Sunscreen Example: Two-way Mixed Crossed

This example is taken from Ott & Longnecker. Two sunscreens are tested on 10 randomly selected subjects. Four 1 inch squares are identified on each subject and the two sunscreens are randomly assigned the four patches (2 reps). Color is measured before and after sun exposure. This is an RCB design, but with replicates.

```
library(lme4)
library(lmerTest)
library(pbkrtest)
library(emmeans)
library(EMSaov)
Sunscreen <- read.csv("C:/hess/STAT512/RNotes/Random2/R2_Sunscreen.csv")
str(Sunscreen)
```

```
## 'data.frame':    40 obs. of  3 variables:
##  $ person  : int  1 1 2 2 3 3 4 4 5 5 ...
##  $ screen  : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ colordif: num  8.2 7.6 3.6 3.5 10.7 10.3 3.9 4.4 12.9 12.1 ...
```

```
#Important: Need to define person, screen as.factor!!!!
Sunscreen$person <- as.factor(Sunscreen$person)
Sunscreen$screen <- as.factor(Sunscreen$screen)
```

Full Model

```
Model1 <- lmer(colordif ~ screen + (1|person) + (1|person:screen), data = Sunscreen)
summary(Model1)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: colordif ~ screen + (1 | person) + (1 | person:screen)
##    Data: Sunscreen
##
## REML criterion at convergence: 106.1
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.2887 -0.6056 -0.2185  0.7176  1.1290
##
## Random effects:
##  Groups        Name        Variance Std.Dev.
##  person:screen (Intercept)  0.266   0.5158
##  person        (Intercept) 14.209   3.7694
##  Residual                   0.132   0.3633
## Number of obs: 40, groups:  person:screen, 20; person, 10
##
## Fixed effects:
##             Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   7.8200     1.2058  9.2079   6.485 0.000102 ***
## screen2      -0.6700     0.2577  8.9999  -2.600 0.028734 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Correlation of Fixed Effects:
##         (Intr)
## screen2 -0.107
```

```
anova(Model1, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##         Sum Sq Mean Sq NumDF DenDF F value  Pr(>F)
## screen 0.89238 0.89238     1     9  6.7605 0.02873 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(Model1, pairwise ~ screen)
```

```
## $emmeans
##  screen emmean   SE   df lower.CL upper.CL
##  1        7.82 1.21 9.21     5.10    10.54
##  2        7.15 1.21 9.21     4.43     9.87
##
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  1 - 2        0.67 0.258  9 2.600   0.0287
```

```
rand(Model1)
```

```
## ANOVA-like table for random-effects: Single term deletions
##
## Model:
## colordif ~ screen + (1 | person) + (1 | person:screen)
##                      npar  logLik    AIC     LRT Df Pr(>Chisq)
## <none>                  5 -53.056 116.11
## (1 | person)            4 -66.997 141.99 27.8811  1   1.29e-07 ***
## (1 | person:screen)     4 -57.550 123.10  8.9878  1   0.002718 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
EMS1 <- EMSanova(colordif ~ screen + person, data = Sunscreen,
                       type = c("F","R"))
EMS1
```

```
##               Df      SS       MS   Fvalue  Pvalue Sig
## screen         1   4.489  4.48900   6.7605  0.0287   *
## person         9 517.486 57.49844 435.5943 <0.0001 ***
## screen:person  9   5.976  0.66400   5.0303  0.0013  **
## Residuals     20   2.640  0.13200
##                                        EMS
## screen        Error+2screen:person+20screen
## person                      Error+4person
## screen:person          Error+2screen:person
## Residuals                         Error
```

Reduced Model (For Illustration)

In this case based on the tests of random effects for Model1, we have NO REASON to drop the random interaction from the model. But for illustration, we consider how the results change when the interaction is dropped from the model.

```
Model2 <- lmer(colordif ~ screen + (1|person), data = Sunscreen)
summary(Model2)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: colordif ~ screen + (1 | person)
##    Data: Sunscreen
##
## REML criterion at convergence: 115.1
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.61057 -0.57641  0.04144  0.55647  1.82017
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  person   (Intercept) 14.3003  3.7816
##  Residual              0.2971  0.5451
## Number of obs: 40, groups:  person, 10
##
## Fixed effects:
##             Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   7.8200     1.2020  9.0932   6.506 0.000106 ***
## screen2      -0.6700     0.1724 29.0000  -3.887 0.000543 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##         (Intr)
## screen2 -0.072
```

```
anova(Model2, ddf = "Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##        Sum Sq Mean Sq NumDF DenDF F value    Pr(>F)
## screen  4.489   4.489     1    29  15.109 0.0005432 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(Model2, pairwise ~ screen)
```

```
## $emmeans
##  screen emmean  SE   df lower.CL upper.CL
##  1        7.82 1.2 9.09     5.11    10.53
##  2        7.15 1.2 9.09     4.44     9.86
##
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
```

```
##  contrast estimate    SE df t.ratio p.value
##  1 - 2        0.67 0.172 29 3.887   0.0005
```