## 10.2 Two Population Means: =σ's ***Pooled t-test***

GOALS:

1. Compare 2 sample means when the population standard deviations are believed to be the same but are not known.
2. Use the distribution of the difference between the sample means to evaluate the samples.
3. Arrive at a conclusion: are the means from the same population or are they different?

Study Ch. 10.2, # 33-43 (27-37), 48 (42), 49
[old 43 different]

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## 10.2 Two Population Means: =σ's

Can standardize to SNC, but rarely have a known δ, so will not consider a z test (p.492)

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

Recap

Instead, either of two *t*-tests:

- $\sigma_1 = \sigma_2$ --> pooled ***t***
  $s_1$ and $s_2$ are estimates of same $\sigma$
- $\sigma_1 \neq \sigma_2$ --> non-pooled ***t***
  $s_1$ and $s_2$ are not known to estimate same $\sigma$

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## 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 $\sigma$

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

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

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



## 10.2 Two Population Means: =σ's

### *Pooled - t Test*

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

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

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 $\mu_1 > \mu_2$

Step 2: Decide $\alpha$ and sketch

Step 3: Compute test statistic: $t_T = \dfrac{(\bar{x}_1 - \bar{x}_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$ $-(\mu_1 - \mu_2)$

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

compare to previous:
$\dfrac{\bar{x} - \mu}{s/\sqrt{n}} = t_T$
Is anything missing?

Step 4: Find P-value

Step 5: Decide whether to reject $H_0$ or not

Step 6: Verbal interpretation

## 10.2 Two Population Means: =σ's

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 |

$\bar{x}_M = 37.6$ $s_M = 38.5$

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

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?

***Pooled - 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 $\mu_1 > \mu_2$

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

Step 4: Find P-value

Step 5: Decide whether to reject $H_0$ or not

Step 6: Verbal interpretation

Note: Test of standard dev (2 sample F test) gets p=0.1140.
So, better to use non-pooled t. For means tests:
Pooled-t: p=.0560 df=58 | Non-Pooled-t: p= 0.056 df=55

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## 10.2 Two Population Means: =σ's

G: * samples of 30 males and 30 females (srs, ~n.d., indep.)
* 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 |
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| 33 | 11 | 59 | 3 | 67 | 3 | 3 | 109 | 27 | 66 |
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| 13 | 23 | 86 | 15 | 19 | 122 | 31 | 27 | 3 | 15 |

$\bar{x}_M = 37.6$ $s_M = 38.5$ } $\sigma_M = \sigma_F$ ?

test $\bar{x}_F = 55.8$ $s_F = 48.3$

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?

***Pooled ? t Test***

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

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
$df = n_1 + n_2 - 2$ Table IV

Step 5: Decide whether to reject $H_0$ or not

Step 6: Verbal interpretation

Note: Test of standard dev (2 sample F test) gets p=0.1140.
So, better to use non-pooled t. For means tests:
Pooled-t: p=.0560 df=58 | Non-Pooled-t: p= 0.056 df=55

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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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# 10.2 Two Population Means: = σ's

3. ND or large samples 4. = σ's

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* tested frame of reference, pointed S, error recorded
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| MALE | | | | | FEMALE | | | | |
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| 10 | 38 | 5 | 167 | 26 | 138 | 128 | 36 | 8 | 176 |
| 13 | 23 | 86 | 15 | 19 | 122 | 31 | 27 | 3 | 15 |

df = 58

$\bar{x}_M = 37.6$ $s_M = 38.5$

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

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?

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: $t = \frac{(\bar{x}_1 - \bar{x}_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$

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

Step 4: Find P-value OR Find CV(s)
df = $n_1 + n_2 - 2$ Table IV

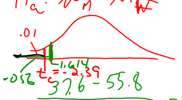
Step 5: Decide whether to reject $H_0$ or not

Step 6: Verbal interpretation

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

① $H_0: \mu_M = \mu_F$ $H_a: \mu_M < \mu_F$

② $\alpha = 0.01$



③ $t = \frac{\bar{x}_M - \bar{x}_F}{s\sqrt{\frac{1}{n_M} + \frac{1}{n_F}}} = \frac{37.6 - 55.8}{43.676\sqrt{\frac{1}{30} + \frac{1}{30}}} = -1.614$

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

④ $p = 0.056$

⑤ $p = 0.056 > .01 = \alpha$
∴ Do NOT rej. $H_0$

⑥ At the 1% s.l., males do not have a better frame of reference than females.

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## 10.2 Two Population Means: = σ's

G: independent SRS, n.d. F: Can use pooled t test?

G: $\bar{x}_1 = 115.1$, $s_1 = 79.4$, $n_1 = 51$
$\bar{x}_2 = 24.3$, $s_2 = 10.5$, $n_2 = 19$

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.
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## 10.2 Two Population Means: = σ's

G: independent SRS, n.d. F: Can use pooled t test?

G: $\bar{x}_1 = 39.04$, $s_1 = 18.82$, $n_1 = 51$
$\bar{x}_2 = 49.92$, $s_2 = 18.97$, $n_2 = 53$

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.
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Yes

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G: independent SRS, n.d. F: Can use pooled t test?

G: $\bar{x}_1 = 39.04$, $s_1 = 18.82$, $n_1 = 51$
$\bar{x}_2 = 49.92$, $s_2 = 18.97$, $n_2 = 53$

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

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Yes

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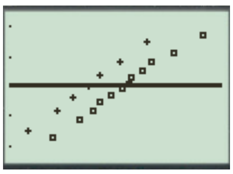
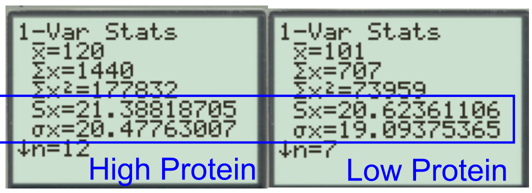
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High protein | 134 | 146 | 104 | 119 | 124 | 161 | 107 | 83 | 113 | 129 | 97 | 123 |
| Low protein | 70 | 118 | 101 | 85 | 107 | 132 | 94 | | | | | |

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.

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## 10.2 Two Population Means: = σ's

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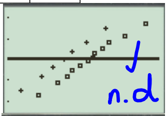
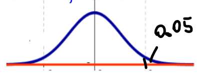
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High protein | 134 | 146 | 104 | 119 | 124 | 161 | 107 | 83 | 113 | 129 | 97 | 123 |
| Low protein | 70 | 118 | 101 | 85 | 107 | 132 | 94 | | | | | |

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




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

$H_a: \mu_1 > \mu_2$




$df = n_1 + n_2 - 2 = 17$

```
2-SampTTest
 Inpt:Data Stats
 List1:L1
 List2:L2
 Freq1:1
 Freq2:1
 μ1:≠μ2 <μ2 >μ2
↓Pooled:No Yes
```

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.

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

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

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

$= 21.121$

```
2-SampTTest
 μ1>μ2
 t=1.891436397
 p=.0378650634
 df=17
 x̄1=120
↓x̄2=101
↑Sx1=21.3881871
 Sx2=20.6236111
 Sxp=21.1214973
 n1=12
 n2=7
```

$\sigma_1 = \sigma_2$

$p = 0.038 < 0.05 = \alpha$
reject $H_0$

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)*



## 10.2 Two Population Means: = σ's

practice for procedure

G: independent SRS, n.d. F: Use pooled t test: a) 2-tailed $\alpha = 0.05$
b) 95% CI

G: $\bar{x}_1 = 10$, $s_1 = 4$, $n_1 = 15$
$\bar{x}_2 = 12$, $s_2 = 5$, $n_2 = 15$

***Pooled - t Test***

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

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 $\alpha$ and sketch

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

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

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

-5.39 to 1.39
t=-1.21 P=0.237 not rej

## 10.2 Two Population Means: = σ's

practice for procedure

G: independent SRS, n.d. F: Use pooled t test: a) 2-tailed $\alpha=0.05$
b) 95% CI

G: $\bar{x}_1 = 10$, $s_1 = 4$, $n_1 = 15$
$\bar{x}_2 = 12$, $s_2 = 5$, $n_2 = 15$

Calculator: CI for 2 means: Pooled-t Interval
STAT/TESTS
2-SampTInt
Stats/
mean1: 10
s1: 4
n1: 15
mean2: 12
s2: 5
n2: 15
C-level: 95
Pooled: yes
calculate

t=-1.21 P=0.237 not rej
-5.39 to 1.39



## 10.2 Two Population Means: = σ's

practice for procedure

G: independent SRS, n.d. F: Use pooled t test: a) left-tailed $\alpha=0.05$

G: $\bar{x}_1 = 20$, $s_1 = 4$, $n_1 = 10$
$\bar{x}_2 = 23$, $s_2 = 5$, $n_2 = 15$

t=-1.59 P=0.063 not rej
-6.24 to 0.24



## 10.2 Two Population Means: = σ's

practice for procedure

G: independent SRS, n.d. F: Use pooled t test: a) right-tailed $\alpha=0.05$

G: $\bar{x}_1 = 20$, $s_1 = 4$, $n_1 = 30$
$\bar{x}_2 = 18$, $s_2 = 5$, $n_2 = 40$

t=1.80 P=0.038 rej
0.15 to 3.85

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## 10.2 Two Population Means: = σ's

p. 505 #37

G: srs, independent samples of native species in two habitats

| | Cropland | Wetland |
|---|---|---|
| mean | 14.06 | 15.36 |
| stdev | 4.83 | 4.95 |
| n | 126 | 98 |

F: At the 5% significance level, is there a difference in the mean number of native species?

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| | Cropland | Wetland |
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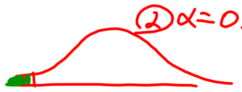
| mean | 14.06 | 15.36 |
| stdev | 4.83 | 4.95 |
| n | 126 | 98 |

F: At the 5% significance level, is there a difference in the mean number of native species?

srs, indep, n large > ~ nd, = σ's

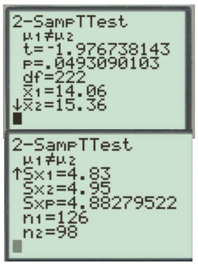
① $H_0: \mu_1 = \mu_2$  $H_a: \mu_1 \neq \mu_2$

② $\alpha = 0.05$



③ $t = \dfrac{\bar{x}_1 - \bar{x}_2}{s_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \dfrac{14.06 - 15.36}{4.883\sqrt{\frac{1}{126}+\frac{1}{98}}} = -1.977$

$s_p = \sqrt{\dfrac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\dfrac{125(4.83)^2 + 97(4.95)^2}{126+98-2}} = 4.883$




④ df = 222  p = 0.0493

⑤ $p = 0.0493 < \alpha = 0.05$
∴ rej. $H_0$

⑥ Conclude: there is a difference in the mean number of native species between cropland and wetlands.

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