Applied Statistical Analysis

EDUC 6050

Week 5

Finding clarity using data

Today

1. Hypothesis Testing with Z Scores (continued)
2. Hypothesis Testing with t-tests (one sample, independent samples, and paired-samples)

Tests

Situation	Test to Use
Single Group: Know population mean and standard deviation	Z-Test
Single Group: Know population mean but not the standard deviation	One-Sample T-Test
Have **two independent** groups that you want to compare	Independent Samples T-Test
Have **same individuals measured two times (or matched pairs)**	Paired Samples T-Test (Dependent Samples T-Test)

Z-Scores for an Individual Point

$$z = \frac{X - \mu}{\sigma}$$

Tells us:

- If the score is above or below the mean
- How large (the magnitude) the deviation from the mean is to other data points

The Z for a Sample Mean

$$Z_{Mean} = \frac{Mean - \mu}{SEM}$$

$$SEM = \frac{\sigma}{\sqrt{N}}$$

Depends on **sample size** (bigger sample, smaller SEM)

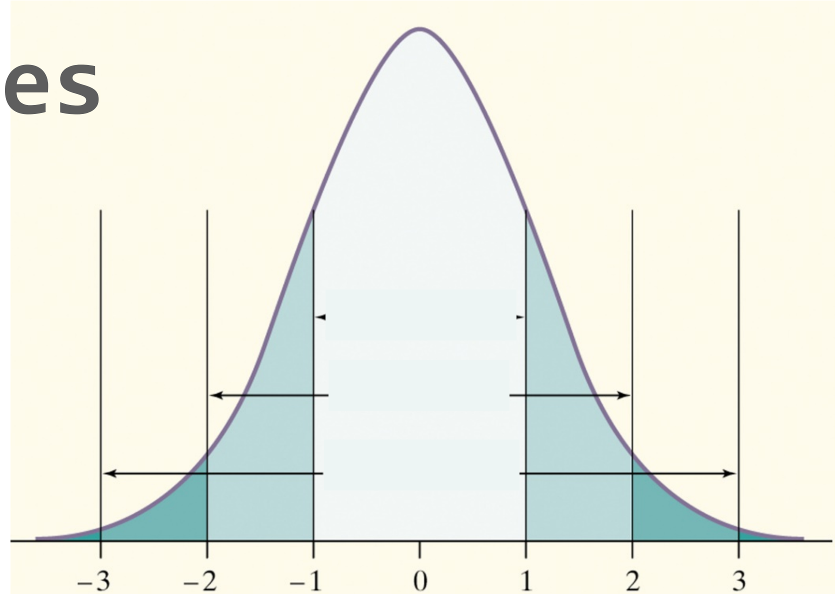
Z-Score and the Standard Normal Curve

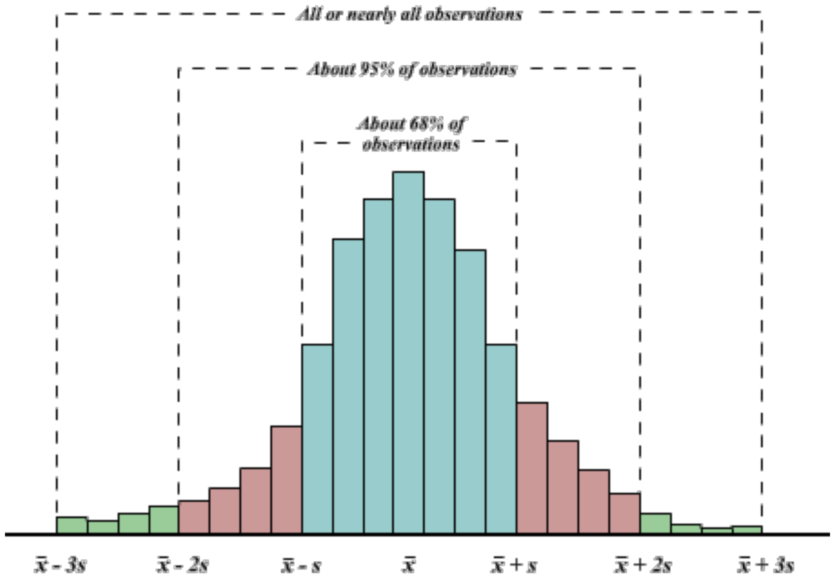
The 68-95-99.7 Rule

In the Normal distribution with mean μ and standard deviation σ:

- Approximately **68%** of the observations fall within σ of μ.
- Approximately **95%** of the observations fall within 2σ of μ.
- Approximately **99.7%** of the observations fall within 3σ of μ.

Appendix A shows more exact p-values





What if we don't know σ ??

We can use a one-sample t-test!

- It's just like the z-test but we estimate σ instead
  - and use a slightly different table for the p-values
- Because it is more common, we will just show an example of the t-test instead of the z-test.

The One-Sample T-test

$$t = \frac{Mean - \mu}{SEM}$$

$$SEM = \frac{SD}{\sqrt{N}}$$

One-Sample T-test vs Z-test

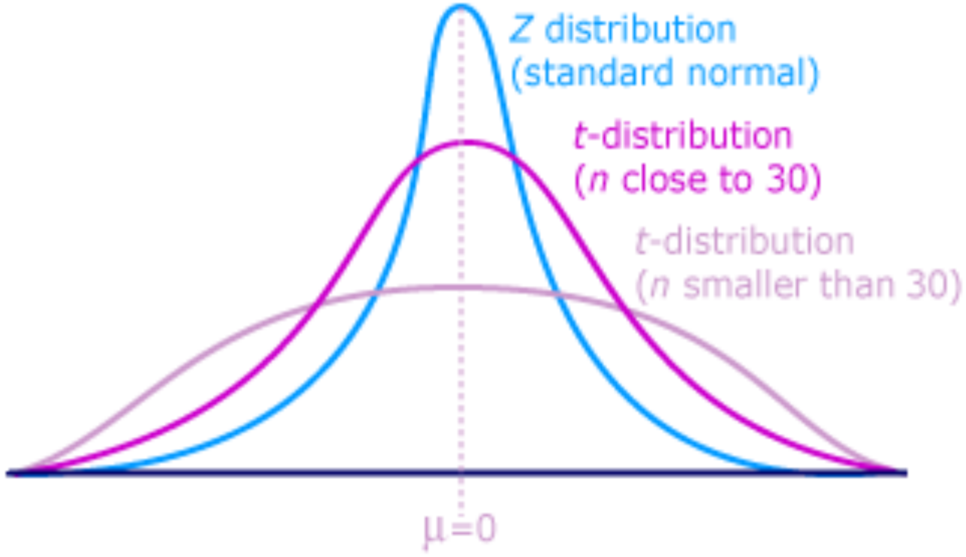
Situation	Test to Use	Formulas
Know population mean and standard deviation	Z-Test	$z = \frac{M - \mu}{\sigma / \sqrt{N}}$ $SEM = \sigma / \sqrt{N}$
Know population mean but not the standard deviation	One-Sample T-Test	$t = \frac{M - \mu}{SD / \sqrt{N}}$ $SEM = SD / \sqrt{N}$

Single-Sample T-tests

Requirements

1. Need a DV on an interval/ratio scale,
2. IV defines one sample, and
3. you do not know the population standard deviation

Slightly different distribution



Hypothesis Testing with T-Tests

The 6-step approach!

1. Examine Variables to Assess Statistical Assumptions
2. State the Null and Research Hypotheses (symbolically and verbally)
3. Define Critical Regions
4. Compute the Test Statistic
5. Compute an Effect Size and Describe it
6. Interpreting the results

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independence of data
2. Appropriate measurement of variables for the analysis
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Individuals are independent of each other (one person’s scores does not affect another’s)

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Here we need interval/ratio DV and an IV that is for a single sample (group)

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

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The outcome needs to be normal (for small samples)

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independence of data
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The variance of our sample is supposed to match the population variance (but do we know it?)

1 Examine Variables to Assess Statistical Assumptions

Examining the Basic Assumptions

1. Independence: random sample
2. Appropriate measurement: know what your variables are
3. Normality: Histograms, skew and kurtosis
4. Homogeneity: Hard to assess

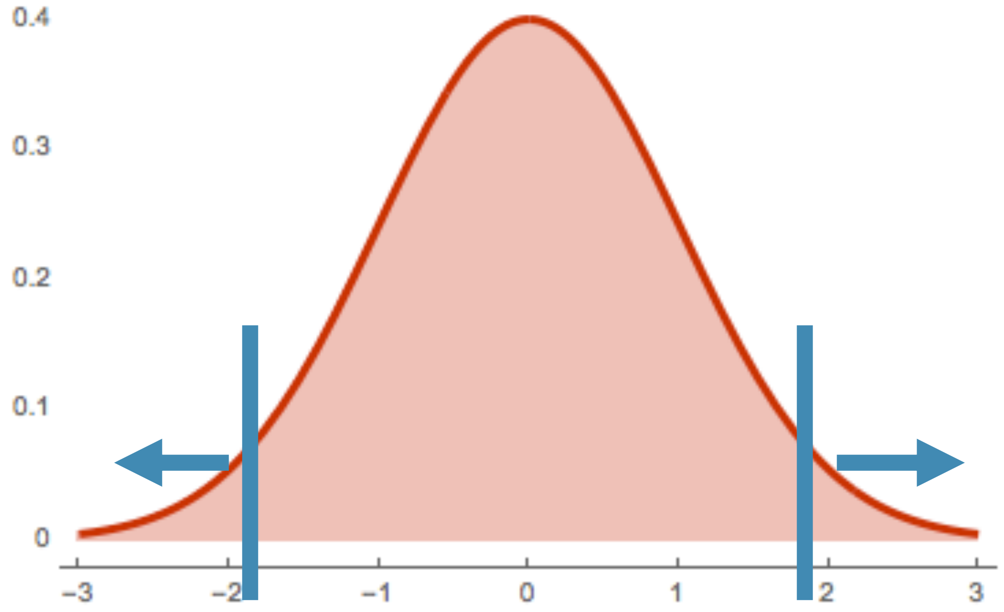
2 State the Null and Research Hypotheses (symbolically and verbally)

Hypothesis Type	Symbolic	Verbal	Difference between means created by:
Research Hypothesis	$\mu_{class} \neq \mu_{population}$	The class's mean is different than the population mean	True differences
Null Hypothesis	$\mu_{class} = \mu_{population}$	There is no *real* difference between the class and the population	Random chance (sampling error)

3 Define Critical Regions

How much evidence is enough to believe the null is not true?

Before analyzing the data, we define the critical regions (generally based on an alpha = .05)



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- Base on alpha and a specific df

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z	0.253347	0.674490	1.281552	1.644854	1.95996	2.32635	2.57583	3.2905
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We decide on an alpha level first

↳ Then calculate the critical value (based on sample size)

$$t_{critical,\,29} = 2.05$$

So our critical regions is defined as:

$$\alpha = .05$$

$$t_{critical,\,29} = 2.05$$

4 Compute the Test Statistic

$$t = \frac{M - \mu}{SD / \sqrt{N}}$$

The SEM, μ, and M will be given to you

Calculate it and compare to $t_{critical}$

Or

Calculate it, look up its p-value, and compare to our α level

5 Compute an Effect Size and Describe it

One of the main effect size estimates is **Cohen's d**

$$d = \frac{M - \mu}{SD}$$

d	Estimated Size of the Effect
Close to .2	Small
Close to .5	Moderate
Close to .8	Large

6 Interpreting the results

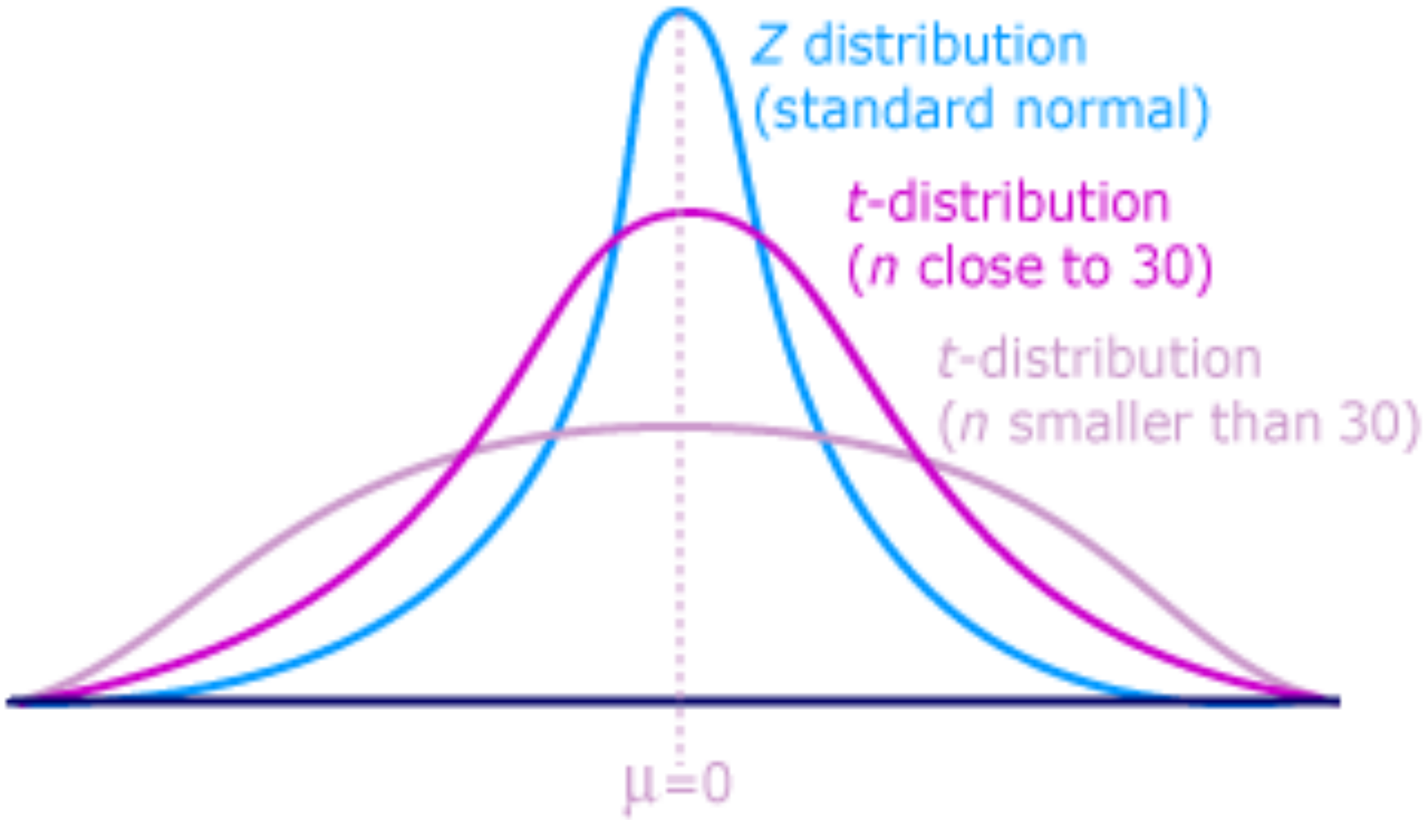
Put your results into words

Use the example on page 216 as a template

Independent Samples t-test vs One-Sample t-test

Situation	Test to Use	Formulas
Know population mean and want to **compare our single sample** to it	One-Sample T-Test	$t = \frac{M - \mu}{SD/\sqrt{N}}$
Have **two independent** groups that you want to compare	Independent Samples T-Test	$t = \frac{M_1 - M_2 - (\mu_1 - \mu_2)}{SD_p/\sqrt{N}}$ SD_p is a pooled standard deviation

Still using the same t-distribution



Requirements

1. Need a DV on an interval/ratio scale,
2. IV defines two different groups
3. The groups are independent (not repeated measures)

ID	Outcome	Group
1	8	1
2	8	1
3	9	1
4	7	1
5	7	2
6	9	2
7	5	2
8	5	2

Hypothesis Testing with T-Tests

The same 6 step approach!

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Individuals are independent of each other (one person's scores does not affect another's)

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The variances of the two groups should be equal (although we can handle not equality)

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Examining the Basic Assumptions

1. Independence: random sample
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4. Homogeneity: Levene's Test

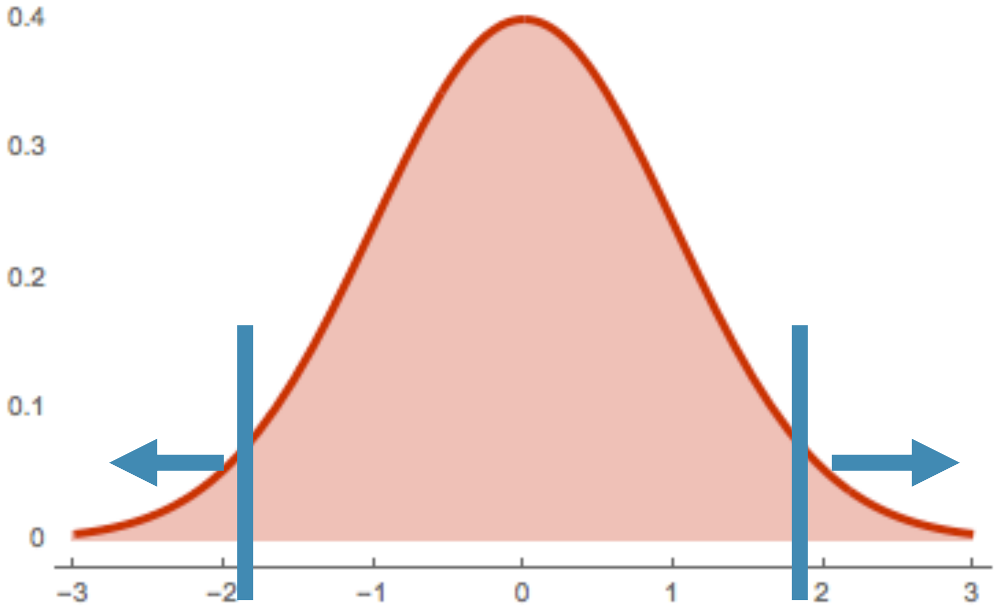
2 State the Null and Research Hypotheses (symbolically and verbally)

Hypothesis Type	Symbolic	Verbal	Difference between means created by:
Research Hypothesis	$\mu_{group\ 1} \neq \mu_{group\ 2}$	One of the groups' means is different than the other	True differences
Null Hypothesis	$\mu_{group\ 1} = \mu_{group\ 2}$	There is no *real* difference between the group 1 and the group 2	Random chance (sampling error)

3 Define Critical Regions

How much evidence is enough to believe the null is not true?

Before analyzing the data, we define the critical regions (generally based on an alpha = .05)



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8	0.261921	0.706387	1.396815	1.859548	2.30600	2.89646	3.35539	5.0413
9	0.260955	0.702722	1.383029	1.833113	2.26216	2.82144	3.24984	4.7809
10	0.260185	0.699812	1.372184	1.812461	2.22814	2.76377	3.16927	4.5869
11	0.259556	0.697445	1.363430	1.795885	2.20099	2.71808	3.10581	4.4370
12	0.259033	0.695483	1.356217	1.782288	2.17881	2.68100	3.05454	43178
13	0.258591	0.693829	1.350171	1.770933	2.16037	2.65031	3.01228	4.2208
14	0.258213	0.692417	1.345030	1.761310	2.14479	2.62449	2.97684	4.1405
15	0.257885	0.691197	1.340606	1.753050	2.13145	2.60248	2.94671	4.0728
16	0.257599	0.690132	1.336757	1.745884	2.11991	2.58349	2.92078	4.0150
17	0.257347	0.689195	1.333379	1.739607	2.10982	2.56693	2.89823	3.9651
18	0.257123	0.688364	1.330391	1.734064	2.10092	2.55238	2.87844	3.9216
19	0.256923	0.687621	1.327728	1.729133	2.09302	2.53948	2.86093	3.8834
20	0.256743	0.686954	1.325341	1.724718	2.08596	2.52798	2.84534	3.8495
21	0.256580	0.686352	1.323188	1.720743	2.07961	2.51765	2.83136	3.8193
22	0.256432	0.685805	1.321237	1.717144	2.07387	2.50832	2.81876	3.7921
23	0.256297	0.685306	1.319460	1.713872	2.06866	2.49987	2.80734	3.7676
24	0.256173	0.684850	1.317836	1.710882	2.06390	2.49216	2.79694	3.7454
25	0.256060	0.684430	1.316345	1.708141	2.05954	2.48511	2.78744	3.7251
26	0.255955	0.684043	1.314972	1.705618	2.05553	2.47863	2.77871	3.7066
27	0.255858	0.683685	1.313703	1.703288	2.05183	2.47266	2.77068	3.6896
28	0.255768	0.683353	1.312527	1.701131	2.04841	2.46714	2.76326	3.6739
29	0.255684	0.683044	1.311434	1.699127	2.04523	2.46202	2.75639	3.6594
30	0.255605	0.682756	1.310415	1.697261	2.04227	2.45726	2.75000	3.6460
z	0.253347	0.674490	1.281552	1.644854	1.95996	2.32635	2.57583	3.2905
CI	———	———	80%	90%	95%	98%	99%	99.9%

3 Define Critical Regions

We decide on an alpha level first

↳ Then calculate the critical value (based on sample size)

$$t_{critical,29} = 2.05$$

So our critical regions is defined as:

$$\alpha = .05$$

$$t_{critical,29} = 2.05$$

4 Compute the Test Statistic

$$t = \frac{M_1 - M_2 - (\mu_1 - \mu_2)}{SD/\sqrt{N}}$$

The SEM, μ, and M will be given to you

Calculate it and compare to $t_{critical}$

Or

Calculate it, look up its p-value, and compare to our α level

5 Compute an Effect Size and Describe it

One of the main effect size estimates is **Cohen's d**

$$d = \frac{M_1 - M_2}{SD_p}$$

d	Estimated Size of the Effect
Close to .2	Small
Close to .5	Moderate
Close to .8	Large

6 Interpreting the results

Put your results into words

Use the example on page XX as a template

Paired Samples T-test

Situation	Test to Use	Formulas
Have **two independent** groups that you want to compare	Independent Samples T-Test	$t = \frac{M_1 - M_2 - (\mu_1 - \mu_2)}{SD_p / \sqrt{N}}$
Have **same individuals measured two times**	Paired Samples T-Test (Dependent Samples T-Test)	$t = \frac{M_{diff} - (\mu_{diff})}{SD_{DIFF} / \sqrt{N}}$ SD_{DIFF} is the standard devation of the difference

Requirements

1. Need a DV on an interval/ratio scale,
2. IV defines two time points
3. Same individuals measured twice

ID	Time 1	Time 2
1	8	7
2	8	8
3	9	6
4	7	6
5	7	8
6	9	5
7	5	3
8	5	3

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independence of data
2. Appropriate measurement of variables for the analysis
3. Normality of distributions
4. Homogeneity of variance

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independence of data
2. Appr priat
   for he a
3. Normality
4. Homogeneity of variance

Individuals are independent of each other (one person’s scores does not affect another’s)

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independence of data
2. Appropriate measurement of variables for the analysis
3. Normality
4. Homog…

Here we need two interval/ratio DVs (one for each time point)

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independe…
2. Appr… for the analysis
3. Normality of distributions
4. Homogeneity of variance

The outcome needs to be normal (for small samples)

1 Examine Variables to Assess Statistical Assumptions

Basic Assumptions

1. Independence of data
2. Appropriate measurement of variables for the
3. Normality of distributions
4. Homogeneity of variance

The variances of the two time points should be equal

1 Examine Variables to Assess Statistical Assumptions

Examining the Basic Assumptions

1. **Independence:** random sample
2. **Appropriate measurement:** know what your variables are
3. **Normality:** Histograms, skew and kurtosis
4. **Homogeneity:** Levene's Test

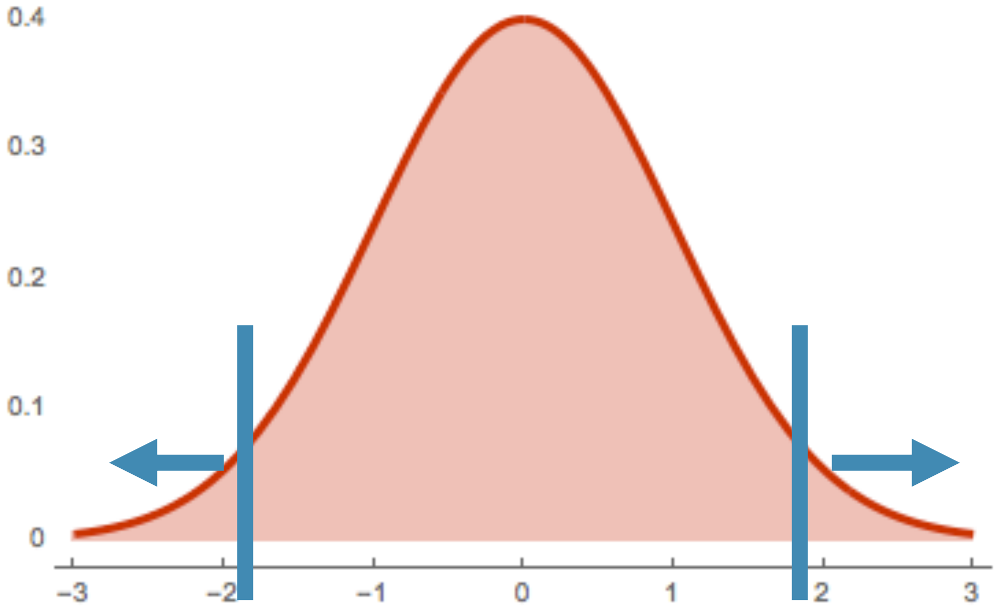
2 State the Null and Research Hypotheses (symbolically and verbally)

Hypothesis Type	Symbolic	Verbal	Difference between means created by:
Research Hypothesis	$\mu_{time\ 1} \neq \mu_{time\ 2}$	One of the groups' means is different than the other	True differences
Null Hypothesis	$\mu_{time\ 1} = \mu_{time\ 2}$	There is no *real* difference between the mean at time 1 and the mean at time 2	Random chance (sampling error)

3 Define Critical Regions

How much evidence is enough to believe the null is not true?

Before analyzing the data, we define the critical regions (generally based on an alpha = .05)



3 Define Critical Regions

We decide on an alpha level first

↳ Then calculate the critical value (based on sample size)

3 Define Critical

We decide on an alpha le

↳ Then calculate the c

(based on sample si

I'll provide a table for you for the t values

- Base on alpha and a specific df

$$df = N_{diff} - 1$$

df/p	0.40	0.25	0.10	0.05	0.025	0.01	0.005	0.0005
1	0.324920	1.000000	3.077684	6.313752	12.70620	31.82052	63.65674	636.6192
2	0.288675	0.816497	1.885618	2.919986	4.30265	6.96456	9.92484	31.5991
3	0.276671	0.764892	1.637744	2.353363	3.18245	4.54070	5.84091	12.9240
4	0.270722	0.740697	1.533206	2.131847	2.77645	3.74695	4.60409	8.6103
5	0.267181	0.726687	1.475884	2.015048	2.57058	3.36493	4.03214	6.8688
6	0.264835	0.717558	1.439756	1.943180	2.44691	3.14267	3.70743	5.9588
7	0.263167	0.711142	1.414924	1.894579	2.36462	2.99795	3.49948	5.4079
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Close to .2	Small
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6 Interpreting the results

Put your results into words

Questions?

Please post them to the discussion board before class starts

End of Pre-Recorded Lecture Slides

In-class discussion slides

Hypothesis Testing with T-tests

Let's practice!

- Study about height and our "Creation of Super-Tall Humans" intervention
- $\mu_{pop} = 63$ and $\sigma = ?$ (https://en.wikipedia.org/wiki/IQ_classification)
- $M = 70$ and $SD = 10$ with a N = 36
- We think our intervention works so we want to test it

- What test would you use?
- Can we say that it does work?

Hypothesis Testing with T-tests

Let's practice!

- Study about ping pong ability and our "Creation of Pong-ers" intervention
- $M_{Time1} = 10, M_{Time2} = 8$ and $SD_{diff} = 1$ with a N = 36
- We think our intervention works so we want to test it

- What test would you use?
- Can we say that it does work?

Hypothesis Testing with T-tests

Let's practice!

- Study about attention span and our "Creation of Totally Distracted People" intervention
- Two groups: 1) Treatment and 2) Control
- $M_1 = 70, M_2 = 75$ and $SD_1 = 10, SD_2 = 10$ with a N = 100 in both groups
- We think our intervention works so we want to test it

- What test would you use?
- Can we say that it does work?

Hypothesis Testing Rules

We make a handful of decisions along this process

- Alpha level
- Research and Null Hypotheses

These are related to Type I and Type II errors

Reject that Null!

We don't accept either the research or null hypotheses

Rather it is either evidence for or against the null

We do say that we "reject" or "fail to reject" the null

What is a p-value?

The probability of getting an obtained value or a more extreme value assuming the null is true

Whether results are due to chance (sampling error)

Page 163

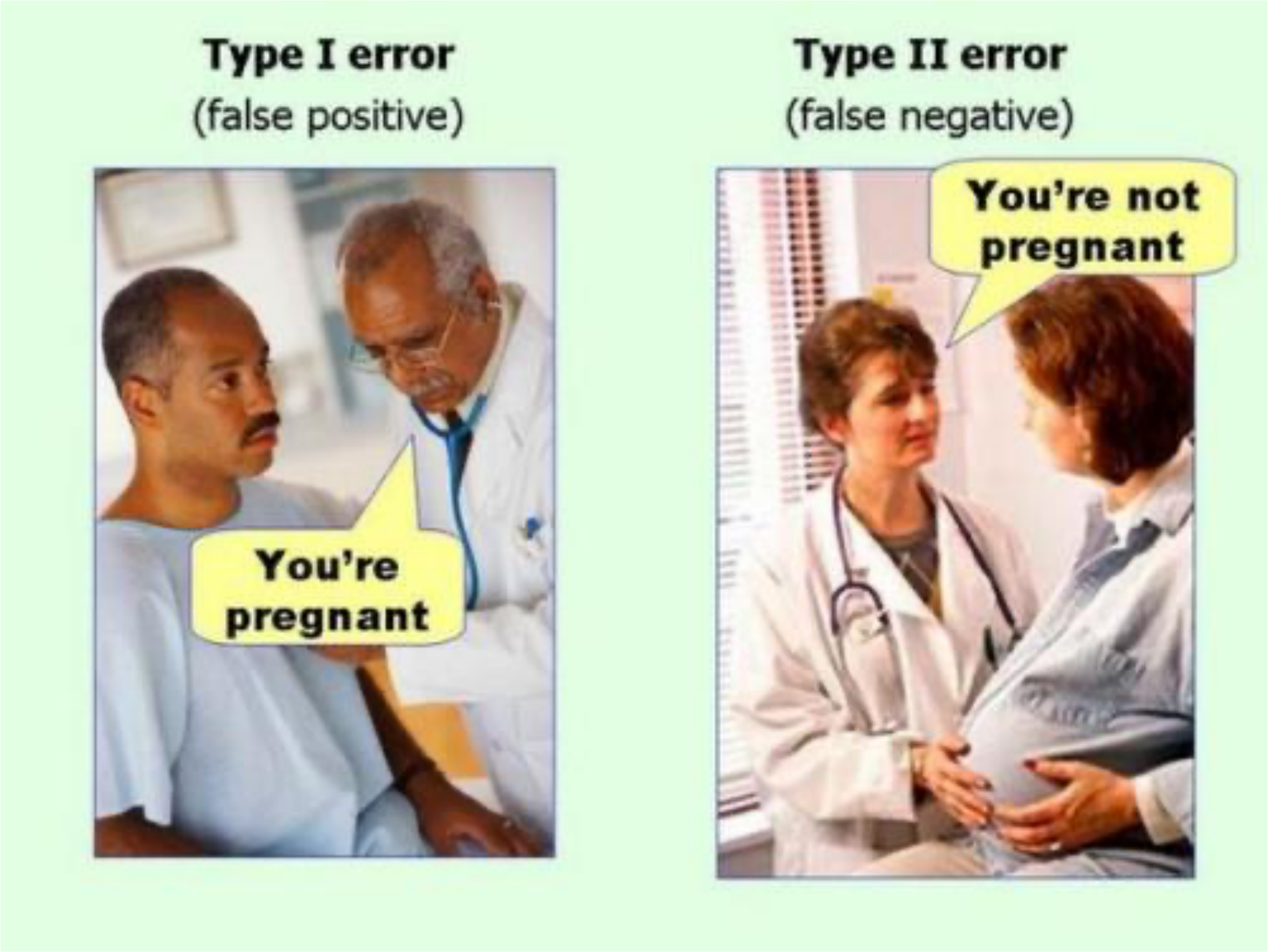
Evidence vs. Proof

Since we use p-values, there is always a chance that we made a Type I or Type II error

So we have evidence for or against it but we do NOT have PROOF of the research or null hypotheses

I like the discussion on Page 165 about this

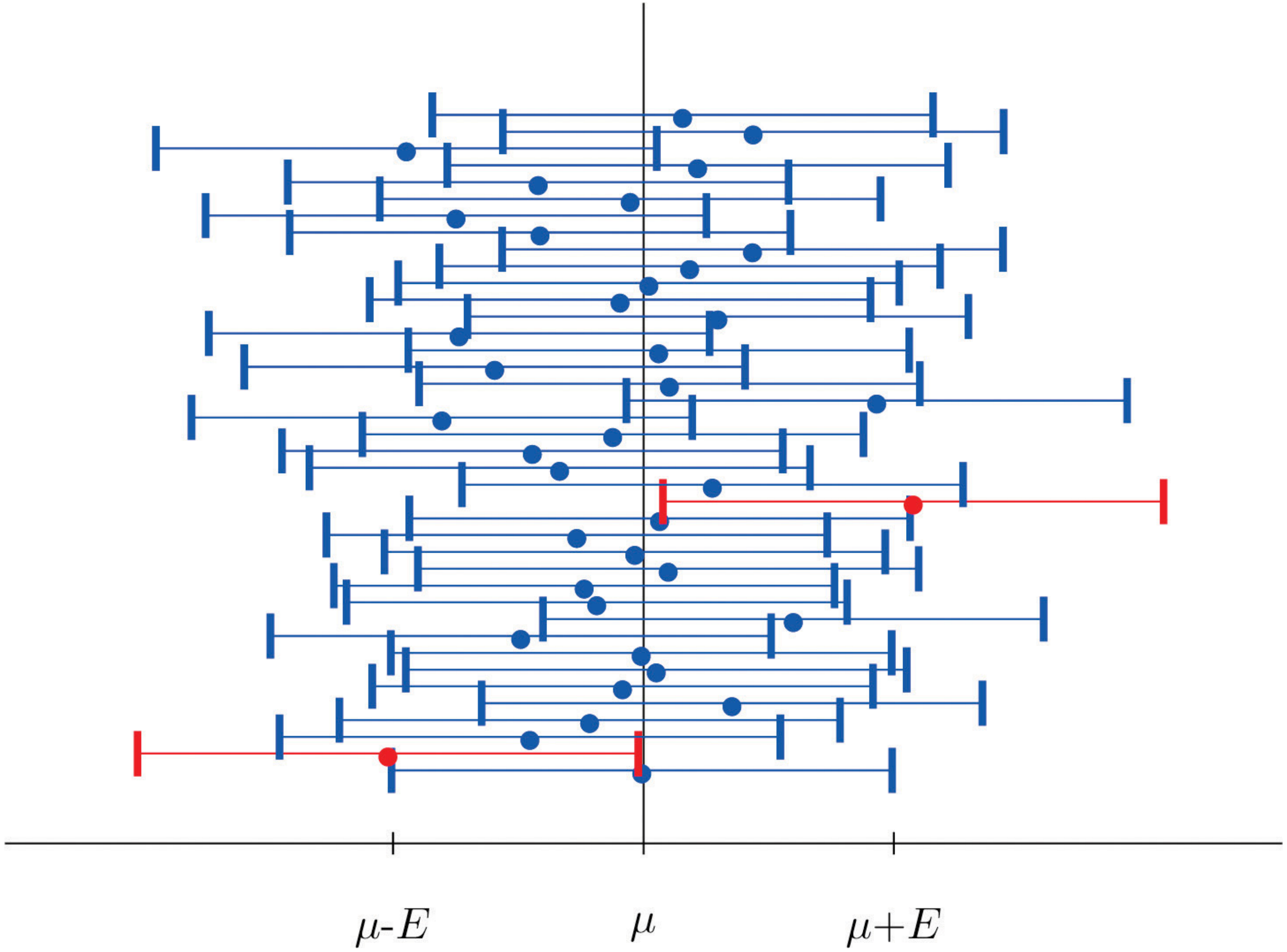
Errors in Hypothesis Testing (any type)



CI

Confidence Intervals

Theory Behind It



CI Confidence Intervals

How we use it →

$$Estimate \pm t_{critical} * SE_{est}$$

CI Confidence Intervals

Interpretation: We are 95% (when $\alpha = .05$) confident that the true population value is between [Lower] and [Upper].

Application

Example Using the Class Data &
The Office/Parks and Rec Data Set

Full Hypothesis Test Example
(t-tests)