Homework 7

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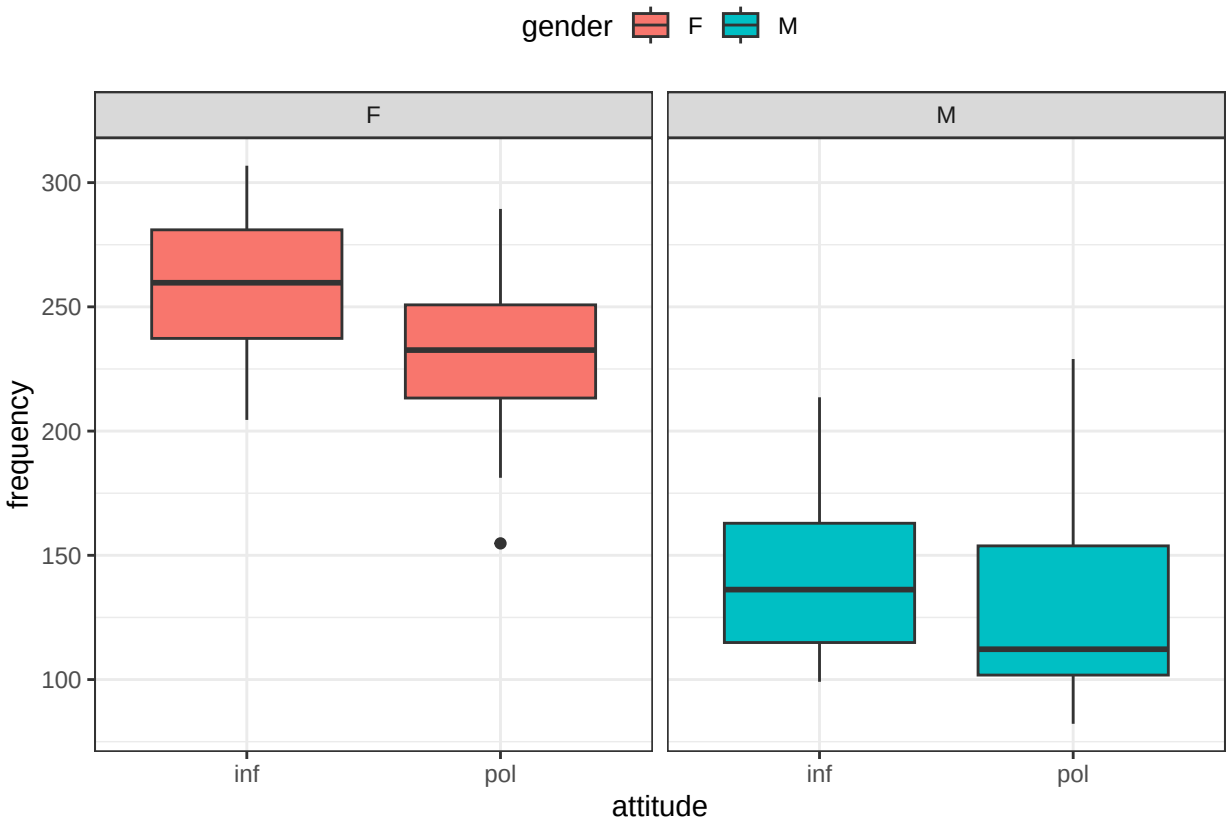
```
# data prep
df = read_csv("HW7-politeness_data.csv")
```

(a) Exploratory Analysis

```
# gender/attitude and pitch
df |>
  ggplot(aes(x = attitude, y = frequency, fill = gender)) +
  geom_boxplot() +
  facet_wrap(~gender)
```



```r
gender <- df$gender
attitude <- df$attitude
subject <- df$subject
frequency <- df$frequency
scenario <- df$scenario
```

The boxplots illustrates the relation between gender/attitude and pitch. We can see that Female tend to have higher frequency than Male, and lower frequency is more likely to be considered as formal (pol).

(b) LMM with random intercepts

I will fit a mixed effects model with random intercepts for different subjects with gender and attitude being the fixed effects.

```r
# LMM with random intercept
# gender, attitude fixed
LMM1 <- lme(frequency ~ gender + attitude, random = ~1 | subject, method = "REML")

summary(LMM1)
```

```
## Linear mixed-effects model fit by REML
##   Data: NULL
##        AIC      BIC    logLik
##   806.0805 818.0527 -398.0402
##
## Random effects:
##  Formula: ~1 | subject
##         (Intercept) Residual
## StdDev:    24.45803 29.11537
##
## Fixed effects:  frequency ~ gender + attitude
##                  Value Std.Error DF   t-value p-value
## (Intercept)  256.98690 15.154986 77 16.957251  0.0000
## genderM     -108.79762 20.956235  4 -5.191659  0.0066
## attitudepol  -20.00238  6.353495 77 -3.148248  0.0023
##  Correlation:
##             (Intr) gendrM
## genderM     -0.691
## attitudepol -0.210  0.000
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.3564422 -0.5658319 -0.2011979  0.4617895  3.2997610
##
## Number of Observations: 84
## Number of Groups: 6
```

```r
VarCorr(LMM1)
```

```
## subject = pdLogChol(1)
##             Variance StdDev
## (Intercept) 598.1953 24.45803
## Residual    847.7049 29.11537
```

Given the output,

$$cov(Y_i) = \begin{pmatrix} 1445.90 & 598.20 & ... & 598.20 \\ 598.20 & 1445.90 & ... & 598.20 \\ ... & & & \\ 598.20 & 598.20 & ... & 1445.90 \end{pmatrix}$$

The covariance matrix for the estimates of fixed effects are as follows:

```
vcov(LMM1)
```

```
##             (Intercept)       genderM   attitudepol
## (Intercept)   229.67362 -2.195819e+02 -2.018345e+01
## genderM      -219.58189  4.391638e+02  2.879122e-15
## attitudepol   -20.18345  2.879122e-15  4.036690e+01
```

The best linear unbiased predictions (BLUPs) for subject-specific intercepts:

```
random.effects(LMM1)
```

```
##    (Intercept)
## F1  -13.575831
## F2   10.170522
## F3    3.405309
## M3   27.960288
## M4    4.739325
## M7  -32.699613
```

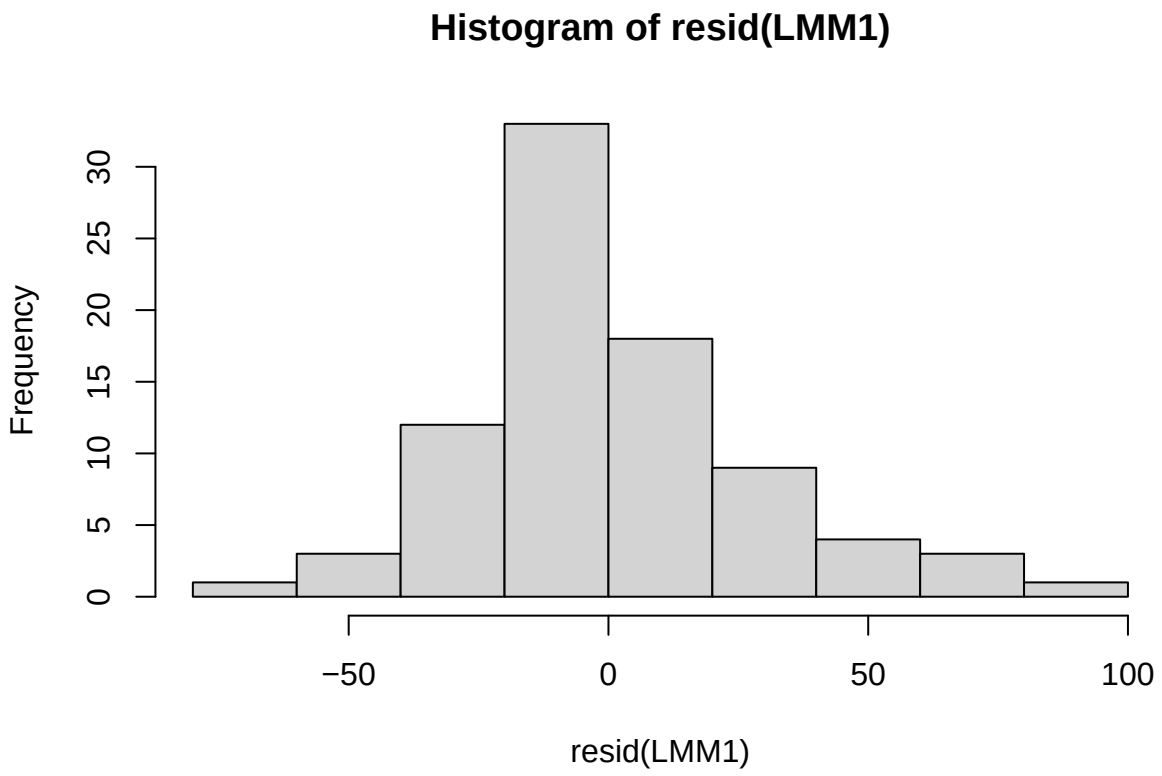
Residuals:

```
resid(LMM1)
```

```
##          F1          F1          F1          F1          F1          F1
## -10.1086926 -38.9110735  61.6913074  16.2889265 -19.5086926  43.4889265
##          F1          F1          F1          F1          F1          F1
##  27.3913074  33.3889265   8.4913074   8.9889265 -42.2086926 -12.7110735
##          F1          F1          F3          F3          F3          F3
## -26.9110735 -68.6086926 -10.6898326 -23.0922136  -3.5898326  -9.3922136
##          F3          F3          F3          F3          F3          F3
##  26.6101674   5.6077864  35.0101674  46.4077864  -7.7898326  -7.8922136
##          F3          F3          F3          F3          M4          M4
## -13.8898326  18.4077864   4.0077864 -54.8898326 -22.2262298 -29.3286108
##          M4          M4          M4          M4          M4          M4
##  96.0737702 -38.0286108 -20.7262298  60.6713892  60.4737702   9.9713892
##          M4          M4          M4          M4          M4          M4
## -31.1262298 -26.0286108 -22.9262298 -16.7286108  -6.9286108  -6.4262298
##          M7          M7          M7          M7          M7          M7
##  -9.3872916 -16.3896725 -13.2872916 -11.1896725  -9.5872916  -5.2896725
##          M7          M7          M7          M7          M7          M7
##   1.6127084   4.5103275  -1.7872916 -12.5896725  13.3127084  -7.2896725
##          M7          M7          F2          F2          F2          F2
##   8.9103275  12.1127084 -14.4550462 -35.8574271  -0.8550462  -7.4574271
##          F2          F2          F2          F2          F2          F2
```

```
##  42.2449538  34.6425729  -3.9550462  29.0425729  30.5449538  27.0425729
##          F2          F2          F2          F2          M3          M3
## -39.1550462 -41.2574271  13.8425729 -19.9550462  -2.3471929  12.6504261
##          M3          M3          M3          M3          M3          M3
## -13.7471929  23.5504261   4.0528071   9.9504261  51.3528071  14.7504261
##          M3          M3          M3          M3          M3          M3
##   4.5528071 -19.6495739  -9.4471929 -18.1495739 -15.0495739  -2.8471929
## attr(,"label")
## [1] "Residuals"
```

```
hist(resid(LMM1))
```



(c) LMM with random intercepts and interaction

I will fit a mixed effects model with random intercepts for different subjects with gender, attitude and their interaction being the fixed effects.

```
# LMM with random intercept
# gender, attitude, gender*attitude fixed
LMM2 <- lme(frequency ~ gender + attitude + gender*attitude, random = ~1 | subject, method = "REML")

summary(LMM2)
```

```
## Linear mixed-effects model fit by REML
```

```
##   Data: NULL
##        AIC     BIC    logLik
##   799.8018 814.094 -393.9009
##
## Random effects:
##  Formula: ~1 | subject
##         (Intercept) Residual
## StdDev:    24.46382 29.04716
##
## Fixed effects:  frequency ~ gender + attitude + gender * attitude
##                            Value Std.Error DF   t-value p-value
## (Intercept)           260.68571 15.481307 76 16.838740  0.0000
## genderM              -116.19524 21.893875  4 -5.307203  0.0061
## attitudepol           -27.40000  8.964149 76 -3.056620  0.0031
## genderM:attitudepol    14.79524 12.677221 76  1.167073  0.2468
##  Correlation:
##                       (Intr) gendrM atttdp
## genderM               -0.707
## attitudepol           -0.290  0.205
## genderM:attitudepol    0.205 -0.290 -0.707
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.2344163 -0.5454437 -0.1646159  0.4697182  3.1800944
##
## Number of Observations: 84
## Number of Groups: 6
```

The output indicates that the interaction term does not have a significant influence on the response variable.

Now, I will refit LMM1 and LMM2 using ML method for the likelihood ratio test.

```
LMM1.1 <- lme(frequency ~ gender + attitude, random = ~1 | subject, method = "ML")
LMM2.1 <- lme(frequency ~ gender + attitude + gender*attitude, random = ~1 | subject, method = "ML")

# LRT of interaction
anova(LMM1.1, LMM2.1)
```

```
##        Model df      AIC      BIC    logLik   Test  L.Ratio p-value
## LMM1.1     1  5 825.6363 837.7904 -407.8182
## LMM2.1     2  6 826.2508 840.8357 -407.1254 1 vs 2 1.385523  0.2392
```

Given the result (p-value > 0.05), we fail to reject the null hypothesis. Therefore, we conclude that including the interaction term is not significantly associated with pitch.

(d) LMM with random intercept for both subject and scenarios

I will fit a mixed effects model with random intercepts for different subjects and scenarios with gender and attitude being the fixed effects.

```
LMM3 <- lmer(frequency ~ gender + attitude + (1 | subject) + (1 | scenario))

summary(LMM3)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: frequency ~ gender + attitude + (1 | subject) + (1 | scenario)
##
## REML criterion at convergence: 784.1
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.2690 -0.6331 -0.0878  0.5204  3.5326
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  scenario (Intercept) 224.5    14.98
##  subject  (Intercept) 613.2    24.76
##  Residual             637.8    25.25
## Number of obs: 84, groups:  scenario, 7; subject, 6
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  256.987     16.101  15.961
## genderM     -108.798     20.956  -5.192
## attitudepol  -20.002      5.511  -3.630
##
## Correlation of Fixed Effects:
##             (Intr) gendrM
## genderM     -0.651
## attitudepol -0.171  0.000
```

```
print(VarCorr(LMM3), comp = "Variance")
```

```
##  Groups   Name        Variance
##  scenario (Intercept) 224.50
##  subject  (Intercept) 613.19
##  Residual             637.78
```

Given the output,

$$cov(Y_i) = \begin{pmatrix} 1475.47 & 837.69 & ... & 837.69 \\ 837.69 & 1475.47 & ... & 837.69 \\ ... & & & \\ 837.69 & 837.69 & ... & 1475.47 \end{pmatrix}$$

The coefficient for the fixed effect `attitudepol` is -20.00. This means that the pitch is lower in polite speech than in informal speech, by about 20 Hz holding other variable constant.