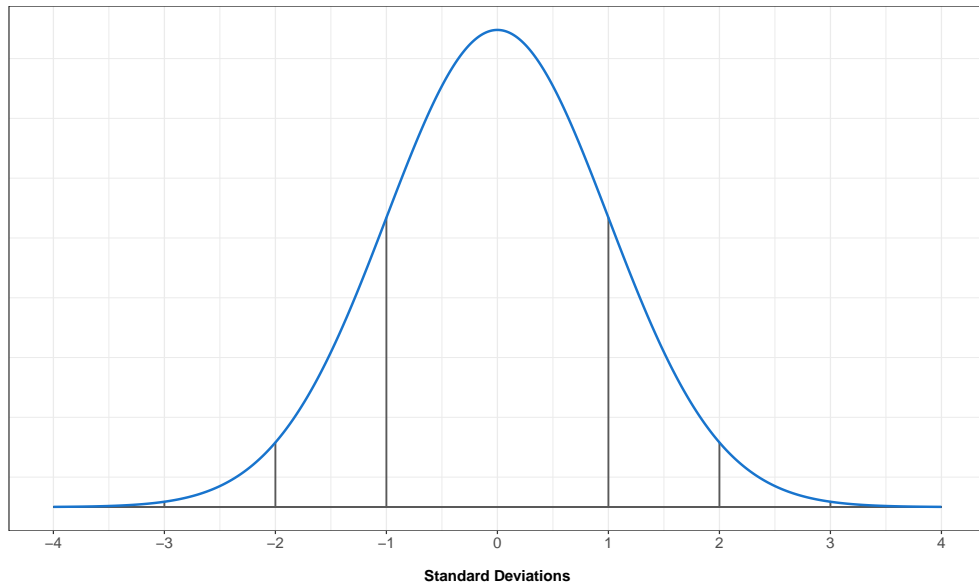
# Descriptive Statistics

- In fact, we assume that the population distribution of baby weights is “normal”

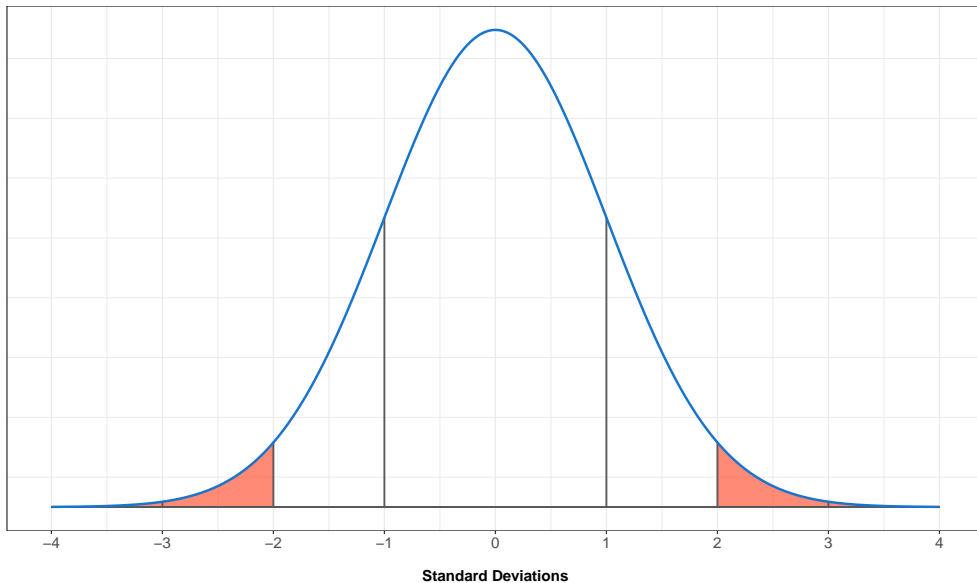
# Normal Distribution



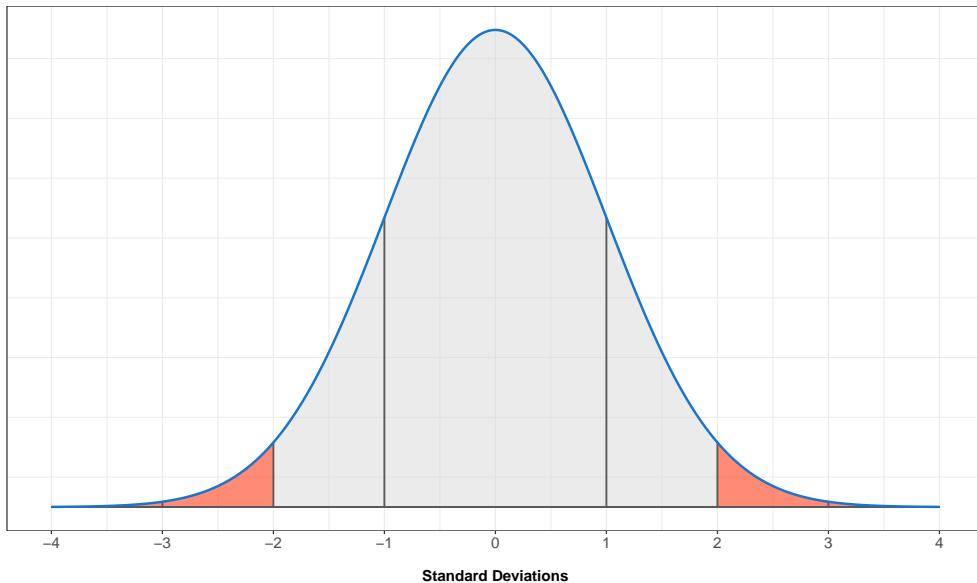
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# Normal Distribution



# Normal Distribution





# INFERENTIAL STATISTICS

# Inferential Statistics

- More useful than descriptives
- Allow for making predictions or generalizations
- Key to hypothesis testing
- Two varieties:
  1. 95% confidence intervals (CIs)
  2. Null-hypothesis significance testing (NHST)

# Inferential Statistics

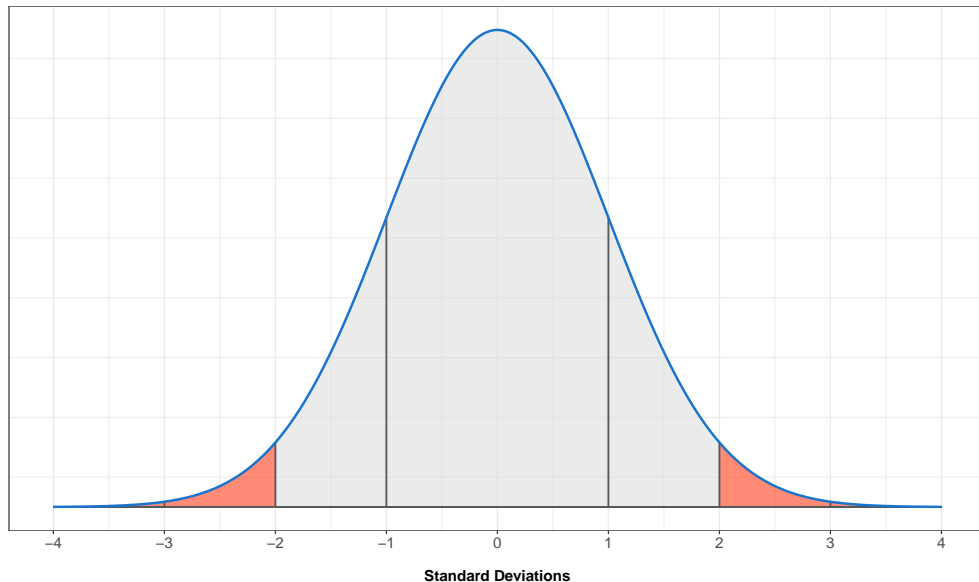
## Question:

*Do babies born to mothers who smoked during pregnancy weigh less than those born to mothers who did not?*

# Inferential Statistics::Confidence Intervals

- Since we are interested in the mean difference in birth weights *in the population*, a first inferential step is to calculate a 95% confidence interval
- Confidence intervals are a plausible range of values for a population parameter
- Point estimates often may not represent the population parameter
- CIs are more likely to capture the population parameter than a point estimate alone

# Inferential Statistics::Confidence Intervals



# Inferential Statistics::Confidence Intervals

- 95% CI:

$$(M_1 - M_2) \pm 2 \times \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

# Inferential Statistics::Confidence Intervals

- 95% CI:

$$(6.11_{NS} - 6.74_S) \pm 2 \times \sqrt{\frac{2.12_{NS}}{74_{NS}} + \frac{2.75_S}{115_S}}$$

# Inferential Statistics::Confidence Intervals

- 95% CI:

$$-0.63 \pm (2 \times 0.229) = \\ (-1.09, -0.17)$$

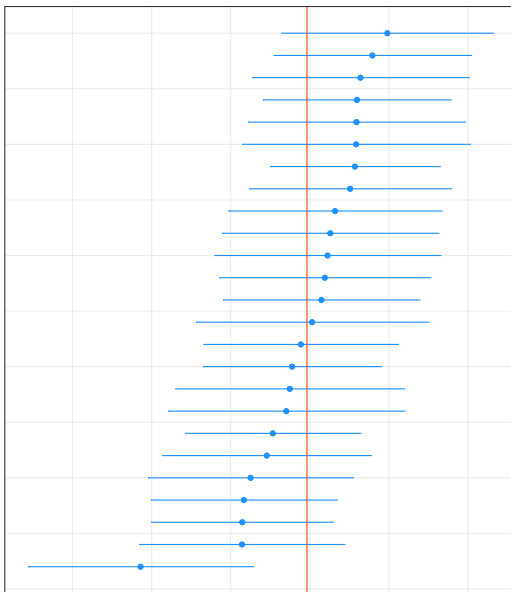
- Thus, we can be 95% confident that, in the population, the true difference in birth weight of babies born to smoking mothers compared to those born to non-smoking mothers is between -1.09 and -0.17 lbs. less, on average.



# Inferential Statistics::Confidence Intervals

- In other words, if we replicated this study 25 times, 24 of the 25 replications would include the true population parameter

# Inferential Statistics::Confidence Intervals



# Inferential Statistics

## Question:

*Do babies born to mothers who smoked during pregnancy weigh [STATISTICALLY SIGNIFICANTLY] less than those born to mothers who did not?*

- How should we answer this question?

# Inferential Statistics::Hypothesis Testing

- What do we mean by statistical significance?

# Inferential Statistics::Hypothesis Testing

- What do we mean by statistical significance?
- Observed differences which exceed “normality.”

# Inferential Statistics::Hypothesis Testing

- We usually consider differences beyond  $\pm 2$  SDs from  $M$  to be “statistically significant”
- **NOTE:** Statistical significance  $\neq$  practical significance

# Low Birth Weight Study

## Question:

- Do babies born to mothers who smoked during pregnancy weigh less than those born to mothers who did not?

# Low Birth Weight Study

## Hypotheses:

- $H_0$ : There is no mean difference in the birth weight of babies born to mothers who did and did not smoke during pregnancy
  - $(M_{non-smoker} - M_{smoker} = 0)$
- $H_1$ : There is some difference in the birth weight of babies born to mothers who did and did not smoke during pregnancy
  - $(M_{non-smoker} - M_{smoker} \neq 0)$



# Low Birth Weight Study

- Let's test our hypothesis using an independent-samples  $t$ -test
  - IV: Mothers' smoking status (smoker, non-smoker)
  - DV: Baby birth weight

$$t = \frac{\overline{X}_{non-smokers} - \overline{X}_{smokers}}{\sqrt{\frac{s^2_{non-smokers}}{N_{non-smokers}} + \frac{s^2_{smokers}}{N_{smokers}}}}$$

# Results

Table 1: Results of Independent-Samples  $t$ -Test

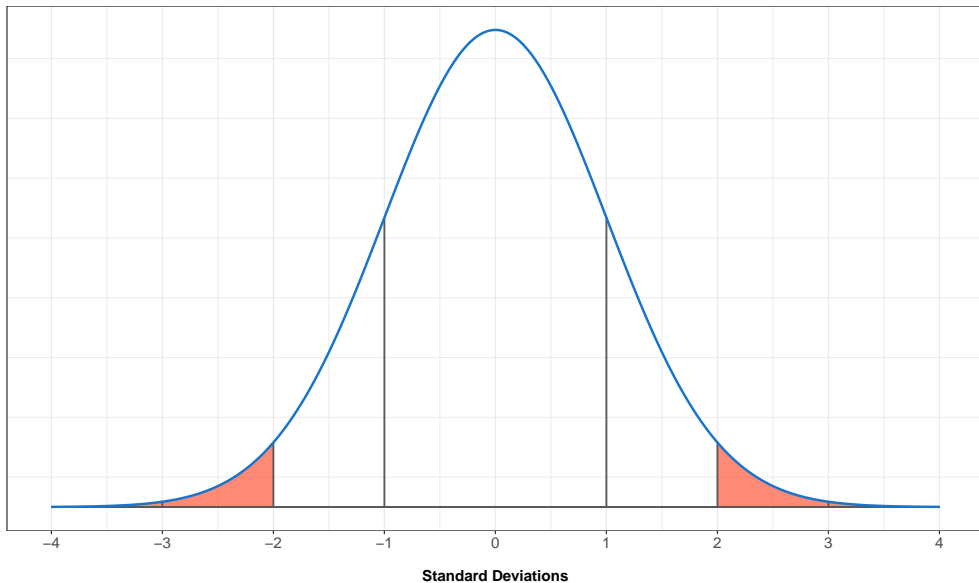
	Non-Smokers			Smokers			$t(187)$	$p$	$\omega^2$
	$n$	$M$	$SD$	$n$	$M$	$SD$			
Baby birth weight	115	6.74	1.66	47	6.11	1.46	2.63	0.009	0.008

Note:  $M$  = Mean;  $SD$  = Standard deviation

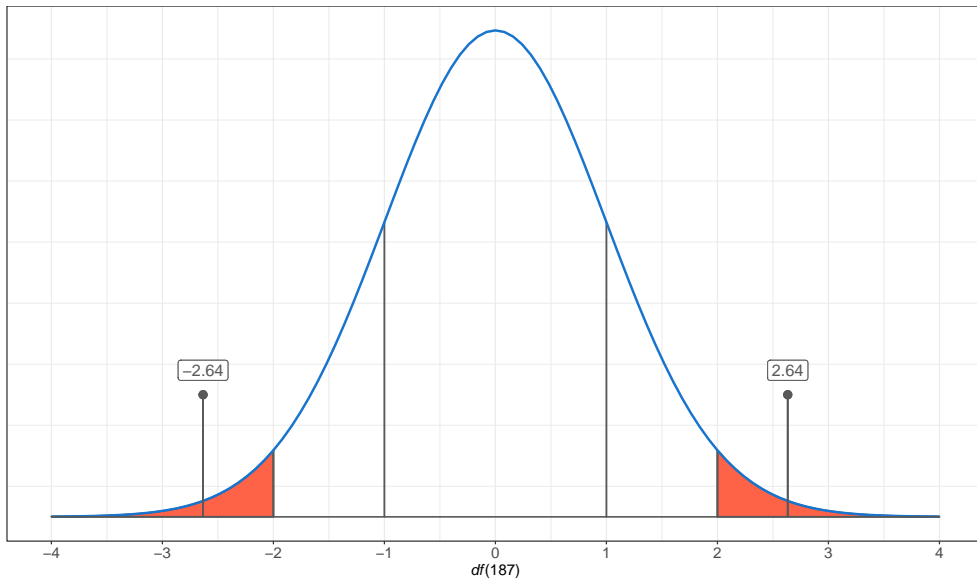
# Results

- Assuming the null hypothesis, in reality, is true, the probability of obtaining a mean difference in birth weight  $\geq 0.62$  lbs. is 0.009 (0.90%)
- Birth weights appear to differ statistically significantly

# Results



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- But, is the difference of  $M = 0.62$  lbs. meaningful?
- A meaningful difference implies practicality or usefulness in the real world
- Effect size ( $\omega^2$ ): Proportion of variance explained in the model
- Smoking status explains 0.009 (0.90%) of the variance in baby birth weight
- Thus,  $100\% - 0.991\% = 99.10\%$  of the variance in baby birth weight is left unexplained

**RECAP**

# Recap

- Descriptive statistics allow us to summarize data from a sample
- Inferential statistics allow us to predict and generalize about a population
- Hypothesis testing allows us to construct a sense of meaning about the world

# Next Time

- Making decisions using hypothesis testing and prediction
  - Statistical variables
  - Multiple group comparisons (ANOVA)
  - Predicting outcomes (Regression)