When to do what?

1. How many separate samples?
   - more than two
     - Independent
   - two
     - Matched or independent samples?
       - matched
         - Independent
       - one
         - How many independent variables?
           - two
           - Repeated Measures ANOVA Chapter 14
           - Related-Samples t Test Chapter 11
           - Independent-Measures t Test Chapter 10
           - Repeated-Measures ANOVA Chapter 14
           - Single-Factor ANOVA Chapter 13
           - Two-Factor ANOVA Chapter 15
       - matched
         - Independent
   - one
     - How many scores for each subject?
       - more than two
         - Related-Samples t Test Chapter 11
         - Single-Sample t Test Chapter 9
         - z-Score Test Chapter 8
       - two
         - z-Score Test Chapter 8
       - one
         - z-Score Test Chapter 8

2. When to do what?
Independent (between) vs. dependent (within) measures designs

- Dependent (within) subjects
  - repeated measures- study in which a sample of individuals is measure more than once (same subject in all Tx conditions; e.g., “ assortative mating,” teen problems)
  - matched samples - each individual in one sample is matched with a subject in another sample (e.g., on race, gender, IQ, age)

Table 11-1 (p. 344)
Reaction time measurements taken before and after taking an over-the-counter cold medication.

<table>
<thead>
<tr>
<th>PERSON</th>
<th>BEFORE MEDICATION ($X_1$)</th>
<th>AFTER MEDICATION ($X_2$)</th>
<th>DIFFERENCE $D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>215</td>
<td>210</td>
<td>-5</td>
</tr>
<tr>
<td>B</td>
<td>221</td>
<td>242</td>
<td>21</td>
</tr>
<tr>
<td>C</td>
<td>196</td>
<td>219</td>
<td>23</td>
</tr>
<tr>
<td>D</td>
<td>203</td>
<td>228</td>
<td>25</td>
</tr>
</tbody>
</table>

$\Sigma D = 64$

$M_D = \frac{\Sigma D}{n} = \frac{64}{4} = 16$
(contd.)

- $H_0$: $\mu_D = 0$
- $H_1$: $\mu_D <> 0$
- recall (C. 9):

$$t = \frac{M - \mu}{S_M}$$

$$t = \frac{M_D - \mu_D}{S_{MD}} \quad S_{MD} = \frac{s^2}{n} \quad \text{or} \quad S_{MD} = \frac{s}{\sqrt{n}}$$

- now consider an example...

**Hypothetical distribution of sample Ds**

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{X}_{11}$</td>
<td>$\bar{X}_{21}$</td>
<td>$\bar{X}<em>{11} - \bar{X}</em>{21}$</td>
</tr>
<tr>
<td>$\bar{X}_{12}$</td>
<td>$\bar{X}_{22}$</td>
<td>$\bar{X}<em>{12} - \bar{X}</em>{22}$</td>
</tr>
<tr>
<td>$\bar{X}_{13}$</td>
<td>$\bar{X}_{23}$</td>
<td>$\bar{X}<em>{13} - \bar{X}</em>{23}$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$\bar{X}_{1n}$</td>
<td>$\bar{X}_{2n}$</td>
<td>$\bar{X}<em>{1n} - \bar{X}</em>{2n}$</td>
</tr>
</tbody>
</table>

- Mean: $\mu_1$, $\mu_2$, $\mu_1 - \mu_2$
- Variance: $\sigma^2_1$, $\sigma^2_2$, $\sigma^2_1 - \sigma^2_2$
- Standard deviation: $\frac{\sigma_1}{\sqrt{N_1}}$, $\frac{\sigma_2}{\sqrt{N_2}}$, $\sqrt{\frac{\sigma^2_1}{N_1} + \frac{\sigma^2_2}{N_2}}$
A sample of \( n = 4 \) is selected from the population. Each individual is measured twice, once in treatment I and once in treatment II, and a difference score, \( D \), is computed for each individual. This sample of difference scores is intended to represent the population. Note that we are using a sample of difference scores to represent a population of difference scores. Specifically, we are interested in the mean difference for the general population. The null hypothesis states that for the general population there is no consistent or systematic difference between the two treatments, so the population mean difference is \( \mu_D = 0 \).

**Table 11.2 (p.348)**

<table>
<thead>
<tr>
<th>Subject</th>
<th>I</th>
<th>II</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>13</td>
<td>-2</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>11</td>
<td>12</td>
<td>1</td>
</tr>
</tbody>
</table>

The number of doses of medication needed for asthma attacks before and after relaxation training.

\[
t = \frac{M_D - \mu_D}{s_{M_D}} = \frac{-3.2 - 0}{.86} = -3.72
\]

\[
M_D = \frac{\Sigma D}{n} = \frac{-16}{5} = -3.2
\]

\[
SS = \Sigma D^2 - \frac{(\Sigma D)^2}{n} = 66 - \frac{(-16)^2}{5}
\]

\[
\frac{\Sigma D^2}{n} = 66 - \frac{51.2}{5} = 14.8
\]

\[
s_{M_D} = \sqrt{\frac{SS}{n-1}} = \sqrt{\frac{14.8}{4}} = 3.7
\]
Figure 11-4 (p. 351)
The sample of difference scores from Example 11.1. The mean is $MD = -3.20$ and the standard deviation is $s = 1.92$. It does not appear that this sample was obtained from a population with a mean of $\mu_D = 0$.

![Diagram showing a sample of difference scores with mean $MD = -3.20$ and standard deviation $s = 1.92$.]

$H_0$: $\mu_D = 0$

Figure 11-3 (p. 349)
The critical regions with $\alpha = .05$ and $df = 4$ begin at $+2.776$ and $-2.776$ in the $t$ distribution. Obtained values of $t$ that are more extreme than these values will lie in a critical region. In that case, the null hypothesis would be rejected.

$\frac{d = \frac{M_D}{s}}{s = 1.92} = 1.67$ Reporting results: $t(4) = -3.72, p < .05, d = 1.67$

![Diagram illustrating critical regions and $t$ distribution with rejection of $H_0$.]
Directional hypotheses and 1-tailed tests (asthma example)

- $D = \text{after} - \text{before} = \text{negative change}$
- $H_0: \mu_D \geq 0$ (medication is not reduced after training)
- $H_1: \mu_D < 0$
- select $\alpha$ (.05)
- collect data and compute $t$
- look up $t$ for $df$, one-tailed test
- make a decision (interpret): relaxation training did significantly reduce meds

Figure 11-5 (p. 352)
The one-tailed critical region for $\alpha$ - .05 in the $t$ distribution with $df = 4$. 

![Graph showing the one-tailed critical region for $t$ distribution with $df = 4$.]
Ho testing with a matched subjects design

- match on age, gender, IQ, SES, etc. in an effort to make the two groups the same, i.e., controlling for age, gender, etc.
- purpose of matching: so differences can be attributed to the treatment (indep var)

Example 11.3:

- Group 1 (Tx new reading program)
- Group 2 (comparison group: regular coursework)
- but... Group 1 kids could be better readers from the start
- thus... match Group 1 (Joe) with Group 2 (Bill) on prior reading achievement scores (so both groups the same at time 1)
- $H_0: \mu_D = 0$ (Tx has no effect on reading)
- $H_1: \mu_D <> 0$ (Tx has an effect, it works!)
Uses and assumptions

- design: repeated or independent measures?
- Number of subjects: repeated measures design is more powerful, hence need fewer subjects
- Studies of change over time: repeated measures
- Individual difference confounds are eliminated in the repeated measures design

Note: both show a 5-pt difference with Tx

- but... 3 people in Group 2 (independent) may be more intelligent, or more support
- power $s = 5.77$ $t = .87 \ vs. 1.15, t = -4.35$
Problems with repeated measures designs

- Carry over effects - response (t2) is altered by carryover effects from t1
  - Effectiveness of two drugs on same person
  - Difficulty of two performance tasks
- Progressive effects - when responses change consistently over time independent of treatment it is difficult to interpret (e.g., adolescence)
- Solution: counterbalance - use two orders and compare statistically (hard-easy; task 1- task 2)

Assumptions of the related-sample t-test

- Independent observations (e.g., TV violence where subjects come from same family).
- The population distribution of differences scores ($D$ values) must be normal.