Experimental Design

Between and within subjects

“The most important decision that you will ever make.”
Internal Validity

• An experiment can be said to be internally valid if the changes observed in the DV were due to the manipulation of the IV.
How subjects are assigned to conditions

• **Between subjects** *(independent groups)* design: different groups of subjects are assigned to different conditions

• **Within subjects** *(repeated measures)* design: each subject participates in each condition

• **Mixed** design: one or more factors are between subject factors, and one or more are within subject factors
How subjects are assigned to conditions

Use WITHIN subjects designs *whenever possible.*
Use WITHIN subjects designs whenever possible. Why?

<table>
<thead>
<tr>
<th>Condition A:</th>
<th>Condition B:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7, 10, 12, 15, 20, 21, 30</td>
<td>6, 15, 17, 22, 24, 28, 31</td>
</tr>
</tbody>
</table>

mean of a = 16.4  
mean of b = 20.4

Between: $t(12) = .915$, n.s.

The IV has a fairly small effect on the DV. There is a wide range of individual difference in the DV. Hence a between subjects design would not be very powerful.
Why are these people smiling?

Condition A: 7, 10, 12, 15, 20, 21, 30
Condition B: 6, 15, 17, 22, 24, 28, 31

mean of a = 16.4
mean of b = 20.4

Within (paired): t(6) = 3.53, p < .01

The IV has a fairly small effect on the DV. There is a wide range of individual difference in the DV. Hence a between subjects design would not be very powerful.
Hand posture is likely to produce a very small effect. There are also very large individual differences in reaction time. A between subjects design would not be a good choice.

The IV has a fairly small effect on the DV. There is a wide range of individual difference in the DV. Hence a between subjects design would not be very powerful.
How subjects are assigned to conditions

When is it **not possible** to use a within subjects design?

1. one treatment/condition may have effects that carry over to another condition
2. one treatment/condition may permanently change the subject (e.g., knowledge about the manipulation)
3. it would take too much time.
Between Subjects Design

Biggest “danger”:
The subject groups are different before the experiment begins.

(Some attribute of the subjects is confounded with the condition/treatment.)

Also, the study compared students who chose coaching to those who did not, rather than randomly assigning students to one group or another.

Still, some experts on educational testing, like Stephen Klein, a senior...
Between Subjects Design

Procedures to equate subject groups (before the experiment)

1. **Randomization** (most common) – randomly assign subjects to conditions
   - Each subject has an equal chance of being assigned to any of the conditions
   - Don’t use arrival order!
   - Advantage: can control for unknown extraneous variables. **Why?**
Between Subjects Design

Procedures to equate subject groups (before the experiment)

2. **Matching**— measure some characteristic related to the DV, then divide subjects into matched pairs.
   - **Advantage:** guaranteed to yield equal values on the extraneous variable of concern.
   - **Disadvantage:** you have to know exactly what you want to control for and how to measure it.
Within Subjects Design

Biggest “danger”:
The subject changes during the experiment.

Dr. Laird said most of the studies that showed big gains simply compared test scores before and after students were coached. But they did not include, for comparison, the scores of students who were not coached but who simply took the tests again. Retaking itself usually...
Within Subjects Design

• Reasons for a change in the subject
  • Carry-over effects – when the treatment affects performance in other conditions
  • Order or Sequence effects
    • Practice effect
    • Fatigue effect
Healthy children were used as the subjects to test the treatment's efficacy before allowing sick children to use it, and because the use of a single pain stimulus will generate more consistent results, Dahlquist said.

In the first set of tests, nothing was used to distract the youngsters' attention when they immersed their hands in the ice water. The average endurance was only 28 seconds, she said.

In the second test, the children immersed their hands in the ice water and then watched a video of someone else playing "Finding Nemo." The average endurance rose to 34 seconds, she said. For the third test, each participant immersed one hand in the ice water and used the other to play the game while wearing the VR helmet. The average endurance soared to 60 seconds; several kids endured the maximum of four minutes.
How to control for these changes

(control = “equate” not “eliminate”)

1. • Mix the conditions from trial to trial randomly.
   (common in cognitive psychology)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Memory set</th>
<th>Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>365213</td>
<td>5</td>
</tr>
<tr>
<td>Trial 2</td>
<td>543</td>
<td>1</td>
</tr>
<tr>
<td>Trial 3</td>
<td>3235</td>
<td>4</td>
</tr>
<tr>
<td>Trial 4</td>
<td>75844</td>
<td>6</td>
</tr>
<tr>
<td>Trial 5</td>
<td>45691</td>
<td>5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

But sometimes conditions must be blocked (e.g., Donders). Why?
Can’t vary these from trial to trial very easily.

But the desire to do so led to an interesting experiment…. 
How to control for these changes

(control = “equate” not “eliminate”)

2. Counterbalancing – scrambling the order of the conditions in a systematic way (when they cannot be randomly mixed from trial to trial)
   • Complete counterbalancing (use all possible orders of conditions)
   • Incomplete counterbalancing (latin squares)
Complete counterbalancing (use all possible orders of conditions)

<table>
<thead>
<tr>
<th>Subject</th>
<th>First Condition</th>
<th>Second Condition</th>
<th>Third Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

$4! = 24, \ 5! = 120$
**Incomplete counterbalancing (Latin squares)**

Use a carefully chosen subset of the condition orders.

<table>
<thead>
<tr>
<th>Subject</th>
<th>First Condition</th>
<th>Second Condition</th>
<th>Third Condition</th>
<th>Fourth Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

But this design still is at risk for carry over effects.  *Why?*
Balanced Latin Square

<table>
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<td>D</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>D</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>A</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>

1. Generate first row: A, B, n, C, n-1, D, n-2, E...
   where n = the last condition
2. fill down
   (For odd number of conditions do one square, then a mirror-image. S serves in a row from each square.)
Factorial designs

Two or more independent variables are studied simultaneously. Each level of each IV occurs with each level of every other IV.

Design could be:

- Entirely within subjects
- Entirely between subjects
- Mixed: one or more factors varied between subjects and one or more varied within subjects.

<table>
<thead>
<tr>
<th>Probe presence</th>
<th>Memory set size (number of items)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Present</td>
<td><img src="image1" alt="Image" /></td>
</tr>
<tr>
<td>Absent</td>
<td><img src="image7" alt="Image" /></td>
</tr>
</tbody>
</table>