10.1 Sampling Distribution of Differences between 2 independent sample means

How is this different?

G: * random samples of 30 males and 30 females
* tested frame of reference, pointed S, error recorded
* table of pointing errors, in degrees, with:

MALE					FEMALE				
13	68	60	22	30	14	78	18	32	80
130	18	5	70	8	8	69	35	35	91
39	3	9	58	20	20	111	111	12	68
33	11	59	3	67	3	3	109	27	66
10	38	5	167	26	138	128	36	8	176
13	23	86	15	19	122	31	27	3	15

$\overline{X}_M = 37.6$ $\overline{X}_F = 55.8$

$S_M = 38.5$ $S_F = 48.3$

<- New is 2 sample test. Previous (below) is 1-sample test.

G: BTUs consumed/household/year in US:
$\mu = 92.2$ mill BTU, n.d., $\sigma = 15$ mill BTU
n = 20 household in West US (mill BTUs)

104	84	72	95	69
80	78	74	76	81
82	61	94	65	100
70	65	83	76	84

F: Do households in the West US use a different amount of energy?

F: At the 1% significance level, do the data provide sufficient evidence to conclude that, on average, males have a better sense of direction and, in particular, a better frame of reference than females?

from 10.2

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Statistics Home Page Class Notes

10.1 Sampling Distribution of Differences between 2 Independent sample means
10.2 Two Population Means: = σ's ***Pooled t-test***
10.3 Two Population Means: σs NOT equal ***Non-Pooled t-test***

GOALS:
1. Consider how two samples can be compared to determine if they are the same or different or come from the same or different populations.
2. Consider the distribution of the difference of sample means, including:
- the mean of the difference
- the standard deviation of the difference
3. Use the Pooled-t Test to compare sample means when $\sigma_1 = \sigma_2$
4. Use the Non-Pooled t Test to compare means when $\sigma_1 \neq \sigma_2$

Read Ch. 10.1, Study Key Fact 10.1
Study Ch. 10.2, # 33-43, 48, 49
Study Ch. 10.3, 67-70 all, 73-77(no CI), 81, 83

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10.1 Sampling Distribution of Differences between 2 independent sample means

How do we start to compare the males and females?

Know that mean for males is ~ nd for large samples.
Know that mean for females is ~ nd for large samples.

How do we compare them?

$\bar{X}_M = 37.6$ $\bar{X}_F = 55.8$

$S_M = 38.5$ $S_F = 48.3$

We see that: mean for males < mean for females

or $\bar{X}_M < \bar{X}_F$

or $\bar{X}_M - \bar{X}_F < 0$

or

$\bar{X}_1 = \bar{X}_2$

$\bar{X}_1 - \bar{X}_2 = 0$

$\bar{X}_1 - \bar{X}_2$

or

$\bar{X}_1 > \bar{X}_2$

$\bar{X}_1 - \bar{X}_2 > 0$

$\bar{X}_1 - \bar{X}_2$

We need to examine the distribution of

$$\bar{X}_M - \bar{X}_F$$

In general: the distribution of $\bar{X}_1 - \bar{X}_2$

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10.1 Sampling Distribution of Differences between 2 independent sample means

the distribution of $\bar{X}_1 - \bar{X}_2$

If x is ~ nd on each of the populations 1 and 2, then $\bar{X}_1 - \bar{X}_2$ is ~nd and:

$$\mu_{\bar{X}_1 - \bar{X}_2} = \mu_1 - \mu_2$$

$$\sigma_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

Chapter 7

comparison

Mean of the Sample Mean

$$\mu_{\bar{x}} = \mu$$

Standard Deviation of the Sample Mean

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

Standard Error (of the Mean)

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} = \sqrt{\frac{\sigma^2}{n}}$$

$$\sigma = \sqrt{\sigma^2}$$

$$\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$$

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10.1 Sampling Distribution of Differences between 2 independent sample means

When σ is known, can standardize to SNC,

But **rarely have a known σ, so will not consider a z test**

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

No, z test

Instead, either of two *t*-tests: **σ_1, σ_2 unknown**

Yes, 2 t - tests

- $\sigma_1 = \sigma_2$ --> pooled ***t***

  s_1 and s_2 are estimates of same σ

- $\sigma_1 \neq \sigma_2$ --> non-pooled ***t***

  s_1 and s_2 are not known to estimate same σ

10.2 Two Population Means: = σ's

Instead, either of two *t*-tests:

- $\sigma_1 = \sigma_2$ --> pooled ***t***

  s_1 and s_2 are estimates of same σ

Using s_1 and s_2 as estimates of same σ, s_p is computed by weighting each sample s by the size of the sample it represents.

$$s_p = s_{pooled} = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

$$df = n_1 + n_2 - 2$$

No need to memorize. Use textbook, ***pooled-t test***, and copy formula down in your solution.

10.2 Two Population Means: = σ's

$\sigma_1 \neq \sigma_2$ Non-Pooled t Test

s_1 and s_2 are estimates of σ_1 and σ_2, so there are actually 4 variables: s_1, s_2, $\bar{X}_1$, $\bar{X}_2$

This requires a different way to compute the **Degrees of Freedom**

$$\Delta = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$$

will get from calculator,

write df value for a problem.

Wikipedia

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10.2 Two Population Means: = σ's

Pooled - t Test

Assumptions: 1. SRS, 2. Independent samples 3. ND or large samples 4. = σ's

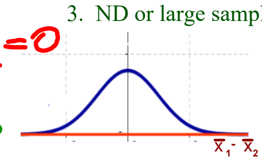
NonPooled - t Test

Assumptions: 1. SRS, 2. Independent samples 3. ND or large samples 4 ≠ σ's

Step 1: H_0: $\mu_1 = \mu_2$ $\mu_1 - \mu_2 = 0$

H_a: $\mu_1 \neq \mu_2$ or $\mu_1 < \mu_2$ or $\mu_1 > \mu_2$

$\mu_1 - \mu_2 \neq 0$ $\mu_1 - \mu_2 < 0$ $\mu_1 - \mu_2 > 0$



Step 2: Decide α and sketch

Step 3: Compute test statistic: $t_T = \frac{(\bar{x}_1 - \bar{x}_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$

where $s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$ $df = n_1 + n_2 - 2$

NonPooled: $t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

$$\Delta = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$$

Step 4: Find P-value

Step 5: Decide whether to reject H_0 or not : Reject H_o if $p \leq \alpha$

Step 6: Verbal interpretation NOT Reject H_o if $p > \alpha$

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Two events are independent if the occurrence of one does not change the probability of the occurrence of the other.

10.2 Two Population Means: = σ's

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* table of pointing errors, in degrees, with:

MALE					FEMALE				
13	68	60	22	30	14	78	18	32	80
130	18	5	70	8	8	69	35	35	91
39	3	9	58	20	20	111	111	12	68
33	11	59	3	67	3	3	109	27	66
10	38	5	167	26	138	128	36	8	176
13	23	86	15	19	122	31	27	3	15

$\overline{X}_M = 37.6$ $\overline{X}_F = 55.8$

$s_M = 38.5$ $s_F = 48.3$

F: At the 1% significance level, do the data provide sufficient evidence to conclude that, on average, males have a better sense of direction and, in particular, a better frame of reference than females?

Pooled? or Non-Pooled?

Pooled - t Test

Assumptions: 1. SRS,
3. ND or large samples

Step 1: H_0: $\mu_1 = \mu_2$
H_a: $\mu_1 \neq \mu_2$ or μ_1

Step 2: Decide α and sketch

Step 3: Compute test statistic

where

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s}{n_1 + n_2 - 2}}$$

Step 4: Find P-value

Step 5: Decide whether to re

Step 6: Verbal interpretation

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10.2 Two Population Means: = σ's

G: * random samples of 30 males and 30 females
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$\bar{X}_M = 37.6$ $s_M = 38.5$

$\bar{X}_F = 55.8$ $s_F = 48.3$

F: At the 1% significance level, do the data provide sufficient evidence to conclude that, on average, males have a better sense of direction and, in particular, a better frame of reference than females?

3. ND or large samples 4. = σs

Step 1: H_0: $\mu_1 = \mu_2$
H_a: $\mu_1 \neq \mu_2$ or $\mu_1 < \mu_2$ or $\mu_1 > \mu_2$

Step 2: Decide α and sketch

Step 3: Compute test statistic: $t = \dfrac{(\bar{x}_1 - \bar{x}_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$

where $s_p = \sqrt{\dfrac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2 - 2}}$

Step 4: Find P-value OR Find CV(s)

df = $n_1 + n_2 - 2$ Table IV

Step 5: Decide whether to reject H_0 or not

Step 6: Verbal interpretation

df = 58

1) A: SRS, ~n.d, indep, =σ's

σ = ? $\frac{48.3}{38.5} \approx 1.25$ not very different

2) $H_0: \mu_M = \mu_F$ $H_a: \mu_M < \mu_F$

3) $\alpha = 0.01$

4) $t = \dfrac{\bar{x}_M - \bar{x}_F}{s\sqrt{\frac{1}{n_M} + \frac{1}{n_F}}} = \dfrac{37.6 - 55.8}{43.6\sqrt{\frac{1}{30} + \frac{1}{30}}} = -1.614$

P-.056 $t_c = -2.39$ −1.614

5) $s_p = \sqrt{\dfrac{(n_M-1)s_M^2 + (n_F-1)s_F^2}{n_M + n_F - 2}} = \sqrt{\dfrac{29(38.5)^2 + 29(48.3)^2}{58}} = 43.676$

$df = n_1 + n_2 - 2 = 58$

P = 0.056

6) P = 0.056 > .01 = α
∴ Do NOT rej. H_0.

7) At the 1% s.l., the evidence is insufficient to declare that males have a better frame of reference than females.

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10.3 Two Population Means: σs NOT equal

G: Seasgrass taller, thicker in Corpus Christy Bay than in Lower Laguna Madre. To compare ammonium concentrations, collected random samples. A normal probability plot of the Laguna Madre data was approximately a straight line.

At the 1% significance level, is the mean ammonium concentration in Corpus Christy Bay larger than that in Lower Laguna Madre?

$\bar{X}_c = 115.1$, $s_c = 79.4$, $n_c = 51$
$\bar{X}_L = 24.3$, $s_L = 10.5$, $n_L = 19$

Pooled? or Non-Pooled?

$t = \dfrac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

$\Delta = \dfrac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$

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10.3 Two Population Means: σs NOT equal

non-pooled

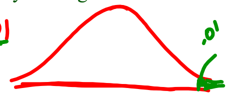
G: Seasgrass taller, thicker in Corpus Christy Bay than in Lower Laguna Madre. To compare ammonium concentrations, collected random samples. A normal probability plot of the Laguna Madre data was approximately a straight line.

Independent

At the 1% significance level, is the mean ammonium concentration in Corpus Christy Bay larger than that in Lower Laguna Madre?

$\alpha = 0.01$

Non-pooled-t



$\bar{x}_c = 115.1$, $s_c = 79.4$, $n_c = 51$

$\bar{x}_L = 24.3$, $s_L = 10.5$, $n_L = 19$

A: srs, NPP → norm, indep. $\sigma \neq \sigma$ ∴ non-pooled

① $H_0: \mu_c = \mu_L$

$H_a: \mu_c > \mu_L$

③ $$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{115.1 - 24.3}{\sqrt{\frac{79.4^2}{51} + \frac{10.5^2}{19}}} = 7.962$$

$$\Delta = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}} = 54.47$$

$54 = df$

④ $p = 4.98(10^{-11}) = 0.0000$

⑤ $p = 0.0000 < 0.01 = \alpha$ ∴ rej. H_0

⑥ There is very strong evidence. Concl. Concentration of ammonium at C is greater than at L.

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10.2 Two Population Means: = σ's

Researchers are investigating how the amount of protein in the diet relates to weight gain. They randomly select 19 female rats, and consider their gain in weight between 28 and 84 days after birth. 12 were fed a high protein diet and 7 were fed a low protein diet. At the 95% confidence level, does the high protein diet relate to a higher weight gain?

High protein	134	146	104	119	124	161	107	83	113	129	97	123
Low protein	70	118	101	85	107	132	94					

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10.2 Two Population Means: = σ's

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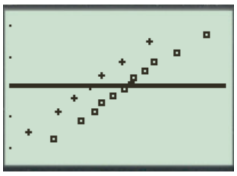
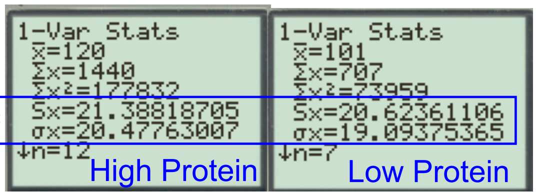
High protein	134	146	104	119	124	161	107	83	113	129	97	123
Low protein	70	118	101	85	107	132	94					

Assumpt: srs, nd?, $\sigma_1 = \sigma_2$? NPP first, confirm nd and $\sigma_1 = \sigma_2$, then finish



~nd ✓

✓ $\sigma_1 = \sigma_2$



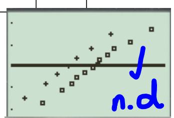
Can use pooled -t procedure.

10.2 Two Population Means: = σ's

Researchers are investigating how the amount of protein in the diet relates to weight gain. They randomly select 19 female rats, and consider their gain in weight between 28 and 84 days after birth. 12 were fed a high protein diet and 7 were fed a low protein diet. At the 95% confidence level, does the high protein diet relate to a higher weight gain?

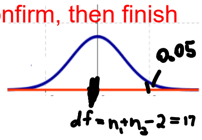
1	High protein	134	146	104	119	124	161	107	83	113	129	97	123
2	Low protein	70	118	101	85	107	132	94					

Assumpt: srs, nd?, $\sigma_1 = \sigma_2$? NPP first, confirm, then finish

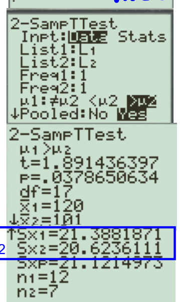


$H_0: \mu_1 = \mu_2$ $\alpha = 1 - .95 = .05$

$H_a: \mu_1 > \mu_2$



Can avoid 1-variable stats and go straight to 2-sample t-test
BUT, be sure to check s_1 and s_2 before proceeding.



$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{120-101}{21.121\sqrt{\frac{1}{12}+\frac{1}{7}}} = 1.891$$

$df = 12+7-2 = 17$

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

$$= \sqrt{\frac{11(21.39)^2 + 6(20.62)^2}{12+7-2}} = 21.121$$

$p = 0.038 < 0.05 = \alpha$ reject H_0 96.2% conf.

Conclude: The high protein diet relates to increased weight gain.

(Note: Cannot reject if a 2-tailed test: p= 2(0.038) = 0.0757 > 0.05)

10.3 Two Population Means: σs NOT equal

randomly select who answers

True or False:

1. pooled-t requires independent samples, but non-pooled t does not.
2. pooled-t requires that population standard deviations can be assumed to be equal, but non-pooled t does not.
3. the non-pooled t test requires degrees of freedom but the pooled t test does not.
4. the pooled t test pools the sample means
5. reject the null hypothesis when p > **a**

ard deviations.

True or False

1. F, 2. T, 3. F, 4. F, 5. F

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10.3 Two Population Means: σs NOT equal

Ch 10 True/False Questions					
	BREAK ROOMS				
Question	1	2	3	4	5
1					
2					
3					
4					
5					

randomly select who

True or False:

1. pooled-t requires independent samples, but non-pooled t does not.
2. pooled-t requires that the standard deviations can assumed to be equal, but non-pooled t does not.
3. the non-pooled t test requires degrees of freedom but the pooled t test does not.
4. the pooled t test pools the sample means
5. reject the null hypothesis when p > α

True or False

1. False. Both require independent samples.
2. True
3. False. All t tests require df.
4. False. The pooled t test pools the sample standard deviations.
5. False. Reject the null hypothesis whenever p≤α

1. F, 2. T, 3. F, 4. F, 5. F

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10.3 Two Population Means: σs NOT equal

If we assume that the population standard deviations are equal, but they are not, how poor an outcome would we expect?

If we find a 95% confidence interval:

% of intervals that contain $\mu_1 - \mu_2$: $\sigma_1 = 10$

assuming equal standard deviations and $\sigma_1 = 10$

n_1	n_2	$\sigma_2 = 2$	$\sigma_2 = 5$	$\sigma_2 = 10$	$\sigma_2 = 20$	$\sigma_2 = 50$
10	10	93.7	94.5	94.9	94.8	93.7
10	20	82.9	88.7	95.0	98.2	98.9
10	40	68.5	81.8	95.0	99.5	99.9

table from JB Statistics

1. Slightly less confidence if same sample sizes.
2. If different sample sizes:
   a) a **BIG** decrease in confidence if the larger sample has a smaller standard deviation.
   b) an increase in confidence if the larger sample has a larger standard deviation.

Conclude: Better to use Non-pooled if there is a question about equal population standard deviations; ie: not sure that $\sigma_1 = \sigma_2$ especially **if the sample sizes are different**.

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10.2 Two Population Means: = σ's

Pooled or Non-pooled Variances: **= ? or Not ?**

• If **sample sizes are equal** and s_1 and s_2 are similar, assumption of equal population variance may be reasonable and the pooled procedure can be used.
• If sample sizes are equal and s_1 and s_2 are different, use non-pooled procedure.

• If sample sizes are **very different** and **s_1 and s_2 are similar**, and the larger sample size produced the larger standard deviation, the pooled procedure is acceptable because it will be conservative.

• If sample sizes are very different and **s_1 and s_2 are different**, **do not use** the pooled procedure. The pooled test can be quite misleading unless sample standard deviations are similar, especially if the smaller standard deviation accompanies the larger sample size.

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10.3 Two Population Means: σs NOT equal

students set up

G: Efforts to reduce disabilities of bus drivers by improving bus routes (intervention) to alleviate stress. Heart rates of drivers on improved routes were compared to that of drivers on normal routes (control).
G: Independent - diff. drivers, srs, nd

At the 5% significance level, does the intervention reduce the mean heart rate in bus drivers?

$\bar{x}_I = 67.90, \quad s_I = 5.49, \quad n_I = 10$
$\bar{x}_c = 66.81, \quad s_c = 9.04, \quad n_c = 31$

9.04/5.49=1.6
could use pooled...
But, 31/10=3.1

Calculator: 2 Sample t Test
STAT/TESTS
2-SampTTest
Stats/
mean1: ___
s1: ___
n1: ___
mean2: ___
s2: ___
n2: ___
μ1: ≠μ2 <μ2 >μ2
Pooled: No Yes
calculate

Approach:
What kind of problem is this? *"At 1% s.l..." -> hypothesis test*
Which procedure?
2 samples -> either pooled-t or non-pooled-t (at this point)
Need nd for both: Given
Need $\sigma_1 = \sigma_2$ for pooled-t but $n_C > n_I$ and $s_C > s_I$, so pooled would be conservative; use NON-pooled

$$\Delta = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$$

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10.3 Two Population Means: σs NOT equal

students set up

G: Efforts to reduce disabilities of bus drivers by improving bus routes (intervention) to alleviate stress. Heart rates of drivers on improved routes were compared to that of drivers on normal routes (control). (Independent - diff. drivers, srs, nd)

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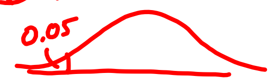
$\bar{x}_c = 66.81, \quad s_c = 9.04, \quad n_c = 31$

① $H_0: \mu_I = \mu_c \quad H_a: \mu_I < \mu_c$ ② $\alpha = 0.05$



③ $t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{67.90 - 66.81}{\sqrt{\frac{5.49^2}{10} + \frac{9.04^2}{31}}}$

$= 0.459$

$$\Delta = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\left[\frac{s_1^2}{n_1}\right]^2 + \left[\frac{s_2^2}{n_2}\right]^2} = \frac{\left[\frac{5.49^2}{10} + \frac{9.04^2}{31}\right]^2}{\left(\frac{5.49^2}{10}\right)^2 + \left(\frac{9.04^2}{31}\right)^2} = 25.74$$

df = 25

④ $p = 0.675$

⑤ $p = 0.675 > \alpha = 0.05$ Do NOT rej. H_0.

⑥ Conclude that data is insufficient to support the intervention as a means of reducing mean heart rate of bus drivers.

$$\Delta = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$$

Class Notes: Prof. G. Battaly, Westchester Community College, NY

Statistics Home Page Class Notes Homework

ATTENDANCE QUESTION:

G: Indep. random samples: 126 cropland, 98 grassland, to compare the number of native species. n.d.

Samples	Mean	Stdev	n
Cropland	14.1	4.83	126
Grassland	15.3	4.95	98

F: At 5% s.l. does a difference exist in the mean number of native species?

Which procedure should you use to answer the question?

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Statistics Home Page

Class Notes

Attachments

HypTestingFunPuzzle_2means.notebook