**i-Test Example**

This second example of the independent-groups (independent-samples, between-subjects) d-test compares teacher satisfaction at public and charter schools, but, this time, notice that the variability among teachers' ratings is much lower. In the previous example given in class, the two means were the same, 6 vs. 9, for public and charter, respectively. The variances in the first example were 10 for public and 4 for charter \((s = 3.16 \text{ and } s = 2)\), and the calculated \(i\)-value was not significant, \(i(8) = -1.80, \text{ ns}^1\).

### Second Teacher Satisfaction Example

<table>
<thead>
<tr>
<th>Public</th>
<th>Charter</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

\[ \overline{Y}_1 = 6 \quad \overline{Y}_2 = 9 \]
\[ s^2 = 4 \quad s^2 = 1 \]

#### Compute the pooled variance

\[
s_{pooled}^2 = \left[ \frac{n_1 - 1}{n_1 + n_2 - 2} \right] s_1^2 + \left[ \frac{n_2 - 1}{n_1 + n_2 - 2} \right] s_2^2
\]

\[
= \left[ \frac{5 - 1}{5 + 5 - 2} \right] 4 + \left[ \frac{5 - 1}{5 + 5 - 2} \right] 1
\]

\[
= \left[ \frac{4}{8} \right] 4 + \left[ \frac{4}{8} \right] 1
\]

\[
= 2 + .5 = 2.5
\]

[Formulas are on pp. 129-130 of Myers, Well, & Lorch (2010). A simpler formula for \(s_{pooled}^2\), Eq 6.8 on p. 130, can be used if group sample sizes are equal.]

\[ s_{pooled} = \sqrt{s_{pooled}^2} = \sqrt{2.5} = 1.58 \]

#### Compute the standard error of the differences

\[ s_{\overline{Y}_1-\overline{Y}_2} = s_{pooled} \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \]

\[ = 1.58 \sqrt{\frac{1}{5} + \frac{1}{5}} \]

\[ = 1.58 \sqrt{\frac{4}{5}} \]

\[ = (1.58)(.63) \]

\[ = 1.00 \]

#### Compute \(t\)

\[ t = \frac{\overline{Y}_1 - \overline{Y}_2}{s_{\overline{Y}_1-\overline{Y}_2}} \]

\[ = \frac{6 - 9}{1} \]

\[ = -3 \]

#### Compute the 95\% confidence interval

\[ CI = (\overline{Y}_1 - \overline{Y}_2) \pm \left( t_{df, \alpha/2} s_{\overline{Y}_1-\overline{Y}_2} \right) \]

\[ = -3 \pm \left( (2.306)(1) \right) \]

\[ = -3 \pm 2.306 \]

\[ = -5.306, -.649 \]

\( t_{df, \alpha/2} \) is the critical value of \(t\) from the \(t\)-table with the appropriate \(df\) for a two-tailed test indicated by \(\alpha/2\).

Note that it is traditional to report positive values for the \(t\) and the accompanying confidence interval, because which direction you subtract is arbitrary. So, most authors would report a \(t\)-value of 3.00 here and CI of \(-.65, .51\).

#### Compute Cohen's \(d\) standardized effect size measure

\[ d = \frac{\overline{Y}_1 - \overline{Y}_2}{s_{pooled}} \]

\[ = \frac{6 - 9}{1.58} \]

\[ = \frac{3}{1.58} = 1.89 \]

---

1 The use of \(ns\) for “nonsignificant” is no longer indicated by the current version of the APA style manual. The exact \(p\)-value is supposed to be given (unless \(p < .001\)) whether the statistic is significant or not. In the case of hand computation, there is not a choice.
The degrees of freedom for a between-groups \( t \)-test are \( df = n_1 + n_2 - 2 = 10 - 2 = 8 \). The two-tailed critical value of \( t \) (obtained from the Table C.3 in the back of the text) if \( \alpha = .05 \) is equal to 2.306. If the negative sign for the calculated \( t \)-value is ignored, the calculated value exceeds the critical value, so the difference is significant at the \( \alpha = .05 \) level.

**Syntax**

```
t-test groups=type(0,1) /variables=satisfaction.
```

*side-by-side (or above and below) plots (suppressed to save space).

```
xamine variables=satisfaction by type /plot=histogram /statistics=none /nototal.
```

```
xamine variables=satisfaction by type /plot=boxplot /statistics=none /nototal.
```

**SPSS Menus Steps**

Analyze \( \rightarrow \) Compare Means \( \rightarrow \) Independent Samples t-test. Move over the test variable and grouping variable to the appropriate boxes. “Test Variable” is the dependent variable and “Grouping Variable” is the variable indicating the two groups (e.g., treatment and control groups). Click “Define groups”: Place the two values of the grouping variable into the boxes for Group 1 and Group 2 (values are 0 and 1 in my data set). Click “Continue”. “Ok.”

**SPSS Output**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>public</td>
<td>5</td>
<td>6.00</td>
<td>2.000</td>
<td>.894</td>
</tr>
<tr>
<td>charter</td>
<td>5</td>
<td>9.00</td>
<td>1.000</td>
<td>.447</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>t</th>
<th>df</th>
<th>Sig (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>rating of school</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances</td>
<td></td>
<td></td>
<td>-.3000</td>
<td>8</td>
<td>.017</td>
<td>-3.000</td>
<td>1.000</td>
<td>-5.306 - -5.694</td>
</tr>
<tr>
<td>assumed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances</td>
<td></td>
<td></td>
<td>-.3000</td>
<td>5.882</td>
<td>.025</td>
<td>-3.000</td>
<td>1.000</td>
<td>-5.459 - -5.541</td>
</tr>
<tr>
<td>not assumed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Independent Samples Effect Sizes**

<table>
<thead>
<tr>
<th></th>
<th>Cohen’s d</th>
<th>Point Estimate</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standardizer</td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>rating of school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohen’s d</td>
<td>1.691</td>
<td>-1.897</td>
<td>-3.490</td>
</tr>
<tr>
<td>Hedges correction</td>
<td>1.752</td>
<td>-1.713</td>
<td>-3.089</td>
</tr>
<tr>
<td>Glass’s delta</td>
<td>1.600</td>
<td>-3.000</td>
<td>-5.315</td>
</tr>
</tbody>
</table>

* The denominator used in estimating the effect sizes.
  * Cohen’s \( d \) uses the pooled standard deviation.
  * Hedges’s correction uses the pooled standard deviation, plus a correction factor.
  * Glass’s \( d \) uses the sample standard deviation of the control group.

The raw “point estimate” of Cohen’s \( d \) is the most commonly reported effect size measure. See Section 6.7.1 in the Myers et al. (2010) text for information on the Hedges and Glass corrections.

**R**

```
#clear active frame from previous analyses
rm(mydata)
```

```
library(lessR)
mydata = Read("c:/jason/spsswin/uvclass/ttest.sav",quiet=TRUE)
```

```
#obtain t-test
ttest(satisfaction ~ type)
```

```
#lessR generates side-by-side density plots by default
#boxplot by groups-suppressed here to save space
#Plot(satisfaction, by1=type, vbs.plot="boxplot")
```
# Histogram(satisfaction, by1=type)

------ Description ------
satisfaction for type charter: n.miss = 0, n = 5, mean = 9.00, sd = 1.00
satisfaction for type public: n.miss = 0, n = 5, mean = 6.00, sd = 2.00

Within-group Standard Deviation: 1.58

--- Assume equal population variances of satisfaction for each type

t-cutoff: tcut = 2.306
Standard Error of Mean Difference: SE = 1.00
Hypothesis Test of 0 Mean Diff: t = 3.000, df = 8, p-value = 0.017

Margin of Error for 95% Confidence Level: 2.31
95% Confidence Interval for Mean Difference: 0.69 to 5.31

--- Do not assume equal population variances of satisfaction for each type

t-cutoff: tcut = 2.459
Standard Error of Mean Difference: SE = 1.00
Hypothesis Test of 0 Mean Diff: t = 3.000, df = 5.882, p-value = 0.025

Margin of Error for 95% Confidence Level: 2.46
95% Confidence Interval for Mean Difference: 0.54 to 5.46

------ Effect Size ------
--- Assume equal population variances of satisfaction for each type
Sample Mean Difference of satisfaction: 3.00
Standardized Mean Difference of satisfaction, Cohen's d: 1.90
Write-up Example
A t test was used to compare charter and public school teachers on their job satisfaction ratings. On average, charter school teachers had higher satisfaction ratings ($M = 9.00$, $SD = 2$) than public school teachers had ($M = 6.00$, $SD = 1$). This difference was statistically significant, $t(8) = 3.00$, $p = .017$, 95% CI[.69,5.31], indicating that the higher average satisfaction of charter school teachers was more than what would have been expected due to chance. Moreover, the difference between the two groups was large, $d = 1.89$.\(^2\)

\(^2\) Citation for Cohen’s $d$ is considered unnecessary, as it is regarded as a common statistic. For less common statistics or newer statistics, a citation and sometimes a phrase to describe the statistic is needed. Confidence limits are usually recommended—just remember that they are constructed around the mean difference, not the t-value. According to the APA Manual 7th Edition, in the first use, use 95% CI[.], but on subsequent uses drop 95%. 