Course Business

- Midterm assignment due on Canvas by Monday, 1:30 PM
  - Unsure if an article is suitable? Run it by me, by Friday
  - Don’t need to submit if just auditing the course

- New dataset on Canvas
- Add-on package to install for today:
  - afex

- The look ahead:
  - This week: Finish categorical predictors
  - Next Monday: Categorical outcomes
  - Next Wednesday: No class!
Week 8.2: Orthogonal Contrasts

- Factors with More than 2 Levels
  - Treatment Coding
  - Problem of Multiple Comparisons
  - Orthogonal Contrasts
    - Example
    - Implementation
    - Definition
    - Practice
- Overview of Coding Systems
- Additional Tests
  - Testing an Overall Factor
  - Random Slopes
Alice in Um-derland (Fraundorf & Watson, 2011)

- How do disfluencies in speech (e.g., “uh”, “um”) change listener comprehension?
- Disfluencies more common with *more difficult material*, so might lead listeners to pay more attention
- But: Any benefit might be confounded with just *having more time* to process
  - Control: Speaker coughing, matched in duration
Alice in Um-derland (Fraundorf & Watson, 2011)

- disfluency.csv on CourseWeb

- Each participant hears stories based on Alice in Wonderland
  - Later, test recall of each chapter – scored from 0 to 10

- Conditions:
  - Some chapters told fluently (control)
  - Some chapters contain speech fillers
  - Some have coughs matched in duration to the fillers
  - Each subject hears some chapters in all 3 conditions
  - Each chapter heard in all 3 conditions across subjects
Alice in Um-derland (Fraundorf & Watson, 2011)

- Average memory score in each condition:
  - `disfluency %>%
    group_by(InterruptionType) %>%
    summarize(MemoryM=mean(MemoryScore))`

<table>
<thead>
<tr>
<th>InterruptionType</th>
<th>MemoryM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.06</td>
</tr>
<tr>
<td>Cough</td>
<td>6.29</td>
</tr>
<tr>
<td>Filler</td>
<td>7.54</td>
</tr>
</tbody>
</table>
Factors with More Than 2 Levels

• How can we code a variable with three categories?
  • Control = 0, Cough = 1, Filler = 2?
  • Let’s imagine the equations:

Control: \[ \text{Score} = \gamma_{000} + \gamma_{100} \times \text{InterruptionType} \]

Cough: \[ \text{Score} = \gamma_{000} + \gamma_{100} \times \text{InterruptionType} \]

Filler: \[ \text{Score} = \gamma_{000} + \gamma_{100} \times \text{InterruptionType} \]
Factors with More Than 2 Levels

- How can we code a variable with three categories?
  - Control = 0, Cough = 1, Filler = 2?
  - Let’s imagine the equations:

<table>
<thead>
<tr>
<th>Control</th>
<th>Score = γ₀₀₀ + γ₁₀₀ * 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>Score = γ₀₀₀ + γ₁₀₀ * 1</td>
</tr>
<tr>
<td>Filler</td>
<td>Score = γ₀₀₀ + γ₁₀₀ * 2</td>
</tr>
</tbody>
</table>
Factors with More Than 2 Levels

- How can we code a variable with three categories?
  - Control = 0, Cough = 1, Filler = 2?
- Let’s imagine the equations:

<table>
<thead>
<tr>
<th>Category</th>
<th>Score Equation</th>
<th>Score</th>
<th>Differ by</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>$\gamma_{000} + \gamma_{100}$</td>
<td>0</td>
<td>$\gamma_{100}$</td>
<td>0</td>
</tr>
<tr>
<td>Cough</td>
<td>$\gamma_{000} + \gamma_{100}$</td>
<td>1</td>
<td>$\gamma_{100}$</td>
<td>1</td>
</tr>
<tr>
<td>Filler</td>
<td>$\gamma_{000} + \gamma_{100}$</td>
<td>2</td>
<td>$\gamma_{100}$</td>
<td>2</td>
</tr>
</tbody>
</table>

- This coding scheme assumes Control & Cough differ by the same amount as Cough & Filler
- Probably not true. Not a safe assumption
Factors with More Than 2 Levels

• To actually represent three levels, we need *two sets of codes*
  • “InterruptionType1” and “InterruptionType2”

• If a factor has 3 or more levels, R *automatically* creates multiple sets of codes
  • `contrasts(disfluency$InterruptionType)`

One set of codes (“InterruptionType1”). 1 for Cough, 0 for everything else.

Another, different set of codes (“InterruptionType2”). 1 for Filler, 0 for everything else.
Week 8.2: Orthogonal Contrasts

- Factors with More than 2 Levels
- Treatment Coding
  - Problem of Multiple Comparisons
  - Orthogonal Contrasts
    - Example
    - Implementation
    - Definition
    - Practice
  - Overview of Coding Systems
- Additional Tests
  - Testing an Overall Factor
  - Random Slopes
## Treatment Coding With >2 Levels

- The two sets of codes are 2 separate variables in the underlying regression equation:

<table>
<thead>
<tr>
<th>Control</th>
<th>Score  = $\gamma_{000} + \gamma_{100} \times \text{InterruptionType1} + \gamma_{200} \times \text{InterruptionType2} $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>Score  = $\gamma_{000} + \gamma_{100} \times \text{InterruptionType1} + \gamma_{200} \times \text{InterruptionType2} $</td>
</tr>
<tr>
<td>Filler</td>
<td>Score  = $\gamma_{000} + \gamma_{100} \times \text{InterruptionType1} + \gamma_{200} \times \text{InterruptionType2} $</td>
</tr>
</tbody>
</table>
## Treatment Coding With >2 Levels

- The two sets of codes are 2 separate variables in the underlying regression equation:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Score Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>$\text{Score} = \gamma_{000} + \gamma_{100} * 0 + \gamma_{200} * 0$</td>
</tr>
<tr>
<td>Cough</td>
<td>$\text{Score} = \gamma_{000} + \gamma_{100} * \text{InterruptionType1} + \gamma_{200} * \text{InterruptionType2}$</td>
</tr>
<tr>
<td>Filler</td>
<td>$\text{Score} = \gamma_{000} + \gamma_{100} * \text{InterruptionType1} + \gamma_{200} * \text{InterruptionType2}$</td>
</tr>
</tbody>
</table>
Treatment Coding With >2 Levels

• The two sets of codes are 2 separate variables in the underlying regression equation:

\[ \text{Score} = \gamma_{000} + \gamma_{100} \times \text{InterruptionType1} + \gamma_{200} \times \text{InterruptionType2} \]

Once again, the intercept is just performance in the baseline level (the one coded with all 0s)

Control: \[ \text{Score} = \gamma_{000} \]

Cough: \[ \text{Score} = \gamma_{000} + \gamma_{100} \times 1 + \gamma_{200} \times 0 \]

Filler: \[ \text{Score} = \gamma_{000} + \gamma_{100} \times \text{InterruptionType1} + \gamma_{200} \times \text{InterruptionType2} \]
Treatment Coding With >2 Levels

- The two sets of codes are 2 separate variables in the underlying regression equation:

\[ \text{Score} = \gamma_{000} + \gamma_{100} \times \text{InterruptionType1} + \gamma_{200} \times \text{InterruptionType2} \]

- Once again, the intercept is just performance in the baseline level (the one coded with all 0s)

\[ \text{Score} = \gamma_{000} \]

\[ \text{Score} = \gamma_{000} + \gamma_{100} \]

- InterruptionType1 = Difference between fluent story & coughs

\[ \text{Score} = \gamma_{000} + \gamma_{100} \]

\[ \gamma_{200} \]

\[ \gamma_{200} \]

- Filler

\[ \gamma_{200} \]

\[ \gamma_{200} \]

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Treatment Coding With >2 Levels

- The two sets of codes are 2 separate variables in the underlying regression equation:

  \[ \text{Score} = \gamma_{000} \]

  Once again, the intercept is just performance in the baseline level (the one coded with all 0s)

  \[ \text{Control} \]

  \[ \text{Score} = \gamma_{000} + \gamma_{100} \]

  InterruptionType1 = Difference between fluent story & coughs

  \[ \text{Cough} \]

  \[ \text{Score} = \gamma_{000} + \gamma_{200} \]

  InterruptionType2 = Difference between fluent story & fillers

  \[ \text{Filler} \]
Treatment Coding: Results

Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: MemoryScore ~ 1 + InterruptionType + (1 | Subject) + (1 | Chapter)
   Data: disfluency

REML criterion at convergence: 1472.1

Scaled residuals:
   Min  1Q Median       3Q  Max
-3.6598 -0.6178  0.0593  0.06349  2.7545

Random effects:
   Groups     Name         Variance  Std.Dev.
   Subject    (Intercept) 0.4301   0.6558
   Chapter    (Intercept) 0.0955   0.3090
   Residual              1.0349  1.0173
Number of obs: 480, groups: Subject, 40; Chapter, 12

Fixed effects:  Estimate   Std. Error    df  t value   Pr(>|t|)
   (Intercept)      0.6573     0.1587   46.6788   38.171 <2e-16 ***
   InterruptionTypeCough  0.2290    0.1138   427.1141   2.013  0.0447    *
   InterruptionTypeFiller  1.4866    0.1138  427.1141   13.067 <2e-16 ***

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
   (Intr) IntrTC
IntrrptnTyC -0.358
IntrrptnTyF 0.358

Intercept: Baseline score in the control condition

Cough effect: Greater recall with coughs than control fluent condition

Filler effect: Greater recall with speech fillers than control fluent condition
Week 8.2: *Orthogonal Contrasts*

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The Problem of Multiple Comparisons

• It would be nice to have a **direct** comparison of fillers vs. coughs

• Actually, there are a *lot* of other comparisons we could consider…
  • Fillers vs. coughs
  • Fluent story vs. any kind of interruption
  • Fillers vs. mean performance in this task
  • Cough vs. mean performance in this task

• But there is a problem running *too many* comparisons
Recap of Hypothesis Tests

- Under null hypothesis of no effect, extreme $z$- or $t$-values are improbable
Recap of Hypothesis Tests

• Under null hypothesis of no effect, extreme z- or t-values are improbable
• A t-value with < 5% probability: Significant evidence against null hypothesis
• But, possible (just unlikely) even if no real effect

Total probability of a z-score here under H0 = .05
Recap of Hypothesis Tests

• Under null hypothesis of no effect, extreme $z$- or $t$-values are improbable
• A $t$-value with < 5% probability: Significant evidence against null hypothesis
• But, possible (just unlikely) even if no real effect
  • Could just result from chance! (sampling error)
  • We’d conclude that there is an effect, but it doesn’t really exist
  • **False positive** or **Type I error**
• 5% probability of this happening
• $\alpha = .05$
Problem of Multiple Comparisons

- With $\alpha = .05$ (Type I error rate of 5%), we’d expect 1 in 20 comparisons to be significant just by chance
- Problem if we want to run lots of comparisons!
- Even if aren’t running 20 comparisons, Type I error will be inflated with >1 comparison

- Probability of fully avoiding Type I error:

\[
1 - \alpha \times 1 - \alpha \approx 90\%
\]
Problem of Multiple Comparisons

• With $\alpha = .05$ (Type I error rate of 5%), we’d expect 1 in 20 comparisons to be significant just by chance
  • Problem if we want to run lots of comparisons!
  • Even if aren’t running 20 comparisons, Type I error will be inflated with $>1$ comparison

• Probability of fully avoiding Type I error:

\[
1 - \alpha \quad (95\%) \times 1 - \alpha \quad (95\%) \times \ldots = (1-\alpha)^c
\]

- $c$ = Number of contrasts

• **Familywise** error rate: $\alpha_{FW} = 1 - (1-\alpha)^c$
  • Probability of making a Type I error somewhere
News

Green Jelly Beans Linked to Acne!

95% Confidence

Only 5% Chance of Coincidence!
Problem of Multiple Comparisons

- Situation gets even more complicated if we use some of the same means in >1 comparison
  - e.g., coughs vs. fluent control
  - and fillers vs. fluent control

By chance, we may have had particularly difficult material in the Control condition (sampling error)

Underestimated true population mean

$\alpha = .05$
Problem of Multiple Comparisons

- Situation gets even more complicated if we use some of the same means in >1 comparison
- If one contrast produces a Type I error, other contrasts involving the same mean(s) have a higher probability of Type I error
  - They’re not independent

\[ \alpha_{FW} > .05 \]
**Problem of Multiple Comparisons**

- These reasons are why R doesn’t perform all possible comparisons between all levels
- In general, for a factor with $g$ levels, $g-1$ contrasts can fully describe the pattern of means

| Fixed effects:                     | Estimate | Std. Error | df  | t value | Pr(>|t|) |
|-----------------------------------|----------|------------|-----|---------|----------|
| (Intercept)                       | 6.0573   | 0.1587     | 46.6788 | 38.171 | <2e-16 *** |
| InterruptionTypeCough             | 0.2290   | 0.1138     | 427.1141 | 2.013 | 0.0447 *   |
| InterruptionTypeFiller            | 1.4866   | 0.1138     | 427.1141 | 13.067 | <2e-16 *** |

- Coughs
  - $M$ score = 6.29
  - Cough effect +0.23
  - Intercept (Control) $M$ score = 6.06

- Fillers
  - $M$ score = 7.55
  - Filler effect +1.49

**Difference must be 1.26!**
Problem of Multiple Comparisons

• These reasons are why R doesn’t perform all possible comparisons between all levels
  • In general, for a factor with \( g \) levels, \( g-1 \) contrasts can fully describe the pattern of means

• In fact, even our current comparisons aren’t totally independent
  • Filler vs. control
  • Coughs vs. control
  • If we have underestimated (or overestimated) performance in Control condition, both comparisons will be affected
Problem of Multiple Comparisons

• Solutions to problem of multiple comparisons of factor levels:
  1. Apply a *correction* for multiple comparisons so that the familywise Type I error stays at \( \alpha = .05 \)
     - The Tukey test from `emmeans`
     - We discussed this on Monday
     - Good when we don’t have strong *a priori* hypothesis, but less power
  2. Run only a limited number of comparisons
     - \( g - 1 \) codes in our model are sufficient to describe the definition
     - Especially those that are *independent*
     - Good when *specific* comparisons suggested by our research questions
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Orthogonal Contrasts

• Another set of comparisons…

CONTRAST 1

FLUENT
CONTROL

COUGHS

FILLERS

CONTRAST 2

Do **coughs** and **fillers** differ?

Do interruptions (in general) differ from **fluent** speech?
Orthogonal Contrasts

These comparisons are independent ("orthogonal")

Knowing that interruptions differ from fluent speech doesn’t tell us *anything* about which type (if any) is better

Do coughs and fillers differ?

Do interruptions (in general) differ from fluent speech?
**Orthogonal Contrasts**

- In each contrast, compares the **positive-coded** level(s) to the **negative-coded** level(s).
- Ignore the level(s) coded as zero.

**CONTRAST 1**

- **FLUENT CONTROL**
- **COUGHS**
- **FILLERS**

Do **coughs and fillers** differ?

**CONTRAST 2**

- Do **interruptions (in general)** differ from **fluent speech**?
**Orthogonal Contrasts**

- In each contrast, compares the positive-coded level(s) to the negative-coded level(s).
- Ignore the level(s) coded as zero.

**CONTRAST 1**

- FLUENT CONTROL: 0
- COUGHS: -1/2
- FILLERS: 1/2

Do coughs and fillers differ?

Centered around mean of 0!

**CONTRAST 2**

- FLUENT CONTROL
- COUGHS
- FILLERS

Do interruptions (in general) differ from fluent speech?
Orthogonal Contrasts

- In each contrast, compares the positive-coded level(s) to the negative-coded level(s).
- Ignore the level(s) coded as zero.

**Contrast 1**
- **Fluent Control**: 0
- **Coughs**: -1/2
- **Fillers**: 1/2

Do coughs and fillers differ?

**Contrast 2**
- **Fluent Control**: -2/3
- **Coughs**: 1/3
- **Fillers**: 1/3

Do interruptions (in general) differ from fluent speech?

Centered around mean of 0!
Orthogonal Contrasts

- In each contrast, compares the **positive-coded** level(s) to the **negative-coded** level(s)
- Ignore the level(s) coded as zero

**CONTRAST 1**
- **FLUENT CONTROL**
  - **COUGHS**
    - 0
  - **FILLERS**
    - -1/2
    - 1/2

**CONTRAST 2**
- **COUGHS**
  - -2/3
- **FILLERS**
  - 1/3

Do **coughs** and **fillers** differ?

Centered around mean of 0!

Number of groups on the opposite side:
- **CONTRAST 2**: -2/3, 1/3

Total number of groups being compared in this contrast:
- **CONTRAST 1**: 0, -1/2, 1/2
- **CONTRAST 2**: -2/3, 1/3

Centers the contrast
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Let’s Change the Contrasts

• As before, we use `<-` to change the contrasts

<table>
<thead>
<tr>
<th>Cough</th>
<th>Filler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
</tr>
<tr>
<td>Cough</td>
<td>1</td>
</tr>
<tr>
<td>Filler</td>
<td>0</td>
</tr>
</tbody>
</table>

• Now, we’re trying to create a matrix of numbers
• Need to stick two columns together with `cbind`

```
contrasts(disfluency$InterruptionType) <- cbind(c(0, -1/2, 1/2), c(-2/3, 1/3, 1/3))
```

<table>
<thead>
<tr>
<th>Contrast 1</th>
<th>Contrast 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.0</td>
</tr>
<tr>
<td>Cough</td>
<td>-0.5</td>
</tr>
<tr>
<td>Filler</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Naming the Contrasts

• Default contrast names are just “1” and “2”

• We can change the names of these columns with `colnames()`
  • `colnames(contrasts(disfluency$InterruptionType)) <- c('FillerVsCough', 'InterruptionVsFluent')`

• Optional—it just makes the output easier to read
Orthogonal Contrasts: Results

- summary(orthogonal.Maximal)

| Fixed effects                                | Estimate | Std. Error | df   | t value | Pr(>|t|) |
|----------------------------------------------|----------|------------|------|---------|----------|
| (Intercept)                                  | 6.66830  | 0.14395    | 31.35702 | 46.324   | < 2e-16  *** |
| InterruptionTypeFillerVsCough                | 1.37715  | 0.19927    | 15.76321 | 6.911    | 3.80e-06 *** |
| InterruptionTypeInterruptionVsFluent         | 0.91769  | 0.09742    | 33.76044 | 9.420    | 5.64e-11 *** |

**Intercept**: Mean score across conditions (because these are centered)

**Contrast 1**: Fillers produce higher recall than coughs
→ *Not* just about the pause in speech

**Contrast 2**: Speech with pauses/interruptions better remembered than totally fluent speech
→ Effect of having more time
Which Model Fits Better?

• `anova(dummycode.Maximal, orthogonal.Maximal)`

<table>
<thead>
<tr>
<th></th>
<th>Df</th>
<th>AIC</th>
<th>BIC</th>
<th>logLik</th>
<th>deviance</th>
</tr>
</thead>
<tbody>
<tr>
<td>dummycode.Maximal</td>
<td>16</td>
<td>1462.8</td>
<td>1529.5</td>
<td>-715.38</td>
<td>1430.8</td>
</tr>
<tr>
<td>orthogonal.Maximal</td>
<td>16</td>
<td>1462.8</td>
<td>1529.5</td>
<td>-715.38</td>
<td>1430.8</td>
</tr>
</tbody>
</table>

• Overall model fit is **identical!**
  • Same **total** amount of variance explained
  • The same information is available to the model either way
  • We’re just dividing it up differently

• Changing coding schemes will **not** change the overall fit of the model
Week 8.2: Orthogonal Contrasts

Factors with More than 2 Levels
Treatment Coding
Problem of Multiple Comparisons
  ● Orthogonal Contrasts
    ● Example
    ● Implementation
    ● Definition
      ● Practice
  ● Overview of Coding Systems
  ● Additional Tests
    ● Testing an Overall Factor
    ● Random Slopes
What Makes Contrasts Orthogonal?
What Makes Contrasts Orthogonal?

• **Criterion 1**: Codes within contrast sum to 0

<p>|</p>
<table>
<thead>
<tr>
<th>CONTRAST 1</th>
<th>CONTRAST 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENT CONTROL</td>
<td>0</td>
</tr>
<tr>
<td>COUGHS</td>
<td>-1/2</td>
</tr>
<tr>
<td>FILLERS</td>
<td>1/2</td>
</tr>
</tbody>
</table>
= 0          |
|             | -2/3       |
|             | 1/3        |
= 0          |
What Makes Contrasts Orthogonal?

- **Criterion 1:** Codes within contrast sum to 0
- *and* **Criterion 2:**
  - Multiply codes for each level across contrasts
  - Then sum across the levels
  - Needs to sum to 0

Yes, orthogonal!

<table>
<thead>
<tr>
<th>CONTRAST 1</th>
<th>CONTRAST 2</th>
<th>PRODUCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENT</td>
<td>-2/3</td>
<td>0</td>
</tr>
<tr>
<td>CONTROL</td>
<td>1/3</td>
<td>-0.165</td>
</tr>
<tr>
<td>COUGHS</td>
<td>1/3</td>
<td>0</td>
</tr>
<tr>
<td>FILLERS</td>
<td>1/2</td>
<td>0.165</td>
</tr>
</tbody>
</table>

\[0 \times \left( -\frac{2}{3} \right) \times \left( \frac{1}{3} \right) + 0.165 = 0\]
What Makes Contrasts Orthogonal?

- **Criterion 1**: Codes within contrast sum to 0
- **and Criterion 2**:
  - Multiply codes for each level across contrasts
  - Then sum across the levels
  - Needs to sum to 0

No, not orthogonal
What Makes Contrasts Orthogonal?

- **Criterion 1:** Codes within contrast sum to 0
- **and** Criterion 2:
  - Multiply codes for each level across contrasts
  - Then sum across the levels
  - Needs to sum to 0

Treatment codes are not orthogonal!
What Makes Contrasts Orthogonal?

- **Criterion 1**: Codes within contrast sum to 0
- **and Criterion 2**:  
  - Multiply codes for each level across contrasts  
  - Then sum across the levels  
  - Needs to sum to 0

- Interpretation given earlier…  
  - Each contrast compares the + and – levels  
  - And ignores the 0-coded levels  
  - …is valid *only* if each pair of contrasts is orthogonal
Week 8.2: Orthogonal Contrasts

- Factors with More than 2 Levels
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Orthogonal Contrasts Practice

• For each set of contrasts, decide whether it IS orthogonal or IS not orthogonal.

(a) 

\[
\begin{bmatrix}
\text{[,1]} & \text{[,2]}
\end{bmatrix}
\]

\[
\text{Divorced} \quad 1 & 0 \\
\text{Married} \quad 0 & 1 \\
\text{Single} \quad 0 & 0
\]

(b) 

\[
> \text{contrasts(L2Vocab$RelationType)}
\]

\[
\begin{bmatrix}
\text{[,1]} & \text{[,2]}
\end{bmatrix}
\]

\[
\text{SimilarMeaning} \quad 0.3333333 & 0.5 \\
\text{SimilarSound} \quad 0.3333333 & -0.5 \\
\text{Unrelated} \quad -0.6666667 & 0.0
\]

(c) 

\[
\begin{bmatrix}
\text{[,1]} & \text{[,2]}
\end{bmatrix}
\]

\[
\text{Young} \quad -1 & -1 \\
\text{MiddleAge} \quad 1 & -1 \\
\text{Older} \quad 0 & 2
\]

(d) 

\[
\begin{bmatrix}
\text{Northeast} & \text{South} & \text{West}
\end{bmatrix}
\]

\[
\text{Midwest} \quad 0 & 0 & 0 \\
\text{Northeast} \quad 1 & 0 & 0 \\
\text{South} \quad 0 & 1 & 0 \\
\text{West} \quad 0 & 0 & 1
\]
Orthogonal Contrasts Practice

• For each set of contrasts, decide whether it IS orthogonal or IS not orthogonal.

(a) NOT orthogonal

(b) orthogonal

(c) orthogonal

(d) NOT orthogonal
• Zebulon is a health psychologist examining the (potentially) protective effect of physical exercise on cognition in older adults. Measures of working memory are obtained from older adults from each of three groups: a control group that just stretches, a group that performs low-intensity exercises, and a group that performs moderate-intensity exercises.

• What is a reasonable set of orthogonal comparisons that Zebulon might make?
Orthogonal Contrasts Practice

• Zebulon is a health psychologist examining the (potentially) protective effect of physical exercise on cognition in older adults. Measures of working memory are obtained from older adults from each of three groups: a control group that just stretches, a group that performs low-intensity exercises, and a group that performs moderate-intensity exercises.

• What is a reasonable set of orthogonal comparisons that Zebulon might make?
  • One plausible set of comparisons is (a) control vs. any type of exercise, and (b) moderate- vs. low-intensity exercise. (Other answers may be possible.)
Orthogonal Contrasts Practice

• Hitomi is a clinical psychologist investigated the effectiveness of talk therapy. She examines the severity of depressive symptoms in three groups: waitlisted controls, people receiving medication, and people receiving medication and talk therapy. In her dataframe, `depression`, this `TreatmentType` variable looks like this:

• Hitomi wants to compare:
  1. The two groups receiving any treatment vs. controls
  2. Medication + talk therapy vs. medication only

• Create some R code to set these 2 contrasts:
Orthogonal Contrasts Practice

• Hitomi is a clinical psychologist investigated the effectiveness of talk therapy. She examines the severity of depressive symptoms in three groups: waitlisted controls, people receiving medication, and people receiving medication and talk therapy. In her dataframe, depression, this TreatmentType variable looks like this:

• Hitomi wants to compare:
  1. The two groups receiving any treatment vs. controls
  2. Medication + talk therapy vs. medication only
• Create some R code to set these 2 contrasts:
  • `contrasts(depression$TreatmentType) <- cbind(c(-2/3, 1/3, 1/3), c(0, -0.5, 0.5))`
Week 8.2: Orthogonal Contrasts

Factors with More than 2 Levels
- Treatment Coding
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    - Definition
    - Practice

Overview of Coding Systems
- Additional Tests
  - Testing an Overall Factor
  - Random Slopes
**Treatment / Dummy Coding**

- **Coding:**
  - Baseline level always coded as 0
  - Each other level is coded as 1 in one of the \( g-1 \) contrasts

- Treatment coding is R’s default, but we might want to set this back (if we switched to something else but we want treatment coding back)

- **Shortcut** to this:
  - `contrasts(disfluency$InterruptionTime) <- contr.treatment(n=3)`
  - \( n=3 \) because there are 3 groups
**Treatment / Dummy Coding**

- **Coding:**
  - Baseline level always coded as 0
  - Each other level is coded as 1 in one of the \(g-1\) contrasts
  - `contr.treatment()` in R

- **Interpretation:**
  - Each contrast compares one condition to the **baseline**

- **Examples:**
  - Compare each of 2 different interventions (talk therapy & medication) to control w/ no intervention
  - In reading time, compare each of helpful and unhelpful context to version with **no** context
Orthogonal Contrasts

• Coding:
  • Each contrast sums to 0
  • Product of weights across contrasts also sums to 0

• Interpretation:
  • Within each contrast, positively coded levels are compared to negative ones

• Examples:
  • Second language learning. Contrast 1 compares words related to 1st language with unrelated words. Contrast 2 compares two types of relations.

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-0.66</td>
<td>0.00</td>
</tr>
<tr>
<td>Cough</td>
<td>0.33</td>
<td>-0.5</td>
</tr>
<tr>
<td>Filler</td>
<td>0.33</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Helmert Contrasts

- Coding:
  - A *subtype* of orthogonal contrast
  - `contr.helmert()` in R

- Interpretation:
  - Each level is compared to the mean of all previous ones

- Use when categories are *ordered*:
  - Changes in time / across phases of an experiment
  - “Easy,” “medium,” or “hard” items
  - Control, mild anxiety, severe anxiety
Orthogonal Polynomials

- Coding:
  - A subtype of orthogonal contrast
  - \texttt{contr.poly()} in R

- Interpretation:
  - Is there a linear effect across levels?
  - Is there a quadratic effect across levels?
  - + cubic, quartic, etc…

- Use when categories are \textit{ordered} and you’re interested in the \textit{form} of the relation
  - Linear increase from low->medium->high arousal, or is medium arousal the best?
**Sum Coding**

- **Coding:**
  - Code one level as -0.5 (or as -1)
  - Each other level is coded as 0.5 (or 1) in one of the \( g-1 \) contrasts
  - `contr.sum()` in R

- **Interpretation:**
  - Each contrast compares one condition to the *overall mean*

- **Used when we don’t want to compare specific conditions & don’t have a clear baseline:**
  - Compare students with various majors to the mean across majors
Week 8.2: Orthogonal Contrasts

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    - Testing an Overall Factor
      - Random Slopes
Testing an Overall Factor

- So far, we have compared specific categories (levels) of a factor

- Sometimes, when we have >2 levels, we also just want to ask if the factor matters at all
  - “Do interruptions affect speech comprehension?”
  - “Are there race/ethnicity differences in feelings of belonging in high school?”
  - “Do different persuasion techniques result in different consumer purchasing behavior?”
  - “Do people with different majors differ in the ease of transition to college?”

- Often asked in ANOVA / experimental contexts
Testing an Overall Factor

- `anova(orthogonal.Maximal)`
- Requires `lmerTest` to be loaded

---

<table>
<thead>
<tr>
<th>Type III Analysis of Variance Table with Satterthwaite's method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum Sq</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>InterruptionType</td>
</tr>
</tbody>
</table>

---

Notes:
- Since this tests the overall contribution of the factor, not affected by how you code the individual levels.
- For a 2-level factor, identical to the main-effect test you get with effects-coding.
Week 8.2: Orthogonal Contrasts

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Random Slopes

• Last week, we saw you could simplify the random-effects structure by omitting random correlations with 
• e.g., correlation between random slope & random intercept
• \((1 + \text{InterruptionType} || \text{Subject})\)
Random Slopes

- For a factor with >2 levels, correlations between the contrasts will still be included
  - `lmer(MemoryScore ~ 1 + InterruptionType + (1 + InterruptionType || Subject) + (1 + InterruptionType || Chapter))`

- To completely eliminate them, load package `afex` and use `lmer_alt()` instead of `lmer()`
  - `lmer_alt(MemoryScore ~ 1 + InterruptionType + (1 + InterruptionType || Subject) + (1 + InterruptionType || Chapter))`

<table>
<thead>
<tr>
<th>Subject.1 InterruptionTypeControl</th>
<th>0.49161</th>
<th>0.7011</th>
</tr>
</thead>
<tbody>
<tr>
<td>InterruptionTypeCough</td>
<td>0.68595</td>
<td>0.8282</td>
</tr>
<tr>
<td>InterruptionTypeFiller</td>
<td>0.24112</td>
<td>0.4910</td>
</tr>
<tr>
<td>0.92</td>
<td>0.73</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject   (Intercept)</th>
<th>0.40713</th>
<th>0.6381</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject.1 re1.InterruptionTypeFillerVsCough</td>
<td>0.08204</td>
<td>0.2864</td>
</tr>
<tr>
<td>Subject.2 re1.InterruptionTypeInterruptionVsFluent</td>
<td>0.00000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>