

MORE REPEATED MEASURES



More complex repeated measures

- As with our between groups ANOVA, we can also have more than one repeated measures factor
- 2-way repeated measures

Two way repeated measures

- Remember that a two factor ANOVA produces three elements of interest
 - 2 main effects and 1 interaction.
- If our two within-subject factors are A and B, the analysis will produce:
 - a main effect of A (using A x Subjects as the error term)
 - a main effect of B (using B x Subjects as the error term)
 - a A X B interaction (using A x B x Subjects as the error term)

Example

- An experiment designed to look at the effects of therapy on self-esteem
- Subjects self-esteem measures
- 5 subjects
- One within-subject effect with 4 levels (weeks 1-4)
- Another with 2 levels (wait,therapy)

Data

| Baseline | | | | Therapy | | | |
|----------|----------|----------|----------|----------|----------|----------|----------|
| <i>1</i> | <i>2</i> | <i>3</i> | <i>4</i> | <i>1</i> | <i>2</i> | <i>3</i> | <i>4</i> |
| 3 | 5 | 9 | 6 | 5 | 6 | 11 | 7 |
| 7 | 11 | 12 | 11 | 10 | 12 | 18 | 15 |
| 9 | 13 | 14 | 12 | 10 | 15 | 15 | 14 |
| 4 | 8 | 11 | 7 | 6 | 9 | 13 | 9 |
| 1 | 3 | 5 | 4 | 3 | 5 | 9 | 7 |

General points

- The interpretation follows the same logic as a One-Way RM ANOVA
- The error terms reflect the differences in individuals' responsiveness to the various treatments

Partitioning the effects

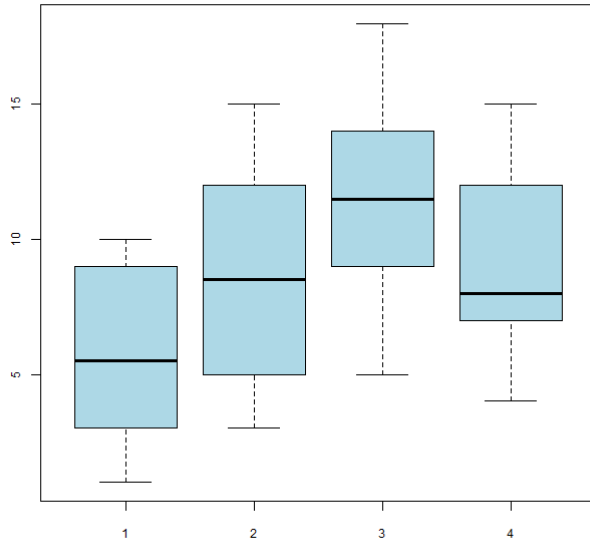
- Recall from the one-way RM design that our error term was a reflection of how different subjects respond differently to different treatments
 - Treatment X subject interaction
- The variance within people was a combination of the treatment effect, the interaction w/ subjects, and random error
- The error term in that situation contained both the interaction effects and random error

Partitioning the effects

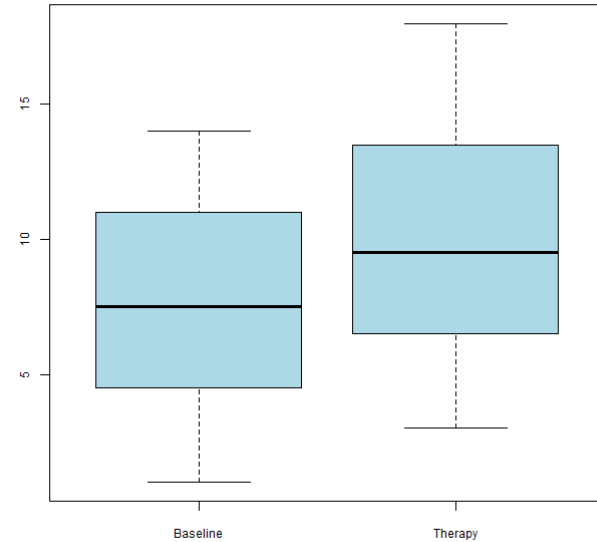
- In the 2-way RM we will have the same situation for main effects and the interaction
 - However, each effect will have its own error term that contains the X subject interaction + error for that effect
 - Gist: we test the significance of any effect with an error term that involves the interaction of that effect with factor S
- Between subjects (S)
 - A
 - Error ($A \times S$)
 - B
 - Error ($B \times S$)
 - $A \times B$
 - Residual Error ($AB \times S$)

Main Effect Results

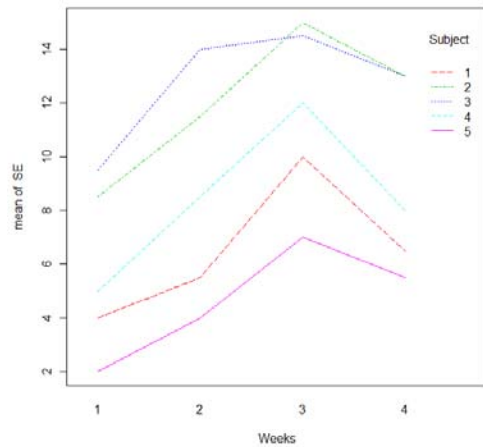
Weeks Main Effect



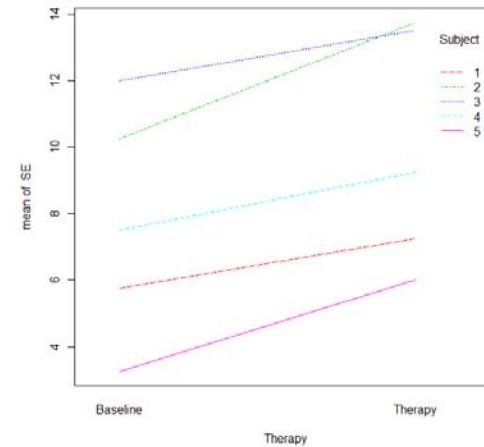
Therapy Main Effect



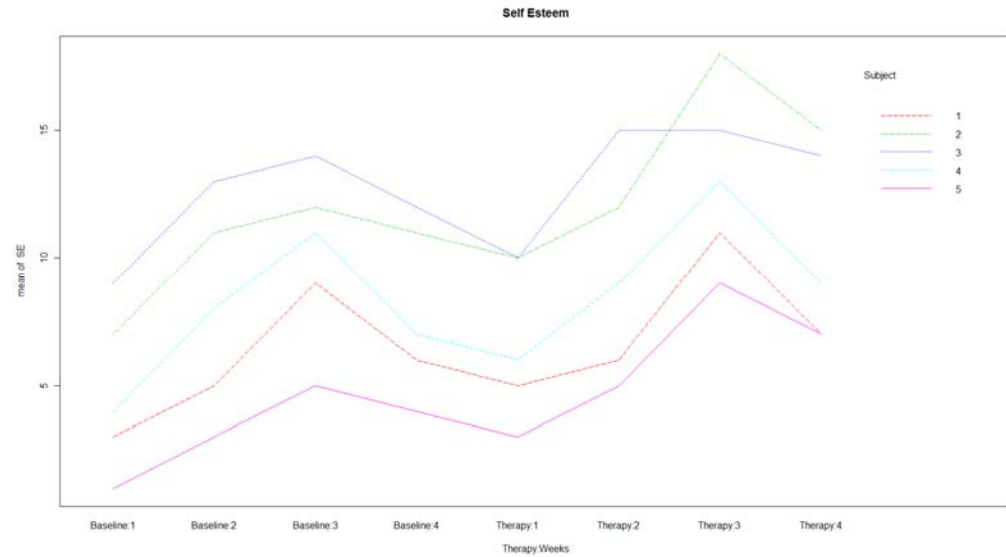
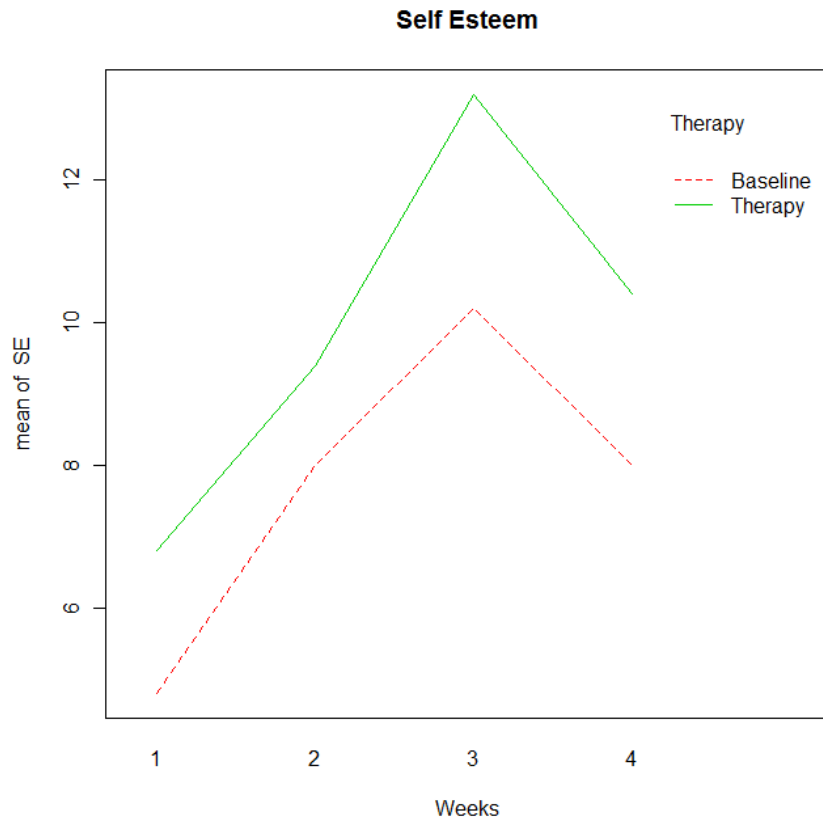
Self Esteem



Self Esteem



Interaction Results



Statistical Results

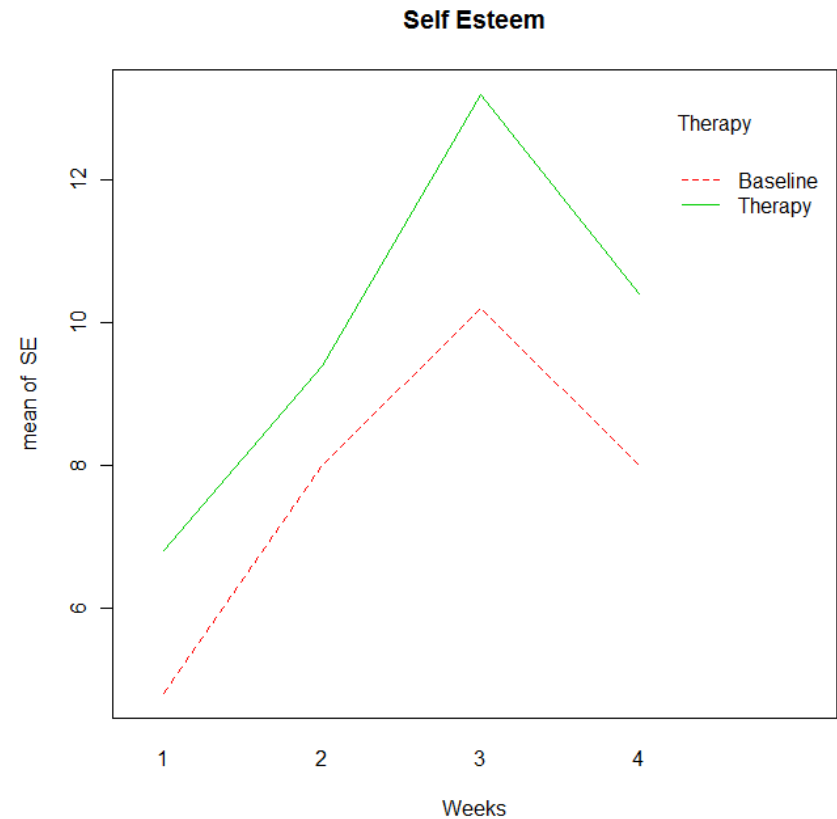
Tests of Within-Subjects Effects

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---------------------|--------------------|-------------------------|----|-------------|--------|------|---------------------|
| therapy | Sphericity Assumed | 48.400 | 1 | 48.400 | 30.488 | .005 | .884 |
| Error(therapy) | Sphericity Assumed | 6.350 | 4 | 1.588 | | | |
| time | Sphericity Assumed | 175.700 | 3 | 58.567 | 45.196 | .000 | .919 |
| Error(time) | Sphericity Assumed | 15.550 | 12 | 1.296 | | | |
| therapy * time | Sphericity Assumed | 3.400 | 3 | 1.133 | 2.325 | .127 | .368 |
| Error(therapy*time) | Sphericity Assumed | 5.850 | 12 | .488 | | | |

Interpretation

- The results suggest that there is an effect of time and whether the person engages in therapy, but no statistically significant interaction
- We could as before perform multiple comparisons by conducting paired comparisons using an appropriate correction (e.g. B-Y)
- As there are only 2 levels for therapy, the main effect is the only comparison



Interpretation

- Technically, a significant interaction is not required to test for simple effects
 - ▣ Plus in this case we had an interesting effect size for the interaction anyway
- Note that this is for demonstration only, with main effects both significant and non significant interaction you should not perform simple effects analysis
 - ▣ But even that suggestion is based on p-values so...
- The error term will be the interaction of the effect X subject at the particular level for the other within subjects factor (e.g. $A \times S$ at B_1)

Simple Effects

Pairwise Comparisons

Measure: MEASURE_1

| time | (I) therapy | (J) therapy | Mean Difference (I-J) | Std. Error | Sig. ^a | 95% Confidence Interval for Difference ^a | |
|------|-------------|-------------|-----------------------|------------|-------------------|---|-------------|
| | | | | | | Lower Bound | Upper Bound |
| 1 | 1 | 2 | -2.000* | .316 | .003 | -2.878 | -1.122 |
| | 2 | 1 | 2.000* | .316 | .003 | 1.122 | 2.878 |
| 2 | 1 | 2 | -1.400* | .245 | .005 | -2.080 | -.720 |
| | 2 | 1 | 1.400* | .245 | .005 | .720 | 2.080 |
| 3 | 1 | 2 | -3.000* | .894 | .028 | -5.483 | -.517 |
| | 2 | 1 | 3.000* | .894 | .028 | .517 | 5.483 |
| 4 | 1 | 2 | -2.400* | .510 | .009 | -3.816 | -.984 |
| | 2 | 1 | 2.400* | .510 | .009 | .984 | 3.816 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Pairwise Comparisons

Measure: MEASURE_1

| therapy | (I) time | (J) time | Mean Difference (I-J) | Std. Error | Sig. ^a | 95% Confidence Interval for Difference ^a | | |
|---------|----------|----------|-----------------------|------------|-------------------|---|-------------|-------|
| | | | | | | Lower Bound | Upper Bound | |
| 1 | 1 | 2 | -3.200* | .490 | .003 | -4.560 | -1.840 | |
| | | 3 | -5.400* | .510 | .000 | -6.816 | -3.984 | |
| | | 4 | -3.200* | .200 | .000 | -3.755 | -2.645 | |
| | 2 | 1 | 3.200* | .490 | .003 | 1.840 | 4.560 | |
| | | 3 | -2.200* | .583 | .020 | -3.819 | -.581 | |
| | | 4 | .000 | .447 | 1.000 | -1.242 | 1.242 | |
| | 3 | 1 | 5.400* | .510 | .000 | 3.984 | 6.816 | |
| | | 2 | 2.200* | .583 | .020 | .581 | 3.819 | |
| | | 4 | 2.200* | .583 | .020 | .581 | 3.819 | |
| | 2 | 1 | 2 | 3.200* | .200 | .000 | 2.645 | 3.755 |
| | | | 2 | .000 | .447 | 1.000 | -1.242 | 1.242 |
| | | | 3 | -2.200* | .583 | .020 | -3.819 | -.581 |
| 2 | | 1 | -2.600* | .678 | .019 | -4.483 | -.717 | |
| | | 3 | -6.400* | .510 | .000 | -7.816 | -4.984 | |
| | | 4 | -3.600* | .510 | .002 | -5.016 | -2.184 | |
| 3 | | 1 | 2.600* | .678 | .019 | .717 | 4.483 | |
| | | 3 | -3.800* | 1.020 | .020 | -6.631 | -.969 | |
| | | 4 | -1.000 | .707 | .230 | -2.963 | .963 | |
| 4 | | 1 | 2 | 6.400* | .510 | .000 | 4.984 | 7.816 |
| | | | 2 | 3.800* | 1.020 | .020 | .969 | 6.631 |
| | | | 4 | 2.800* | .583 | .009 | 1.181 | 4.419 |
| | 2 | 1 | 3.600* | .510 | .002 | 2.184 | 5.016 | |
| | | 2 | 1.000 | .707 | .230 | -.963 | 2.963 | |
| | | 3 | -2.800* | .583 | .009 | -4.419 | -1.181 | |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Another example

- Habituation in mice
- Habituation represents the simplest form of learning
 - ▣ Decline in the tendency to respond to stimuli that have become familiar due to repeated exposure
- For example, a sudden noise may initially elicit reaction, but if we hear it repeatedly, we gradually get use to it so that we are less startled the second time we hear it and eventually just ignore it
- If stimulus is withheld for some period following habituation, the response will recover
 - ▣ Extinction and return

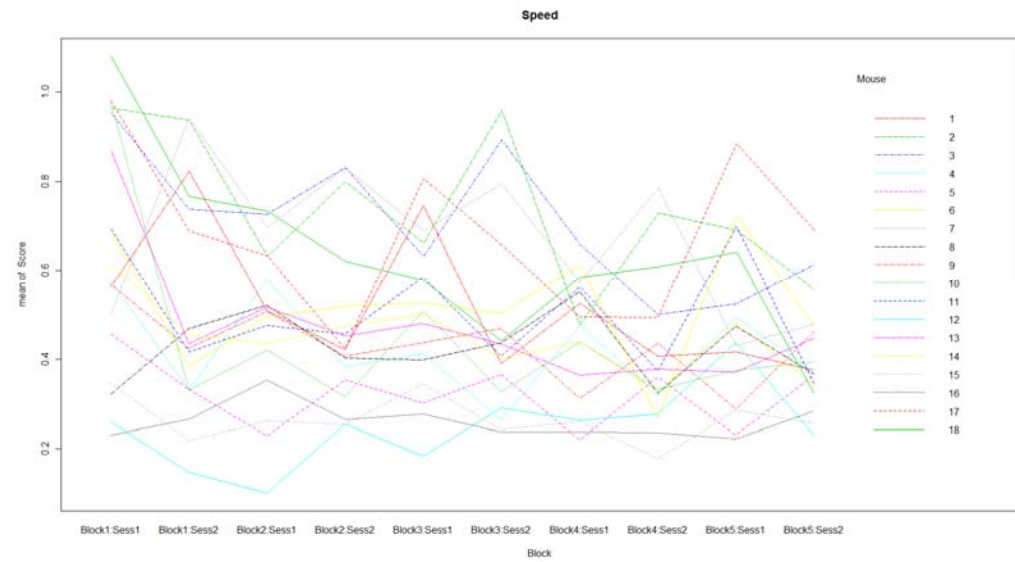
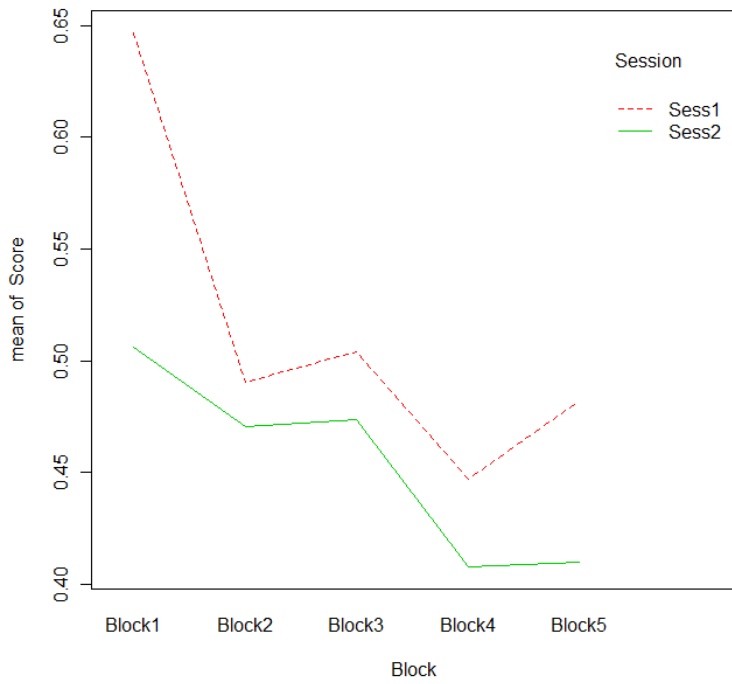
Meces

- Mice were placed in a chamber and presented with a startle tone for 50 trials, and startle response was recorded
- Then they were given a 30 minute break and run again
- Data broken down into 5 blocks of 10 trials each for each session, and it is the blocks that will be analyzed

Graphically



Speed



More

- We may want to test specific pairwise comparisons
- Perhaps we want to know if there was a significant drop from block 1 to block 5 in session 1, which would be habituation
- Then we want to look at recovery from block 5 session 1 to block 1 session 2
- Then see if there is habituation in session 2

Output

Tests of Within-Subjects Effects

Measure: MEASURE_1

Sphericity Assumed

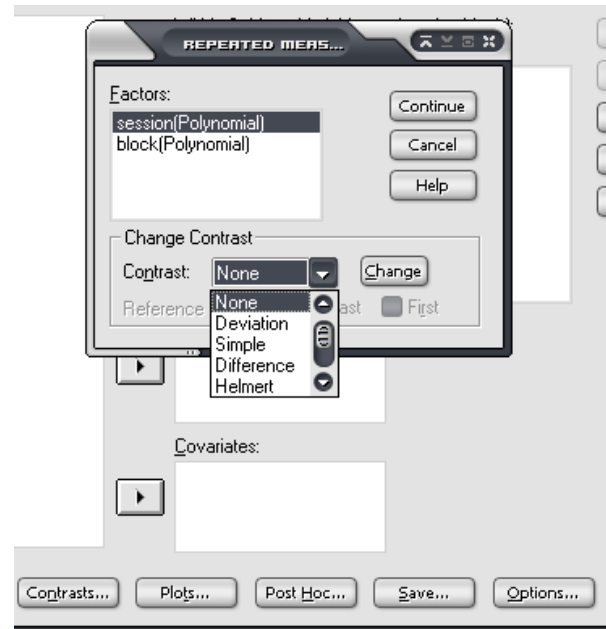
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|----------------------|-------------------------|----|-------------|-------|------|
| SESSION | .165 | 1 | .165 | 5.125 | .037 |
| Error(SESSION) | .547 | 17 | 3.216E-02 | | |
| BLOCK | .475 | 4 | .119 | 9.281 | .000 |
| Error(BLOCK) | .871 | 68 | 1.281E-02 | | |
| SESSION * BLOCK | 8.621E-02 | 4 | 2.155E-02 | 1.959 | .111 |
| Error(SESSION*BLOCK) | .748 | 68 | 1.100E-02 | | |

Paired Samples Test

| | | Paired Differences | | | t | df | Sig. (2-tailed) |
|--------|-------------|--------------------|----------------|-----------------|-------|----|--------------------|
| | | Mean | Std. Deviation | Std. Error Mean | | | |
| Pair 1 | SB11 - SB15 | .1650 | .2196 | 5.177E-02 | 3.186 | 17 | .005 |
| Pair 2 | SB15 - SB21 | -.0241 | .2328 | 5.488E-02 | -.439 | 17 | .667 |
| Pair 3 | SB21 - SB25 | 1.E-01 | .1964 | 4.628E-02 | 2.070 | 17 | .054 |

Contrasts

- Perhaps instead we wanted to test a specific type of contrast
 - ▣ Recall difference, repeated, helmert etc.



Contrasts

- In this example I chose a ‘simple’ contrast to test for habituation for the first session
- Compares each mean to some reference mean
 - ▣ First block

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

| Source | BLOCK | Type III Sum of Squares | df | Mean Square | F | Sig. |
|--------------|---------------------|-------------------------|----|-------------|--------|------|
| BLOCK | Level 2 vs. Level 1 | .441 | 1 | .441 | 10.790 | .004 |
| | Level 3 vs. Level 1 | .368 | 1 | .368 | 9.209 | .007 |
| | Level 4 vs. Level 1 | .717 | 1 | .717 | 13.764 | .002 |
| | Level 5 vs. Level 1 | .490 | 1 | .490 | 10.154 | .005 |
| Error(BLOCK) | Level 2 vs. Level 1 | .695 | 17 | 4.086E-02 | | |
| | Level 3 vs. Level 1 | .679 | 17 | 3.993E-02 | | |
| | Level 4 vs. Level 1 | .885 | 17 | 5.208E-02 | | |
| | Level 5 vs. Level 1 | .820 | 17 | 4.824E-02 | | |

More complex

- Your text provides an example of a 3 way repeated measures design
 - ▣ Had we the trial data we could have done so for the mice example
- The concepts presented here extend to that without having to add any new techniques

| Effects: | df |
|-------------|------------------------|
| □ S | $n-1$ |
| □ A | $a-1$ |
| ▣ A x S | $(a-1)(n-1)$ |
| □ B | $b-1$ |
| ▣ B x S | $(b-1)(n-1)$ |
| □ C | $c-1$ |
| ▣ C x S | $(c-1)(n-1)$ |
| □ A x B | $(a-1)(b-1)$ |
| ▣ AB x S | $(a-1)(b-1)(n-1)$ |
| □ B x C | $(b-1)(c-1)$ |
| ▣ BC x S | $(b-1)(c-1)(n-1)$ |
| □ A x C | $(a-1)(c-1)$ |
| ▣ A C x S | $(a-1)(c-1)(n-1)$ |
| □ A x B x C | $(a-1)(b-1)(c-1)$ |
| ▣ ABC x S | $(a-1)(b-1)(c-1)(n-1)$ |

APPENDIX



Data setup

- Now setting up the data in SPSS follows the same general system
 - ▣ Each row representing a single subject
- The analysis itself is run in the same way as a One-Way RM design, except now we specify 2 factors.
[*Analyze* ⇒ *General Linear Model* ⇒ *Repeated Measures*]

SPSS simple effects

- In SPSS we can use the same emmeans function again
 - `/EMMEANS = TABLES(therapy*time)compare(time)`
 - `/EMMEANS = TABLES(therapy*time)compare(therapy)`

Mice example in SPSS

