Learning Objectives

- **Describe** sampling distributions of means
- **Calculate** the *standard error of the mean*
- **Understand** *Central Limit Theorem*, and its effect on distributions
- **Conduct** *z*-tests (in 6 baby steps)

Steps to using *z*-test

1. Generate hypotheses
   - Directional or non-directional?
2. Set alpha level
3. Calculate *standard error of the mean*
4. Calculate z_{obt}
5. Compare z_{obt} to z_{crit}

Compare p vs. α

6. Reject H_0 or fail to reject H_0

Statisticians suck…

- α
  - Error rate when rejecting H_0 (Type I error)
  - *Y*-intercept in regression formula
- β
  - Type II error rate
  - Standardized slope coefficient

- When to reject H_0…
  - If *p* is <u>smaller</u> than α
  - If z_{obt} is <u>larger</u> than z_{crit}

- *p* is inversely related to test statistics
  - As *p* gets smaller, *z* gets larger
  - As *p* gets smaller, $t/F/\chi^2$ gets larger

Are profs hoarding books?

Normal Deviates Test

- In the population, people buy an average of 14.00 books (w/standard deviation of 5)
- You sample from 24 Psych Profs and find an average of 16.20 books

Step 1:

- H_0: No difference between psych profs & population
- H_1: There is a difference between psych profs & population

Step 2: $\alpha = .05$

Steps to using *z*-test

1. Generate hypotheses
   - Directional or non-directional?
2. Set alpha level
3. Calculate *standard error of the mean*
4. Calculate z_{obt}
5. Compare α *to* p or compare z_{obt} to z_{crit}
6. Reject H_0 or fail to reject H_0

Are profs hoarding books?

Normal Deviates Test

$\bar{X}_{\text{profs}} = 16.2$

$N = 24$

$\sigma_{\bar{X}} =$

$\mu = 14.0$

$\sigma = 5.0$

$\alpha = .05$

Step 3:

$$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{N}} = \frac{5.0}{\sqrt{24}} = 1.0206$$

Step 4:

$$z_{\text{obt}} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{16.2 - 14}{1.0206} = 2.1556$$

Are profs hoarding books?

Normal Deviates Test

$\bar{X}_{\text{profs}} = 16.2$

$N = 24$

$\sigma_{\bar{X}} = 1{,}02$

$\mu = 14.0$

$\sigma = 5.0$

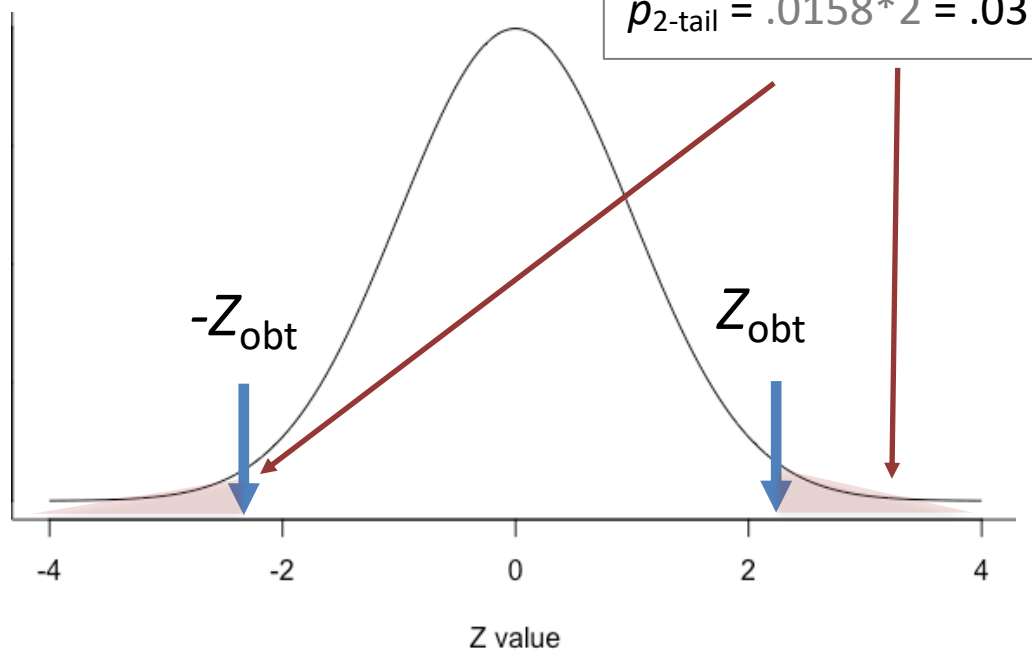
$z_{obt} = 2.15$

$p = .0316$

$\alpha = .05$

Step 5 (*p*-method):

$z_{obt} = 2.15$,
$p_{1\text{-tail}} = .0158$
$p_{2\text{-tail}} = .0158*2 = .0316$



Are profs hoarding books?

Normal Deviates Test

$\bar{X}_{\text{profs}} = 16.2$

$N = 24$

$\sigma_{\bar{X}} = 1.02$

$\mu = 14.0$

$\sigma = 5.0$

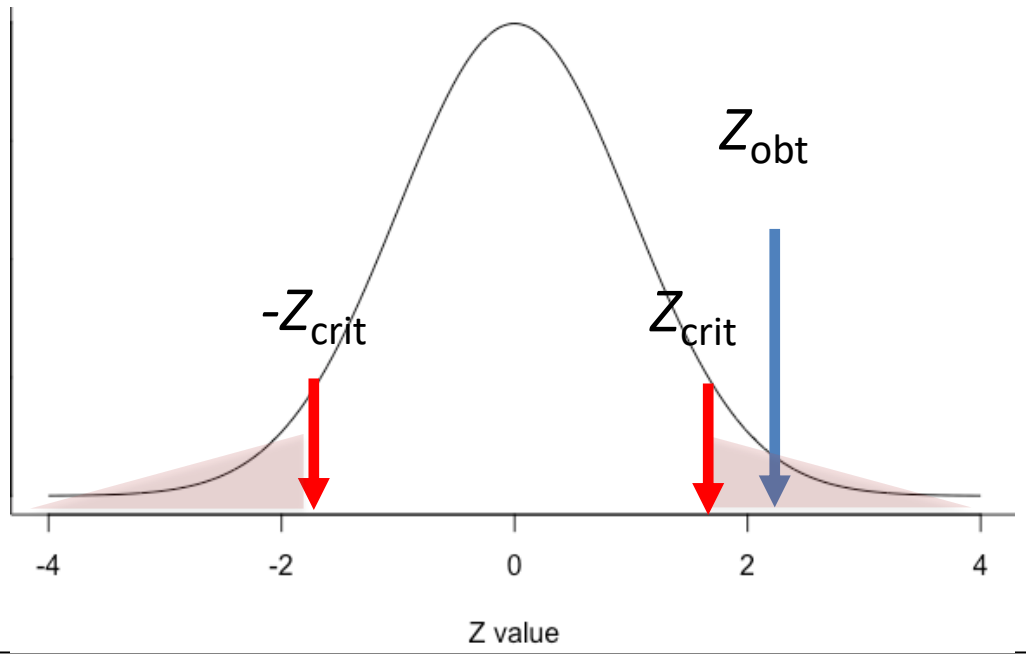
$z_{obt} = 2.15$

$z_{crit} = \pm 1.96$

$\alpha = .05$

Step 5 (alt.): compare z_{obt} & z_{crit}

z_{crit} is value of z when $\alpha_{2\text{-tail}} = .05$



Hillary Clinton

This article is more than **8 years old**

Coin tosses used to determine county delegates in Clinton-Sanders race

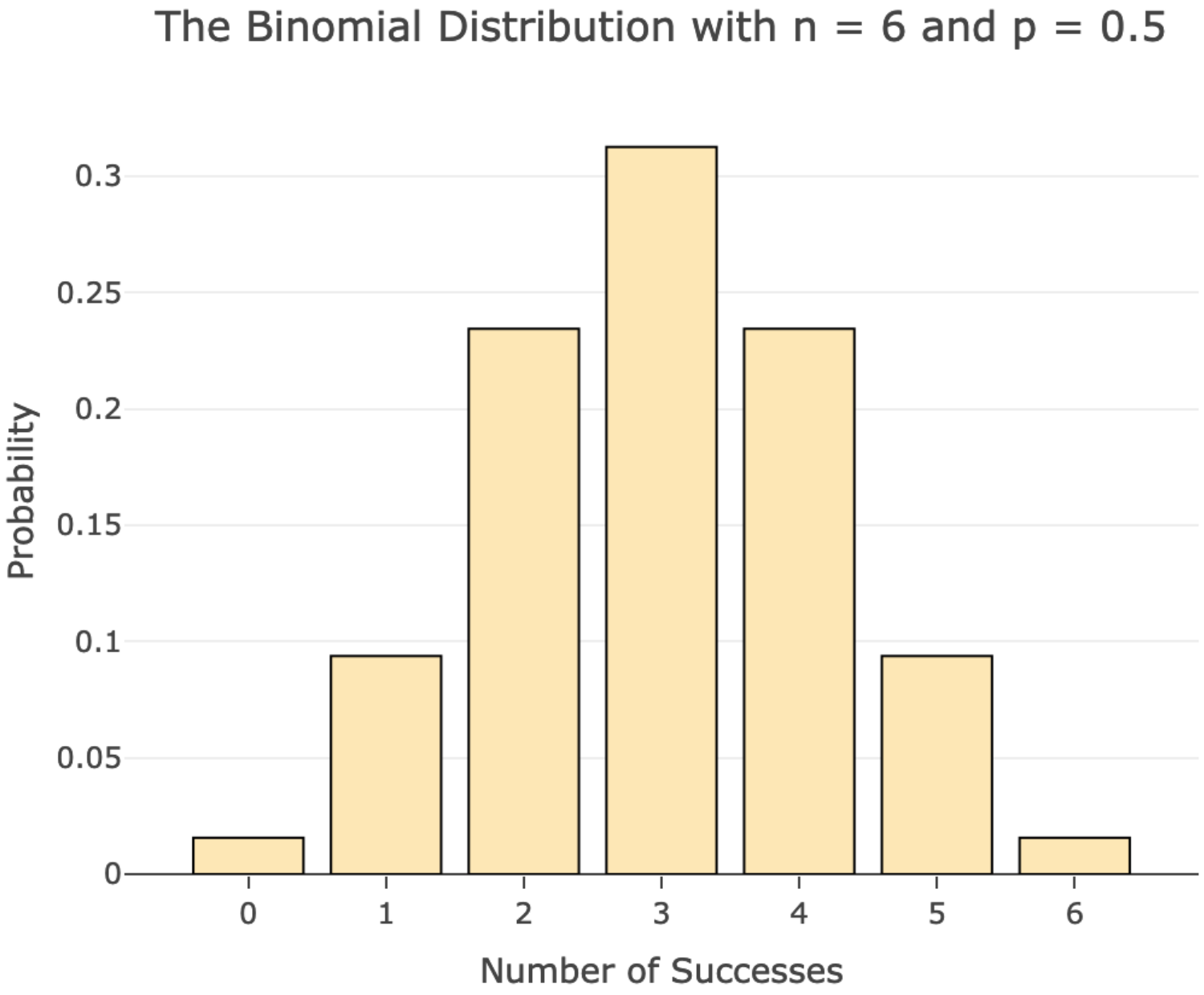
Obscure party rule can be called upon to decide a tied result – and its use shows how close the Democratic race is

Were the coins 'rigged'?

- Coin flips were used to decide the allocation of 6 delegates in Iowa (2016)

- If we're testing whether these coin flips were somehow rigged, what are our hypotheses?

- How can we test these hypotheses?
  - What is our expectation given H_0?
  - One-tail test or two-tail test?
  - What level of Type I error should we accept?


The Binomial Distribution with n = 6 and p = 0.5
Probability
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
Number of Successes

Smarter than average? Q1

Normal Deviates Test

- Population IQ scores have $\mu = 100$, $\sigma = 15$
- You sample from 10 classmates and find $\bar{X} = 107$
  - Are your classmates *reliably different* from the pop. (assuming $\alpha = .05$)?

$$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{N}}$$

$$z_{\text{obt}} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}}$$

Answers

Depending on your method (*p* vs. z_{crit}), you do not need to calculate all of this

$$\sigma_{\bar{X}} = 4.7434$$

$$z_{obt} = 1.4757$$

$$p_{1\text{-tail}} = .0708$$

$$p_{2\text{-tail}} = .1416$$

$$z_{crit} = \pm 1.96$$

Smarter than average? Q2

Normal Deviates Test

- Population IQ scores have $\mu = 100$, $\sigma = 15$
- You sample from **40** classmates and find $\bar{X} = 107$
  - Are your classmates *reliably different* from the pop. (assuming $\alpha = .05$)?

$$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{N}}$$

$$z_{obt} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}}$$

Answers

Depending on your method, you do not need to calculate all of this

$$\sigma_{\bar{X}} = 2.3717$$

$$z_{obt} = 2.9515$$

$$p_{1\text{-tail}} = .0016$$

$$p_{2\text{-tail}} = .0032$$

$$z_{crit} = \pm 1.96$$

Smarter than average? Q3

Normal Deviates Test

- Population IQ scores have $\mu = 100$, $\sigma = 15$
- You sample from 10 classmates and find $\bar{X} = 109$
  - Are your classmates *reliably different* from the pop. (assuming $\alpha = .05$)?

$$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{N}}$$

$$z_{obt} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}}$$

Answers

Depending on your method, you do not need to calculate all of this

$$\sigma_{\bar{X}} = 4.7434$$

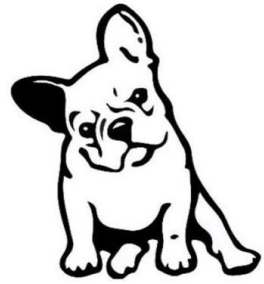
$$z_{obt} = 1.8974$$

$$p_{1\text{-tail}} = .0294$$

$$p_{2\text{-tail}} = .0588$$

$$z_{crit} = \pm 1.96$$

Practice Item



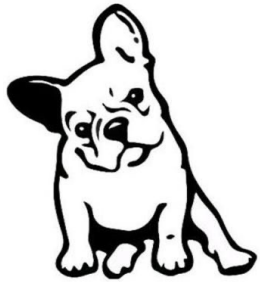
Professor Andrew is interested in testing whether puppy training classes have affected the sitting behavior of dogs in the class. To test this, Andrew measured how long (in ms) it took each of the dogs to sit after Andrew said the command. These data are below: (5 points)

Puppy	Hippo	Piglet	Taco	Chance	Spot	Spruce
Baseline	540	350	1204	300	1280	690
After film	400	338	1035	285	1600	810

Let's perform the *Sign Test* to analyze these data

a) First, define H_0 and H_1

Practice Item



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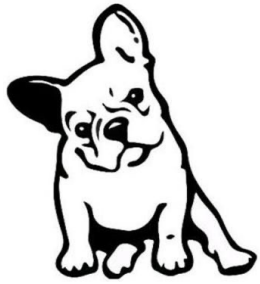
b) Second, let's set the alpha level. Andrew wants to <u>give the benefit of the doubt</u> to the puppy training classes. In other words, Andrew wants to reduce the possibility of making a *Type II error*. Circle the value of alpha below that would best correspond with this:

.005 .01 .05 .10

Practice Item



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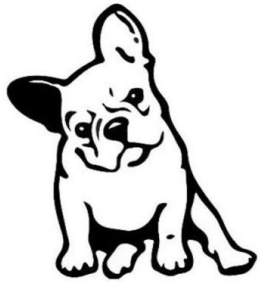
c) Now that we have chosen the alpha level, determine how many dogs would need to improve in order to reject H_0. These are live animals, so please round to the nearest dog!

Practice Item



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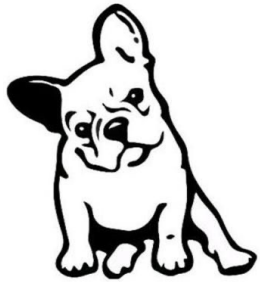
d) Calculate the probability given your hypotheses

Practice Item



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e) Report the decision that Andrew will make and what this would mean <u>in your own words</u>