psyc3010 lecture 12

mixed anova

last week: within-participant anova
next week: a bit on logistic regression, plus
overview of course, SET-Cs, and ***practice exam***

last week → this week

- last week we returned to anova to consider within-participants designs

- this week we reunite within-participants and between-participants anova – mixed factorial anova, with both within and between participants types of factors

- actually not too difficult because we have kind of done it already
  - every time we do within participants anova we deal with a between-participants factor, the random effect of participants
mixed anova

- **also called split-plot anova**
  - Apparently because the first mixed designs emerged in agricultural research where 'plots' of land were assigned - BP treatments as well as divided - WP factors
  - NB **confusion alert:**
    - Mixed anova has a BP factor and a WP factor.
    - Mixed model within-participants ANOVA is the normal way of doing WP ANOVA (where you evaluate sphericity and report an adjusted F, such as GG) – in contrast to MANOVA

- Why mixed anova? **within-participants anova** is great for power, but some variables can be tricky or unethical to manipulate **within-participants**
  - e.g., gender, brain injury
- can also manipulate a variable BP to exclude the potential carry-over effects
  - because observations in BP design are independent

**assumptions**

- **DV is normally distributed**
- **between participants terms:**
  - homogeneity of variance within levels of between-participants factor – the ordinary garden-variety homogeneity of variance assumption
- **within-participants terms:**
  - homogeneity of variance: assume WPFxP interactions constant at all levels of between participant factor
  - variance-covariance matrix same at all levels of WPF
  - pooled (or average) variance-covariance matrix exhibits compound symmetry (c.f. sphericity)
  - usual epsilon adjustments apply when within-participants assumptions are violated
an example

- start with an easy one – just add a between-participants factor to last week’s example
  - we had four blocks of trials in a learning study – each block was a level of the within participants factor
  - let’s say we think a particular bit of the brain is responsible for this particular kind of learning…
  - compare learning of normals (control group) with
    - participants given brain lesion
    - participants given drug

(usually this research would use rats)
### The Split-Plot Design

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Block total: 654 612 512 434 2212 Grand Total
Block mean: 54.50 51.00 42.67 36.17 46.08 Grand Mean
the split-plot design

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block is a fixed within-participants factor

group is a fixed between-participants factor

Because one of the IVs is a within-participants factor, we include the random factor participants in the partitioning of the variance.

The participants factor is said to be NESTED under levels of the between-participants factor GROUP.

(Each participant is tested in only 1 group)
In a two by three mixed ANOVA in which gender (male; female) serves as a between-participants variable and time of test (start of semester, mid-semester, end of semester) serves as a repeated measures variable, participant is crossed with _______ and nested within _______.
partitioning the variance:

\[
\text{SS}_{\text{total}} \quad \text{SS}_{\text{between Ps}} \quad \text{SS}_{\text{within Ps}} \\
\quad \text{SS}_{\text{group}} \quad \text{SS}_{\text{PswithinG}} \quad \text{SS}_{\text{BxPwithinG}} \\
\quad \text{SS}_{\text{block}} \quad \text{SS}_{BG} 
\]

effects and error terms

- this design is a 2-way mixed factorial, so three omnibus effects are to be tested
  - main effect of group
  - main effect of block
  - group x block interaction

- **one error term is required for the between-participants factor** (participants within groups)
- **one error term is required for the within-participants factor and the two-way interaction** (interaction between block and participants within groups)

- Point:
  - last week error was always TR x P (for fully within factors)
  - for WSF x BSF the error for the between main effect is Participants-within-groups  (deviations of mean for each P from group mean)
  - the error for the within main effect and the interaction (WSFxBSF) is WPFxP \text{within group}  (inconsistencies in the effect of the WSF across Ps, adjusted for group diffs)
partitioning the variance:

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\begin{align*}
SST_{\text{total}} & = SSB_{\text{block}} + SSB_{P \times G} + SSB_{P \times \text{within} G} + SSB_{\text{group}} + SSB_{\text{between} P} + SSW_{\text{within} P} \\
SST_{\text{between} P} & = SSB_{P \times G} + SSB_{P \times \text{within} G} + SSB_{\text{group}} \\
SST_{\text{within} P} & = SSB_{P \times G} + SSB_{P \times \text{within} G} + SSB_{\text{group}} \\
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SST_{\text{block}} & = SSB_{\text{block}} + SSW_{\text{within} P} \\
\end{align*}
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TR and error of between participants effect

WP factor effect
Interaction effect
Error for WPF

Understanding the Mixed design

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\[
\begin{align*}
\text{block total} & = 654 & 612 & 512 & 434 & 2212 & \text{Grand Total} \\
\text{block mean} & = 54.50 & 51.00 & 42.67 & 36.17 & 46.08 & \text{Grand Mean} \\
\end{align*}
\]
### Understanding the Mixed design

#### Inconsistencies in the Block effect across participants (Block x P interaction, taking into account group diffs in Ps) are the error for the WP effect

\[
F = \text{ratio of variability among means for WPF levels divided by variability in WPF effect}
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#### Inconsistencies in the Block effect across Ps (Block x P interaction, adjusting for group diffs in Ps) are the error for the WPF x BPF interaction (BxG)

\[
F = \text{ratio of variability among means for WPF levels within each group (adjusted for MEs) divided by variability in WP effect}
\]
degrees of freedom:

- \( df_{total} \)
- \( df_{between Ps} \)
  - \( Df_{between Ps} \)
    - \( Df_{within Ps} \)
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                                                                                                                                                                                                                                                                                    - \( df_{within Ps} \)
### Tests of Within-Subjects Effects

**Measure: MEASURE_1**

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLOCK</td>
<td>Sphericity Assumed</td>
<td>2460.333</td>
<td>3</td>
<td>820.111</td>
<td>108.478</td>
</tr>
<tr>
<td></td>
<td>Greenhouse-Geisser</td>
<td>2460.333</td>
<td>1.225</td>
<td>2098.476</td>
<td>108.478</td>
</tr>
<tr>
<td></td>
<td>Huynh-Feldt</td>
<td>2460.333</td>
<td>1.633</td>
<td>1506.268</td>
<td>108.478</td>
</tr>
<tr>
<td></td>
<td>Lower-bound</td>
<td>2460.333</td>
<td>1.000</td>
<td>2460.333</td>
<td>108.478</td>
</tr>
<tr>
<td>BLOCK * GROUP</td>
<td>Sphericity Assumed</td>
<td>381.042</td>
<td>6</td>
<td>63.507</td>
<td>8.400</td>
</tr>
<tr>
<td></td>
<td>Greenhouse-Geisser</td>
<td>381.042</td>
<td>2.450</td>
<td>155.530</td>
<td>8.400</td>
</tr>
<tr>
<td></td>
<td>Huynh-Feldt</td>
<td>381.042</td>
<td>3.267</td>
<td>116.641</td>
<td>8.400</td>
</tr>
<tr>
<td></td>
<td>Lower-bound</td>
<td>381.042</td>
<td>2.000</td>
<td>190.521</td>
<td>8.400</td>
</tr>
<tr>
<td>Error(BLOCK)</td>
<td>Sphericity Assumed</td>
<td>204.125</td>
<td>21</td>
<td>7.560</td>
<td>6.507</td>
</tr>
<tr>
<td></td>
<td>Greenhouse-Geisser</td>
<td>204.125</td>
<td>11.025</td>
<td>18.515</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Huynh-Feldt</td>
<td>204.125</td>
<td>14.701</td>
<td>13.886</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower-bound</td>
<td>204.125</td>
<td>9.000</td>
<td>22.681</td>
<td></td>
</tr>
</tbody>
</table>

---

**this error term is Block x Ps within Group and is used for the main effect of the WSF and for the interaction of the WSF x BSF**

### Tests of Between-Subjects Effects

**Measure: MEASURE_1**

**Transformed Variable: Average**

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>101636.333</td>
<td>1</td>
<td>101636.333</td>
<td>253.547</td>
</tr>
<tr>
<td>GROUP</td>
<td></td>
<td>5231.792</td>
<td>2</td>
<td>2615.896</td>
<td>6.507</td>
</tr>
<tr>
<td>Error</td>
<td></td>
<td>3618.375</td>
<td>9</td>
<td>402.042</td>
<td></td>
</tr>
</tbody>
</table>

---

**this error term is Ps within Group and is used for the BSF**

Notice how there is buckets more power for the WSF tests - much smaller error term and higher error df
following up main effects

- **between-participants factor**
  - rule is the same as it would be if this were just a 1-way between-participants anova:
  - use original error term from test of between-participants main effect
  - $MS_{Ps\ within\ G}$ in this case

- **within-participants factor**
  - use a separate error term (as per last week)
  - $MS_{B\ comp\ x\ P\ within\ G}$
significant main effect of group

- so if the bit of the brain affected by the lesions and drugs is indeed responsible for the learning in our study, we would expect...
  - the lesion and drug group to have worse (slower) performance than the normal (control) group
  - the lesion group to perform about the same as the drug group (i.e., same process is being interrupted)
  - could test this with a set of orthogonal linear contrast just like the ones we saw earlier in the semester...

significant main effect of group

- mean for G₁ = 35.25
- mean for G₂ = 42.81
- mean for G₃ = 60.19
calculations for contrast 1

\[
L = \sum a_j \bar{X}_j
\]

\[
\text{SS}_{\text{contrast}} = \frac{nL^2}{a_j}
\]

<table>
<thead>
<tr>
<th>Group</th>
<th>Normal</th>
<th>Drug</th>
<th>Lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35.25</td>
<td>42.81</td>
<td>60.19</td>
</tr>
</tbody>
</table>

Contrast 1  
Contrast 2

\[
L = 2(35.25) - 1(42.81) - 1(60.19) = -32.5
\]

\[
\text{SS}_{\text{contrast}} = \frac{(16)(-32.5)^2}{6} = 2816.67
\]

calculations for contrast 2

\[
L = \sum a_j \bar{X}_j
\]

\[
\text{SS}_{\text{contrast}} = \frac{nL^2}{a_j}
\]

<table>
<thead>
<tr>
<th>Group</th>
<th>Normal</th>
<th>Drug</th>
<th>Lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35.25</td>
<td>42.81</td>
<td>60.19</td>
</tr>
</tbody>
</table>

Contrast 1  
Contrast 2

\[
L = 0(35.25) + 1(42.81) - 1(60.19) = -17.38
\]

\[
\text{SS}_{\text{contrast}} = \frac{(16)(-17.38)^2}{2} = 2416.52
\]
summary table

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 vs G2 &amp; G3</td>
<td>2816.67</td>
<td>1</td>
<td>2816.67</td>
<td>7.01 *</td>
</tr>
<tr>
<td>G2 vs G3</td>
<td>2416.52</td>
<td>1</td>
<td>2416.52</td>
<td>6.01 *</td>
</tr>
<tr>
<td>Ss w/in Group</td>
<td>3618.38</td>
<td>9</td>
<td>402.04</td>
<td></td>
</tr>
</tbody>
</table>

$F_{crit}(1,9) = 5.12$

d therefore, averaging over the 4 experimental blocks, the normal (control) group performed better than the drug group and lesion group, and the drug group in turn performed better than the lesion group.

significant main effect of block

- the comparisons between the different groups doesn’t really tell us if any learning occurred –- we need to see that participants are completing the maze faster by the end of the study
  - could test this with a set of linear contrast just like the ones we saw last week…
  - as block is a within-participants factor we have to get the error term for each comparison based upon only the data involved in that comparison
  - for the sake of brevity –- let’s just compare the first block with the last
significant main effect of block

as per last week, we get SS_{Bcomp} and the error term by running a 1-way within-participants anova on our two comparison blocks

The SS_{contrast} is SS_{Bcomp}
The error term is SS_{Bcomp \times P}

block total 654 434 1088 Grand Total
block mean 54.50 36.17 45.33 Grand Mean

summary table

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1 vs Block 4</td>
<td>2016.67</td>
<td>1</td>
<td>2016.67</td>
<td>65.76 *</td>
</tr>
<tr>
<td>Error</td>
<td>337.33</td>
<td>11</td>
<td>30.67</td>
<td></td>
</tr>
</tbody>
</table>

F_{crit}(1, 11) = 4.84

therefore, averaging over the 3 experimental groups, participants were performing significantly better by the end of the experiment – hence learning has occurred
interaction of group x block

![Graph showing interaction of group x block](image-url)
simple effects within-participants factors...

- if we wanted to conduct the simple effects of block (for each group), we always run a 1-way within participants anova on block separately for each group
  - as such, the error term used will be appropriate for each effect
  - using the pooled error term (in this case, $MS_{BlocksPswithinG}$) is not appropriate, and may over or underestimate error component (denominator of F-ratio), even when degrees of freedom are adjusted

Point: Simple effects of WPF should be conducted by running a one-way ANOVA of the WPF at each level of the BPF (each has own error)

summary table

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>1651.50</td>
<td>3</td>
<td>550.50</td>
<td>38.71 *</td>
</tr>
<tr>
<td>Error</td>
<td>128.00</td>
<td>9</td>
<td>14.22</td>
<td></td>
</tr>
<tr>
<td>Drug</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>490.69</td>
<td>3</td>
<td>163.56</td>
<td>58.74 *</td>
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<tr>
<td>Error</td>
<td>25.06</td>
<td>9</td>
<td>2.78</td>
<td></td>
</tr>
<tr>
<td>Lesion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>699.19</td>
<td>3</td>
<td>233.06</td>
<td>41.08 *</td>
</tr>
<tr>
<td>Error</td>
<td>51.06</td>
<td>9</td>
<td>5.67</td>
<td></td>
</tr>
</tbody>
</table>

$F_{crit}(3,9) = 3.86$

Note that the average of these error terms = $(14.22 + 2.78 + 5.67) / 3 = 7.56$; the value of our $MS_{BxPs within G}$
simple effects
between-participants factors...

could also examine simple effects of group for each of the four blocks – here we have two possible approaches:

- use a separate error term for each simple effect
- i.e., run four 1-way between-participants anovas to compare groups at each of the four blocks
- then use $MS_{Ps within G at B1}$, $MS_{Ps within G at B2}$ etc

**OR . . . .**

- a special pooled error term may be used: $MS_{Ps within cell}$
- this error term is an estimate of the average error variance within the 12 cells
  
  $SS_{within cell} = SS_{P within G} + SS_{BxPs within G}$
  $MS_{Ps within cell} = SS_{P within cell} / (df_{Ps within G} + df_{BxPs within G})$

(is OK to pool because between participants effects should be independent)

simple effects
between-participants factors...

- in both cases, the sums of squares for the simple effects are derived just as we have seen in the case of between participants anova (see lecture 3)
- the separate error term method is a little quicker, but you compromise on degrees of freedom
### Summary Table: Separate Error Term

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group at Block1</td>
<td>1263.50</td>
<td>2</td>
<td>631.75</td>
<td>4.74</td>
</tr>
<tr>
<td>Ss w/in G at B1</td>
<td>1199.50</td>
<td>9</td>
<td>133.28</td>
<td></td>
</tr>
<tr>
<td>Group at Block2</td>
<td>1134.00</td>
<td>2</td>
<td>567.00</td>
<td>4.81</td>
</tr>
<tr>
<td>Ss w/in G at B2</td>
<td>1062.00</td>
<td>9</td>
<td>118.00</td>
<td></td>
</tr>
<tr>
<td>Group at Block3</td>
<td>765.17</td>
<td>2</td>
<td>382.58</td>
<td>4.56</td>
</tr>
<tr>
<td>Ss w/in G at B3</td>
<td>755.50</td>
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<td>83.94</td>
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<tr>
<td>Group at Block4</td>
<td>2450.17</td>
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<td>13.69</td>
</tr>
<tr>
<td>Ss w/in G at B4</td>
<td>805.50</td>
<td>9</td>
<td>89.50</td>
<td></td>
</tr>
</tbody>
</table>

F_{crit} (2,9) = 4.26

(aside: might be informative to calculate estimates of effect size – the bigger effect is clearly occurring at block 4)

### Summary Table: Pooled Error Term ($MS_{Ps within cell}$)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group at Block1</td>
<td>1263.50</td>
<td>2</td>
<td>631.75</td>
<td>5.95</td>
</tr>
<tr>
<td>Ss w/in G at B1</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
<tr>
<td>Group at Block2</td>
<td>1134.00</td>
<td>2</td>
<td>567.00</td>
<td>5.34</td>
</tr>
<tr>
<td>Ss w/in G at B2</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
<tr>
<td>Group at Block3</td>
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<td>2</td>
<td>382.58</td>
<td>3.60</td>
</tr>
<tr>
<td>Ss w/in G at B3</td>
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<td>36</td>
<td>106.18</td>
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</tr>
<tr>
<td>Ss w/in G at B4</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
</tbody>
</table>

F_{crit} (2,36) = 2.94

NB

SS_{Ps within cell} = 204.12 + 3618.38 (SS PswithinGr p + SSgrpxblkx P)
### Summary Table

#### Pooled Error Term ($MS_{Ss\ within\ cell}$)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group at Block1</td>
<td>1263.50</td>
<td>2</td>
<td>631.75</td>
<td>5.95 *</td>
</tr>
<tr>
<td>Ss w/in G at B1</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
<tr>
<td>Group at Block2</td>
<td>1134.00</td>
<td>2</td>
<td>567.00</td>
<td>5.34 *</td>
</tr>
<tr>
<td>Ss w/in G at B2</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
<tr>
<td>Group at Block3</td>
<td>765.17</td>
<td>2</td>
<td>382.58</td>
<td>3.60 *</td>
</tr>
<tr>
<td>Ss w/in G at B3</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
<tr>
<td>Group at Block4</td>
<td>2450.17</td>
<td>2</td>
<td>1225.08</td>
<td>11.54 *</td>
</tr>
<tr>
<td>Ss w/in G at B4</td>
<td>3822.50</td>
<td>36</td>
<td>106.18</td>
<td></td>
</tr>
</tbody>
</table>

*F*crit(2,36) = 2.94

**NB** df = 9 + 27

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### Simple Simple Effects

- We could conduct follow-up comparisons for the 3 groups at block 4 – this would be identical to the follow up for the main effect of group we did earlier – i.e. could use linear contrasts with MSPwithinG@B4 [same error term as original simple effect]
- But for now, I think we have all had enough!
summary of findings for the study…

- significant effect of block
  - faster times at block 4 than block 1 (indicates learning)

- significant effect of group
  - normal (control) group was faster than the drug group
    which was faster than the lesion group

- significant interaction
  - learning was occurring for each group
  - groups were performing at a different level at each block
  - if we followed this up further we might find that the largest differences were in block 4
mixed support overall…

possibly some kind of confound leading to the lesion group’s performance being severely impaired

mixed support overall…

Damage was supposed to impair learning, so this graph would have been a more theoretically pleasing result.
bottom line

- the really tricky stuff with within-participants and mixed anova is sorting out the error terms
- the logic is similar though:
  - The error term for between main effects is participants within groups
  - The appropriate error term for within effects is the effect being examined in interactions with the random factor participants

In class next week:
- Brief bit on logistic regression
- Overview of course themes as I see them; general pontificating
- Course and teaching evaluations
- Discussion of exam and practice exam

In the tutes:
- This week: Consult for A2
- Next week: No tute

readings:
- Field (3rd ed): Chapter 14; Field (2nd ed): Chapter 12
  - Howell (all eds): Chapter 14
- Logistic Regression in Field: Ch 16-16.5,16.6

20/05/2011