Repeated-Measures Design

Multiple measurements for each subject
  Different stimulus types, conditions, times, etc.
  All measurements are of the same variable, but in different situations
  Generalizes paired-samples design

Is there an effect of the treatment?
  Variation due to condition, time, stimulus, etc.
  Do the means of the measurements vary?

Same null hypothesis as simple ANOVA
  \( \mu_1 = \mu_2 = \ldots = \mu_k \)

Repeated-Measures Data

Individual differences
  Variation from one subject to another
  Affects all the scores of any given subject

Accounting for Individual Differences

Individual differences complicate hypothesis testing
  Inflate variability of scores
  Don't affect random variability of treatment means
  Contribute to all measurements equally

Basic idea

Subtract subject mean for each score
Don't affect random variability of treatment means

Do simple ANOVA on these differences (\( df_{\text{residual changes}} \))

<table>
<thead>
<tr>
<th>Subject</th>
<th>Measurement</th>
<th>M_S</th>
<th>Difference Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
<td></td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>1</td>
<td>78 73 82 75</td>
<td>77</td>
<td>1 -4 5 -2</td>
</tr>
<tr>
<td>2</td>
<td>108 105 113 106</td>
<td>108</td>
<td>0 -3 5 -2</td>
</tr>
<tr>
<td>3</td>
<td>84 79 89 80</td>
<td>83</td>
<td>1 -4 6 -3</td>
</tr>
<tr>
<td>4</td>
<td>94 88 98 92</td>
<td>93</td>
<td>1 -5 5 -1</td>
</tr>
<tr>
<td>5</td>
<td>121 115 123 117</td>
<td>119</td>
<td>2 -4 4 -2</td>
</tr>
</tbody>
</table>
Partitioning Variability

Break total variability into treatment, subjects, and residual error

\[ SS_{\text{total}} = SS_{\text{subject}} + SS_{\text{treatment}} + SS_{\text{residual}} \]

Total variability

Same as before: \[ SS_{\text{total}} = \sum (X - \bar{M})^2 \]

Variability due to treatment

Same as before: \[ SS_{\text{treatment}} = \sum n(M_i - \bar{M})^2 \]

Variability due to individual differences

Same idea as \( SS_{\text{treatment}} \)

Variability of subject means: \[ SS_{\text{subject}} = \sum k(M_s - \bar{M})^2 \]

Residual variability

Remaining variability

Can calculate directly, but not intuitive

\[ SS_{\text{residual}} = SS_{\text{total}} - SS_{\text{subject}} - SS_{\text{treatment}} \]

Repeated-Measures ANOVA

Does treatment explain significant portion of variability?

Don't want to penalize for variability due to individual differences

Removing \( SS_{\text{subject}} \) reduces \( SS_{\text{residual}} \) and makes it a fair comparison

Hypothesis test for repeated-measures ANOVA: \[ F = \frac{MS_{\text{treatment}}}{MS_{\text{residual}}} \]

Same as regular ANOVA, except we could remove \( SS_{\text{subject}} \)

\( (SS_{\text{subject}} \) not meaningful with simple ANOVA; each subject is only in one group)

Degrees of Freedom

\[ df_{\text{total}} = nk - 1 \]
\[ df_{\text{treatment}} = k - 1 \]
\[ df_{\text{subject}} = n - 1 \]
\[ df_{\text{residual}} = nk - 1 - (k-1) - (n-1) = nk - n - k + 1 \]