

Lecture 8: Chapter 8

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UAB Mathematics

1 March 16

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- A paper claims that most American consumers know that the Kindle is a e-book reader.
- A sample of 103 human body temperatures can be used to test whether or not the mean body temperature for humans is 98.6°F .

§8.2 Basic Hypothesis Testing

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Example

From the previous, testing that the average weight of tennis balls manufactured by Wilson is less than 100 grams would be equivalent to testing the statement

$$\mu < 100,$$

where μ is the average weight of Wilson tennis balls.

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If under the given assumption, the probability of a particular observed event is extremely small, we reject the assumption.

First we must form a hypothesis. Use these general rules:

- The **null** hypothesis H_0 should always be that a population parameter is equal to some value.
- The **alternative** hypothesis H_1 should either be that the same parameter is not equal to, less than, or greater than the value above.

§8.2 Example

Translate into a null hypothesis and an alternative hypothesis the following claim:

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- Testing using a critical value. This method is similar to constructing a confidence interval, except we may have one sided intervals now.
- Testing using a P -value, which describes the area lying beyond a test statistic in a one- or two-sided manner.

§8.2 Test Statistic

Definition (Test Statistic)

A **test statistic** is the result of converting a sample statistic into a value used to test the null hypothesis. They are the “standardized” statistic because they generally take the form

$$\frac{\text{estimate} - \text{hypothesized value}}{\text{standard error}}.$$

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Proportion p	Mean μ with σ	Mean μ w/o σ	Std. Dev. σ
$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}}$	$z = \frac{\bar{x} - \mu}{\frac{\sigma}{\sqrt{n}}}$	$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}}$	$\chi^2 = \frac{(n-1)s^2}{\sigma^2}$

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The significance of a P -test is called α . We reject the null hypothesis if $p \leq \alpha$ and fail to reject it if $p > \alpha$.

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- If the alternative hypothesis is a right-tailed (“greater than”) statement, then the P -value is the area to the right of the statistic ω using the appropriate distribution.
- If the alternative hypothesis is a two-tailed (“not equal to”) statement, then the P -value is the area outside of the interval $(-\omega, \omega)$ (if ω is positive) or $(\omega, -\omega)$ (if ω is negative). In the case of a χ^2 test, we look at the small tail and double the area in that tail for the P -value.

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Definition (Type II Error)

This is the error of failing to reject a false null hypothesis.

This would be like concluding that a population proportion was 50% when it actually was not.

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We use β to denote the probability of making a Type II Error, i.e. it is the probability of failing to reject a false null hypothesis.

The confidence of a test is $1 - \alpha$ (the probability of failing to reject a true null hypothesis), and the power of a test is $1 - \beta$ (the probability of rejecting a false null hypothesis).

§8.3 Example (Proportion)

A survey showed that, among the 514 human resource managers polled, 93% said that the appearance of a job applicant was important. Use a 10% significance level to test the claim that at least 95% of human resources managers think that a job applicant's appearance is important.

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The test statistic is $z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.92996 - 0.95}{\sqrt{\frac{(0.95)(0.05)}{514}}} \approx -2.085$.

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And because $P(Z < -2.085) = 0.0186$, we get that we must reject the null hypothesis.

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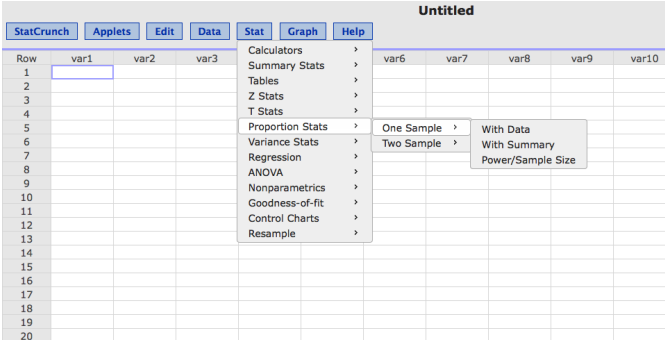
And because $P(Z < -2.085) = 0.0186$, we get that we must reject the null hypothesis. In this case, this means that the data does **not** support our original claim!

§8.3 Using StatCrunch for Hypothesis Testing

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The screenshot shows the StatCrunch interface with the 'Stat' menu open. The 'Proportion Stats' option is selected, and a sub-menu is visible with 'One Sample' and 'Two Sample' options. The 'Two Sample' option is further expanded to show 'With Data', 'With Summary', and 'Power/Sample Size'.

Row	var1	var2	var3	var6	var7	var8	var9	var10
1								
2								
3								
4								
5								
6								
7								
8								
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Untitled

File Edit Data Stat Graph Help

var2 var3 var4 var5 var6 var7 var8 var9 var10 var11 var12 var13

One Sample Prop. Summary

of successes:
478

of observations:
514

Perform:

Hypothesis test for p

$H_0: p = 0.95$

$H_A: p \leq 0.95$

Confidence interval for p

Level: 0.95

Method: Standard-Wald

Output:

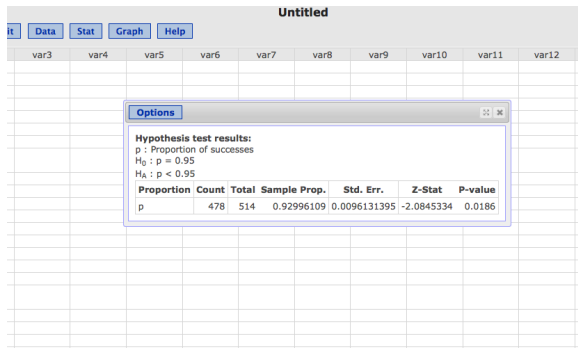
Store in data table

? Cancel Compute!

Learn how to annotate Sta

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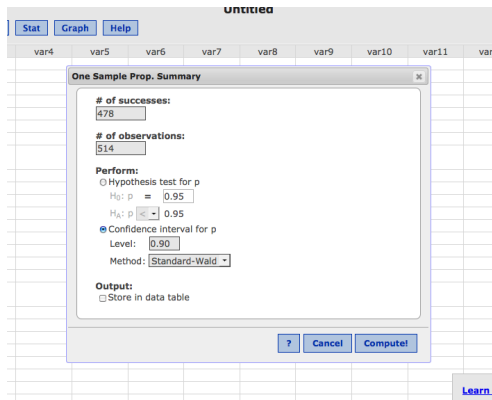


The screenshot shows the StatCrunch interface with a grid of variables (var3 to var12) and a menu bar (Data, Stat, Graph, Help). An "Options" dialog box is open, displaying the results of a hypothesis test for a proportion. The test parameters are: p : Proportion of successes, $H_0 : p = 0.95$, and $H_A : p < 0.95$. The results table shows a sample proportion of 0.92996109, a Z-stat of -2.0845334, and a P-value of 0.0186.

Proportion	Count	Total	Sample Prop.	Std. Err.	Z-Stat	P-value
p	478	514	0.92996109	0.0096131395	-2.0845334	0.0186

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You can also use a confidence interval or critical value to test a hypothesis.



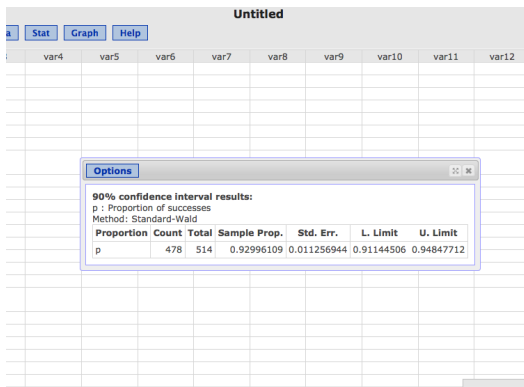
The screenshot shows the StatCrunch interface with a dialog box titled "One Sample Prop. Summary" open over a spreadsheet. The spreadsheet has columns labeled var4 through var11. The dialog box contains the following fields and options:

- # of successes:** 478
- # of observations:** 514
- Perform:**
 - Hypothesis test for p
 - $H_0: p = 0.95$
 - $H_a: p < 0.95$
 - Confidence interval for p
 - Level: 0.90
 - Method: Standard-Wald
- Output:**
 - Store in data table

Buttons at the bottom of the dialog box include a help icon (?), "Cancel", and "Compute!". A "Learn" button is visible in the bottom right corner of the spreadsheet area.

§8.3 Using StatCrunch for Hypothesis Testing

You can also use a confidence interval or critical value to test a hypothesis.



The screenshot shows the StatCrunch interface with a data table and an options window. The data table has columns labeled var4 through var12. The options window displays the following information:

Options

90% confidence interval results:
p : Proportion of successes
Method: Standard-Wald

Proportion	Count	Total	Sample Prop.	Std. Err.	L. Limit	U. Limit
p	478	514	0.92996109	0.011256944	0.91144506	0.94847712

§8.3 Importance of Using an Appropriate Test

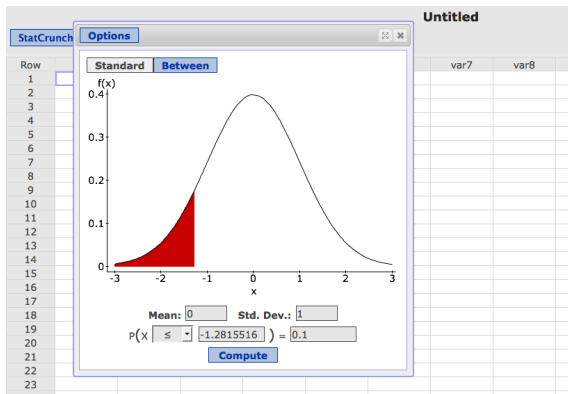
Notice the Confidence Interval Method resulting in failing to reject the null hypothesis because it is inherently **two-tailed**. **You must change the significance/confidence level when testing and one-tailed claim using a confidence interval!**

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Notice the Confidence Interval Method resulting in failing to reject the null hypothesis because it is inherently **two-tailed**. **You must change the significance/confidence level when testing and one-tailed claim using a confidence interval!** We should have doubled our significance and created an 80% CI!

§8.3 Using StatCrunch for Hypothesis Testing

You can also use a confidence interval or critical value to test a hypothesis.



§8.4 Example (Mean)

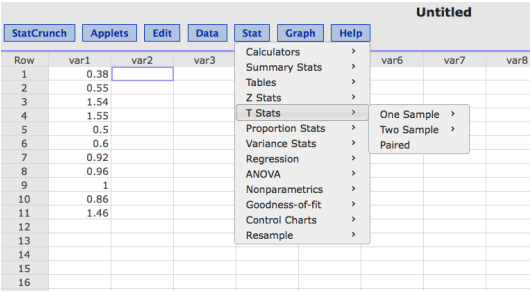
Use a 0.05 significance level to test the claim that the data below comes from a normally distributed population with mean less than 1.

0.38, 0.55, 1.54, 1.55, 0.50, 0.60, 0.92, 0.96, 1.00, 0.86, 1.46.

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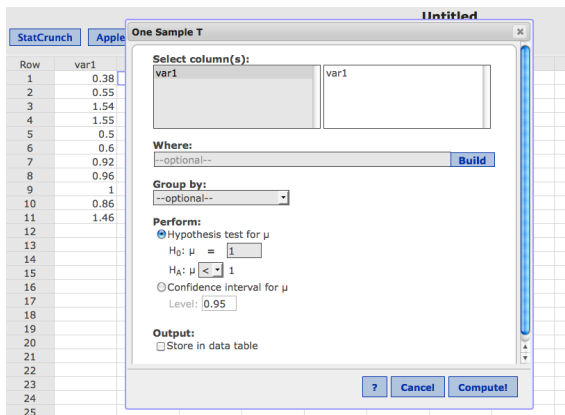
The screenshot shows the StatCrunch software interface. At the top, there are menu tabs: StatCrunch, Applets, Edit, Data, Stat, Graph, and Help. Below these is a data table with 16 rows and 8 columns. The first four columns are labeled var1, var2, var3, and var4. The data values are: Row 1: 0.38; Row 2: 0.55; Row 3: 1.54; Row 4: 1.55; Row 5: 0.5; Row 6: 0.6; Row 7: 0.92; Row 8: 0.96; Row 9: 1; Row 10: 0.86; Row 11: 1.46; Rows 12-16 are empty. A menu is open over the 'Stat' tab, listing various statistical functions: Calculators, Summary Stats, Tables, Z Stats, T Stats, Proportion Stats, Variance Stats, Regression, ANOVA, Nonparametrics, Goodness-of-fit, Control Charts, and Resample. The 'T Stats' option is highlighted, and a sub-menu is open showing 'One Sample', 'Two Sample', and 'Paired' options.

Row	var1	var2	var3	var4	var5	var6	var7	var8
1	0.38							
2	0.55							
3	1.54							
4	1.55							
5	0.5							
6	0.6							
7	0.92							
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The screenshot shows the StatCrunch interface with a data table and a dialog box for a One Sample T test.

Row	var1
1	0.38
2	0.55
3	1.54
4	1.55
5	0.5
6	0.6
7	0.92
8	0.96
9	1
10	0.86
11	1.46
12	
13	
14	
15	
16	
17	
18	
19	
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25	

One Sample T dialog box configuration:

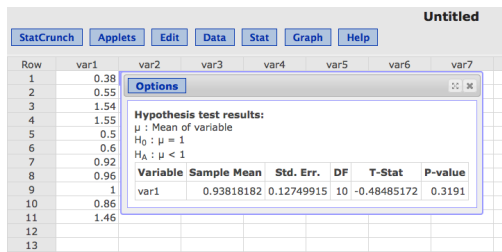
- Select column(s):** var1
- Where:** --optional--
- Group by:** --optional--
- Perform:**
 - Hypothesis test for μ
 - $H_0: \mu = 1$
 - $H_A: \mu < 1$
 - Confidence interval for μ
 - Level: 0.95
- Output:**
 - Store in data table

Buttons: ? Cancel Compute

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StatCrunch Applets Edit Data Stat Graph Help

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12							
13							

Options

Hypothesis test results:
 μ : Mean of variable
 H_0 : $\mu = 1$
 H_A : $\mu < 1$

Variable	Sample Mean	Std. Err.	DF	T-Stat	P-value
var1	0.93818182	0.12749915	10	-0.48485172	0.3191

§8.4 Example (Mean)

Use a 0.05 significance level to test the claim that the data below comes from a normally distributed population with mean less than 1 and standard deviation 0.03.

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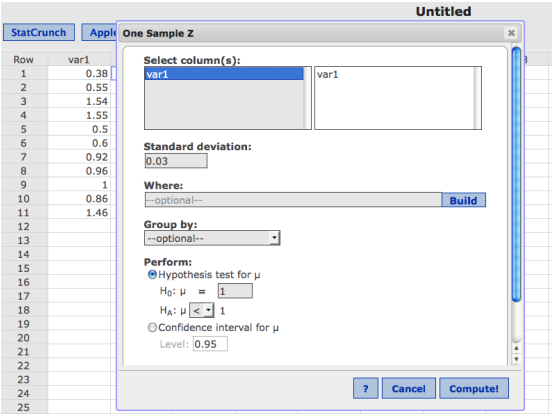
The screenshot shows the StatCrunch interface with a data table and a menu path for Z-Tests. The data table has columns for var1, var2, var3, var6, var7, var8, and var9. The menu path is: Stat > Z Stats > One Sample > With Data.

Row	var1	var2	var3	var6	var7	var8	var9
1	0.38						
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3	1.54						
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25	

One Sample Z

Select column(s):
var1

Standard deviation:
0.03

Where:
--optional-- **Build**

Group by:
--optional--

Perform:
 Hypothesis test for μ
 $H_0: \mu = 1$
 $H_A: \mu < 1$
 Confidence interval for μ
Level: 0.95

? Cancel Compute!

§8.4 Example (Mean)

Use a 0.05 significance level to test the claim that the data below comes from a normally distributed population with mean less than 1 and standard deviation 0.03.

0.38, 0.55, 1.54, 1.55, 0.50, 0.60, 0.92, 0.96, 1.00, 0.86, 1.46.

The screenshot shows the StatCrunch interface with a data table and a hypothesis test results window. The data table has columns for variables var1 through var7 and rows for data points. The hypothesis test results window displays the following information:

Hypothesis test results:
 μ : Mean of variable
 $H_0 : \mu = 1$
 $H_A : \mu < 1$
Standard deviation = 0.03

Variable	n	Sample Mean	Std. Err.	Z-Stat	P-value
var1	11	0.93818182	0.0090453403	-6.8342571	<0.0001

§8.4 Example (Standard Deviation)

Use a 0.01 significance level to test the claim that the data below comes from a normally distributed population with standard deviation equal to 2.6.

70, 71, 69.25, 68.5, 69, 70, 71, 70, 70, 69.5

§8.4 Example (Standard Deviation)

Use a 0.01 significance level to test the claim that the data below comes from a normally distributed population with standard deviation equal to 2.6.

70, 71, 69.25, 68.5, 69, 70, 71, 70, 70, 69.5

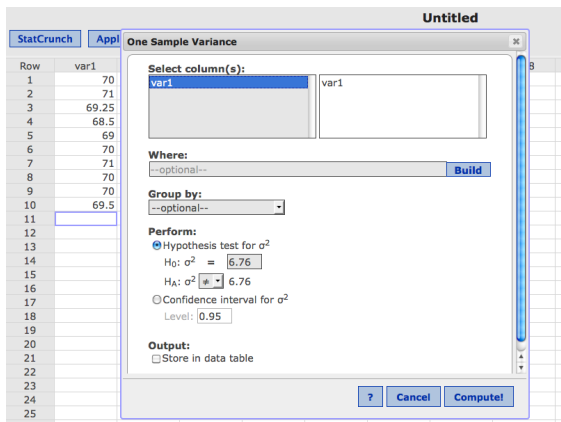
The screenshot shows the StatCrunch software interface. The main window is titled "Untitled" and contains a data table with columns labeled "var1", "var2", "var3", "var6", "var7", "var8", and "var9". The data table has 16 rows, with the first 10 rows containing numerical values: 70, 71, 69.25, 68.5, 69, 70, 71, 70, 70, and 69.5. The "Stat" menu is open, showing a list of statistical tests. The "Variance Stats" option is selected, and a sub-menu is displayed with three options: "One Sample", "Two Sample", and "Homogeneity". The "One Sample" option is further expanded to show "With Data", "With Summary", and "Power/Sample Size".

Row	var1	var2	var3	var6	var7	var8	var9
1	70						
2	71						
3	69.25						
4	68.5						
5	69						
6	70						
7	71						
8	70						
9	70						
10	69.5						
11							
12							
13							
14							
15							
16							

§8.4 Example (Standard Deviation)

Use a 0.01 significance level to test the claim that the data below comes from a normally distributed population with standard deviation equal to 2.6.

70, 71, 69.25, 68.5, 69, 70, 71, 70, 70, 69.5



The screenshot shows the StatCrunch interface with a data table and an open dialog box for a one-sample variance test.

Row	var1
1	70
2	71
3	69.25
4	68.5
5	69
6	70
7	71
8	70
9	70
10	69.5
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

StatCrunch **App** **One Sample Variance**

Select column(s):
var1

Where:
--optional-- **Build**

Group by:
--optional--

Perform:
 Hypothesis test for σ^2
 $H_0: \sigma^2 =$
 $H_A: \sigma^2$
 Confidence interval for σ^2
Level:

Output:
 Store in data table

? **Cancel** **Compute!**

§8.4 Example (Standard Deviation)

Use a 0.01 significance level to test the claim that the data below comes from a normally distributed population with standard deviation equal to 2.6.

70, 71, 69.25, 68.5, 69, 70, 71, 70, 70, 69.5

The screenshot shows the StatCrunch interface with a data table and an options dialog box. The data table has 13 rows and 7 columns (var1 to var7). The values in the var1 column are 70, 71, 69.25, 68.5, 69, 70, 71, 70, 70, 69.5. The options dialog box displays the following hypothesis test results:

Hypothesis test results:
 σ^2 : Variance of variable
 $H_0 : \sigma^2 = 6.76$
 $H_A : \sigma^2 \neq 6.76$

Variable	Sample Var.	DF	Chi-Square Stat	P-value
var1	0.63958333	9	0.85151627	0.0006

What would be a Type I error if the claim was that the proportion of people who write with their left hand is equal to 0.1? What would be a Type 2 error?

§8 Mastery

The claim is that women have heights with $\sigma = 5\text{cm}$. After the test is conducted, it's found that the P -value was 0.0055. If we're conducting a test with 99% confidence, do we support this claim or not?

§8 Mastery

We want to test the claim that at least 98% of Cheez-Its have at least 1.5mg of salt on them. In a sample of 120 Cheez-It crackers, we find that 118 have at least 1.5mg of salt on them. Do we support our claim or not?

§8 Mastery

The brain volumes of cows are given below. We want to test the claim that the population of cow brain volumes has mean equal to 1100 square centimeters. Assume brain volumes of cows are normally distributed.

963, 1027, 1272, 1079, 1070, 1173, 1067, 1347, 1100, 1204

§8 Mastery

The claim is that for nicotine amounts in a certain brand of cigarettes, $\mu > 20.0\text{mg}$. A test of 200 cigarettes showed the mean to be 20.1mg. The standard deviation for nicotine in this brand of cigarettes is 0.9mg. Can we support our claim with a 10% significance?

§8 Mastery

A simple random sample of 40 men results in a standard deviation of 10.3 heartbeats per minute. Men's heartbeats are normally distributed. We wish to test the claim that men's heartbeats have a standard deviation of 10 heartbeats per minute with a significance of 0.05.