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

MIXREGLS estimates a mixed-effects location scale model, including a random subject intercept and a random scale effect. 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. Because the random effects are estimated quantities, resampling of these are performed a specified number of times; this ensures that the uncertainty inherent in these estimates is properly taken into account. Here, we present the steps involved in using these two programs with an example EMA dataset consisting of 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 MIXREGLS**

A location-scale mixed model is estimated using Posmood10 as the outcome and wave and lnAct\_Before 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, wave, lnAct\_Before\_BS, and lnAct\_Before\_WS will be included as regressors in the between-subject (BS) and the within-subject (WS) variance models. The definition file, named PMactive2\_ls\_reg.def, is copied to Mixregls\_random\_Mixreg.def, and then the file Mixregls\_random\_Mixreg.exe is double-clicked on to run the program.

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1. Analysis of Positive Mood - 11 quad pts
2. Random Int with random scale
3. PMLevel\_revi0sed2.dat
4. PMactive2\_ls\_reg
5. 6 1 1 1 0 0 0 1 1 1 1.00E-005 11 1 300 0 0 1 .15 500 0 0 0 0
6. 1 4
7. 2
8. 2
9. 2
10. 3
11. 3
12. 3
13. posmood10
14. wave
15. wave
16. Wave
17. lnAct\_Before
18. lnAct\_Before
19. lnAct\_Before
20. 1 1 1 1
21. 6
22. 5
23. 5
24. 5
25. 5
26. mvpa
27. genderM
28. genderM
29. genderM
30. genderM

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The specifications that are necessary for Mixregls\_Mixreg.def are the following. Lines 1 to 19 are for the MIXREGLS (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 MixRegls\_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

nvar = number of variables in filename.dat.

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

R = number of between-subject (BS) variance regressors (not including intercept or level-1 variables for BS/WS decomposition).

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

pnint = 1 if no intercept in the mean model, 0 else.

rnint = 1 if no intercept in the BS variance model, 0 else.

snint = 1 if no intercept in the WS variance model, 0 else.

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

R1 = number of level-1 between-subject (BS) variance regressors for BS/WS decomposition.

S1 = number of level-1 within-subject (WS) variance regressors for BS/WS decomposition.

conv = convergence requirement for the maximum correction.

qp = number of quadrature points (set to 10 or 11, 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 = effect of mean on WS variance (0=no effect, 1=linear effect, or 2=linear & quadratic effect).

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 not be 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 model regressors in filename.dat.

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

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

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

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

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

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

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

**Line 15** – R labels for BS variance model regressors, separated by blanks.

**Line 16** – S labels for WS variance model regressors, separated by blanks.

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

**Line 18** – R1 labels for level-1 BS variance model regressors for BS/WS decomposition, separated by blanks.

**Line 19** – S1 labels for level-1 WS variance model 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.

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 the interaction between the random effects (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.

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

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

Model WITH RANDOM Scale

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

Total Iterations = 16

Final Ridge value = 0.0

Log Likelihood = -15056.612

Akaike's Information Criterion = -15070.612

Schwarz's Bayesian Criterion = -15089.322

==> multiplied by -2

Log Likelihood = 30113.224

Akaike's Information Criterion = 30141.224

Schwarz's Bayesian Criterion = 30178.644

Variable Estimate AsymStdError z-value p-value

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

BETA (regression coefficients)

Intercept 34.30843 2.65407 12.92675 0.00000

wave -0.18618 0.15815 -1.17725 0.23910

LnAct\_Before\_BS -0.91067 0.66600 -1.36737 0.17151

LnAct\_Before\_WS 0.16517 0.05244 3.14967 0.00163

ALPHA (BS variance parameters: log-linear model)

Intercept 3.82148 0.64268 5.94613 0.00000

wave 0.18900 0.05135 3.68075 0.00023

LnAct\_Before\_BS -0.12722 0.16381 -0.77663 0.43737

LnAct\_Before\_WS -0.02339 0.01703 -1.37366 0.16955

TAU (WS variance parameters: log-linear model)

Intercept 4.65108 0.21650 21.48351 0.00000

wave -0.11805 0.02951 -4.00071 0.00006

LnAct\_Before\_BS -0.12428 0.05498 -2.26044 0.02379

LnAct\_Before\_WS -0.01830 0.01048 -1.74567 0.08087

Random scale standard deviation

Std Dev 0.42643 0.03783 11.27096 0.00000

Random location (mean) effect on WS variance

Loc Eff -0.05988 0.04953 -1.20880 0.22674

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 mood is not significantly related to the wave of measurement, however the BS variance is increased across waves and the WS variance is diminished across waves. The level-1 variable LnAct\_Before has a non-significant BS negative effect on the mean positive affect levels, whereas the WS effect is positive and highly significant. Thus, subjects with overall higher activity levels have somewhat overall lower positive affect (though not significantly so), however controlling for this BS effect, when a subject has higher activity before the prompt their positive affect is increased.

In terms of the BS variance, the random intercept varies significantly across subjects (exp(3.82148) = between-subject variance of 45.67), and this is not significantly influenced by the model covariates other than the positive effect of wave. Thus, subjects are more heterogeneous across waves. The WS variance is influenced by wave, with subjects being more consistent across waves. Also, the WS variance is influenced by the BS version of the activity variable, such that subjects with overall higher activity levels are more consistent in their positive mood. There is considerable scale variability across subjects (scale sd is estimated as 0.426 and is highly significant), but the WS variance is not significantly associated with the random intercept (p=.23). The program also exponentiates all of the variance parameter estimates, and lists out 95% confidence intervals for these parameters.

BS variance ratios and 95% CIs

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Variable Ratio Lower Upper

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ALPHA (BS variance parameters: log-linear model)

Intercept 45.67154 12.95964 160.95280

wave 1.20805 1.09238 1.33596

lnAct\_Before\_BS 0.88054 0.63872 1.21391

lnAct\_Before\_WS 0.97688 0.94482 1.01003

WS variance ratios and 95% CIs

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Variable Ratio Lower Upper

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

TAU (WS variance parameters: log-linear model)

Intercept 104.69836 68.49495 160.03730

wave 0.88865 0.83872 0.94156

lnAct\_Before\_BS 0.88313 0.79291 0.98362

lnAct\_Before\_WS 0.98186 0.96189 1.00225

Random location (mean) effect on WS variance

Location Effect 0.94188 0.85474 1.03791

Random scale standard deviation

Std Dev 1.53179 1.42231 1.64969

For the intercepts, these are simply the BS and WS variance estimates when all covariates equal zero. For the covariates, these represent variance ratios. Thus, for example, the BS effect of the activity level variance ratio estimate of .88 represents a 12% reduction in the WS variance with each unit increase of the activity variable.

**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 moderate to vigorous activity level during the week. 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. Here, we will use mvpa (a 0/1 indicator variable) as the dependent variable in this regression model. Note that treating this binary variable as the outcome in this linear regression analysis is being done mainly for illustrative purposes.

**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 wave (in this subject-level analysis, this variable is the subject average of their level-1 observations) as regressors, and also allow for interactions with the random effects.

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

Note, that this analysis was replicated 200 times 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 parenthesis.

Number of replications = 200

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Final Results

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Average Log Likelihood = -63.255 (sd= 0.820)

Akaike's Information Criterion = -71.255

Schwarz's Bayesian Criterion = -81.946

==> multiplied by -2

Log Likelihood = 126.509

Akaike's Information Criterion = 142.509

Schwarz's Bayesian Criterion = 163.892

Variable Estimate AsymStdError z-value p-value

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

Intercept 0.23984 0.05865 4.08929 0.00004

genderM 0.09276 0.10606 0.87463 0.38178

Locat\_1 0.00111 0.05776 0.01928 0.98462

Locat\_1\*genderM -0.03077 0.09779 -0.31465 0.75303

Scale 0.05169 0.06396 0.80814 0.41901

Scale\*genderM 0.00992 0.11782 0.08417 0.93292

Locat\_1\*Scale -0.11414 0.06593 -1.73127 0.08340

L\*S\*genderM 0.16182 0.12705 1.27370 0.20277

Resid.Variance 0.19101 0.02628 7.26847 0.00000

Here, Locat\_1 refers to the random intercept and Scale is the random scale. 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, other than the residual variance, are significant.

**Further MIXREG analyses**

At this point, it might be of interest to run a MIXREG model, say removing the non-significant genderM interactions. Rather than rerunning the first stage model (MIXREGLS), which takes longer, it is more efficient simply to rerun the second-stage MIXREG model using the first-stage random effects that have already been estimated. This will now be described. In running MIXREG with the multiple resampled datasets, a definition file, named PMactive2\_ls\_reg\_repeat\_mixreg.def, is created. This file is named using the output file prefix specified on line 4 of the file Mixregls\_random\_Mixreg.def (i.e., PMactive2\_ls\_reg) combined with the suffix \_repeat\_mixreg.def. To rerun MIXREG on the multiple resampled datasets, say to remove the Scale by genderM and Location by Scale by gemderM interactions, one can modify this DEF file and then rerun the program. Below is the created DEF file PMactive2\_ls\_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\_ls\_reg\_repeat\_mixreg.def.

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1. PMactive2\_ls\_reg\_level2.dat
2. PMactive2\_ls\_reg\_ebrandom.dat
3. PMactive2\_ls\_reg\_random
4. 6 200 1 1  **1 1** 0.0000000000000000
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 Scale by genderM and Location by Scale by GenderM interactions, two specifications on line 4 need to be changed:

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

Line 4, parameter 7: number of interactions with random location 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 effect, scale random effect, location by scale random effect, and genderM by location random effect, in addition to the model intercept. 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 location\*scale\*genderM interactions**

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PMactive2\_ls\_reg\_level2.dat

PMactive2\_ls\_reg\_ebrandom.dat

PMactive2\_ls\_reg\_random

6 200 1 1 0 0 0.0000000000000000

1 2

3

4

mvpa

genderM

genderM

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

The results of this set of MIXREG runs (replicated 200 times), which are saved in PMactive2\_ls\_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 = -64.432 (sd= 0.531)

Akaike's Information Criterion = -70.432

Schwarz's Bayesian Criterion = -78.451

==> multiplied by -2

Log Likelihood = 128.864

Akaike's Information Criterion = 140.864

Schwarz's Bayesian Criterion = 156.901

Variable Estimate AsymStdError z-value p-value

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Intercept 0.24253 0.05667 4.27978 0.00002

genderM 0.11639 0.10193 1.14183 0.25353

Locat\_1 -0.01119 0.05725 -0.19538 0.84509

Locat\_1\*genderM -0.01392 0.09707 -0.14342 0.88596

Scale 0.04350 0.05286 0.82293 0.41055

Locat\_1\*Scale -0.06906 0.05492 -1.25743 0.20860

Resid.Variance 0.19525 0.02676 7.29492 0.00000

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

1. Make modifications toPMactive2\_ls\_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\_ls\_reg\_random\_200.out file.

**Model adding scale\*genderM interaction**

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PMactive2\_ls\_reg\_level2.dat

PMactive2\_ls\_reg\_ebrandom.dat

PMactive2\_ls\_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 = -64.323 (sd= 0.553)

Akaike's Information Criterion = -71.323

Schwarz's Bayesian Criterion = -80.677

==> multiplied by -2

Log Likelihood = 128.645

Akaike's Information Criterion = 142.645

Schwarz's Bayesian Criterion = 161.355

Variable Estimate AsymStdError z-value p-value

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

Intercept 0.24636 0.05879 4.19022 0.00003

genderM 0.10934 0.10609 1.03065 0.30271

Locat\_1 -0.01180 0.05730 -0.20600 0.83679

Locat\_1\*genderM -0.01605 0.09749 -0.16466 0.86921

Scale 0.03531 0.06296 0.56092 0.57485

Scale\*genderM 0.02824 0.11724 0.24091 0.80962

Locat\_1\*Scale -0.06715 0.05577 -1.20411 0.22855

Resid.Variance 0.19485 0.02672 7.29335 0.00000

**Main effects model**

It may be of interest to run a model without the location by scale interaction, and only include main effects of genderM, random location, and random scale. To remove the location 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 location by scale interaction. In many of the previous DEF files, this has been set to 0, and so no variables interacted with the location by scale interaction. However, in some cases, it might also be useful to remove this location by scale interaction, which is accomplished by specifying the value of -1 for this parameter.

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PMactive2\_ls\_reg\_level2.dat

PMactive2\_ls\_reg\_ebrandom.dat

PMactive2\_ls\_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 = -65.388 (sd= 0.212)

Akaike's Information Criterion = -69.388

Schwarz's Bayesian Criterion = -74.733

==> multiplied by -2

Log Likelihood = 130.775

Akaike's Information Criterion = 138.775

Schwarz's Bayesian Criterion = 149.466

Variable Estimate AsymStdError z-value p-value

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

Intercept 0.24894 0.05629 4.42219 0.00001

genderM 0.09950 0.09840 1.01119 0.31192

Locat\_1 -0.02829 0.04533 -0.62402 0.53262

Scale 0.02563 0.05097 0.50294 0.61501

Resid.Variance 0.19876 0.02719 7.31126 0.00000

**Summary**

Use of the combined MIXREGLS and MIXREG programs allows one to:

1. Perform a location-scale mixed model analysis 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 MIXREGLS analysis
5. Interactions can be of the type:
6. Location by scale
7. Predictor(s) by location
8. Predictor(s) by scale
9. Predictor(s) by location by scale