**Running the two-stage MIXREGMLS and MIXREG models**

MIXREGMLS estimates a mixed-effects location scale model, including a random subject intercept and slope(s), as well as random subject scale effects. The random subject intercept and slope(s) are considered location effects because they reflect a subject’s influence on their mean response, while the random subject scale effect reflects a subject’s influence on their variability. All of these random subject effects can then be used in a linear regression model to predict a continuous subject-level outcome using the MIXREG program. The random effects can be included in the linear regression model as main effects and as interactions with other subject-level regressors. Here, we present the steps involved in using these two programs with the new dataset provided. The dataset has EMA data from 107 subjects and a total of 4292 observations. In this dataset the level-1 occasions are nested within the level-2 subjects. The dataset is named PMLevel\_revised2.dat and contains the following variables: id, wave, lnAct\_Before, posmood10, genderM, and mvpa. Posmood10 is the level-1 (occasion-level) outcome indicating the level of positive mood at the time of the EMA prompt and lnAct\_Before is a level-1 (occasion-level) variable indicating the level of physical activity in the 30-minute period before the EMA prompt. It is log-transformed to reduce the influence of some extreme high-valued observations. These EMA data were measured at three waves, and wave is coded sequentially as 0, 1, 2 for the three waves, respectively. The variable genderM is a subject-level dummy variable coded 0=female and 1=male, and mvpa is a subject-level variable indicating whether or not the subject achieved the recommended level of moderate to vigorous physical activity during the week (0=no, 1=yes). **The data are sorted by ID - this is important as the program will not produce correct results if the data are not sorted by the level-2 ID variable**. Also, the variables in the dataset are numeric only (i.e., no letters or non-numeric text can be present in the dataset) and the variables are separated by tabs, commas, or one or more spaces in the dataset.

**Running MIXREGMLS**

A location-scale mixed model is estimated using Posmood10 as the outcome and lnAct\_Before and wave as regressors in the mean model. For lnAct\_Before , we will decompose it into its between-subject effect (the subject mean across occasions, lnAct\_Before\_BS) and its within-subject effect (the occasion-specific deviation relative to the subject mean, lnAct\_Before\_WS), and include both in the mean model. Also, in addition to a random subject intercept, the model will include a random subject slope for lnAct\_Before\_WS, thus the relationship between physical activity before the prompt and positive mood is allowed to vary across subjects. For illustration, we will include lnAct\_Before and wave in the within-subject (WS) variance model. The definition file is named PMactive2\_mls\_reg.def. This file is copied to MixRegMLS\_random\_Mixreg.def, and then the file MixRegMLS\_random\_Mixreg.exe is double-clicked on to run the program.

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1. Analysis of Positive Mood - 15 quad pts
2. Random Int and lnActiv with random scale
3. PMLevel\_revised2.dat
4. PMactive2\_mls\_reg
5. 6 1 0 1 0 0 0 1 1 1 0.0001 15 1 300 0 0 1 .2 200 0 0 0 0
6. 1 4
7. 2
8. 2
9. 3
10. 3
11. 3
12. posmood10
13. wave
14. wave
15. lnAct\_Before
16. lnAct\_Before
17. lnAct\_Before
18. 1 1 1 1
19. 6
20. 5
21. 5
22. 5
23. 5
24. mvpa
25. genderM
26. genderM
27. genderM
28. genderM

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The specifications that are necessary for MixRegMLS\_random\_Mixreg.def are listed below. Lines 1 to 19 are for the MIXREGMLS (first-stage) model, and lines 20 and beyond are for the MIXREG (second-stage) model. To aid with the DEF file specifications, line numbers are included in the listing above, however line numbers should not be included in the MixRegMLS\_random\_Mixreg.def file to run the program.

**Line 1** – title of 72 characters.

**Line 2** – subtitle of 72 characters.

**Line 3** – filename.dat (input data file).

**Line 4** – output file prefix

**Line 5** – nvar P R S pnint rnint snint P1 R1 S1 conv qp aq maxit yMiss ncent ncov ridgein nsamp cutoff nors no2nd discard0

nvar = number of variables in filename.dat.

P = number of mean regressors (not including intercept or level-1 variables for BS/WS decomposition)

R = number of location random effects (not including intercept or level-1 variables for BS/WS decomposition)

S = number of scale regressors (not including intercept or level-1 variables for BS/WS decomposition)

pnint = 1 if no fixed intercept, 0 else

rnint = 1 if no random intercept, 0 else

snint = 1 if no scale intercept, 0 else

P1 = number of level-1 mean regressors for BS/WS decomposition.

R1 = number of level-1 location random effects for BS/WS decomposition (note: only the WS component will be treated as a random effect, since the BS component cannot be random at level-2)

S1 = number of level-1 scale regressors for BS/WS decomposition.

conv = convergence requirement for the maximum correction

qp = number of quadrature points (usually set to 10 or 11, however more points may be necessary for complex models)

aq = 1 for adaptive quadrature, 0 for non-adaptive quadrature (usually set to 1)

maxit = maximum number of iterations

yMiss = real value representing a missing value code for all variables, 0 for no missing values

ncent = 1 to center and scale all variables in P, R, and S, 0 else

ncov = 0 for no association of random location & scale, 1 for assocition

ridgein = initial value for a ridge (a numeric value that adds to the diagonal of the second derivative matrix, which can aid in convergence of the solution; usually set to 0 or some small fractional value)

nsamp = number of resamples of the random effect estimates in the stage 2 analysis.

cutoff = 0 if no observations are to be excluded from stage 2 analysis; or lower bound for the random scale estimates to be included in the stage 2 analysis; values below this lower bound are not included in the stage 2 analysis. THIS IS USUALLY SET TO 0.

nors = 0 if random scale is included, or 1 if random scale is not included

no2nd = 0 if the stage 2 analysis is to be performed, or 1 if only a stage 1 analysis is requested (Note that in this case, lines 20+ of the DEF file are not used)

discard0 = 0 if no subjects are to be excluded from analysis; or 1 to exclude subjects with the same outcome value across all observations.

**Line 6** – two parameters: fields of the id variable and the stage 1 outcome variable in filename.dat.

**Line 7** – P parameters: field(s) of mean regressors in filename.dat.

**Line 8** – R parameters: field(s) of random regressors in filename.dat.

**Line 9** – S parameters: field(s) of scale regressors in filename.dat.

**Line 10** – P1 parameters: field(s) of level-1 mean regressors for BS/WS decomposition in filename.dat.

**Line 11** – R1 parameters: field(s) of level-1 location random effects for BS/WS decomposition in filename.dat.

**Line 12** – S1 parameters: field(s) of level-1 scale regressors for BS/WS decomposition in filename.dat.

**Line 13** – label for the dependent variable for stage 1.

**Line 14** – P labels for mean regressors, separated by blanks.

**Line 15** – R labels for random regressors, separated by blanks.

**Line 16** – S labels for scale regressors, separated by blanks.

**Line 17** – P1 labels for level-1 mean regressors for BS/WS decomposition, separated by blanks.

**Line 18** – R1 labels for level-1 location random effects for BS/WS decomposition, separated by blanks.

**Line 19** – S1 labels for level-1 scale regressors for BS/WS decomposition, separated by blanks.

**Line 20** – pfixed ptheta pomega pto

Pfixed = number of regressors (not including the random effects).

Ptheta = number of interactions with the location random effect(s).

Pomega = number of interactions with the scale random effect.

Pto = number of interactions with the interaction of the location and scale random effects. This equals

-1 if all interaction between the random effects (1st location and scale) is to be suppressed.

**Line 21** – one parameter: field of the stage 2 outcome variable in filename.dat.

**Line 22** – Pfixed parameters: field(s) of fixed regressors in filename.dat.

**Line 23** – Ptheta parameters: field(s) in filename.dat of regressors to interact with the location random effect(s).

**Line 24** – Pomega parameters: field(s) in filename.dat of regressors to interact with the scale random effect.

**Line 25** – Pto parameters: field(s) in filename.dat of regressors to interact with the interaction of location and scale random effects.

**Line 26** – label for the dependent variable for stage 2.

**next line(s)** – Pfixed labels for regressors, separated by blanks.

**next line(s)** – Ptheta labels for regressors that will interact with the location random effect(s), separated by blanks.

**next line(s)** – Pomega labels for regressors that will interact with the scale random effect, separated by blanks.

**next line(s)** (if Pto>0) – Pto labels for regressors that will interact with the interaction of 1st location and scale random effects, separated by blanks.

Note that in this example, R=0, and so lines 8 and 15 are blank lines. The program can also allow these blank lines to be deleted from the DEF file.

The output for the stage 1 analysis is written to the file PMactive2\_mls\_reg\_1.out which includes the results of the location-scale mixed model listed below.

------------------------------------------------------

Model WITH RANDOM Scale and Location-Scale Association

------------------------------------------------------

Total Iterations = 18

Final Ridge value = 0.00

Log Likelihood = -15051.913

Akaike's Information Criterion = -15065.913

Schwarz's Bayesian Criterion = -15084.622

==> multiplied by -2

Log Likelihood = 30103.825

Akaike's Information Criterion = 30131.825

Schwarz's Bayesian Criterion = 30169.245

Variable Estimate AsymStdError z-value p-value

---------------- ------------ ------------ ------------ ------------

BETA (regression coefficients)

Intercept 35.81490 2.56289 13.97444 0.00000

wave -0.15836 0.14710 -1.07658 0.28167

lnAct\_Before\_BS -1.31120 0.65554 -2.00019 0.04548

lnAct\_Before\_WS 0.22083 0.07419 2.97660 0.00291

Random (location) Effect Variances and Covariances

Intercept 33.76986 4.83846 6.97947 0.00000

Covariance12 -0.49871 0.41570 -1.19970 0.23026

lnAct\_Before\_WS 0.23290 0.07638 3.04918 0.00229

TAU (WS variance parameters: log-linear model)

Intercept 4.62886 0.21631 21.39935 0.00000

wave -0.10019 0.02950 -3.39685 0.00068

lnAct\_Before\_BS -0.12718 0.05489 -2.31705 0.02050

lnAct\_Before\_WS -0.01009 0.01054 -0.95736 0.33839

Random location effects on WS variance (log-linear model)

Intercept -0.06081 0.04862 -1.25070 0.21104

lnAct\_Before\_WS 0.06705 0.06948 0.96509 0.33450

Random scale standard deviation

Std Dev 0.42087 0.03818 11.02197 0.00000

In this analysis, the level-1 variable LnAct\_Before has been decomposed in terms of its between-subject (BS) version (the subject mean of this variable across all occasions, with suffix \_BS) and the within-subject (WS) version (the subject’s occasion specific deviation of the variable relative to the subject mean, with suffix \_WS). The program creates these two versions from the level-1 variable.

This analysis shows that a person’s average positive affect is not significantly related to the measurement wave. The level-1 variable LnAct\_Before has a significant BS negative effect on the mean positive affect levels, whereas the WS effect is positive. Thus, subjects with overall higher activity levels have overall lower positive affect, however controlling for this BS effect, when a subject has higher activity before the prompt, their positive affect is increased.

The random intercept varies significantly across subjects (variance of 33.77), as does the random slope (variance of 0.233), and the two are not significantly correlated (p=.23 for the covariance). There is considerable scale variability across subjects (scale sd is estimated as 0.421 and is highly significant), but the WS variance is not significantly associated with either random location effect. The WS variance does diminish across waves and with lnAct\_Before\_BS.

Below the estimates, the program also exponentiates all of the WS variance parameter estimates, and lists out 95% confidence intervals for these parameters. For the intercept, this is simply the WS variance estimate when all covariates equal zero. For the covariates, these represent variance ratios. Thus, for example, the variance ratio for wave is approximately .90, indicating that the WS variance diminishes by about 10% with each increasing wave.

WS variance ratios and 95% CIs

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Variable Ratio Lower Upper

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TAU (WS variance parameters: log-linear model)

Intercept 102.39756 67.01429 156.46305

wave 0.90466 0.85385 0.95850

lnAct\_Before\_BS 0.88058 0.79076 0.98059

lnAct\_Before\_WS 0.98996 0.96972 1.01062

Random (location) Effect(s)

Intercept 0.94101 0.85548 1.03508

lnAct\_Before\_WS 1.06935 0.93321 1.22535

Random scale standard deviation

Std Dev 1.52329 1.41345 1.64167

**Running MIXREG**

We will now examine whether the random effects (a subject’s location and scale estimates) from the location scale analysis are associated with a subject’s activity level. For this, we will use a linear regression model treating the subject-level random effects as regressors and possibly interactions with other subject-level regressors. For this example, we will use mvpa (a 0/1 indicator variable) as the dependent variable in this regression model as an illustration of program usage even though this is not a continuous outcome.

**Saturated model**

The first model should contain all potential regressors, and its specifications are included in the original DEF file. We will treat mvpa as the outcome, and the random effects (location and scale) and genderM as regressors, and also allow for interactions with the random effects.

The results from this analysis are in the file PMactive2\_mls\_reg\_2.out and listed below.

Note, that this analysis was replicated 200 times (this is the nsamp specification in the DEF file) using random draws based on the random location and scale effects of each subject (which were estimated in the stage 1 analysis above). The results listed below are averages from these 200 replications. Additionally, the standard deviation associated with the log likelihood values is listed in parentheses.

Number of replications = 200

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Final Results

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Average Log Likelihood = -63.045 (sd= 1.001)

Akaike's Information Criterion = -73.045

Schwarz's Bayesian Criterion = -86.409

==> multiplied by -2

Log Likelihood = 126.089

Akaike's Information Criterion = 146.089

Schwarz's Bayesian Criterion = 172.818

Variable Estimate AsymStdError z-value p-value

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Intercept 0.25111 0.06906 3.63621 0.00028

genderM 0.09469 0.13597 0.69642 0.48616

Locat\_1 -0.00194 0.05950 -0.03266 0.97395

Locat\_1\*genderM -0.01056 0.09853 -0.10714 0.91468

Locat\_2 -0.02331 0.07636 -0.30530 0.76014

Locat\_2\*genderM -0.00826 0.16648 -0.04963 0.96042

Scale 0.05713 0.06613 0.86389 0.38765

Scale\*genderM 0.00801 0.12410 0.06454 0.94854

Locat\_1\*Scale -0.10460 0.06792 -1.53999 0.12356

L\*S\*genderM 0.15783 0.12701 1.24266 0.21399

Resid.Variance 0.19027 0.02626 7.24673 0.00000

Here, Locat\_1 refers to the random intercept, Locat\_2 refers to the random slope, and Scale is the random scale. Currently, only the random intercept and scale are allowed to interact, and the three-way interaction of the random intercept by scale by genderM is abbreviated as L\*S\*genderM. Note that none of the effects in this model are significant.

**Further MIXREG analyses**

At this point, it might be of interest to run a MIXREG model, say only including the main effects of location, scale, and gender. Rather than rerunning the first stage model (MIXREGMLS), which takes a fair amount of time, it is more efficient simply to rerun the second-stage MIXREG model using the first-stage random effects that have already been estimated. In running MIXREG with the multiple resampled datasets, a definition file, named PMactive2\_mls\_reg\_repeat\_mixreg.def, is created. This file is named using the output file prefix specified on line 4 of the file Mixregmls\_random\_Mixreg.def (i.e., PMactive2\_mls\_reg) combined with the suffix \_repeat\_mixreg.def. To rerun MIXREG on the multiple resampled datasets, say to remove the Scale by genderM and Location1 by Scale by genderM interactions, one can modify this DEF file and then rerun the program. Below is the created DEF file PMactive2\_mls\_reg\_repeat\_mixreg.def, which we will modify to rerun the program. While this DEF file has many specifications, there are relatively few modifications that need to be made for our purposes here. Again, line numbers have been added to this DEF file listing below, however these would not appear in the actual DEF file PMactive2\_mls\_reg\_repeat\_mixreg.def.

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1. PMactive2\_mls\_reg\_level2.dat
2. PMactive2\_mls\_reg\_ebrandom.dat
3. PMactive2\_mls\_reg\_random
4. 6 200 1 1 **1 1** 0.0000000000
5. 1 2
6. 3
7. 4
8. **5**
9. **6**
10. mvpa
11. genderM
12. genderM
13. **genderM**
14. **genderM**

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In order to remove the genderM by Scale and genderM by Location1 by Scale interactions, two specifications on line 4 need to be changed:

Line 4, parameter 5: number of interactions with random scale

Line 4, parameter 6: number of interactions with random location1 by scale

Thus, if one wanted to remove both of these interactions the values of 1 (in bold) would be changed to zero. One would also then remove lines 8-9, which specify the location of these two interactions, respectively, in the dataset. Similarly, lines 13-14 would be removed as these indicate the label of the interacting variable with these two random effect terms.

Once these changes are made, one should save the file as repeat\_mixreg.def (overwriting the previous version of this file). Below is a modified repeat\_mixreg.def file that only includes the main effect of genderM, location random effects, scale random effect, location by scale random effect, and genderM by location random effects, in addition to the model intercept and the residual variance. Once these changes have been made and this file saved as repeat\_mixreg.def, and the user double-clicks on the file repeat\_mixreg.exe to run this analysis.

**Model without scale\*genderM and location1\*scale\*genderM interactions**

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PMactive2\_mls\_reg\_level2.dat

PMactive2\_mls\_reg\_ebrandom.dat

PMactive2\_mls\_reg\_random

6 200 1 1 0 0 0.0000000000000000

1 2

3

4

mvpa

genderM

genderM

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The results of this set of MIXREG runs (replicated 200 times), which are saved in PMactive2\_mls\_reg\_random\_200.out (the suffix 200 is because 200 resampled datasets were specified in the original DEF file) are listed below.

Number of replications = 200

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Final Results

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Average Log Likelihood = -64.207 (sd= 0.805)

Akaike's Information Criterion = -72.207

Schwarz's Bayesian Criterion = -82.899

==> multiplied by -2

Log Likelihood = 128.415

Akaike's Information Criterion = 144.415

Schwarz's Bayesian Criterion = 165.797

Variable Estimate AsymStdError z-value p-value

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Intercept 0.25268 0.06833 3.69803 0.00022

genderM 0.12612 0.13457 0.93720 0.34866

Locat\_1 -0.01496 0.05906 -0.25326 0.80007

Locat\_1\*genderM -0.00712 0.09871 -0.07216 0.94247

Locat\_2 -0.02287 0.07634 -0.29957 0.76450

Locat\_2\*genderM -0.02266 0.15885 -0.14267 0.88655

Scale 0.04897 0.05556 0.88141 0.37810

Locat\_1\*Scale -0.05729 0.05731 -0.99965 0.31748

Resid.Variance 0.19444 0.02674 7.27045 0.00000

At this point, one can make other changes to the file PMactive2\_mls\_reg\_repeat\_mixreg.def, in order to run other reduced versions of the full model. The procedure is the following:

1. Make modifications toPMactive2\_mls\_reg\_repeat\_mixreg.def
2. Save to repeat\_mixreg.def
3. Double click on repeat\_mixreg.exe

In what follows, several examples of modified DEF files and the corresponding output that was produced are listed. In all cases, the output is contained in the PMactive2\_mls\_reg\_random\_200.out file.

**Model adding scale\*genderM interaction**

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PMactive2\_mls\_reg\_level2.dat

PMactive2\_mls\_reg\_ebrandom.dat

PMactive2\_mls\_reg\_random

6 200 1 1 1 0 0.0000000000000000

1 2

3

4

5

mvpa

genderM

genderM

genderM

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Number of replications = 200

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Final Results

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Average Log Likelihood = -64.074 (sd= 0.859)

Akaike's Information Criterion = -73.074

Schwarz's Bayesian Criterion = -85.101

==> multiplied by -2

Log Likelihood = 128.147

Akaike's Information Criterion = 146.147

Schwarz's Bayesian Criterion = 170.202

Variable Estimate AsymStdError z-value p-value

---------------- ------------ ------------ ------------ ------------

Intercept 0.25631 0.06936 3.69559 0.00022

genderM 0.12277 0.13478 0.91092 0.36234

Locat\_1 -0.01526 0.05902 -0.25849 0.79603

Locat\_1\*genderM -0.00822 0.09877 -0.08326 0.93365

Locat\_2 -0.02154 0.07667 -0.28095 0.77875

Locat\_2\*genderM -0.03137 0.16529 -0.18977 0.84949

Scale 0.03969 0.06480 0.61243 0.54026

Scale\*genderM 0.03415 0.12262 0.27851 0.78062

Locat\_1\*Scale -0.05554 0.05782 -0.96047 0.33682

Resid.Variance 0.19396 0.02670 7.26446 0.00000

**Main effects model**

It may be of interest to run a model without the location1 by scale interaction, and only include main effects of genderM, random location(s), and random scale. To remove the location1 by scale interaction, notice the -1 specification for the 7th parameter on the 4th line in the DEF file listed below. This parameter indicates the number of interactions with the location1 by scale interaction. In many of the previous DEF files, this has been set to 0, and so no variables interacted with the location1 by scale interaction. However, in some cases, it might also be useful to remove this location1 by scale interaction, which is accomplished by specifying the value of -1 for this parameter. In a similar way, one could remove the location1 effect (-1 for the 4th parameter on line 4), location 2 effect (-1 for the 5th parameter on line 4), or the scale effect (-1 for the 6th parameter on line 4).

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PMactive2\_mls\_reg\_level2.dat

PMactive2\_mls\_reg\_ebrandom.dat

PMactive2\_mls\_reg\_random

6 200 1 0 0 -1 0.0000000000000000

1 2

3

mvpa

genderM

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Number of replications = 200

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Final Results

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Average Log Likelihood = -65.094 (sd= 0.472)

Akaike's Information Criterion = -70.094

Schwarz's Bayesian Criterion = -76.776

==> multiplied by -2

Log Likelihood = 130.187

Akaike's Information Criterion = 140.187

Schwarz's Bayesian Criterion = 153.552

Variable Estimate AsymStdError z-value p-value

---------------- ------------ ------------ ------------ ------------

Intercept 0.25700 0.06422 4.00173 0.00006

genderM 0.10200 0.09876 1.03281 0.30169

Locat\_1 -0.02595 0.04543 -0.57124 0.56784

Locat\_2 -0.02235 0.06719 -0.33268 0.73938

Scale 0.03261 0.05251 0.62108 0.53454

Resid.Variance 0.19767 0.02708 7.29918 0.00000

**Summary**

Use of the MIXREGMLS and MIXREG programs allows one to:

1. Perform a mixed-effects location-scale analysis, including multiple random location effects, on a level-1 outcome.
2. Model a level-2 continuous outcome in terms of
3. Level-2 predictors
4. Level-2 random location and scale effects from the MIXREGMLS analysis
5. Interactions can be of the type:
6. 1st Location by scale
7. Predictor(s) by location
8. Predictor(s) by scale
9. Predictor(s) by 1st location by scale