Chapter 14: Nested & Split-plot Designs

Class 24, 5/6/09 W

Slide 1 Chapter 14:
Nested & Split-plot Designs

NOTES:

HW 16 due Tues 5/12/09 Noon
Submit as Mymame-HW16.doc (or *.rtf)
- Read Chapter 14 Multifactor studies without replication
- For Weds read Chapter 23: Elements of Research Design
- For Monday Chapters 18-19: Comparisons of Proportions or Odds
- Final Class: Weds May 13 Research designs Designs
- Class schedule May 6 (Nesting and Experimental Designs), May
  11 (Overview of generalized linear models) Exptl design May 13
  W Last class
- Winba Sessions: new times; Monday night 8 pm-9
- Homework 16: Due Tuesday 5/12/09 Noon
- Final Exam 5/2/2009 Friday 8-11 am, This is the official time
  * Or 5/10/09 Tuesday 6-11 am, I'll find a room

Slide 2 HW 16 due Tues 5/12/09 Noon
NOTES:

NOTES:

NOTES:

Slide 3

NOTES:

Display 23.4
Checklist of tasks involved in the design of a study

- 1. State the objective. What is the question of interest?
- 2. Determine the scope of inference.
- 3. Will this be a randomized experiment or an observational study?
- 4. What experimental or sampling units will be used?
- 5. What are the populations of interest?
- 6. Understand the system under study.
- 7. Decide how to measure a response.
- 8. List factors that can affect the response.
- 9. Design factors
- 10. Factors to vary (treatments & controls)
- 11. Factors to fix
- 12. Confounding factors
- 13. Factors to control by design (blocking)
- 14. Factors to control by analysis (covariates)
- 15. Factors to control by randomization
- 16. Plan the context of the experiment (time line).
- 17. Outline the statistical analysis.
- 18. Determine the sample size

Attempt this
Slide 4  Nested (=hierarchical) ANOVA

NOTES:

Slide 5  Pseudoreplication= model misspecification

NOTES:

Slide 6  Nested design (Experimental units [buckets] nested within treatment)

NOTES:
Class 24: Sleuth Ch 14 & Nested Designs

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**Slide 7** Nested (hierarchical) ANOVA

**NOTES:**

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**Slide 8** Nested ANOVA, with Experimental (or Survey) Units random

**NOTES:**

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**Slide 9** How to perform Nested ANOVA

1 of 3, 3 methods if experimental units are random factors

- Decide *a priori* whether experimental or survey units (Rocky areas, companies, chimps, buckets, classes) are random or fixed factors
  - If random, the design is a mixed model ANOVA with treatment as fixed and experimental (observational) units as random
  - If fixed, the design is a fixed-factor nested ANOVA
  - The results are identical to that obtained using linear contrasts
  - Different denominator mean squares for testing main effects with random and fixed ‘units’

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Page 3 of 18
How to perform a Nested ANOVA

3 of 3

- Method 1: A tried-and-true method: perform analyses as separate one-way ANOVAs
  - 1) Test for differences among experimental units to produce 'Among Experimental Units' SS (and df) (differences among the 8 buckets in the Skagit example)
  - 2) Combine experimental units within treatments and perform 1-way ANOVA to produce among treatment SS (and df)
  - 3) Subtract Among Treatment SS from 'Among experimental units SS' to produce 'Units within treatment' SS (and df)
  - 4) Calculate Mean squares by dividing by df
  - 5) Test treatment effects
    - A) Mixed model (Units as random factors): F Test Among treatment MS/Units within treatment MS
    - B) Fixed model: Test Among treatment MS/Error MS

How to perform a Nested ANOVA

3 of 3

- Method 2: Alternatively for mixed model, calculate the mean response within each experimental unit and perform the 1-way ANOVA on the means
  - Hurlbert (1984) noted that nested ANOVAs are identical to performing ANOVAs on the unit means
- Method 3: SPSS. Must use syntax to specify the nested or hierarchical ANOVA tests.

```
* Case 1401.
UNIANOVA Item & B & sign chimp sex
METHOD = SSTYPE(3)
INTERCEPT = INCLUDE
CRITERIA = ALPHA(05)
RANDOM = chimp
DESIGN = sign sex chimp(sex) .
```

Effects of predation on Hobsonia

8 cores per bucket, Eastern & Western Blocks

- Ambiente: Pred.
- East: Pred.
- West: Pred.

NOTES:
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Slide 13 Nested ANOVA

NOTES:

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Slide 14 Mixed model nested ANOVA equivalent to ANOVA on the means

NOTES:

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Slide 15 Blocked ANOVA removes East vs. West variance

NOTES:
Nesting vs. Blocked ANOVA

- Nesting: subsamples from experimental units can not be treated as replicates (pooling may be permissible only if "Exptl Units within Treatment MS has p>0.5, see Winer et al.)
- In designing an experiment or survey with a nested structure, investigator should strive to replicate experimental or survey units, not subsamples of experimental or survey units.
- The final df will be partitioned as if only the means for each experimental unit were analyzed.
  - There is a huge benefit from taking replicate subsamples in that the estimated means will be less variable (AvgV/n, central limit theorem)
- Blocking usually produces a more powerful design.

Is there a gender difference in learning?

4 experimental units (chimons). 2 genders.

Chimpanzee data on cognitive performance.

![Graph showing performance differences between genders.]

Chimp Nested ANOVA

- Sex is a 0,1 indicator variable
- Chim is the experimental unit, chimp variability nested within gender

UNIANOVA
Innin  BY sign chimp sex
/METHOD = SSTYPE(3)
/INTERCEPT = INCLUDE
/Criteria = ALPHA(.05)
/RANDOM = chimp
/DESIGN = sign sex chimp

* Or, UNANNOVA
Innin  BY sign chimp sex
/METHOD = SSTYPE(3)
/INTERCEPT = INCLUDE
/Criteria = ALPHA(.05)
/RANDOM = chimp
/DESIGN = sign sex chimp(sex).

The two italicized syntax lines specify identical nested analyses.
If chimps random, test gender effect over ‘among chimp within gender’ mean square

If chimps are a random sample of chimps within gender, no effect of gender (p=0.62) on time to learn signs

Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Type II 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>515.158</td>
<td>1</td>
<td>515.158</td>
<td>235.173</td>
<td>.004</td>
</tr>
<tr>
<td>Error</td>
<td>5.164</td>
<td>2</td>
<td>2.582*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sign</td>
<td>65.969</td>
<td>9</td>
<td>7.337</td>
<td>1.866E-06</td>
<td>.164*</td>
</tr>
<tr>
<td>Error</td>
<td>17.643</td>
<td>27</td>
<td>0.672</td>
<td></td>
<td></td>
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<tr>
<td>sex</td>
<td>101.148</td>
<td>1</td>
<td>101.148</td>
<td>243.173</td>
<td>.001</td>
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<td>Error</td>
<td>5.164</td>
<td>2</td>
<td>2.582*</td>
<td></td>
<td>.023</td>
</tr>
<tr>
<td>chimp(sex)</td>
<td>5.164</td>
<td>2</td>
<td>2.582*</td>
<td>3.100</td>
<td>.021</td>
</tr>
</tbody>
</table>

No gender effect

Note, there is evidence for significant chimp-within-gender variance (p=0.031)

Chiromps should be regarded as a fixed not a random factor

Test treatment over error mean square, see Netter et al. (1986)

Note that nested ANOVAs are usually classified as nested models with superscripts or survey units being random not fixed effects. These analyses could not be regarded as random or even representative samples of a larger chimp population, as one chimp within gender variance should be a fixed factor and otherwise in a larger chimp population are not warranted.

Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Type II Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
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</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>51.023*</td>
<td>12</td>
<td>4.392</td>
<td>6.30</td>
<td>.008</td>
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<tr>
<td>Intercept</td>
<td>615.158</td>
<td>1</td>
<td>615.158</td>
<td>143.30</td>
<td>.002</td>
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<tr>
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<td>1</td>
<td>101.148</td>
<td>243.173</td>
<td>.001</td>
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<tr>
<td>Error</td>
<td>5.164</td>
<td>2</td>
<td>2.582*</td>
<td></td>
<td>.023</td>
</tr>
<tr>
<td>chimp(sex)</td>
<td>5.164</td>
<td>2</td>
<td>2.582*</td>
<td>3.100</td>
<td>.021</td>
</tr>
</tbody>
</table>

R Squared = .743 (Adjusted R Squared = .726)

Nested ANOVA with chimp as a fixed effect is identical to a linear contrast on sex (specified a priori)

- UNIANOVA
- Immin BY sign chimp
- /METHOD = SSTYPE(3)
- /LMATRIX = "Male v. Female" * chimp 1/2 1/2 -1/2 -1/2
- /INTERCEPT = INCLUDE
- /CRITERIA = ALPHA(.05)
- /DESIGN = sign chimp.

The denominator for Treatment F test is the error mean square
**Results of testing gender effect using linear contrast: chimp 1/2 1/2 -1/2 -1/2**

<table>
<thead>
<tr>
<th>Contrast Results (K Matrix)</th>
<th>Dependent Variable (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td></td>
</tr>
<tr>
<td>Contrast Estimate</td>
<td>-0.13</td>
</tr>
<tr>
<td>Hypothesized Value</td>
<td>.00</td>
</tr>
<tr>
<td>Difference (Estimate - Hypothesized)</td>
<td>-0.13</td>
</tr>
<tr>
<td>Std. Error</td>
<td>.36</td>
</tr>
<tr>
<td>Sig.</td>
<td>.62</td>
</tr>
<tr>
<td>95% Confidence Interval</td>
<td>Low: -0.65</td>
</tr>
<tr>
<td></td>
<td>High: 0.40</td>
</tr>
</tbody>
</table>

a. Based on the non-specified contrast differences for the various patterns.

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**Neter et al. On distinguishing between crossed and nested designs**

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**Nested vs. Crossed Factors**

<table>
<thead>
<tr>
<th>Schools</th>
<th>Mechanic Training School</th>
<th>1</th>
<th>2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta</td>
<td></td>
<td>17</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Chicago</td>
<td></td>
<td>1</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>San Francisco</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

---

**Slide 22** Results of testing gender effect using linear contrast: chimp 1/2 1/2 -1/2 -1/2

**NOTES:**

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**Slide 23** Neter et al. On distinguishing between crossed and nested designs

**NOTES:**

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**Slide 24** Nested vs. Crossed Factors

**NOTES:**
**Nested vs. Crossed**

The training example is nested, not crossed. Instructor-to-instructor variability is nested within cities & class-to-class variability is nested within instructors.

A factorial ANOVA for School and instructor can not be performed because each school has different instructors. Instructors are a nested factor, not crossed.

**Figure 28.3** Dot Plots of Class Learning Scores—Training School Example.

- **San Francisco (6 x 3):**
  - 

- **Chicago (6 x 2):**
  - 

- **Atlanta (6 x 1):**
  - 

**NOTES:**

**Slide 25** Nested vs. Crossed

**Slide 26**

**NOTES:**

**Slide 27** Are experimental units fixed or random factors?

- **Experimental Units (instructors) within treatment (cities)**

**NOTES:**

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### Slide 28  Two-factor Fixed Effects model

**NOTES:**

### Slide 29

**NOTES:**

### Slide 30  This example: Fixed factor (Model I) nested ANOVA

**NOTES:**

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**Two-factor Fixed Effects model**

Neter et al. (1996) consider instructors to be a fixed effect, not a random effect.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F(2,6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor B (within A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test for City effect over error mean square, not over instructor within city mean square.

---

**Example:** Based on the analysis of variance in Table 28.4a for the training school example, we conduct the first test to determine whether or not main school effects exist. The alternatives are given in (28.17a), and test statistic (28.17b) here is:

\[
F^* = \frac{MS_A}{MS_{E}} = \frac{11.2}{5.14} = 2.17
\]

For level of significance \(\alpha = 0.05\), we require \(F(2,6; 0.05) = 4.46\). Since \(F^* = 2.17 < 4.46\), we conclude that there is no evidence that the schools differ in learning effects.

Next is a test for differences in mean learning effects between instructors within each school. The alternatives are given in (28.18a), and test statistic (28.18b) here is:

\[
F^* = \frac{MS_I}{MS_{E}} = \frac{27.0}{7.00} = 3.86
\]

For \(\alpha = 0.05\), we require \(F(1,5; 0.05) = 7.45\). Since \(F^* = 3.86 < 7.45\), we conclude that instructors within at least one school differ in terms of mean learning effects. The \(P\)-value of this test is 0.007.

---

**This example: Fixed factor (Model I) nested ANOVA**

- Neter et al. (1996) analyze the City and instructor problem as a Model I or fixed effects Nested ANOVA.
- If the goal is to assess whether there are differences in the quality of the city training facilities (rather than the instructors), the model should probably be analyzed as a mixed model ANOVA, with instructors as random factors.
  - Note that there is no evidence that instructors are a random sample of some larger population of instructors, so the fixed model is appropriate here.
  - The inference can not be made that the city effect would be observed with a different set of instructors.
- With a mixed model nested ANOVA, the city effect is assessed vs. ‘instructors within city’ MS.
### Slide 31 Instructors as fixed factors

**UNIANOVA score BY city instructor**

/METHOD = SSTYPE(3)  
/INTERCEPT = INCLUDE  
/CRITERIA = ALPHA(.05)  
/DESIGN = city instructor(city)

<table>
<thead>
<tr>
<th>Source</th>
<th>Type II Sum of Squares</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>42.280</td>
<td>6</td>
<td>7.05</td>
<td>.005</td>
</tr>
<tr>
<td>city</td>
<td>296.520</td>
<td>9</td>
<td>33.06</td>
<td>.000</td>
</tr>
<tr>
<td>Instructor(city)</td>
<td>196.430</td>
<td>11</td>
<td>18.61</td>
<td>.000</td>
</tr>
<tr>
<td>Error</td>
<td>356.235</td>
<td>276</td>
<td>1.29</td>
<td>.883</td>
</tr>
<tr>
<td>Total</td>
<td>428.465</td>
<td>286</td>
<td>1.29</td>
<td>.883</td>
</tr>
</tbody>
</table>

* Adjusted R Square = .469

### Slide 32 Instructors as random factors

Permits inferences beyond these 6 instructors, if these instructors can be regarded as random samples from a larger pool of instructors.

**UNIANOVA score BY city instructor**

/METHOD = SSTYPE(3)  
/INTERCEPT = INCLUDE  
/CRITERIA = ALPHA(.05)  
/RANDOM = instructor  
/DESIGN = city instructor(city)

### Slide 33 If instructors treated as a random factor, there is no effect of city

**Tests of Between-Subjects Effects**

<table>
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<td>356.235</td>
<td>276</td>
<td>1.29</td>
<td>.883</td>
</tr>
</tbody>
</table>

**Business implication:** Transfer or train the instructors rather than close down an inferior city's airport repair facility.

### NOTES:

- Instructors as fixed factors
- Instructors as random factors
- If instructors treated as a random factor, there is no effect of city
Repeated Measures ANOVA

Chapter 16

If the responses are from repeated measurements of the same individual (plot, beaker, animal), the observations cannot be treated as if they are independent. Observations from the same individual are often positively correlated. A repeated measures analysis must be used. It is usually advantageous to do so, because more powerful tests of hypotheses are possible.

Repeated measures designs

Sampling units serve as their own controls

- Observations are collected at different times on the same sampling unit
- Placebo, control drug trials
- Sampling the same quadrat (area) through time
- The errors within a subject are correlated

- Within and between subject factors
  - Within subject factors: two different observations of the same sampling unit (e.g., time or drug dose)
  - Between subject factors: disjoint groups of sampling units (patients, plots, treatment, order of treatment)

- Repeated measures designs offer much more powerful tests than non-repeated designs

Advantages & Disadvantages

From Neter et al. (1996)

- Advantages
  - Increased precision because between-subject variability is excluded from experimental error
  - Economizes on subjects
  - When the shape of the time effect is important, measures of the same subject (fitting population growth is possible)

- Disadvantages & Interferences
  - Order effect
  - Carryover effect (bland soup, good soup, grocery shopping [full & empty trips])

- Other disadvantages: more complicated assumptions and models
Analyzing repeated measures designs

Three classes of repeated measures analysis

- Repeated measures designs
  - Common features
    - Repeated measures from the same individual at or across time
    - Within-subjects at the subject level
    - Correlated outcomes
    - Multivariate outcome
    - Repeatedly measured
- 1) Univariate repeated measures (Winer et al.)
  - Developed by Fisher, Bonferroni as a random effect
  - Repeated Sphericity
  - 2) Multivariate (Repeated Measures, Profile analysis)
  - Handling of F and other multivariate statistics
    - Scheffe 2001 on MANOVA vs. End (2001) on repeated measures
- 3) Longitudinal models
  - Giger & Wing (1980) multivariate longitudinal time
    - Multivariate longitudinal models (Giger & Wing 1995, Filmusman et al., 2004)
    - More detailed analysis of within-subjects and within-subjects effects
  - More uncorrelated errors in assessment time effects
  - SAS Proc mixed, SPSS Mixed
- If there are just two paired variables, use a paired t test
- Nonparametric test: Friedman's ANOVA

NOTES:

Case study 16.2

- 20 subjects
- Randomized, double blind, crossover trial
- 1-wk baseline on normal diet
- Randomly assigned to high and low fiber diet
- 6 weeks on blood chemistry
- Normal diet for 2 weeks
- Crossed over to other diet

NOTES:

SPSS Syntax for cholesterol

```plaintext
GLM multivariate (=MANOVA) in SPSS advanced modules

* Compare to Display 1610 in text
GLM baseline hflr lowflr
/AWSFACTOR = diet 3 Difference
/METHOD = SSTYPE(3)
/PLOT = PROFILE(diet)
/EMMEANS = TABLES(diet)
/PRINT = DESCRIPTIVE
/CINTERVAL = ALPHA(.05)
/WSDESIGN = diet .
```

The assumption for the multivariate approach is that the vector of the response variables follow a multivariate normal distribution, and the variance-covariance matrices are equal across the cells formed by the between-subjects effects.

NOTES:
**Large differences in diet effects on cholesterol**

No reason to reject the sphericity assumption

| Source        | Type I Sum of Squares | df | Mean Square | Sig. | F
|---------------|-----------------------|----|-------------|------|---
| Sphericity Assumed | 2419.306 | 2 | 1209.153 | 0.775 | 3.702C-004
| Greenhouse-Geisser | 2410.203 | 1.999 | 1205.714 | 0.776 | 3.704C-004
| Hoge-Feld | 2410.306 | 3.999 | 1399.609 | 0.776 | 3.706C-004
| Lower-Bound | 2410.306 | 1.999 | 1205.714 | 0.776 | 3.704C-004
| Error (diet) | 4869.003 | 28 | 173.861 | 0.123 | 1.000C-003

Report that, 'univariate repeated measures ANOVA' found strong evidence for diet effects on cholesterol (p=0.0004)

---

**Effect of high fiber diet**

Little difference between High and Low-fiber diet

Note Bonferroni C.I.'s narrower than the [-8, 8.1, 10] C.I.'s using the 'T' multiplier (Display 16.10)

**Pathwise Comparisons**

| Pair | Mean Difference | Std. Error | Sig. | 95% Confidence Interval for Difference
|------|-----------------|------------|------|---------------------------------------
| 1 2  | -13.853*        | 3.533      | .003 | Lower Bound Upper Bound               |
| 3 2  | 13.006*         | 3.473      | .004 | 3.892 22.118                         |
| 3 3  | -8.600          | 3.528      | .000 | -16.110 8.450                      |
| 1 3  | -13.006*        | 3.473      | .004 | -22.118 -3.892                      |
| 2 3  | -8.600          | 3.528      | .000 | -16.110 8.450                      |

Based on estimated marginal means

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

# Adjustment for multiple comparisons. Bonferroni.

---

**Display 16.11**

High-baseline and high-low cholesterol levels, by the order of assignment

NOTES:
Test for an order effect

Order is a between-subjects factor, diet is within subjects

* Repeated measures between subjects test.

GLM
baseline hflbr lfofr BY order
/WSFACTOR = diet 3 Difference
/CONTRAST (order)=Difference
/METHOD = SSTYPE(3)
/PLOT = PROFILE(diet order) diet
/CRIERIA = ALPHA(.05)
/WSDESIGN = diet
/DESIGN = order.

NOTES:

No order effect on diet

Sphericity assumption appears justified here.

<table>
<thead>
<tr>
<th>Source of Error</th>
<th>dfd</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
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</thead>
<tbody>
<tr>
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<td>1234.567</td>
<td>8.91</td>
<td>.0000</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>6</td>
<td>1234.567</td>
<td>8.91</td>
<td>.0000</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>7</td>
<td>1234.567</td>
<td>8.91</td>
<td>.0000</td>
</tr>
<tr>
<td>Lower Bound</td>
<td>8</td>
<td>1234.567</td>
<td>8.91</td>
<td>.0000</td>
</tr>
<tr>
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<td>8.91</td>
<td>.0000</td>
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<tr>
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<td>8.91</td>
<td>.0000</td>
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<tr>
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<td>8.91</td>
<td>.0000</td>
</tr>
<tr>
<td>Lower Bound</td>
<td>8</td>
<td>1234.567</td>
<td>8.91</td>
<td>.0000</td>
</tr>
</tbody>
</table>

There is little evidence (repeated measures ANOVA diet*order effect, p=0.24) that diet order affects cholesterol differences among diets.

NOTES:

Friedman’s Nonparametric repeated measures ANOVA

Example from Hollander & Wolfe

NOTES:
Rank within subject

Must assume no Player x Treatment Interaction

<table>
<thead>
<tr>
<th>Player</th>
<th>Treatment</th>
<th>Rank</th>
<th>Subject</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
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<td>F</td>
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<tr>
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<td>4.0</td>
</tr>
<tr>
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<td>H</td>
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</tr>
<tr>
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<tr>
<td>10</td>
<td>J</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Note that observations can be converted to ranks for testing more complicated models.

Multi-level longitudinal models

www.ats.ucla.edu/stat/examples/alda

- Multi-level longitudinal models are an increasingly powerful method for analyzing longitudinal data
- Fits model parameters using maximum likelihood estimators, allows fitting of more complex variance/covariance matrices

Is the individual growth trajectory discontinuous?

Wage trajectories of male SEAD cases

- Visual inspection
- Subject matter expertise
- Indicator of having a "jump" in the wage trajectory

Three plausible alternative discontinuous multilevel models for change

Y_{ij} = \beta_0 + \beta_1 Y_{i,j-1} + \beta_2 X_{ij} + \epsilon_{ij}

Notes:

- ...
Class 24: Sleuth Ch 14 & Nested Designs

Slide 49

NOTES:

Slide 50

NOTES:

Slide 51 Maximum likelihood estimation

NOTES:
12 red & black marbles in a bucket, 5 marbles drawn & 3 red marbles found: What is the maximum likelihood estimate for the number of red marbles in the bucket?

Hypergeometric distribution:
Gallagher's matlab m.file
k=[0.5];
pr=LMTheorem030301(5,k,7,12)
pr =0.0013 0.0442 0.2652
0.4419 0.2210 0.0285

Display 21.12: The number of red marbles found in each sample of 5 marbles drawn from a bucket of 12 red & 7 black marbles.

NOTES: