

Independent
Samples:
Comparing
Proportions

Robb T.
Koether

Confidence
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 $\mu_1 - \mu_2$

Confidence
Intervals for
 $\mu_1 - \mu_2$ on
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Independent Samples: Comparing Proportions

Lecture 39
Section 11.5

Robb T. Koether

Hampden-Sydney College

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- Confidence intervals for $\mu_1 - \mu_2$ use the same theory.
- The point estimate is $\bar{x}_1 - \bar{x}_2$.
- The standard deviation of $\bar{x}_1 - \bar{x}_2$ is approximately

$$s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

Confidence Intervals

- The confidence interval is either

$$(\bar{X}_1 - \bar{X}_2) \pm z_{\alpha/2} \sigma \sqrt{\frac{1}{n_1} + \frac{1}{n_2}},$$

or

$$(\bar{X}_1 - \bar{X}_2) \pm z_{\alpha/2} s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}},$$

or

$$(\bar{X}_1 - \bar{X}_2) \pm t_{df, \alpha/2} s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}},$$

depending on the circumstances.

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- The choice depends on
 - Whether σ is known.
 - Whether the populations are normal.
 - Whether the sample sizes are large.

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The Hypotheses

- Find a 95% confidence interval for $\mu_1 - \mu_2$ in Example 11.4, p. 699.
- $\bar{x}_1 - \bar{x}_2 = 3.2$.
- $s_p = 5.052$.
- Use $t_{18,0.025} = 2.101$.
- The confidence interval is

$$3.2 \pm (2.101)(2.259) = 3.2 \pm 4.75.$$

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The TI-83 - Means of Independent Samples

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The Hypotheses

- To find a confidence interval for the difference between means on the TI-83,
 - Press `STAT > TESTS`.
 - Choose either `2-SampZInt` or `2-SampTInt`, depending on circumstances.
 - Choose `Data` or `Stats`.
 - Provide the information that is called for.
 - `2-SampTTest` will ask whether to use a pooled estimate of σ . Answer “yes.”
 - Press `Calculate`.
- The confidence interval appears.

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- Find a 95% confidence interval for $\mu_1 - \mu_2$ in Example 11.4, p. 699 using the TI-83.

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The Hypotheses

- We will now do for proportions what we just did for means.
- We will test hypotheses concerning the difference between proportions from two different populations.
- Again we will encounter the concept of a pooled estimate, this time for p .
- Some of the formulas get a bit messy, but there will be a formula sheet given out later.

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The Hypotheses

- We wish to compare proportions between **two populations**.
- We should compare proportions for the same attribute in order for it to make sense.
- For example, we could measure the proportion of NC residents living below the poverty level and the proportion of VA residents living below the poverty level.
 - Populations - people in NC and VA.
 - Variable - whether the resident is living below the poverty level.

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The Hypotheses

- The “gender gap” refers to the difference between the proportion of men who vote Republican and the proportion of women who vote Republican.
- There are several ways to view this.
 - Two populations (males and females), one variable (how one votes).
 - Two populations (Dems and Reps), one variable (one’s sex).
 - One population, two variables (sex, vote).

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- The proportion of patients given treatment A who recovered vs. the proportion of patients given treatment B who recovered.
 - p_1 = recovery rate under treatment A .
 - p_2 = recovery rate under treatment B .
- The important question is, which is greater, p_1 or p_2 ?

Comparing proportions

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The Hypotheses

- We will work with the single number $p_1 - p_2$.
- To estimate the difference between population proportions p_1 and p_2 , we will use the sample proportions \hat{p}_1 and \hat{p}_2 .
- The sample difference $\hat{p}_1 - \hat{p}_2$ is an estimator of the population difference $p_1 - p_2$.

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Article

City Hall turmoil: Richmond Times-Dispatch poll

- Test the hypothesis that a higher proportion of men than women believe that Mayor Wilder is doing a good or excellent job as mayor of Richmond.

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- Let p_1 = proportion of men who believe that Mayor Wilder is doing a good or excellent job.
- Let p_2 = proportion of women who believe that Mayor Wilder is doing a good or excellent job.

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The Hypotheses

- The data:

- 500 people surveyed.
- 48% were male; 52% were female.
- 41% of men rated Wilder's performance good or excellent.
- 37% of men rated Wilder's performance good or excellent.

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Hypothesis Testing Procedure

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- The hypotheses.

$$H_0 : p_1 = p_2$$

$$H_1 : p_1 > p_2$$

- The significance level is $\alpha = 0.05$.
- What is the test statistic?
- That depends on the sampling distribution of $\hat{p}_1 - \hat{p}_2$.
- Here we go again...

The Sampling Distribution of $\hat{p}_1 - \hat{p}_2$

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- If the sample sizes are large enough, then \hat{p}_1 is $N(p_1, \sigma_{\hat{p}_1})$, where

$$\sigma_{\hat{p}_1} = \sqrt{\frac{p_1(1 - p_1)}{n_1}}$$

and \hat{p}_2 is $N(p_2, \sigma_{\hat{p}_2})$, where

$$\sigma_{\hat{p}_2} = \sqrt{\frac{p_2(1 - p_2)}{n_2}}$$

The Sampling Distribution of $\hat{p}_1 - \hat{p}_2$

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- The sample sizes will be large enough if
 - $n_1 p_1 \geq 5$, and $n_1(1 - p_1) \geq 5$, and
 - $n_2 p_2 \geq 5$, and $n_2(1 - p_2) \geq 5$.

Statistical Facts, Again

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The Hypotheses

- Recall the statistical facts.
- For any two random variables X and Y ,

$$\mu_{X-Y} = \mu_X - \mu_Y$$

$$\sigma_{X-Y}^2 = \sigma_X^2 + \sigma_Y^2$$

$$\sigma_{X-Y} = \sqrt{\sigma_X^2 + \sigma_Y^2}$$

- Furthermore, if X and Y are both normal, then $X - Y$ is normal.

The Sampling Distribution of $\hat{p}_1 - \hat{p}_2$

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- Therefore, $\hat{p}_1 - \hat{p}_2$ is normal with

$$\mu_{\hat{p}_1 - \hat{p}_2} = p_1 - p_2$$

$$\sigma_{\hat{p}_1 - \hat{p}_2}^2 = \sigma_{\hat{p}_1}^2 + \sigma_{\hat{p}_2}^2 = \frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}$$

$$\sigma_{\hat{p}_1 - \hat{p}_2} = \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}$$

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- Therefore, the test statistic **would be**

$$Z = \frac{(\hat{p}_1 - \hat{p}_2) - 0}{\sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}}$$

except that...

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- ...we do not know the values of p_1 and p_2 .
- We will approximate p_1 and p_2 with \hat{p}_1 and \hat{p}_2 .
- Therefore, the test statistic **would be**

$$Z = \frac{(\hat{p}_1 - \hat{p}_2) - 0}{\sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}}$$

except that...

Pooled Estimate of p

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- ...we can do better.
- The null hypothesis is

$$H_0 : p_1 = p_2$$

- Under that assumption,

\hat{p}_1 and \hat{p}_2 are both estimators of a common value, which we will call p .

Pooled Estimate of p

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- Rather than use either \hat{p}_1 or \hat{p}_2 alone to estimate p , we will use the **pooled estimate**.
- The pooled estimate is the proportion that we would get if we pooled the two samples together into one.
- We would have a total count of $x_1 + x_2$ members out of a sample of $n_1 + n_2$, for a pooled proportion of

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2}.$$

The Test Statistic

- This leads to a better estimator of the standard deviation of $\hat{p}_1 - \hat{p}_2$.

$$\sigma_{\hat{p}_1 - \hat{p}_2} = \sqrt{\hat{p}(1 - \hat{p}) \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}.$$

- So the test statistic is

$$Z = \frac{(\hat{p}_1 - \hat{p}_2) - 0}{\sqrt{\hat{p}(1 - \hat{p}) \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}},$$

where

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2}.$$

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- In the survey, we had 240 males (48%) and 260 females (52%).
- 41% of the males, or 98 males, said Wilder is doing good or excellent.
- 37% of the females, or 96 females, said he is doing good or excellent.
- Therefore, altogether, 194 people out of 500, or 38.8%, said he is doing good or excellent.

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The Hypotheses

- Now compute

$$\sigma_{\hat{p}_1 - \hat{p}_2} = \sqrt{(0.388)(0.612) \left(\frac{1}{240} + \frac{1}{260} \right)} = 0.04362.$$

- For comparison, estimate $\sigma_{\hat{p}_1 - \hat{p}_2}$ without using the pooled estimate. There will not be much difference. Nevertheless, we should always use the pooled estimate.

The Value of the Test Statistic

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- Now compute z :

$$z = \frac{0.04}{0.04362} = 0.9170.$$

- Compute the p -value:

$$P(Z > 0.9170) = 0.1796.$$

- Accept H_0 .
- Equal proportions of men and women believe that Mayor Wilder is doing a good or excellent job.

Turmoil at City Hall, Continued

Independent
Samples:
Comparing
Proportions

Robb T.
Koether

Confidence
Intervals for
 $\mu_1 - \mu_2$

Confidence
Intervals for
 $\mu_1 - \mu_2$ on
the TI-83

Introduction to
Proportions

Comparing
Proportions

Example -
Turmoil at City
Hall

The
Hypothesis
Testing for
 $p_1 - p_2$

The Hypotheses

- Do equal proportions of whites and blacks believe that Mayor Wilder is doing a good or excellent job?
- Do equal proportions of Republicans and Democrats believe that Mayor Wilder is doing a good or excellent job?
- Let's learn how to do this on the TI-83 and then test those hypotheses.

Summary

Summary

- The point estimate for $p_1 - p_2$ is $\hat{p}_1 - \hat{p}_2$.
- The sampling distribution of $\hat{p}_1 - \hat{p}_2$ is normal with

$$\mu_{\hat{p}_1 - \hat{p}_2} = p_1 - p_2$$

and

$$\sigma_{\hat{p}_1 - \hat{p}_2} = \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}.$$

- However, we use the pooled estimate

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2}$$

in place of both p_1 and p_2 in the formula.

- Otherwise, the hypothesis-testing procedure is the same as before.