Repeated measure

Guy

Load required packages

```
library(RcmdrMisc)
```

```
Loading required package: car
```

```
Loading required package: carData
```

```
Loading required package: sandwich
```

```
library(ggplot2)
library(nlme)
library(emmeans)
```

```
Welcome to emmeans.
Caution: You lose important information if you filter this package's results.
See '? untidy'
```

Importing data

```
chap9data1 <- read.csv("chap9data1.csv", sep=",", header=T)
View(chap9data1)
```

Let us do the example in chapter 9 (“Biometry 721/821 Workbook(2024).pdf”) #Example 1

```r
chap9data1$Food <- as.factor(chap9data1$Food)
chap9data1$Calf <- as.factor(chap9data1$Calf)
chap9data1$Month <- as.factor(chap9data1$Month)
```

#fit model

```r
chap9data1.model1 <- lme(Weight~Month*Food,random=~1|Calf,data=chap9data1)
anova(chap9data1.model1)
```

```
            numDF denDF  F-value p-value
(Intercept)     1    24 465.2000  <.0001
Month           3    24  15.6277  <.0001
Food            1     8   1.4088  0.2693
Month:Food      3    24   0.8711  0.4697
```

```r
chap9data1.model2 <- aov(Weight~Food*Month + Error(Calf),data=chap9data1)
summary(chap9data1.model2)
```

```
Error: Calf
          Df Sum Sq Mean Sq F value Pr(>F)
Food       1  409.6   409.6   1.409  0.269
Residuals  8 2326.0   290.8

Error: Within
           Df Sum Sq Mean Sq F value   Pr(>F)
Month       3 1036.9   345.6  15.628 7.58e-06 ***
Food:Month  3   57.8    19.3   0.871     0.47
Residuals  24  530.8    22.1
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Interpretation of the ANOVA Results

The analysis of variance (ANOVA) was conducted using a linear mixed-effects model (`lme`) to understand the effects of `Month`, `Food`, and their interaction (`Month:Food`) on the `Weight` of calves. Here is the interpretation of the ANOVA table generated:

1. **Intercept:**

   - **F-value:** 465.2000
   - **p-value:** `<.0001`
   - This indicates that the intercept is highly significant. In mixed-effects models, the intercept represents the baseline level of the dependent variable (`Weight`) when all predictors are at their reference level. A highly significant intercept suggests that the mean `Weight` of the calves is significantly different from zero.

2. **Month:**

   - **Degrees of Freedom (numDF):** 3
   - **F-value:** 15.6277
   - **p-value:** `<.0001`
   - The variable `Month` has a highly significant effect on `Weight` (p-value < 0.0001). This suggests that the average `Weight` of the calves changes significantly across different months.

3. **Food:**

   - **Degrees of Freedom (numDF):** 1
   - **F-value:** 1.4088
   - **p-value:** 0.2693
   - The variable `Food` does not have a statistically significant effect on `Weight` (p-value $=$ 0.2693). This indicates that, after accounting for other variables in the model, different types of food do not significantly affect the calves' weight.

4. **Interaction Between Month and Food (Month:Food):**

   - **Degrees of Freedom (numDF):** 3
   - **F-value:** 0.8711

- **p-value:** 0.4697

- The interaction between `Month` and `Food` is not statistically significant (p-value = 0.4697). This suggests that the effect of `Food` on `Weight` does not vary significantly across different months.

Conclusion:

- The results indicate that the calves' weight varies significantly over the months (`Month` is significant), but there is no significant effect of `Food` or the interaction between `Month` and `Food` on the weight. Therefore, month-to-month changes are the main driver of differences in weight, rather than the type of food or any combined effect of the month and food type. " " "

Interpretation of the ANOVA Summary

The analysis of variance (ANOVA) was conducted using the `aov` function with an `Error` term for the random effect of `Calf`. This model evaluates the effects of `Food`, `Month`, and their interaction (`Food:Month`) on the `Weight` of calves while accounting for the random effect of `Calf`. Here is the interpretation of the ANOVA summary:

1. Error: Calf (Random Effect)

- This section represents the variance attributed to differences between calves (treated as a random effect).
- **Food:**
  - **Degrees of Freedom (Df):** 1
  - **Sum of Squares (Sum Sq):** 409.6
  - **Mean Square (Mean Sq):** 409.6
  - **F-value:** 1.409
  - **p-value (Pr(>F)):** 0.269
  - The effect of `Food` is not statistically significant (p-value = 0.269). This suggests that differences in the type of food do not significantly contribute to variations in weight among different calves.

2. Error: Within (Within-Groups Effects)

- This section shows the variance explained by the fixed effects (`Month` and `Food:Month`) within the groups (calves).
- **Month:**
  - **Degrees of Freedom (Df):** 3
  - **Sum of Squares (Sum Sq):** 1036.9
  - **Mean Square (Mean Sq):** 345.6
  - **F-value:** 15.628
  - **p-value (Pr(>F)):** 7.58e-06 (very significant, denoted by ***)
  - The effect of `Month` on `Weight` is highly significant (p-value < 0.0001). This indicates that the weight of calves changes significantly across different months.
- **Food:Month Interaction:**
  - **Degrees of Freedom (Df):** 3
  - **Sum of Squares (Sum Sq):** 57.8
  - **Mean Square (Mean Sq):** 19.3
  - **F-value:** 0.871
  - **p-value (Pr(>F)):** 0.47
  - The interaction between `Food` and `Month` is not statistically significant (p-value = 0.47). This suggests that the effect of `Food` on `Weight` does not vary significantly over different months.

3. Residuals

- Represents the unexplained variance within the groups after accounting for the fixed effects (`Month` and `Food:Month`).
- **Degrees of Freedom (Df):** 24
- **Sum of Squares (Sum Sq):** 530.8
- **Mean Square (Mean Sq):** 22.1

Conclusion

- The weight of calves varies significantly across different months, indicating a strong effect of `Month`.
- There is no significant effect of `Food` alone or the interaction between `Food` and `Month` on the weight of calves.
- The differences between individual calves (random effect of `Calf`) and other unexplained factors account for the remaining variance.

#Multiple comparisons

```
# Calculate estimated marginal means for the model
emmeans_result <- emmeans(chap9data1.model1, ~ Month)
```

```
NOTE: Results may be misleading due to involvement in interactions
```

```
# Display the estimated marginal means
summary(emmeans_result)
```

```
 Month emmean   SE df lower.CL upper.CL
 3       50.7 2.99  8     43.8     57.6
 4       57.2 2.99  8     50.3     64.1
 5       59.9 2.99  8     53.0     66.8
 6       64.8 2.99  8     57.9     71.7

Results are averaged over the levels of: Food
Degrees-of-freedom method: containment
Confidence level used: 0.95
```

```
# Conduct pairwise comparisons
pairs(emmeans_result)
```

```
 contrast        estimate  SE df t.ratio p.value
 Month3 - Month4     -6.5 2.1 24  -3.091  0.0241
 Month3 - Month5     -9.2 2.1 24  -4.374  0.0011
 Month3 - Month6    -14.1 2.1 24  -6.704  <.0001
 Month4 - Month5     -2.7 2.1 24  -1.284  0.5817
 Month4 - Month6     -7.6 2.1 24  -3.614  0.0071
 Month5 - Month6     -4.9 2.1 24  -2.330  0.1192

Results are averaged over the levels of: Food
Degrees-of-freedom method: containment
P value adjustment: tukey method for comparing a family of 4 estimates
```

Interpretation of Estimated Marginal Means and Pairwise Comparisons

The analysis gives the estimated marginal means (EMMs) for different months and the pairwise comparisons between these months. Here is the interpretation:

1. Estimated Marginal Means (EMMs) for `Month`

- The table provides the estimated marginal means (`emmeans`) for each month along with their standard errors (`SE`), degrees of freedom (`df`), and confidence intervals (`lower.CL` and `upper.CL`).
- These EMMs represent the average weight for each month, adjusted for the levels of `Food`.

Example Values:

- **Month 3:** Estimated mean weight is 50.7 with a 95% confidence interval from 43.8 to 57.6.
- **Month 4:** Estimated mean weight is 57.2 with a 95% confidence interval from 50.3 to 64.1.
- **Month 5:** Estimated mean weight is 59.9 with a 95% confidence interval from 53.0 to 66.8.
- **Month 6:** Estimated mean weight is 64.8 with a 95% confidence interval from 57.9 to 71.7.

Note: There is a warning that results may be misleading due to involvement in interactions, so interpretation should consider the presence of significant interactions in the model.

2. Pairwise Comparisons Between Months

- Pairwise comparisons were performed between the different months to evaluate if there are significant differences in mean weights.

Contrast Estimates:

- **Month 3 vs. Month 4:** Difference in means is -6.5 (Month 3 lower), with a p-value of 0.0241 (significant).
- **Month 3 vs. Month 5:** Difference in means is -9.2 (Month 3 lower), with a p-value of 0.0011 (highly significant).
- **Month 3 vs. Month 6:** Difference in means is -14.1 (Month 3 lower), with a p-value < 0.0001 (very highly significant).

- **Month 4 vs. Month 5:** Difference in means is -2.7 (Month 4 lower), with a p-value of 0.5817 (not significant).
- **Month 4 vs. Month 6:** Difference in means is -7.6 (Month 4 lower), with a p-value of 0.0071 (significant).
- **Month 5 vs. Month 6:** Difference in means is -4.9 (Month 5 lower), with a p-value of 0.1192 (not significant).

Conclusion from Pairwise Comparisons:

- Significant differences in weight exist between several months, particularly between Month 3 and the other months (4, 5, and 6), indicating that weights vary significantly as time progresses.

3. P-Value Adjustment

- The p-values are adjusted using the Tukey method for multiple comparisons, ensuring that the family-wise error rate is controlled.

Conclusion

- The estimated marginal means reveal a general increase in weight from Month 3 to Month 6.
- Significant differences exist between several months, particularly Month 3 versus later months, suggesting time-related effects on weight.
- Results should be interpreted cautiously, considering potential interaction effects between `Month` and other variables such as `Food`.

Exercises

Do all the exercices in page 66 on document "Biometry 721/821 Workbook(2024).pdf"