Pillow Example: BIBD treating blocks as random

We return to the Pillow Data (from ExpDesign3) an experiment run in a balanced incomplete block design (BIBD). This time we treat blocks as random. Comparing to our original analysis (treating blocks as fixed) we see that the results are different.

```
library(lme4)
library(lmerTest)
library(pbkrtest)
library(emmeans)
library(multcompView)
Pillow <- read.csv("C:/hess/STAT512/RNotes/ExpDesign3/ED3_PillowBIBD.csv")
str(Pillow)
```

```
## 'data.frame':    36 obs. of  3 variables:
##  $ blk     : int  1 1 1 2 2 2 3 3 3 4 ...
##  $ pillow  : Factor w/ 9 levels "A","B","C","D",..: 1 2 3 4 5 6 7 8 9 1 ...
##  $ firmness: int  59 26 38 85 92 69 74 52 27 62 ...
```

```
#Important: Need to define blk as.factor!!!!
Pillow$blk<-as.factor(Pillow$blk)
Model <- lmer (firmness ~ pillow + (1|blk), data = Pillow)
summary(Model)
```

```
## Linear mixed model fit by REML t-tests use Satterthwaite approximations
##   to degrees of freedom [lmerMod]
## Formula: firmness ~ pillow + (1 | blk)
##    Data: Pillow
##
## REML criterion at convergence: 185.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.5281 -0.7596 -0.0081  0.5565  1.3103
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  blk      (Intercept)  2.041   1.429
##  Residual             33.381   5.778
## Number of obs: 36, groups:  blk, 12
##
## Fixed effects:
##             Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   59.286      2.969  26.866  19.969  < 2e-16 ***
## pillowB      -36.425      4.167  24.185  -8.741 5.95e-09 ***
## pillowC      -20.435      4.167  24.185  -4.904 5.20e-05 ***
## pillowD       17.624      4.167  24.185   4.229 0.000291 ***
## pillowE       30.081      4.167  24.185   7.219 1.77e-07 ***
## pillowF       10.372      4.167  24.185   2.489 0.020072 *
## pillowG       15.359      4.167  24.185   3.686 0.001150 **
## pillowH       -8.143      4.167  24.185  -1.954 0.062335 .
## pillowI      -25.753      4.167  24.185  -6.180 2.12e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Correlation of Fixed Effects:
##         (Intr) pillwB pillwC pillwD pillwE pillwF pillwG pillwH
## pillowB -0.702
## pillowC -0.702  0.500
## pillowD -0.702  0.500  0.500
## pillowE -0.702  0.500  0.500  0.500
## pillowF -0.702  0.500  0.500  0.500  0.500
## pillowG -0.702  0.500  0.500  0.500  0.500  0.500
## pillowH -0.702  0.500  0.500  0.500  0.500  0.500  0.500
## pillowI -0.702  0.500  0.500  0.500  0.500  0.500  0.500  0.500
```

```
anova(Model, ddf="Kenward-Roger")
```

```
## Analysis of Variance Table of type III  with  Kenward-Roger
## approximation for degrees of freedom
##        Sum Sq Mean Sq NumDF  DenDF F.value    Pr(>F)
## pillow  13422  1677.8     8 24.859  50.261 1.889e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emout <- emmeans(Model, pairwise ~ pillow)
emout
```

```
## $emmeans
##  pillow   emmean       SE   df lower.CL upper.CL
##  A      59.28555 3.152629 26.9 52.81577 65.75533
##  B      22.86030 3.152629 26.9 16.39052 29.33008
##  C      38.85078 3.152629 26.9 32.38100 45.32056
##  D      76.90929 3.152629 26.9 70.43951 83.37908
##  E      89.36702 3.152629 26.9 82.89724 95.83680
##  F      69.65789 3.152629 26.9 63.18811 76.12768
##  G      74.64446 3.152629 26.9 68.17468 81.11424
##  H      51.14250 3.152629 26.9 44.67272 57.61228
##  I      33.53219 3.152629 26.9 27.06241 40.00197
##
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast   estimate       SE    df t.ratio p.value
##  A - B     36.425249 4.460253 24.86   8.167  <.0001
##  A - C     20.434770 4.460253 24.86   4.582  0.0030
##  A - D    -17.623742 4.460253 24.86  -3.951  0.0139
##  A - E    -30.081469 4.460253 24.86  -6.744  <.0001
##  A - F    -10.372341 4.460253 24.86  -2.326  0.3651
##  A - G    -15.358903 4.460253 24.86  -3.444  0.0443
##  A - H      8.143056 4.460253 24.86   1.826  0.6660
##  A - I     25.753359 4.460253 24.86   5.774  0.0002
##  B - C    -15.990480 4.460253 24.86  -3.585  0.0323
##  B - D    -54.048991 4.460253 24.86 -12.118  <.0001
##  B - E    -66.506719 4.460253 24.86 -14.911  <.0001
##  B - F    -46.797590 4.460253 24.86 -10.492  <.0001
##  B - G    -51.784153 4.460253 24.86 -11.610  <.0001
##  B - H    -28.282194 4.460253 24.86  -6.341  <.0001
##  B - I    -10.671890 4.460253 24.86  -2.393  0.3302
```

```
##  C - D    -38.058511 4.460253 24.86  -8.533  <.0001
##  C - E    -50.516239 4.460253 24.86 -11.326  <.0001
##  C - F    -30.807111 4.460253 24.86  -6.907  <.0001
##  C - G    -35.793673 4.460253 24.86  -8.025  <.0001
##  C - H    -12.291714 4.460253 24.86  -2.756  0.1792
##  C - I      5.318590 4.460253 24.86   1.192  0.9508
##  D - E    -12.457728 4.460253 24.86  -2.793  0.1674
##  D - F      7.251401 4.460253 24.86   1.626  0.7823
##  D - G      2.264838 4.460253 24.86   0.508  0.9998
##  D - H     25.766797 4.460253 24.86   5.777  0.0002
##  D - I     43.377101 4.460253 24.86   9.725  <.0001
##  E - F     19.709129 4.460253 24.86   4.419  0.0045
##  E - G     14.722566 4.460253 24.86   3.301  0.0604
##  E - H     38.224525 4.460253 24.86   8.570  <.0001
##  E - I     55.834829 4.460253 24.86  12.518  <.0001
##  F - G     -4.986562 4.460253 24.86  -1.118  0.9657
##  F - H     18.515397 4.460253 24.86   4.151  0.0086
##  F - I     36.125700 4.460253 24.86   8.099  <.0001
##  G - H     23.501959 4.460253 24.86   5.269  0.0005
##  G - I     41.112263 4.460253 24.86   9.217  <.0001
##  H - I     17.610304 4.460253 24.86   3.948  0.0140
##
## P value adjustment: tukey method for comparing a family of 9 estimates
```

```
cld(emout$emmeans)
```

```
##  pillow   emmean       SE   df lower.CL upper.CL .group
##  B      22.86030 3.152629 26.9 16.39052 29.33008  1
##  I      33.53219 3.152629 26.9 27.06241 40.00197  12
##  C      38.85078 3.152629 26.9 32.38100 45.32056   23
##  H      51.14250 3.152629 26.9 44.67272 57.61228    34
##  A      59.28555 3.152629 26.9 52.81577 65.75533     45
##  F      69.65789 3.152629 26.9 63.18811 76.12768      56
##  G      74.64446 3.152629 26.9 68.17468 81.11424       67
##  D      76.90929 3.152629 26.9 70.43951 83.37908       67
##  E      89.36702 3.152629 26.9 82.89724 95.83680        7
##
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 9 estimates
## significance level used: alpha = 0.05
```