HSB Examples using the lme4 Package in R

To this point, we have only used the `nlme` package in R (Pinheiro & Bates, 2001). `nlme` is an older package and has been largely replaced by `lme4` (Bates, 2010), which has a few advantages, including profile likelihood confidence intervals that do not require adjustments to the variance tests, mixture (chi-bar) tests for likelihood ratio chi-square nested tests, and the availability of Kenward-Roger degrees of freedom (see illustrations for these last two features, using the `lmerTest` package that works with lme4, in subsequent handouts).

All of the models we have tested thus far using `nlme` can be estimated with `lme4`, and I illustrate these below. With profile likelihood confidence intervals, we can use the 95% confidence intervals for the variance components because they are asymmetric (i.e., there is no reason to obtain 90% CIs). ICC values can be obtained in the same way as illustrated earlier—the `psychometric` package `ICC1.lme` function does not require that a prior model be tested.

Random Effects ANOVA (Intercept-only, Empty, Null) Model

```
> library(lme4)
> #ANOVA (intercept only, empty, null) model
> modeln <- lmer (mathach ~ 1 + (1 | schoolid), data=mydata,REML=TRUE)
> summary(modeln)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: mathach ~ 1 + (1 | schoolid)
   Data: mydata

REML criterion at convergence: 47116.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.0631 -0.7539  0.0267  0.7606  2.7426

Random effects:
 Groups   Name        Variance Std.Dev.
 schoolid (Intercept)  8.614   2.935
 Residual             39.148   6.257
Number of obs: 7185, groups:  schoolid, 160

Fixed effects:
            Estimate Std. Error       df t value            Pr(>|t|)
(Intercept)  12.6370     0.2444 156.6473   51.71 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> #profile likelihood CIs (signames=FALSE gives more meaningful row names)
> confint(modeln,signames=FALSE)
Computing profile confidence intervals ...
                             2.5 %    97.5 %
sd_(Intercept)|schoolid  2.594729  3.315880
sigma                    6.154803  6.361786
(Intercept)             12.156289 13.117121
```

Random Effects ANCOVA Model with Homogeneous Slopes

```
> library(lme4)
> #ANCOVA with homogeneous slopes
> modelf <- lmer (mathach ~ ses + (1 | schoolid), data=mydata,REML=TRUE)
> summary(modelf)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: mathach ~ ses + (1 | schoolid)
   Data: mydata

REML criterion at convergence: 46645.2

Scaled residuals:
     Min       1Q   Median       3Q      Max
-3.12607 -0.72720  0.02188  0.75772  2.91912

Random effects:
 Groups   Name        Variance Std.Dev.
 schoolid (Intercept)  4.768   2.184
 Residual             37.034   6.086
Number of obs: 7185, groups:  schoolid, 160

Fixed effects:
            Estimate Std. Error        df t value            Pr(>|t|)
(Intercept)  12.6575     0.1880  148.3022   67.33 <0.0000000000000002 ***
ses           2.3902     0.1057 6838.0776   22.61 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Correlation of Fixed Effects:
    (Intr)
ses 0.003
> confint(modelf,signames=FALSE)
Computing profile confidence intervals ...
                             2.5 %    97.5 %
sd_(Intercept)|schoolid  1.903659  2.492279
sigma                    5.985886  6.187314
(Intercept)             12.287552 13.026643
ses                      2.179836  2.603106
```

Random Slopes Model

```
> library(lme4)
> #random slopes model
> model2 <- lmer (mathach ~ ses +(ses|schoolid), data=mydata,REML=TRUE)
> summary(model2)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: mathach ~ ses + (ses | schoolid)
   Data: mydata

REML criterion at convergence: 46640.4

Scaled residuals:
     Min       1Q   Median       3Q      Max
-3.12272 -0.73046  0.02144  0.75610  2.94356

Random effects:
Groups   Name        Variance Std.Dev. Corr
 schoolid (Intercept)  4.8287  2.1974
          ses          0.4129  0.6426   -0.11
 Residual             36.8301  6.0688
Number of obs: 7185, groups:  schoolid, 160

Fixed effects:
            Estimate Std. Error       df t value            Pr(>|t|)
(Intercept)  12.6650     0.1898 145.5479   66.71 <0.0000000000000002 ***
ses           2.3938     0.1181 157.5299   20.27 <0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
    (Intr)
ses -0.045
> confint(model2,signames=FALSE)
Computing profile confidence intervals ...
                                    2.5 %     97.5 %
sd_(Intercept)|schoolid       1.91159319  2.5112984
sd_ses|schoolid               0.08487179  0.9666040
cor_ses.(Intercept)|schoolid -1.00000000  0.3078228
sigma                         5.96867353  6.1719565
(Intercept)                  12.28852890 13.0406703
ses                           2.15925014  2.6317003

Warning messages:
1: In FUN(X[[i]], ...) :
  non-monotonic profile for cor_ses.(Intercept)|schoolid
2: In confint.thpr(pp, level = level, zeta = zeta) :
  bad spline fit for cor_ses.(Intercept)|schoolid: falling back to linear interpolation
```

Obtain Rights & Sterba R-square Values

```
> #get R-sq values
> library(r2mlm)
> r2mlm(model2)
$Decompositions
                     total
fixed           0.076681033
slope variation 0.005525803
mean variation  0.106381710
sigma2          0.811411454

$R2s
          total
f   0.076681033
v   0.005525803
m   0.106381710
fv  0.082206836
fvm 0.188588546
```

References

Bates, D. M. (2010). *lme4: Mixed-effects modeling with R.* https://people.math.ethz.ch/~maechler/MEMo-pages/lMMwR_2018-03-05.pdf
Pinheiro, J.C., & Bates, D.M. (2001). *Mixed Models in S and S-Plus.* Springer-Verlag.