Within-subjects Designs

Repeated Measures Designs

Within-subjects designs

- IV is manipulated within subjects: subjects receive ALL levels of the IV(s)
- Each subject serves as his/her own control for individual differences across groups
- Used to control for across-group differences

Advantages of within-subject designs

- Reduction of error due to the control of individual differences:
  - When error is removed from the error term, what is the effect on the $F$ ratio?
  - Test has more power to detect an effect: $F$ will be larger when error is reduced, therefore more likely to reject the null hypothesis

Disadvantages of within-subject designs

- Procedure takes longer per subject
  - Subject attrition
  - Fatigue effects

- Carry-over effects: experiencing multiple conditions can change subject responses
  - Lose control of individual differences if subjects change from condition to condition
  - Sources: learning/practice, habituation, fatigue/boredom, contrast, order

Important for studies where subjects are difficult to obtain or costly to run
- e.g., specialized patient populations, limited compensation resources, expensive procedures
**Within-subjects designs**

- **Disadvantages of within-subject designs**
  - Dealing with carry-over effects: counterbalancing
    - Full: use all possible condition orders
    - randomly assign subjects to one order
  - Latin square design:
    - number of orders = number of conditions
    - randomly assign subjects to one order to spread order effect across all subjects

**Latin square designs**

- **Two types of designs:**
  
  1. Cyclic Latin square
  2. Diagram-balanced Latin square

**Example for 4 conditions:**

<table>
<thead>
<tr>
<th>S1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>S3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>S4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

- **Within-subject designs**
  
  - Counterbalancing can’t control ALL carry-over effects - some may remain (e.g., contrast effects; see p. 371 for examples)
  - Can also test order as an IV (between-subjects) to MEASURE order effect

- **Disadvantages of within-subject designs**
  - More restrictive test assumptions
    - Sphericity – the variance of populations of difference scores are equal
Data Analyses with ANOVA

- Subjects are treated as a within-groups factor; SS_{Between} does not change, but SS_{Within} (error term) does change.
- In between-subjects designs, error variance comes from individual differences + other kinds of error.

Data Analyses with ANOVA

- In within-subjects designs we use SS_{AxS} as our error term (instead of SS_{S/A}) because we have controlled for the SS_{S/A} differences.
- We are only concerned now with how the subjects within a group differ across groups (i.e., the subject by group interaction - how subject differences differ across groups).

Data Analyses with ANOVA

- One-way within-subjects design
  - Analyzed as a two-way design with IV-A as one factor and subjects (S) as the other factor.
  - We can think of this as a full two-way design with marginal means for IV-A levels and levels of subjects (each individual) and consider deviations from the grand mean.

One-way within design

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F ratio: \( \frac{MS_A}{MS_{AxS}} \)

- The new error term will use error due to subject differences that are inconsistent across levels of A.
- We’ve controlled for differences between a set of subjects across the levels by having subjects serve as their own control.
- Now we focus on differences within groups that differ across A1, A2, etc.

One-way within design

- You can test for the main effect of subjects (and SPSS will provide it), but it won’t be of interest in interpreting the results.
- As with the between-subjects design, you will focus on the main effect of IV-A to look for causal effects.
One-way within design

- The result is that the error term \( SS_{S/A} \) will be smaller than the \( SS_{S/A} \) term we use with between-subjects designs because we’ve removed some of the error that contributes to that term in between-Ss designs.
- The result is a more powerful test of the IV-A effect due to a smaller denominator in the \( F \) ratio.

Example (Conceptual Formula)

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>( \bar{Y}_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_1</td>
<td>8</td>
<td>12</td>
<td>9</td>
<td>9.7</td>
</tr>
<tr>
<td>S_2</td>
<td>8</td>
<td>13</td>
<td>14</td>
<td>11.7</td>
</tr>
<tr>
<td>S_3</td>
<td>9</td>
<td>15</td>
<td>6</td>
<td>10.0</td>
</tr>
<tr>
<td>S_4</td>
<td>0</td>
<td>18</td>
<td>12</td>
<td>10.0</td>
</tr>
<tr>
<td>S_5</td>
<td>13</td>
<td>15</td>
<td>18</td>
<td>15.3</td>
</tr>
<tr>
<td>S_6</td>
<td>10</td>
<td>17</td>
<td>7</td>
<td>11.3</td>
</tr>
<tr>
<td>( \bar{Y}_A )</td>
<td>8</td>
<td>15</td>
<td>11</td>
<td>( \bar{Y}_T = 11.3 )</td>
</tr>
</tbody>
</table>

Example (Conceptual Formula)

- \( SS_A = 6[(8-11.3)^2 + (15-11.3)^2 + (11-11.3)^2] = 148.02 \)
- \( df_A = 3-1 = 2 \)
- \( MS_A = \frac{148.02}{2} = 74.01 \)

Example (Conceptual Formula)

- \( SS_{AxS} = [(8-8-9.7+11.3)^2 + (8-8-11.7+11.3)^2 + \ldots + (7-11-11.3+11.3)^2] = 156.7 \)
- \( df_{AxS} = (3-1)(6-1) = 10 \)
- \( MS_{AxS} = \frac{156.7}{10} = 15.67 \)

Example (Conceptual Formula)

- \( F = 74.01 = 4.72 \text{ vs. } F_{crit}(2,10) = 4.10 \)
- \( 15.67 \)
- Significant effect of IV-A
### Assumptions of Test

- Same assumptions as ANOVA for between-subjects:
  - Normality
  - Homogeneity of variance
- Plus new assumption
  - Sphericity - differences between pairs of scores in population have same variance

<table>
<thead>
<tr>
<th>Assumptions of Test</th>
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<tbody>
<tr>
<td><strong>Sphericity</strong></td>
</tr>
<tr>
<td>Violations increase ( \alpha )</td>
</tr>
<tr>
<td>Techniques exist to correct for violations</td>
</tr>
<tr>
<td>SPSS will conduct a test for violation of assumption - just like it can test for homogeneity of variance assumption</td>
</tr>
</tbody>
</table>