Stat 201: Introduction to Statistics

Standard 26: Confidence Intervals – for Means

Means Sampling Distributions

Recall:

- The mean of the sampling distribution for a sample mean

$$\mu_{\bar{x}} = \textit{the mean of all possible sample means}$$
$$= \mu_x = \textit{the population mean}$$

- The standard error, the standard deviation of all sample means, is:

$$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{n}}$$

Confidence Intervals

- Often, we do not know the population mean
- We use our sample means to make inference on the population parameter
- We **MUST** make sure that the data is obtained through randomization and that distribution of the data is approximately normal
  - Recall Central limit theorem:
    - For this we require $n>30$ or the population to be normal to begin with

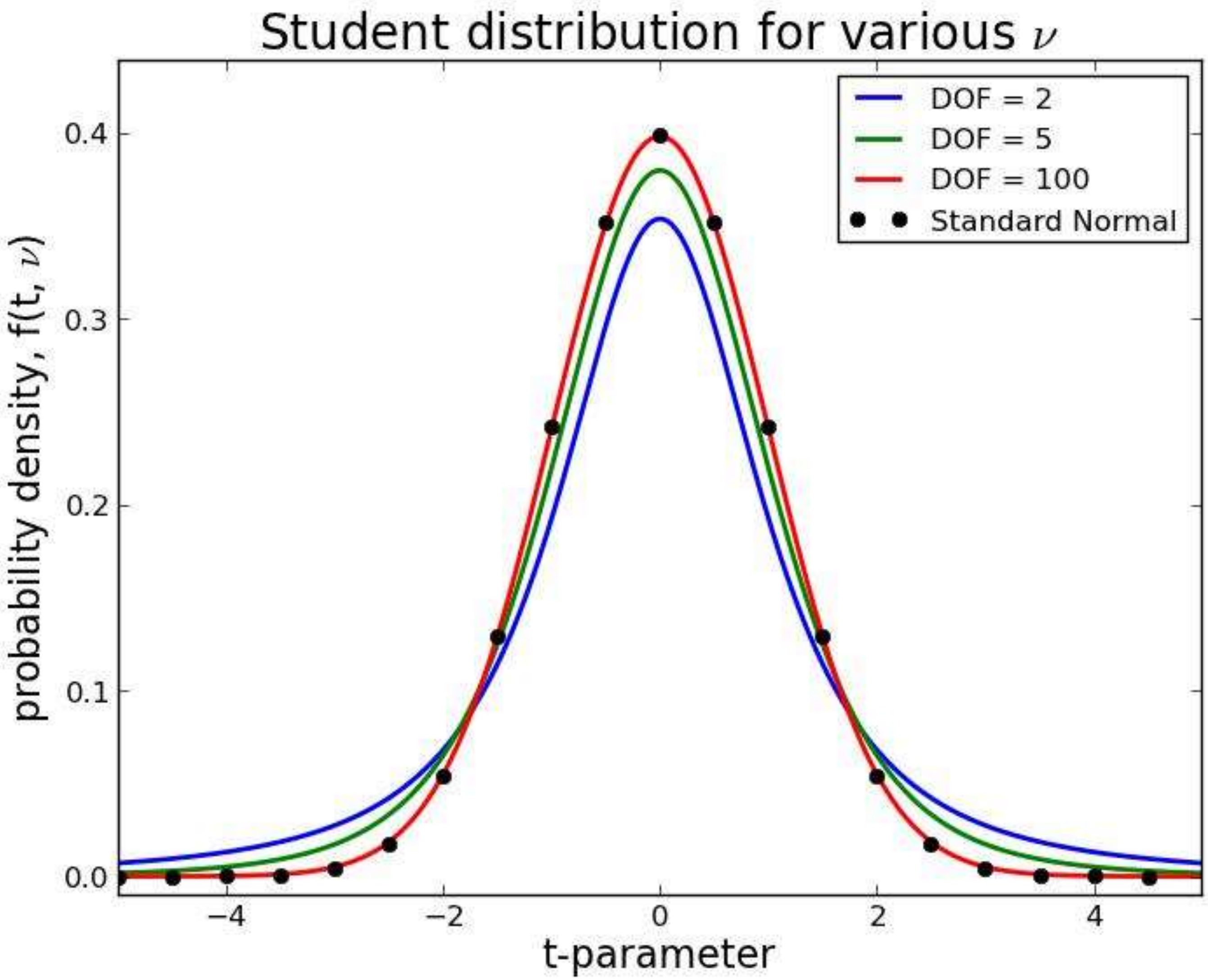
Confidence Intervals For the Population Mean

- When we talk about confidence intervals for the population mean we have two approaches
  1. When we know σ_x **(we are rarely in this case)**
     - Here we'll use the z-statistic
  2. When we don't know σ_x
     - Here we'll use the t-statistic
     - T is very similar to Z
     - Degrees of freedom = sample size – 1 = n-1

Properties of the t-distribution

1. The t-distribution is different for different degrees of freedom
2. The t-distribution is centered and symmetric at 0
3. The area under the curve is 1 and ½ on either side of 0
4. The probability approaches 0 as we move away from 0
5. The t-distribution has fatter tails than the standard normal
6. As the sample size increases t gets close to z

The t-distribution



Confidence Intervals When We Know σ_x

- $\bar{x}$ is our **point-estimate** for the population mean
  - Our 'best' guess for the true population , mean is our sample mean

Confidence Intervals When We Know σ_x

- We use our sample means to make inference on the population mean

$$\bar{x} \pm z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$$

- $\bar{x}$ is our **point-estimate** for the population mean
- $z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$is our **margin of error**

Confidence Intervals: Margin of Error When We Know σ_x

- $z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$ is our **margin of error**
  - **As n increases**, $\left(\frac{\sigma_x}{\sqrt{n}}\right)$ decreases, causing the margin of error to decrease causing the width of the confidence interval to narrow
  - **As n decreases**, $\left(\frac{\sigma_x}{\sqrt{n}}\right)$ increases, causing the margin of error to increase causing the width of the confidence interval to widen

Confidence Intervals: Margin of Error When We Know σ_x

- $z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$ is our **margin of error**
  - **As the confidence level decreases**, z decreases causing the margin of error to decrease, causing the width of the confidence interval to narrow
  - **As the confidence level increases**, z increases causing the margin of error to increase, causing the width of the confidence interval to grow wider

Confidence Intervals Bounds When We Know σ_x

$$\text{Lower Bound} = \bar{x} - z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$$

$$\text{Upper Bound} = \bar{x} + z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$$

We are --% confident that the true population mean, μ_x, is between the **lower** and **upper** bound.

Confidence Intervals When We Don't Know σ_x

- We use our sample means to make inference on the population mean

$$\bar{x} \pm t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$$

- $\bar{x}$ is our **point-estimate** for the population mean
- $t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$ is our **margin of error**
  - s_x **is the sample standard deviation**

Confidence Intervals: Margin of Error When We Don't Know σ_x

- $t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$ is our **margin of error**
  - **As n increases**, t decreases and $\left(\frac{s_x}{\sqrt{n}}\right)$ decreases, causing the margin of error to decrease causing the width of the confidence interval to narrow
  - **As n decreases**, t increases and $\left(\frac{s_x}{\sqrt{n}}\right)$ increases, causing the margin of error to increase causing the width of the confidence interval to widen

Confidence Intervals: Margin of Error When We Don't Know σ_x

- $t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$ is our **margin of error**
  - **As the confidence level decreases**, t decreases causing the margin of error to decrease, causing the width of the confidence interval to narrow
  - **As the confidence level increases**, t increases causing the margin of error to increase, causing the width of the confidence interval to grow wider

Confidence Intervals Bounds When We Don't Know σ_x

$$\text{Lower Bound} = \bar{x} - t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$$

$$\text{Upper Bound} = \bar{x} + t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$$

- We are --% confident that the true population mean, μ, is between the lower and upper bounds.

Confidence Intervals When We Don't Know σ_x

- t is based on the t distribution which is a lot like the normal distribution but with fatter tails
  - You can find the correct t-value by finding the cross-hair of degrees of freedom, n-1, and the two tailed alpha
  - http://www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf

Finding t for Our Confidence Intervals

- Say we were trying to find the t-value for a 95% confidence with n=10
- This means $\alpha = 1 - .95 = .05$ and the degrees of freedom = 10 - 1 = 9
- $t_{1-\frac{.05}{2},9}$ = 2.262

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587

Zoom In

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
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10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587

- A is the degrees of freedom, n-1
- B is the significance level – for confidence intervals we look for α in the two-tail row
- C is the t-value associated with the provided degrees of freedom and significance level

Finding t for Our Confidence Intervals

- Say we were trying to find the t-value for a 99% confidence with n=9
- This means $\alpha = 1 - .99 = .01$ and the degrees of freedom = 9 - 1 = 8
- $t_{1-\frac{.01}{2},8}$=3.355

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	B 0.002	0.001
df											
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7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
A 8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	C 4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
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Zoom In

	cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
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- A is the degrees of freedom, n-1
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Finding t for Our Confidence Intervals

- Say we were trying to find the t-value for a 90% confidence with n=11
- This means $\alpha = 1 - .90 = .10$ and the degrees of freedom = 11 - 1 = 10
- $t_{1-\frac{.10}{2},10} = 1.812$

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
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- A is the degrees of freedom, n-1
- B is the significance level – for confidence intervals we look for α in the two-tail row
- C is the t-value associated with the provided degrees of freedom and significance level

Confidence Interval Bounds When We Don't Know σ_x

$$\bar{x} \pm t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$$

Lower Bound= $\bar{x} - t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$

Upper Bound= $\bar{x} + t_{1-\frac{\propto}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$

Example 1

- Suppose a random sample of 81 students from the University of South Carolina was taken. Among the sampled students the **sample mean** number of times they inappropriately used the word like in a five minute conversation was **13 times** with a **sample standard deviation of 2.**
- Our sample mean = $\bar{x}$ = 13
- Our sample standard deviation = s_x = 2

Example 1

- Among the sampled students the sample mean number of times they inappropriately used the word like in a five minute conversation was 13 times with a sample standard deviation of 2.
- Check Assumptions
  - n>30 so it is safe to assume the distribution of $\bar{x}$ is bell-shaped
  - The data is from a random sample

Example 1

- 95% Confidence Interval for population mean number of times a University of South Carolina student inappropriately says like in a five minute conversation:

$$\bar{x} \pm t_{1-\frac{.05}{2},80}\left(\frac{s_x}{\sqrt{n}}\right)$$

$$= 13 \ \pm (1.990)\left(\frac{2}{\sqrt{81}}\right)$$

(11.5578, 14.4422)

Example 1

(11.5578, 14.4422)

- We are 95% confident that the true population mean number of times a University of South Carolina student inappropriately says like in a five minute conversation is between 11.5578 and 14.4422 times

Example 2

- Suppose a random sample of 38 yearly average temperature measures in New Haven, CT. Among the sampled years the **sample mean temperature was 51.0474** degrees Fahrenheit with a **sample standard deviation of 1.3112.**
- Our sample mean = $\bar{x}$ = 51.0474
- Our sample standard deviation = s_x = 1.3112

Example 2

- Suppose a random sample of 38 yearly average temperature measures in New Haven, CT. Among the sampled years the sample mean temperature was 51.0474 degrees Fahrenheit with a sample standard deviation of 1.3112.
- Check Assumptions
  - n>30 so it is safe to assume the distribution of $\bar{x}$ is bell-shaped
  - The data is from a random sample

Example 2

- 95% Confidence Interval for population the true population mean yearly average temperature reading in New Haven is:

$$\bar{x} \pm t_{1-\frac{.05}{2},38-1}\left(\frac{s_x}{\sqrt{n}}\right)$$

$$= 51.0474 \pm (2.021)\left(\frac{1.3112}{\sqrt{38}}\right)$$

(50.61752, 51.47728)

Example 2

(50.61752, 51.47728)

- We are 95% confident that the true population mean yearly average temperature reading in New Haven is between 50.61752 and 51.47728 degrees Fahrenheit

Confidence Intervals for Means on your TI Calculator

- Confidence Intervals for means TI83/84
  - https://www.youtube.com/watch?v=H3uU-Tx2Yq0
- Raw Data
  - https://www.youtube.com/watch?v=k2tV34JniHc
  - https://www.youtube.com/watch?v=uUXfr8pZAO0

Confidence Intervals for Means on your TI Calculator

- **When we know σ_x, with data**
- **<u>INPUT:</u>**
  1. Press STAT
  2. Press → to TESTS
  3. Highlight '7: ZInterval'
  4. Press ENTER
  5. **With Data**
     1. Enter the population standard deviation next to 'σ:'
     2. You should have your data table entered in L1
        - If you forgot: Press STAT, Press ENTER with 'Edit' highlighted, Enter the data into the L1 col.
     3. Next to 'List:' press 2^{nd} then press 1
     4. Set 'Frequency' to 1
     5. Enter the desired Confidence Level next to 'C-Level:'
     6. Highlight Calculate
     7. Press ENTER

Confidence Intervals for Means on your TI Calculator

- **When we know $\boldsymbol{\sigma_x}$, with data**
- <u>**OUTPUT:**</u>
  - (lower bound, upper bound) is our confidence interval
  - $\bar{x}$ is the sample mean for the problem
  - s_x is the sample standard deviation for the problem
  - n is the sample size and should match the number you entered

Confidence Intervals for Means on your TI Calculator

- **When we know σ_x, with stats**
- **<u>INPUT:</u>**

1. Press STAT
2. Press → to TESTS
3. Highlight ‘7: ZInterval’
4. Press ENTER
5. **With Stats**
   1. Enter the population standard deviation next to ‘σ:’
   2. Put the sample mean next to ‘$\bar{x}$:’
   3. Put the sample size next to ‘n:’
   4. Enter the desired Confidence Level next to ‘C-Level:’
   5. Highlight Calculate
   6. Press ENTER

Confidence Intervals for Means on your TI Calculator

- **When we know $\boldsymbol{\sigma_x}$, with stats**
- **<u>OUTPUT:</u>**
  - (lower bound, upper bound) is our confidence interval
  - $\bar{x}$ is the sample mean for the problem and should match the number you entered
  - n is the sample size and should match the number you entered

Confidence Intervals for Means on your TI Calculator

- **When we don't know σ_x, with data**
- **<u>INPUT:</u>**
  1. Press STAT
  2. Press → to TESTS
  3. Scroll down using ↓ to highlight '8: TInterval'
  4. Press ENTER
  - **With Data**
    1. You should have your data table entered in L1
       - If you forgot: Press STAT, Press ENTER with 'Edit' highlighted, Enter the data into the L1 col.
    2. Next to 'List:' press 2nd then press 1
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- **When we don't know σ_x, with data**
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  5. **With Stats**
     1. Put the sample mean next to '$\bar{x}$:'
     2. Enter the sample standard deviation next to 's_x:'
     3. Put the sample size next to 'n:'
     4. Enter the desired Confidence Level next to 'C-Level:'
     5. Highlight Calculate
     6. Press ENTER

Confidence Intervals for Means on your TI Calculator

- **When we don’t know σ_x, with stats**
- **<u>OUTPUT:</u>**
  - (lower bound, upper bound) is our confidence interval
  - $\bar{x}$ is the sample mean for the problem and should match the number you entered in stem 6b
  - s_x is the sample standard deviation for the problem
  - n is the sample size and should match the number you entered in step 6c above

Confidence Intervals for Means unknown: When we don't know σ_x

- **StatCrunch Commands w/ data**
  - Stat→T Stats→One Sample →with data (if you have the a list of data)→Choose the column→choose confidence interval→enter the significance level → Compute

- **StatCrunch Commands w/ summaries**
  - Stat→T Stats→One Sample →with summary (if you have the count) → enter the mean, standard deviation and sample size→ choose confidence interval→enter the significance level → Compute

Confidence Intervals for Means unknown: When we know σ_x

- **StatCrunch Commands w/ data**
  - Stat→Z Stats→One Sample →with data (if you have the a list of data)→Choose the column→choose confidence interval→enter the significance level → Compute

- **StatCrunch Commands w/ summaries**
  - Stat→Z Stats→One Sample →with summary (if you have the count) → enter the mean, standard deviation and sample size→ choose confidence interval→enter the significance level → Compute

Confidence Intervals known σ_x

Assumptions	Point Estimate	Margin of Error	Margin of Error
1. *Random Sample* 2. $n > 30$ OR the population is bell shaped	$\bar{x}$	$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{n}}$	$\bar{x} \pm z_{\frac{\alpha}{2}}\left(\frac{\sigma_x}{\sqrt{n}}\right)$

- We are --% confident that the true population mean lays on the confidence interval.

Confidence Intervals unknown σ_x

Assumptions	Point Estimate	Margin of Error	Margin of Error
1. Random Sample 2. $n > 30$ OR the population is bell shaped	$\bar{x}$	$\sigma_{\bar{x}} = \frac{s_x}{\sqrt{n}}$	$\bar{x} \pm t_{1-\frac{\alpha}{2},n-1}\left(\frac{s_x}{\sqrt{n}}\right)$

- We are --% confident that the true population mean lays on the confidence interval.