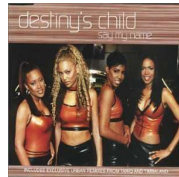


Unit 1: Introduction to data

4. Introduction to statistical inference

Sta 101 - Spring 2019

Duke University, Department of Statistical Science



[Dr. Ellison](#)

Slides posted at
<https://www2.stat.duke.edu/courses/Spring19/sta101.001/>

Outline

1. Housekeeping
2. 🗣️ 🖐️ Case study: Is yawning contagious?
 1. Competing claims
 2. Testing via simulation
 3. Checking for independence
3. 🗣️ 🖐️ Case study: Tapping on caffeine
4. Application exercise

Announcements

Coming up...

- ▶ Lab Assignment 1 is due **Thursday just before your lab section time.**
- ▶ Problem Set 1 is due **Friday night (11:55pm)**
- ▶ Performance Assessment 1 is due **Sunday night (11:55pm)**
- ▶ Readiness Assessment 2 is **next Monday**, so start reviewing resources for Unit 2, don't wait till Sunday!
- ▶ We will start grading for clickers on Monday!

1

Outline



Research Question: Is yawning contagious?

Outline

1. Housekeeping
2. Case study: Is yawning contagious?
 1. Competing claims
 2. Testing via simulation
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3. Case study: Tapping on caffeine
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Is yawning contagious?

An experiment conducted by the MythBusters tested if a person can be subconsciously influenced into yawning if another person near them yawns.



<https://www.youtube.com/watch?v=bCCCxV3nNgs&feature=youtu.be>

3

Outline

What are the variables in this research question?

- Which is the **independent** and which is the **dependent** variable?
- Are these variables categorical or numerical?
- What sample statistics can we calculate?


Study Type

- Is this an experiment or an observational study?

Outline

Original Sample Data Collected

Was the person exposed to a yawn? <i>(Independent Variable)</i> <i>(Categorical-2 Levels)</i>	Did the person yawn? <i>(Dependent Variable)</i> <i>(Categorical-2 Levels)</i>
yes (treatment)	Not Yawn
yes (treatment)	Yawn
yes (treatment)	Yawn
no (control)	Not Yawn
yes (treatment)	Not Yawn
no (control)	Not Yawn
no (control)	Not Yawn
no (control)	Yawn
yes (treatment)	Not Yawn
yes (treatment)	Not Yawn
no (control)	Yawn
...	...



Experiment summary

50 people were randomly assigned to two groups:

- ▶ **treatment**: see someone yawn, $n = 34$
- ▶ **control**: don't see someone yawn, $n = 16$

	Treatment	Control	Total
Yawn	10	4	14
Not Yawn	24	12	36
Total	34	16	50
% Yawners			

4

Experiment summary

50 people were randomly assigned to two groups:

- ▶ **treatment**: see someone yawn, $n = 34$
- ▶ **control**: don't see someone yawn, $n = 16$

	Treatment	Control	Total
Yawn	10	4	14
Not Yawn	24	12	36
Total	34	16	50
% Yawners	$\frac{10}{34} = 0.29$	$\frac{4}{16} = 0.25$	

4

Experiment summary

	Treatment (Saw a Yawn)	Control (Didn't see a Yawn)
% Yawners	$\hat{p}_{saw\ yawn} = 0.29$	$\hat{p}_{didn't\ see\ yawn} = 0.25$

4% Difference!

4

Outline

Interpreting 4% Difference:

Is a difference of 4% or more big enough to suggest yawning is contagious?

OR

Could it be the case that yawning is NOT contagious and a 4% or more difference was just due to random chance?

Outline

What do we expect this to be centered at?

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

What do we expect this to be centered at?

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

Interpreting 4% Difference:

What if we had this information?

Is a difference of 4% or more big enough to suggest yawning is contagious?

OR

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All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

-0.25 0.00 0.25
% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

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Is a difference of 4% or more big enough to suggest yawning is contagious?

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All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

-0.25 0.00 0.25
% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

Interpreting 4% Difference:

What if we had this information?

Is a difference of 4% or more big enough to suggest yawning is contagious?

OR

Could it be the case that yawning is NOT contagious and a 4% or more difference was just due to random chance?

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

Interpreting 4% Difference:

What if we had this information?

There is NOT enough evidence to suggest that yawning is contagious and a 4% or more difference could just be due to random chance.

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

Interpreting 4% Difference:

What if we had this information?

Is a difference of 4% or more big enough to suggest yawning is contagious?

OR

Could it be the case that yawning is NOT contagious and a 4% or more difference was just due to random chance?

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

Interpreting 4% Difference:

What if we had this information?

Is a difference of 4% or more big enough to suggest yawning is contagious?

OR

Could it be the case that yawning is NOT contagious and a 4% or more difference was just due to random chance?

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

% of Yawners in Treatment (size 34) - % of Yawners in Control (size 16)

Outline

Interpreting **4%** Difference:

Is a difference of 4% or more big enough to suggest yawning is contagious?

What if we had [this information?](#)

OR

Could it be the case that yawning is NOT contagious and a 4% or more difference was just due to random chance?

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

Outline

Interpreting **4%** Difference:

A difference of 4% or more is big enough to suggest yawning is contagious.

What if we had [this information?](#)

All % Differences we Would Expect to See IF YAWNING WASNT CONTAGIOUS

Outline

Main Goal in Randomization Testing

What would be great to have (but we don't)

Randomization Distribution

Simulate this

Outline

Main Goal in Randomization Testing

(for two categorical variables):

Step 0: Set up two competing claims/hypotheses.

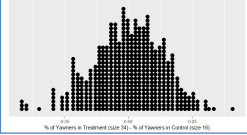
Outline

Main Goal in Randomization Testing *(for two categorical variables):*

Randomization Distribution

Step 0: Set up two competing claims/hypotheses.

Step 1: Generate a *simulated* histogram or dot plot that shows us the expected differences in sample proportions we might see IF *the variables are independent in the population (i.e. the population proportions are equal!)* This distribution is called a **Randomization Distribution**.



Outline

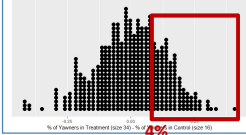
Main Goal in Randomization Testing *(for two categorical variables):*

Randomization Distribution

Step 0: Set up two competing claims/hypotheses.


Step 1: Generate a *simulated* histogram or dot plot that shows us the expected differences in sample proportions we might see IF *the variables are independent in the population (i.e. the population proportions are equal!)* This distribution is called a **Randomization Distribution**.

Step 2: Use **Randomization Distribution** and our actual observed differences in sample proportions to make an inference about the relationship between two variables in the population.



Outline

Let's perform randomization testing for yawning experiment!



Outline

Randomization Testing

Step 0: How do we set up null and alternative hypotheses?

Ho: _____

Ha: _____

Outline

1. Housekeeping
2. Case study: Is yawning contagious?
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Two competing claims

Ho: Null Hypothesis

"There is nothing going on."

↕

Seeing someone yawn and yawning are **independent**.

↕

Interpretations: In the population there is no difference in the proportions of yawners who did and did not see a yawn.

↕

The observed difference in the proportion of yawners in the treatment and control is simply due to chance.

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Two competing claims

Ho: Null Hypothesis	Ha: Alternative Hypothesis
"There is nothing going on."	"There is something going on."
↕	↕
Seeing someone yawn and yawning are independent .	Seeing someone yawn and yawning are dependent .
↕	↕
Interpretations: In the <u>population</u> there is <u>no</u> difference in the proportions of yawners who did and did not see a yawn.	In the <u>population</u> the proportion of yawners who did see a yawn is <u>greater</u> than those who didn't.
↕	↕
The <u>observed</u> difference in the proportion of yawners in the treatment and control is simply <u>due to chance</u> .	The <u>observed</u> difference in the proportion of yawners in the treatment and control is <u>not due to chance</u> .

6

Outline

Randomization Testing

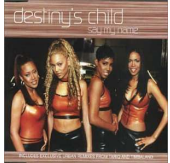
Step 0: Set up null and alternative hypotheses.

Ho: $p_{saw\ yawn} = p_{didn't\ see\ yawn}$

Ha: $p_{saw\ yawn} > p_{didn't\ see\ yawn}$

Hypothesis testing is natural

Step 1: Formulate hypotheses/claims.
 H_0 : Your partner isn't cheating.
 H_A : Your partner is cheating.

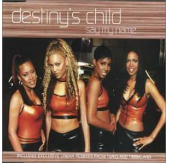


7

Hypothesis testing is natural

Step 1: Formulate hypotheses/claims.
 H_0 : Your partner isn't cheating.
 H_A : Your partner is cheating.

Step 2:
 Collect the **evidence**



Evidence:

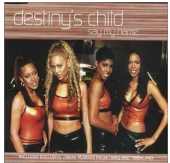
- Partner isn't saying your name on the phone.
- Partner isn't saying "I love you" on the phone.
- Every other word is "uh huh... yeah ok" on the phone.
- ...

7

Hypothesis testing is natural

Step 1: Formulate hypotheses/claims.
 H_0 : Your partner isn't cheating.
 H_A : Your partner is cheating.

Step 2:
 Collect the **evidence**



Evidence:

- Partner isn't saying your name on the phone.
- Partner isn't saying "I love you" on the phone.
- Every other word is "uh huh... yeah ok" on the phone.
- ...

Step 3:
 Judge the evidence: "Could these data plausibly have happened by chance if the null hypothesis were true?"

Judge the Evidence

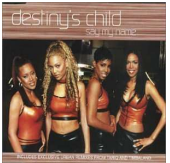
- Shady!

7

Hypothesis testing is natural

Step 1: Formulate hypotheses/claims.
 H_0 : Your partner isn't cheating.
 H_A : Your partner is cheating.

Step 2:
 Collect the **evidence**



Evidence:

- Partner isn't saying your name on the phone.
- Partner isn't saying "I love you" on the phone.
- Every other word is "uh huh... yeah ok" on the phone.
- ...

Step 3:
 Judge the evidence: "Could these data plausibly have happened by chance if the null hypothesis were true?"

Step 4:
 Make a decision: "How unlikely is unlikely?"

Judge the Evidence

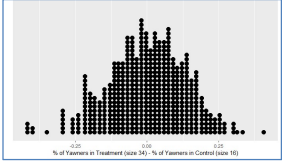

- Shady!

7

Outline

Step 1: How do we generate the randomization distribution that allows us to judge the evidence for our two competing claims?

Randomization Distribution

Outline

1. Housekeeping
2. Case study: Is yawning contagious?
 1. Competing claims
 2. Testing via simulation
 3. Checking for independence
3. Case study: Tapping on caffeine
4. Application exercise

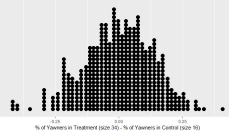
Simulation setup

Generating the Randomization Distribution (two categorical variables).

1. Write the dependent variable values from the sample data on index cards.

Was the person exposed to a yawn? <i>(Independent Variable)</i> <i>(Categorical-2 Levels)</i>	Did the person yawn? <i>(Dependent Variable)</i> <i>(Categorical-2 Levels)</i>
yes (treatment)	Not Yawn
yes (treatment)	Yawn
yes (treatment)	Yawn
yes (treatment)	Yawn
2. Do the following many times:
 - a) Shuffle the index cards 7 times.
 - b) Deal the index cards into two groups:
 - a) "Treatment Group" (# of cards = Treatment Group Size)
 - b) "Control Group" (# of cards = Control Group Size)
 - c) Note the difference in proportions between the treatment and control groups and plot the difference in a dot plot.

Randomization Distribution



8

Simulation setup

Generating the Randomization Distribution (two categorical variables).

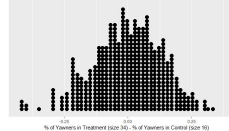
1. Write the dependent variable values from the sample data on index cards

(50 cards = yawning experiment sample size = total number of actors)

14 Say yawn, 36 say not yawn

Was the person exposed to a yawn? <i>(Independent Variable)</i> <i>(Categorical-2 Levels)</i>	Did the person yawn? <i>(Dependent Variable)</i> <i>(Categorical-2 Levels)</i>
yes (treatment)	Not Yawn
yes (treatment)	Yawn
yes (treatment)	Yawn
yes (treatment)	Yawn
2. Do the following many times:
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 - a) "Treatment Group" (# of cards = Treatment Group Size)
 - b) "Control Group" (# of cards = Control Group Size)
 - c) Note the difference in proportions between the treatment and control groups and plot the difference in a dot plot.

Randomization Distribution



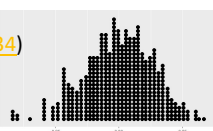
8

Simulation setup

Generating the Randomization Distribution (two categorical variables).

- Write the dependent variable values from the sample data on index cards
(50 cards = yawning experiment sample size = total number of actors)
14 Say yawn, 36 say not yawn

Was the person exposed to a yawn? (Independent Variable) (Categorical-2 Levels)	Did the person yawn? (Dependent Variable) (Categorical-2 Levels)
yes (treatment)	Not Yawn
yes (treatment)	Yawn
yes (treatment)	Yawn
- Do the following many times:
 - Shuffle the index cards 7 times.
 - Deal the index cards into two groups:
 - "Treatment Group" (# of cards = 34)
 - "Control Group" (# of cards = 16)
 - Note the difference in proportions (of yawn cards) between the treatment and control groups and plot the difference in a dot plot.

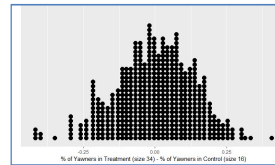


Randomization Distribution

8

Outline

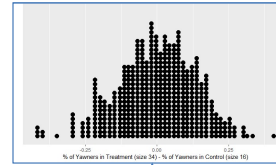
What do we expect this randomization distribution to be centered at?




Randomization Distribution

Outline

What do we expect this randomization distribution to be centered at?



Randomization Distribution

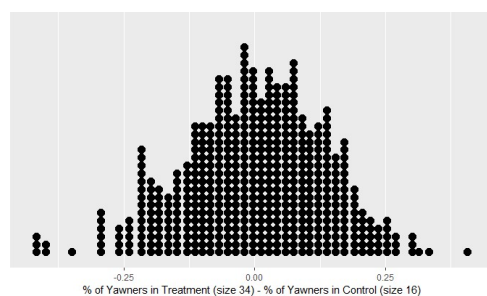


0

Outline

See R simulation

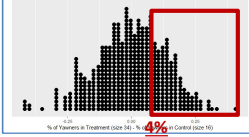
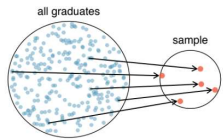
- Simulate the Yawning Experiment under the assumption of independence 500 times.



Outline



Step 2: Once we have our **randomization distribution**, how do we use **this** and **our observed difference** to make an inference about the relationship between two variables in the population?

Randomization Distribution

Outline

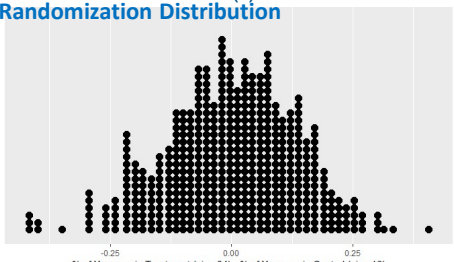
1. Housekeeping
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Clicker question  

Do the simulation results suggest that yawning is contagious, i.e. does seeing someone yawn and yawning appear to be dependent?
 (Hint: In the actual data the difference was 0.04, does this appear to be an unusual observation for the chance model?)

(a) Yes (b) No

Randomization Distribution

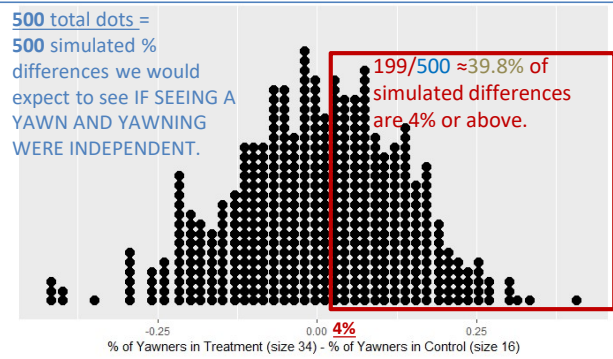


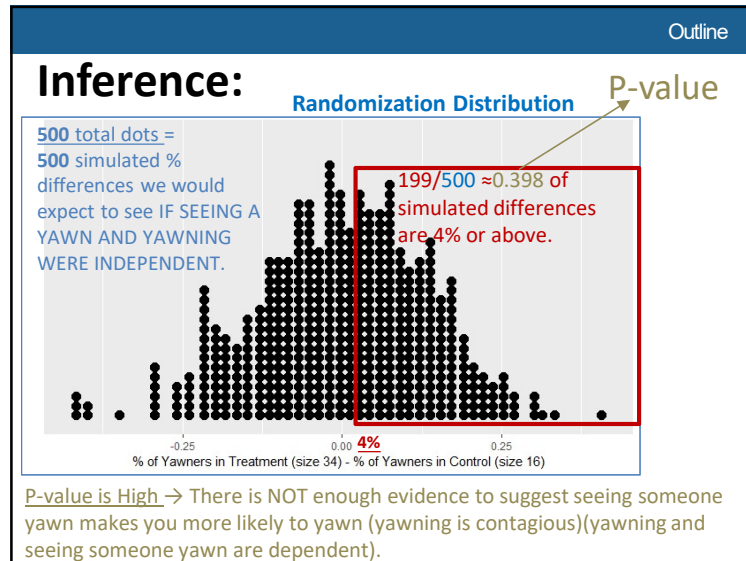
10

Outline

Inference: Randomization Distribution

500 total dots = 500 simulated % differences we would expect to see IF SEEING A YAWN AND YAWNING WERE INDEPENDENT.





- Outline
1. Housekeeping
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 4. Application exercise

Outline

Research Question:

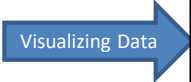
Does caffeine intake increase tapping rate?

- Tapping on caffeine
- ▶ In a double-blind experiment a sample of 20 male college students were randomly assigned to two groups of 10 students each.
 - ▶ Each student drank the equivalent of about two cups of coffee, which included about **200 mg of caffeine** for the students in one group, but was **decaffeinated coffee** for the second group.
 - ▶ After a two hour period, each student was tested to measure **finger tapping rate** (taps per minute).
- 11

Data

Original Sample Data Collected

	Had Caffeine? <i>(Independent Variable)</i> <i>(Categorical-2 Levels)</i>	# of Taps <i>(Dependent Variable)</i> <i>(Numerical)</i>
1	Caffeine (Treatment)	246
2	Caffeine (Treatment)	248
3	Caffeine (Treatment)	250
4	Caffeine (Treatment)	252
5	Caffeine (Treatment)	248
6	Caffeine (Treatment)	250
7	No Caffeine (Control)	248
...
20	No Caffeine (Control)	250



12

Clicker question

What type of plot would be useful to visualize the distributions of tapping rate in the caffeine and no caffeine groups.

- (a) Bar plot
- (b) Mosaic plot
- (c) Pie chart
- (d) Side-by-side box plots
- (e) Single box plot

13

Clicker question

What type of plot would be useful to visualize the distributions of tapping rate in the caffeine and no caffeine groups.

categorical variable

numerical variable

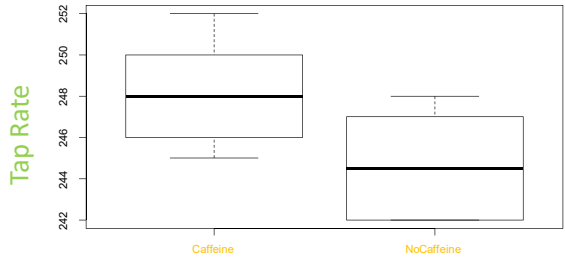
- (a) Bar plot
- (b) Mosaic plot
- (c) Pie chart
- (d) *Side-by-side box plots*
- (e) Single box plot

13

Exploratory data analysis

Compare the distributions of tapping rates in the caffeine and no caffeine groups.

	Caffeine	No Caffeine	Difference
mean	248.3	244.8	3.5
SD	2.21	2.39	-0.18
median	248	245	3
IQR	3.5	4.25	-0.75



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Randomization Testing

Step 0: Set up null and alternative hypotheses.

Ho: _____
Ha: _____

Clicker question

We are interested in finding out if **caffeine** **increases** **tapping rate**. Which of the following are the correct set of hypotheses?

- (a) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} < \mu_{no\ caff}$
- (b) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} > \mu_{no\ caff}$
- (c) $H_0 : \bar{x}_{caff} = \bar{x}_{no\ caff}$
 $H_A : \bar{x}_{caff} > \bar{x}_{no\ caff}$
- (d) $H_0 : \mu_{caff} > \mu_{no\ caff}$
 $H_A : \mu_{caff} = \mu_{no\ caff}$
- (e) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} \neq \mu_{no\ caff}$

15

Clicker question

We are interested in finding out if **caffeine** **increases** **tapping rate**. Which of the following are the correct set of hypotheses?

- (a) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} < \mu_{no\ caff}$
- (b) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} > \mu_{no\ caff}$
- (c) $H_0 : \bar{x}_{caff} = \bar{x}_{no\ caff}$
 $H_A : \bar{x}_{caff} > \bar{x}_{no\ caff}$
- (d) $H_0 : \mu_{caff} > \mu_{no\ caff}$
 $H_A : \mu_{caff} = \mu_{no\ caff}$
- (e) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} \neq \mu_{no\ caff}$

15

Clicker question

We are interested in finding out if **caffeine** **increases** **tapping rate**. Which of the following are the correct set of hypotheses?

- (a) $H_0 : \mu_{caff} = \mu_{no\ caff}$
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- (b) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} > \mu_{no\ caff}$
- (c) ~~$H_0 : \bar{x}_{caff} = \bar{x}_{no\ caff}$
 $H_A : \bar{x}_{caff} > \bar{x}_{no\ caff}$~~
- (d) $H_0 : \mu_{caff} > \mu_{no\ caff}$
 $H_A : \mu_{caff} = \mu_{no\ caff}$
- (e) $H_0 : \mu_{caff} = \mu_{no\ caff}$
 $H_A : \mu_{caff} \neq \mu_{no\ caff}$

...for a much larger population than 20 college males.

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Outline

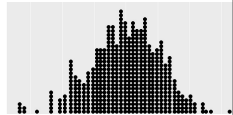
Randomization Testing

Step 1: Generate randomization distribution.

Simulation setup

Generating the Randomization Distribution (one cat. variable/one num. variable)

- Write the dependent variable values from the sample on index cards.

	Had Caffeine? <small>(Independent Variable) (Categorical-2 Levels)</small>	# of Taps <small>(Dependent Variable) (Numerical)</small>
1	Caffeine (Treatment)	246
2	Caffeine (Treatment)	248
3	Caffeine (Treatment)	250
4	Caffeine (Treatment)	252
5	Caffeine (Treatment)	248
6	Caffeine (Treatment)	250
7	No Caffeine (Control)	248
...
20	No Caffeine (Control)	250
- Do the following many times:
 - Shuffle the index cards 7 times.
 - Deal the index cards into two groups:
 - "Treatment Group" (# of cards = Treatment Group Size)
 - "Control Group" (# of cards = Control Group Size)
 - Note the difference in means (or medians) between the treatment and control groups and plot the difference in a dot plot.
 

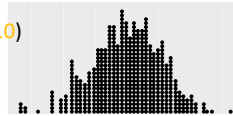
8

Simulation setup

Generating the Randomization Distribution (one cat. variable/one num. variable)

- Write the dependent variable values from the sample on index cards.

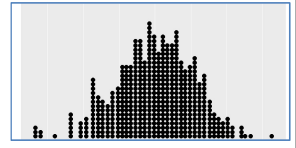
	Had Caffeine? <small>(Independent Variable) (Categorical-2 Levels)</small>	# of Taps <small>(Dependent Variable) (Numerical)</small>
1	Caffeine (Treatment)	246
2	Caffeine (Treatment)	248
3	Caffeine (Treatment)	250
4	Caffeine (Treatment)	252
5	Caffeine (Treatment)	248
6	Caffeine (Treatment)	250
7	No Caffeine (Control)	248
...
20	No Caffeine (Control)	250

*(20 cards = total number of students in sample)
Card 1="246", Card 2="248"...*
- Do the following many times:
 - Shuffle the index cards 7 times.
 - Deal the index cards into two groups:
 - "Treatment Group" (# of cards = 10)
 - "Control Group" (# of cards = 10)
 - Note the difference in means (or medians) between the treatment and control groups and plot the difference in a dot plot.
 

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Outline

What do we expect this randomization distribution to be centered at?

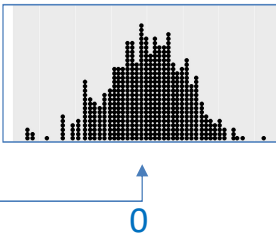


Outline

What do we expect this randomization distribution to be centered at?



Randomization Distribution



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Outline

Randomization Testing

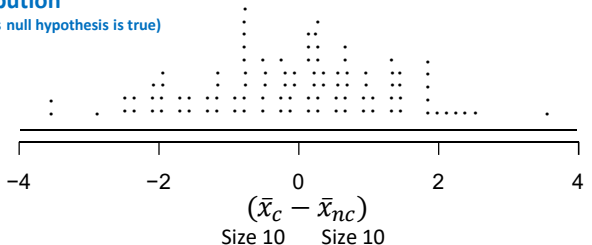
Step 2: Use the **randomization distribution** and **observed sample difference** to calculate the **p-value** to determine if there is enough evidence to suggest the alternative hypothesis.

Making a decision

Below is a randomization distribution of 100 simulated differences in means $(\bar{x}_c - \bar{x}_{nc})$. Calculate the p-value for the hypothesis test evaluating whether **caffeine** increases average tapping rate.

	Caffeine	No Caffeine	Difference
mean	248.3	244.8	3.5

Randomization Distribution
(assumes null hypothesis is true)



$(\bar{x}_c - \bar{x}_{nc})$
Size 10 Size 10

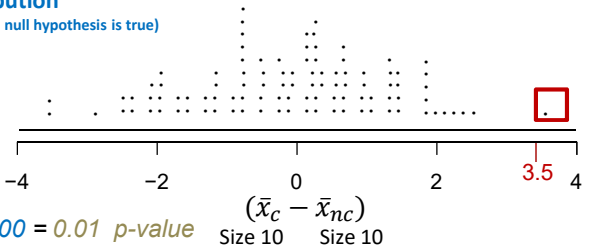
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Making a decision

Below is a randomization distribution of 100 simulated differences in means $(\bar{x}_c - \bar{x}_{nc})$. Calculate the p-value for the hypothesis test evaluating whether **caffeine** increases average tapping rate.

	Caffeine	No Caffeine	Difference
mean	248.3	244.8	3.5

Randomization Distribution
(assumes null hypothesis is true)



$(\bar{x}_c - \bar{x}_{nc})$
Size 10 Size 10

$1/100 = 0.01$ p-value

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Making a decision

Below is a randomization distribution of 100 simulated differences in means ($\bar{x}_c - \bar{x}_{nc}$). Calculate the p-value for the hypothesis test evaluating whether caffeine increases average tapping rate.

	Caffeine	No Caffeine	Difference
mean	248.3	244.8	3.5

Randomization Distribution
(assumes null hypothesis is true)

P-value is Low → There IS enough evidence to suggest caffeine increases average tapping rate.

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Testing for the median

Describe how could we use the same approach to test whether the median tapping rate is higher for the caffeine group?

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Testing for the median

Describe how could we use the same approach to test whether the median tapping rate is higher for the caffeine group?

Use the same simulation scheme but record the difference between the medians instead of the means, and calculate the p-value as the proportion of simulations where the simulated difference in medians is at least 3.

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Testing for the median

	Caffeine	No Caffeine	Difference
median	248	245	3

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Outline
1. Housekeeping
2. Case study: Is yawning contagious? <ol style="list-style-type: none">1. Competing claims2. Testing via simulation3. Checking for independence
3. Case study: Tapping on caffeine
4. Application exercise

Application exercise: 1.4 Randomization testing

See the course website for instructions.

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