Excercise Cows

```
# rm(list = ls()) # Clean the workspace
# Read the data
cows<-read.table(file="C:/Users/toledo/Dropbox/UNIPD/Biostatistics Curse  R Spring 2018/curso STAT phD 2018 Mi
                 stringsAsFactors = TRUE,header = TRUE,sep = "\t")
cows$parity<-as.factor(cows$parity) # Set parity as factor
cows$herd<-as.factor(cows$herd)     # Set herd as factor
contrasts(cows$parity)<-contr.SAS   # Change the reference grid to SAS
contrasts(cows$herd)<-contr.SAS     # Change the reference grid to SAS

#install.packages("lme4")  # If necesary install the library
library(lme4)              # Call the library to the workspace
library(car)               # Call the library to the workspace
library(lsmeans)           # Call the library to the workspace
# Fit the model
lmm<-lmer(milk ~ parity + weight + (1 | herd) ,data = cows, REML = TRUE)
summary(lmm)            # Results of the mixed model
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: milk ~ parity + weight + (1 | herd)
##    Data: cows
##
## REML criterion at convergence: 388
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.5897 -0.5578  0.1287  0.7297  1.5893
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  herd     (Intercept)  3.407   1.846
##  Residual             11.831   3.440
## Number of obs: 72, groups:  herd, 6
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 17.17861   14.98365   1.146
## parity1     -7.38790    1.63848  -4.509
## parity2     -2.85477    1.09722  -2.602
## weight       0.01732    0.02287   0.757
##
## Correlation of Fixed Effects:
##         (Intr) party1 party2
## parity1 -0.814
## parity2 -0.454  0.613
## weight  -0.998  0.795  0.425
```

```
AIC(lmm)               # Akaike's Information Criterion (small is better)
```

```
## [1] 400.0195
```

```
BIC(lmm)               # Bayesian Information Criterion (small is better)
```

```
## [1] 413.6795
```

```
Anova(lmm, type=3,test.statistic = "F") # ANOVA table SS type III
```

```
## Analysis of Deviance Table (Type III Wald F tests with Kenward-Roger df)
##
## Response: milk
```

```
##                   F Df Df.res    Pr(>F)
## (Intercept)  1.2837  1 66.293 0.2612908
## parity      10.0323  2 64.057 0.0001621 ***
## weight       0.5601  1 66.035 0.4568590
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
lsmeans(lmm,"parity")      # LSM
```

```
##  parity   lsmean       SE    df lower.CL upper.CL
##  1      20.66521 1.252830 20.13 18.05291 23.27751
##  2      25.19834 1.037309 10.59 23.03543 27.36126
##  3      28.05311 1.187009 16.92 25.57806 30.52816
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
```

```r
getME(lmm, name=c("X"))    #  Extract the matrix X
```

```
##    (Intercept) parity1 parity2 weight
## 1            1       1       0    600
## 2            1       1       0    570
## 3            1       1       0    580
## 4            1       1       0    602
## 5            1       0       1    650
## 6            1       0       1    600
## 7            1       0       1    630
## 8            1       0       1    580
## 9            1       0       0    690
## 10           1       0       0    610
## 11           1       0       0    590
## 12           1       0       0    640
## 13           1       1       0    590
## 14           1       1       0    610
## 15           1       1       0    590
## 16           1       1       0    590
## 17           1       0       1    660
## 18           1       0       1    640
## 19           1       0       1    620
## 20           1       0       1    630
## 21           1       0       0    660
## 22           1       0       0    670
## 23           1       0       0    660
## 24           1       0       0    660
## 25           1       1       0    590
## 26           1       1       0    610
## 27           1       1       0    610
## 28           1       1       0    570
## 29           1       0       1    650
## 30           1       0       1    620
## 31           1       0       1    630
## 32           1       0       1    620
## 33           1       0       0    670
## 34           1       0       0    650
## 35           1       0       0    680
## 36           1       0       0    650
## 37           1       1       0    580
## 38           1       1       0    610
## 39           1       1       0    600
## 40           1       1       0    620
## 41           1       0       1    630
```

```
## 42           1       0       1    660
## 43           1       0       1    630
## 44           1       0       1    620
## 45           1       0       0    660
## 46           1       0       0    650
## 47           1       0       0    650
## 48           1       0       0    660
## 49           1       1       0    620
## 50           1       1       0    600
## 51           1       1       0    620
## 52           1       1       0    600
## 53           1       0       1    660
## 54           1       0       1    620
## 55           1       0       1    650
## 56           1       0       1    630
## 57           1       0       0    660
## 58           1       0       0    640
## 59           1       0       0    680
## 60           1       0       0    680
## 61           1       1       0    590
## 62           1       1       0    600
## 63           1       1       0    580
## 64           1       1       0    590
## 65           1       0       1    650
## 66           1       0       1    630
## 67           1       0       1    640
## 68           1       0       1    650
## 69           1       0       0    660
## 70           1       0       0    640
## 71           1       0       0    650
## 72           1       0       0    630
## attr(,"assign")
## [1] 0 1 1 2
## attr(,"contrasts")
## attr(,"contrasts")$parity
##   1 2
## 1 1 0
## 2 0 1
## 3 0 0
##
## attr(,"msgScaleX")
## character(0)
```

```
getME(lmm, name=c("Z"))    #  Extract the matrix Z
```

```
## 72 x 6 sparse Matrix of class "dgCMatrix"
##    1 2 3 4 5 6
## 1  1 . . . . .
## 2  1 . . . . .
## 3  . 1 . . . .
## 4  . 1 . . . .
## 5  1 . . . . .
## 6  1 . . . . .
## 7  . 1 . . . .
## 8  . 1 . . . .
## 9  1 . . . . .
## 10 1 . . . . .
## 11 . 1 . . . .
## 12 . 1 . . . .
## 13 1 . . . . .
## 14 1 . . . . .
```

```
## 15 . 1 . . . .
## 16 . 1 . . . .
## 17 1 . . . . .
## 18 1 . . . . .
## 19 . 1 . . . .
## 20 . 1 . . . .
## 21 1 . . . . .
## 22 1 . . . . .
## 23 . 1 . . . .
## 24 . 1 . . . .
## 25 . . 1 . . .
## 26 . . 1 . . .
## 27 . . . 1 . .
## 28 . . . 1 . .
## 29 . . 1 . . .
## 30 . . 1 . . .
## 31 . . . 1 . .
## 32 . . . 1 . .
## 33 . . 1 . . .
## 34 . . 1 . . .
## 35 . . . 1 . .
## 36 . . . 1 . .
## 37 . . 1 . . .
## 38 . . 1 . . .
## 39 . . . 1 . .
## 40 . . . 1 . .
## 41 . . 1 . . .
## 42 . . 1 . . .
## 43 . . . 1 . .
## 44 . . . 1 . .
## 45 . . 1 . . .
## 46 . . 1 . . .
## 47 . . . 1 . .
## 48 . . . 1 . .
## 49 . . . . 1 .
## 50 . . . . 1 .
## 51 . . . . . 1
## 52 . . . . . 1
## 53 . . . . 1 .
## 54 . . . . 1 .
## 55 . . . . . 1
## 56 . . . . . 1
## 57 . . . . 1 .
## 58 . . . . 1 .
## 59 . . . . . 1
## 60 . . . . . 1
## 61 . . . . 1 .
## 62 . . . . 1 .
## 63 . . . . . 1
## 64 . . . . . 1
## 65 . . . . 1 .
## 66 . . . . 1 .
## 67 . . . . . 1
## 68 . . . . . 1
## 69 . . . . 1 .
## 70 . . . . 1 .
## 71 . . . . . 1
## 72 . . . . . 1
```

```r
getME(lmm, name=c("fixef"))#  Extract the BLUE
```

```
## (Intercept)     parity1     parity2      weight
## 17.17860547 -7.38789562 -2.85476524  0.01731762
```

```r
ranef(lmm)                 # Extract the BLUP
```

```
## $herd
##   (Intercept)
## 1  0.19901915
## 2 -0.70047241
## 3  0.81174602
## 4 -0.04831009
## 5  2.30943820
## 6 -2.57142087
```

```r
# Reshape Weight creating levels for weight
cows$weight_c<-NA
cows$weight_c[cows$weight <= 600]<-1
cows$weight_c[cows$weight > 600 & cows$weight <= 630]<-2
cows$weight_c[cows$weight > 630 & cows$weight <= 660]<-3
cows$weight_c[cows$weight > 660]<-4
table(cows$weight_c)
```

```
##
##  1  2  3  4
## 19 22 25  6
```

```r
cows$weight_c<-as.factor(cows$weight_c) # Set Variable as Factor
contrasts(cows$weight_c)<-contr.SAS       # Set Contrasts as SAS
# Fit the model and test contrasts
lmm<-lmer(milk ~ parity + weight_c + (1 | herd) ,data = cows, REML = TRUE)
summary(lmm)            # Results of the mixed model
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: milk ~ parity + weight_c + (1 | herd)
##    Data: cows
##
## REML criterion at convergence: 371.5
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.6320 -0.4947  0.1119  0.7345  1.8331
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  herd     (Intercept)  3.546   1.883
##  Residual             11.548   3.398
## Number of obs: 72, groups:  herd, 6
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   29.584      1.614  18.326
## parity1       -6.365      1.583  -4.021
## parity2       -1.918      1.185  -1.618
## weight_c1     -2.968      2.196  -1.351
## weight_c2     -3.347      1.978  -1.692
## weight_c3     -1.091      1.659  -0.658
##
## Correlation of Fixed Effects:
##           (Intr) party1 party2 wght_1 wght_2
## parity1    0.026
```

```
## parity2    0.024  0.611
## weight_c1 -0.588 -0.670 -0.448
## weight_c2 -0.651 -0.516 -0.531  0.826
## weight_c3 -0.761 -0.192 -0.305  0.696  0.781
```

```
AIC(lmm)                # Akaike's Information Criterion (small is better)
```

```
## [1] 387.5244
```

```
BIC(lmm)                # Bayesian Information Criterion (small is better)
```

```
## [1] 405.7377
```

```
ranef(lmm)                 # Extract the BLUP
```

```
## $herd
##    (Intercept)
## 1  0.003092077
## 2 -0.549440320
## 3  0.779687456
## 4  0.157743112
## 5  2.333933433
## 6 -2.725015758
```

```
Anova(lmm, type=3,test.statistic = "F") # ANOVA table SS type III
```

```
## Analysis of Deviance Table (Type III Wald F tests with Kenward-Roger df)
##
## Response: milk
##                     F Df Df.res    Pr(>F)
## (Intercept) 332.9284  1 38.208 < 2.2e-16 ***
## parity        8.5457  2 62.023 0.0005272 ***
## weight_c      1.3091  3 62.849 0.2793257
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
lsmeans(lmm,"parity")      # LSM
```

```
##  parity   lsmean       SE    df lower.CL upper.CL
##  1      21.36782 1.312626 22.06 18.64606 24.08958
##  2      25.81548 1.140621 14.04 23.45037 28.18058
##  3      27.73300 1.144417 14.17 25.36003 30.10598
##
## Results are averaged over the levels of: weight_c
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
```

```
coef(lmm)                  # See the coefficients of you model
```

```
## $herd
##   (Intercept)   parity1   parity2 weight_c1 weight_c2 weight_c3
## 1    29.58749 -6.365184 -1.917528 -2.968023 -3.346611 -1.090962
## 2    29.03496 -6.365184 -1.917528 -2.968023 -3.346611 -1.090962
## 3    30.36409 -6.365184 -1.917528 -2.968023 -3.346611 -1.090962
## 4    29.74215 -6.365184 -1.917528 -2.968023 -3.346611 -1.090962
## 5    31.91834 -6.365184 -1.917528 -2.968023 -3.346611 -1.090962
## 6    26.85939 -6.365184 -1.917528 -2.968023 -3.346611 -1.090962
##
## attr(,"class")
## [1] "coef.mer"
```

```
library(multcomp)
K <- matrix(c(0, 1, -1, 0, 0, 0), 1)   # Contrast Parity1 vs Parity2
t <- glht(lmm, linfct = K)             # fit a general linear hypothesis test
summary(t)                             # See the results
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Fit: lmer(formula = milk ~ parity + weight_c + (1 | herd), data = cows,
##     REML = TRUE)
##
## Linear Hypotheses:
##        Estimate Std. Error z value Pr(>|z|)
## 1 == 0   -4.448      1.272  -3.498 0.000469 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```
K <- matrix(c(0, 0, 1, 0, 0, 0), 1)    # Contrast Parity2 vs Parity3
t <- glht(lmm, linfct = K)             # fit a general linear hypothesis test
summary(t)                             # See the results
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Fit: lmer(formula = milk ~ parity + weight_c + (1 | herd), data = cows,
##     REML = TRUE)
##
## Linear Hypotheses:
##        Estimate Std. Error z value Pr(>|z|)
## 1 == 0   -1.918      1.185  -1.618    0.106
## (Adjusted p values reported -- single-step method)
```

```
K <- matrix(c(0, 1, 1, 0, 0, 0), 1)    # Contrast Parity1+Parity2 vs Parity3
t <- glht(lmm, linfct = K)             # fit a general linear hypothesis test
summary(t)                             # See the results
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Fit: lmer(formula = milk ~ parity + weight_c + (1 | herd), data = cows,
##     REML = TRUE)
##
## Linear Hypotheses:
##        Estimate Std. Error z value Pr(>|z|)
## 1 == 0   -8.283      2.491  -3.326 0.000882 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```