R2MLwiN

Using the multilevel modelling software package MLwiN from R

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Zhengzheng Zhang

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Bill Browne

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University of Bristol

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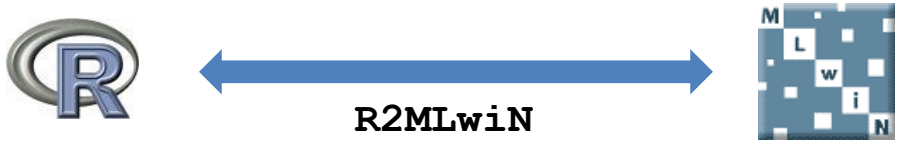

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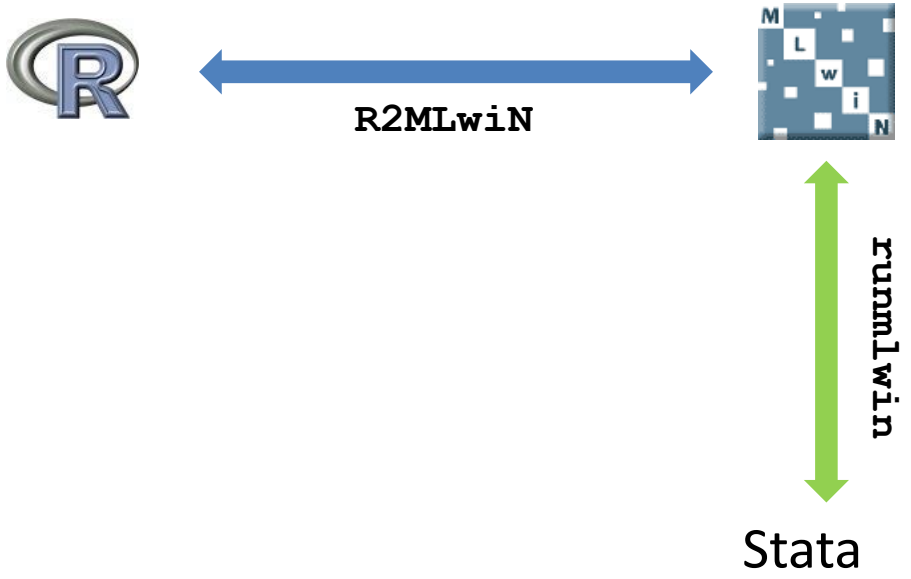

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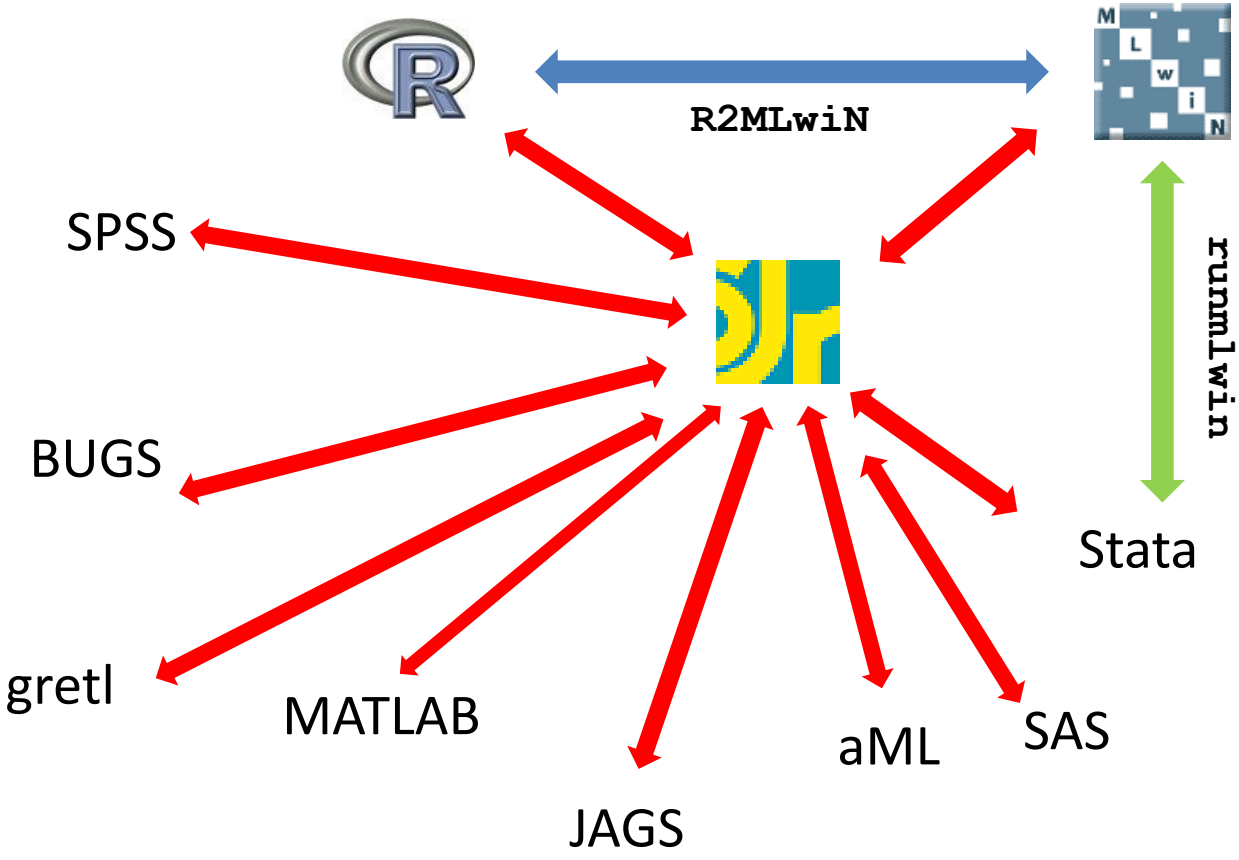

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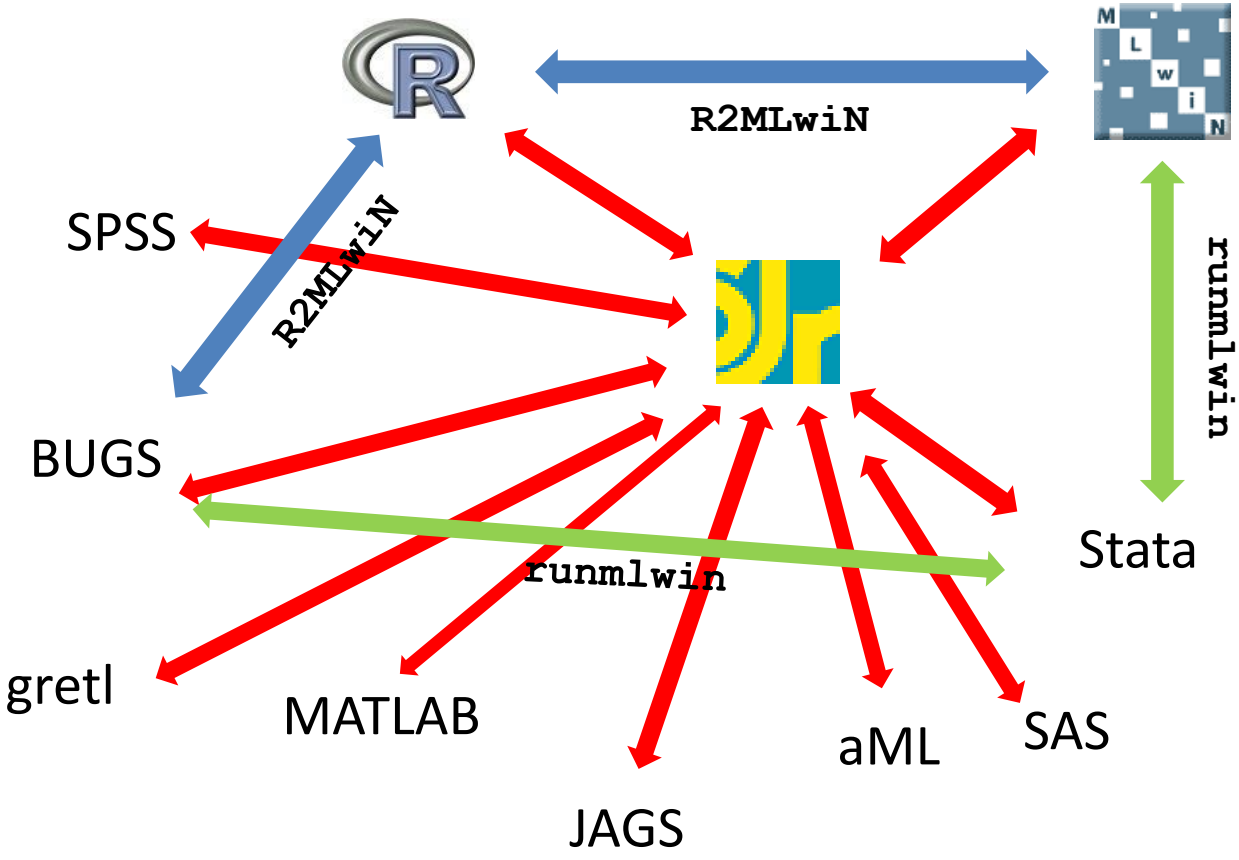

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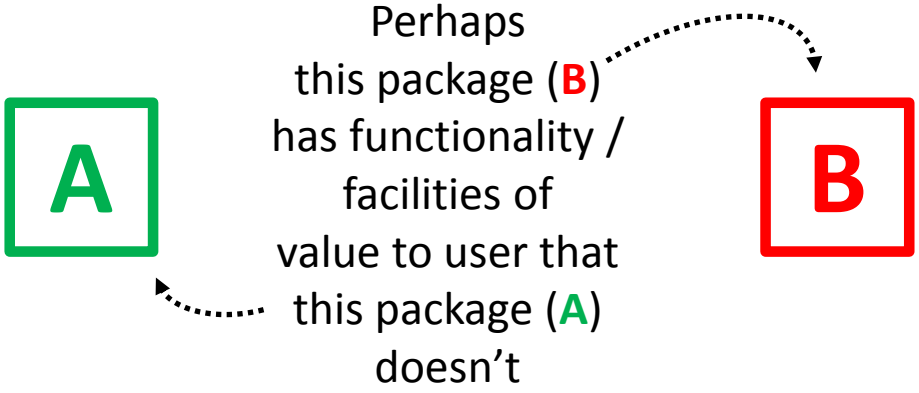

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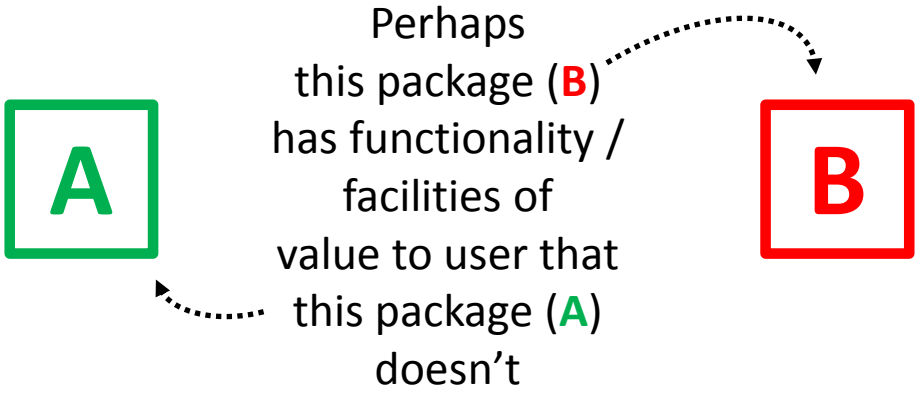

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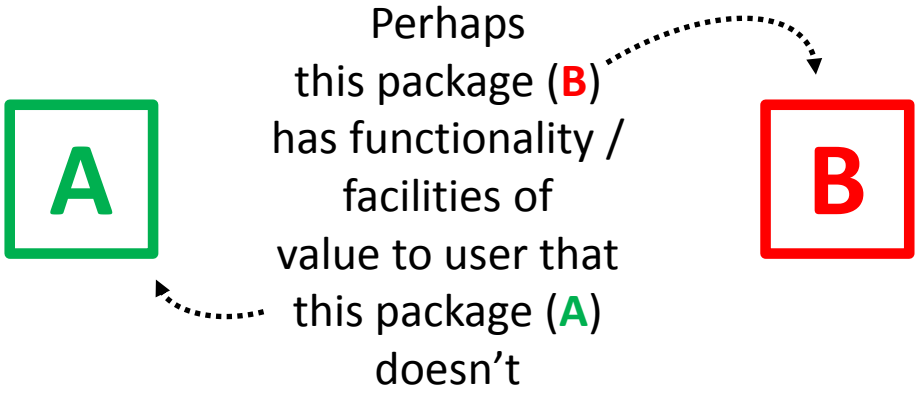

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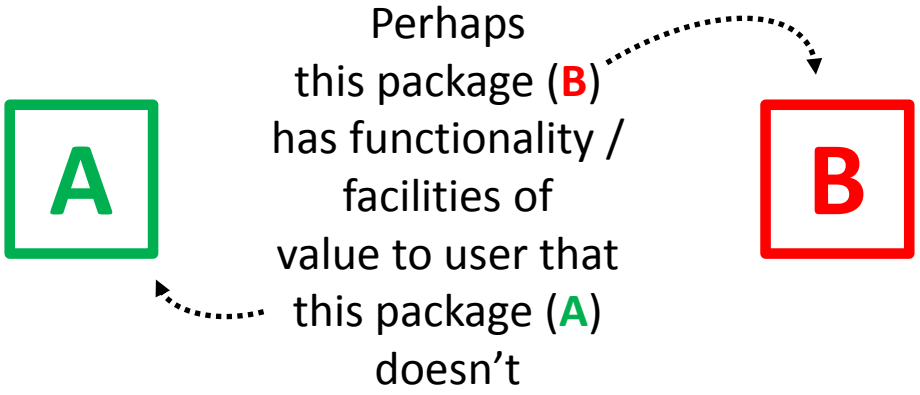

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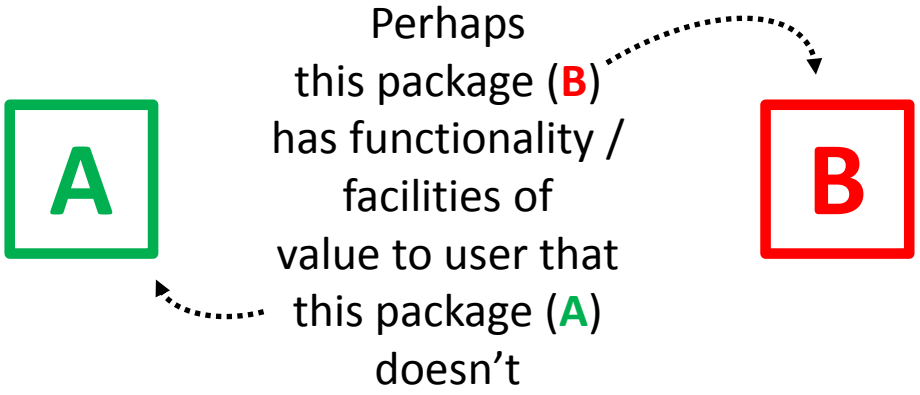

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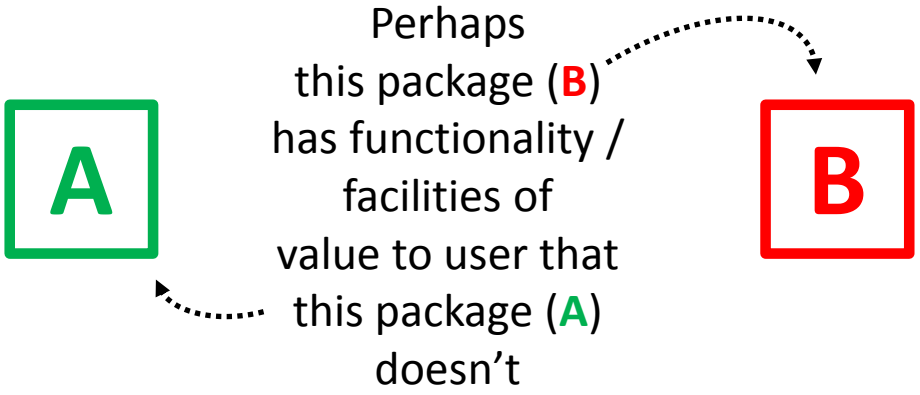

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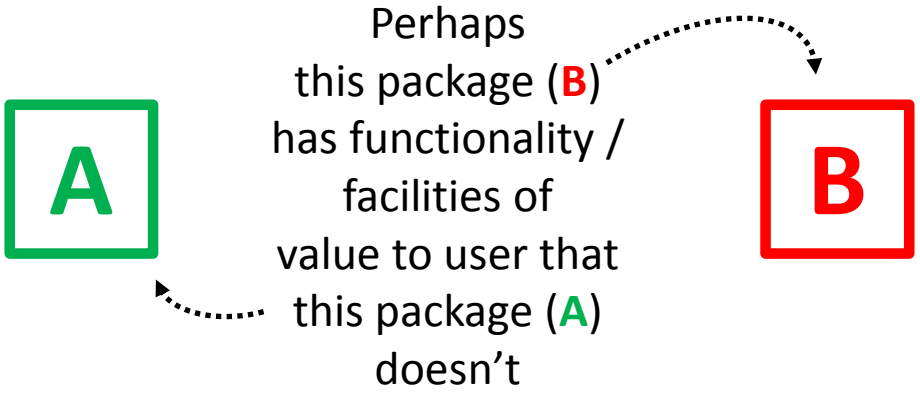

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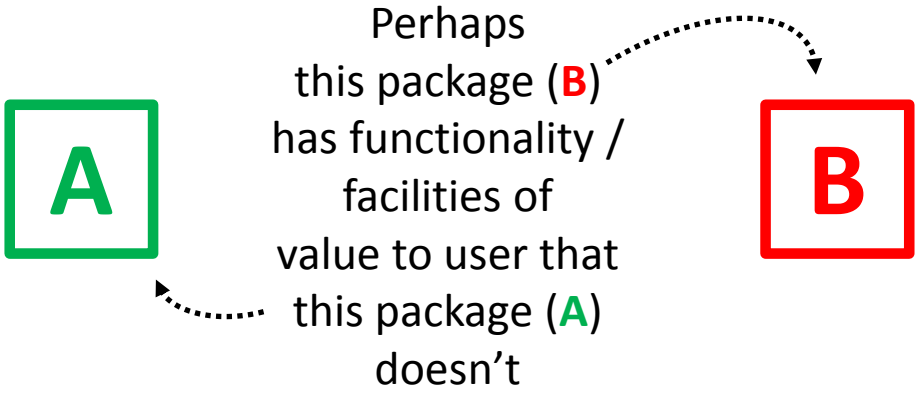

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- fit a certain type of statistical model
- use a quicker / less-biased / etc. means of estimation
- produce a certain type of plot, table, statistic, etc.

…or perhaps package **B** is:

- more familiar
- has useful supporting resources

Why operate one application from another?

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A

B

The user could (in principle) operate package **B** directly…

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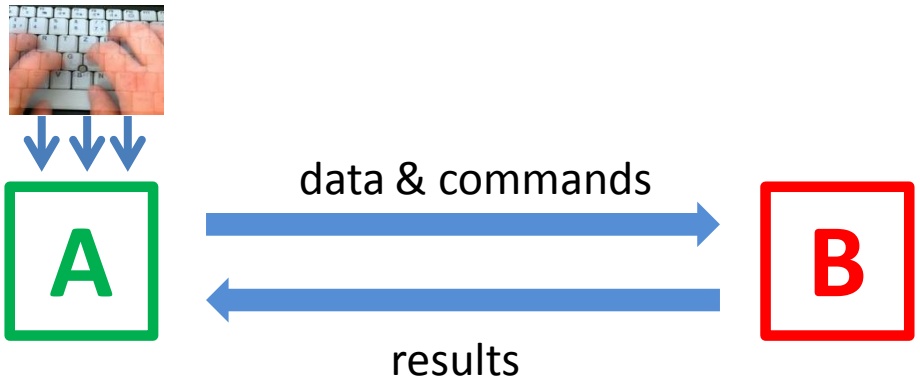

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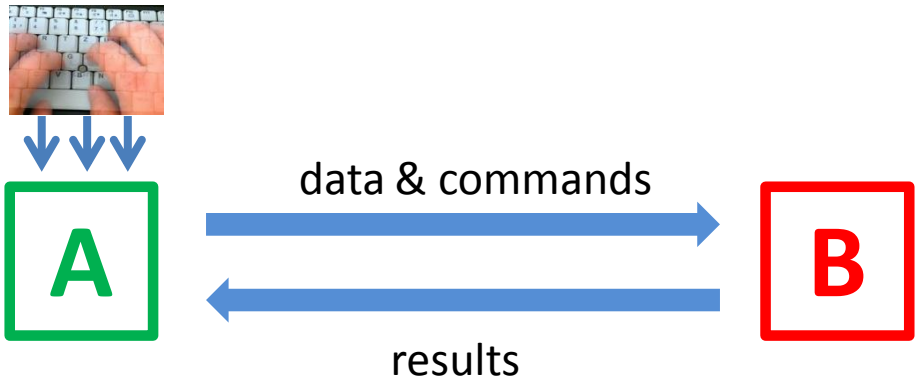

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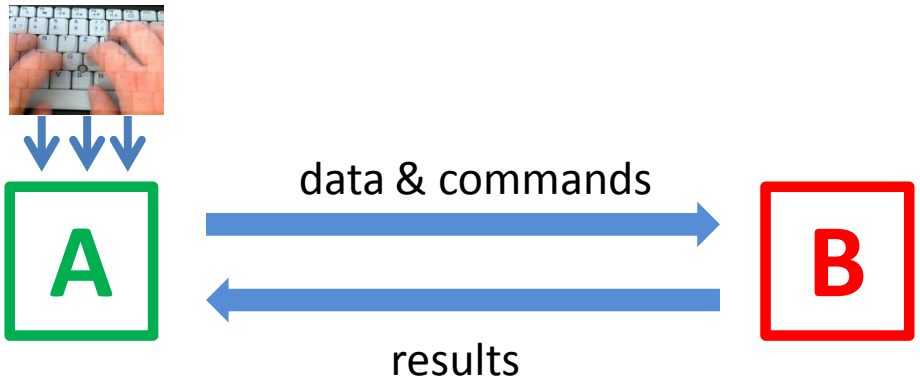

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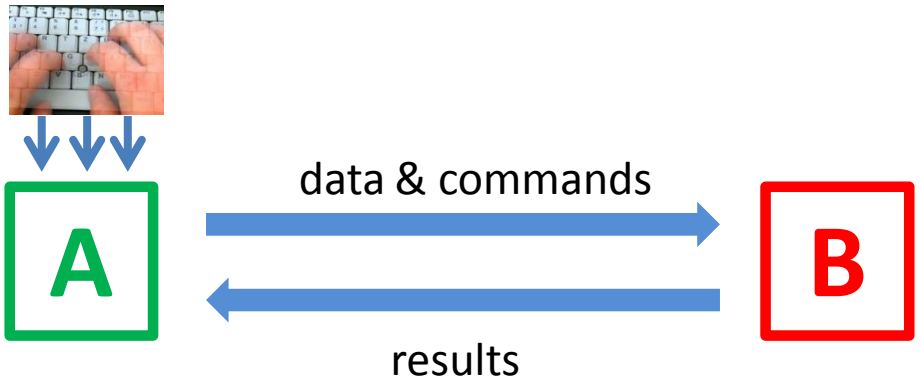

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- The user might *not know* how to operate Package **B**
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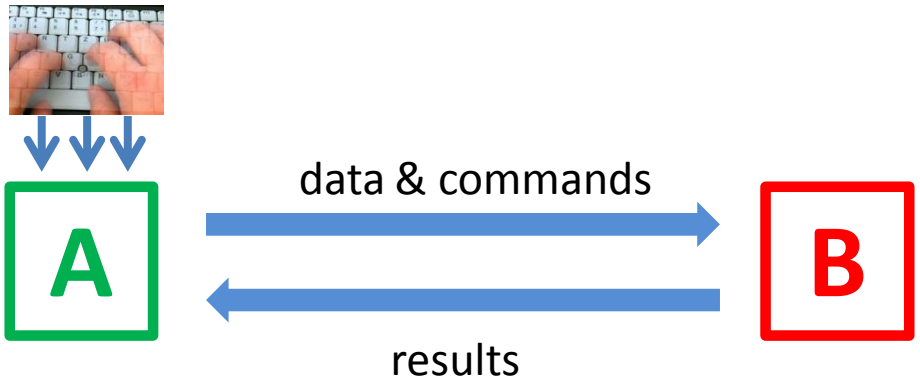

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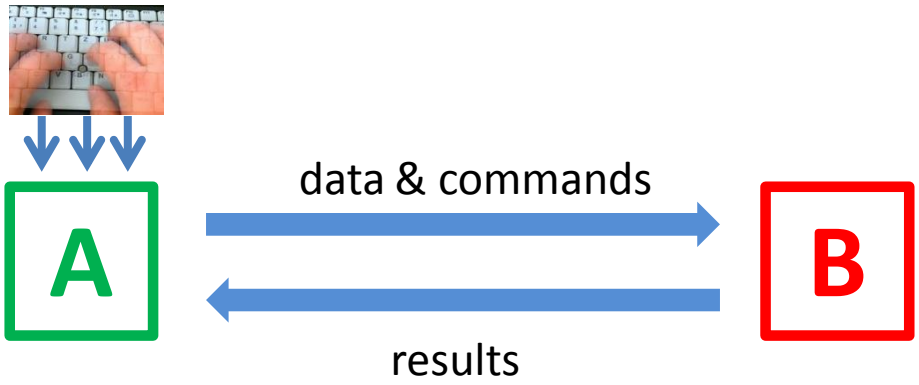

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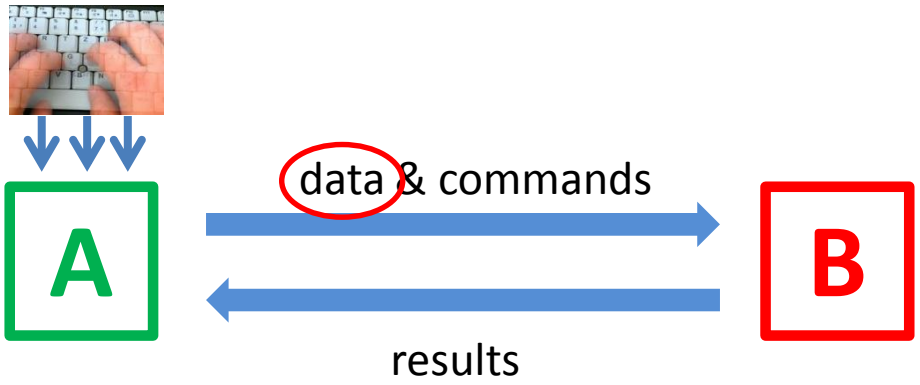

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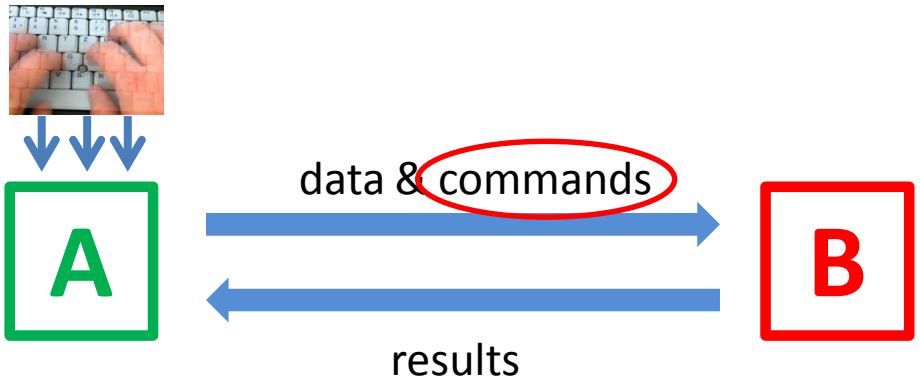

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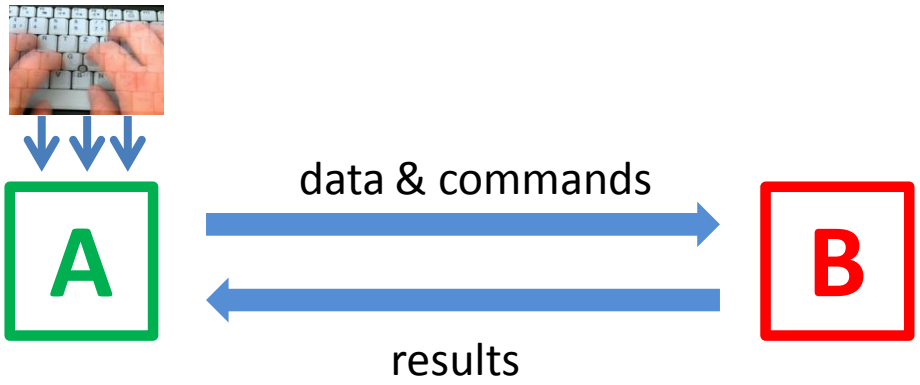

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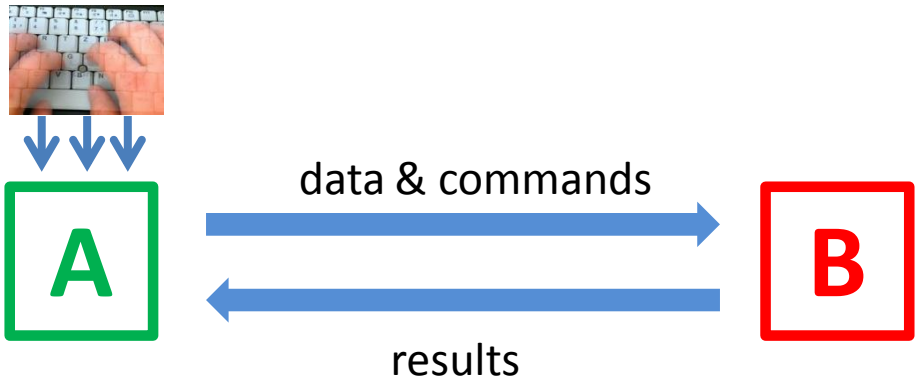

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  - may want to compare model fits from many packages…

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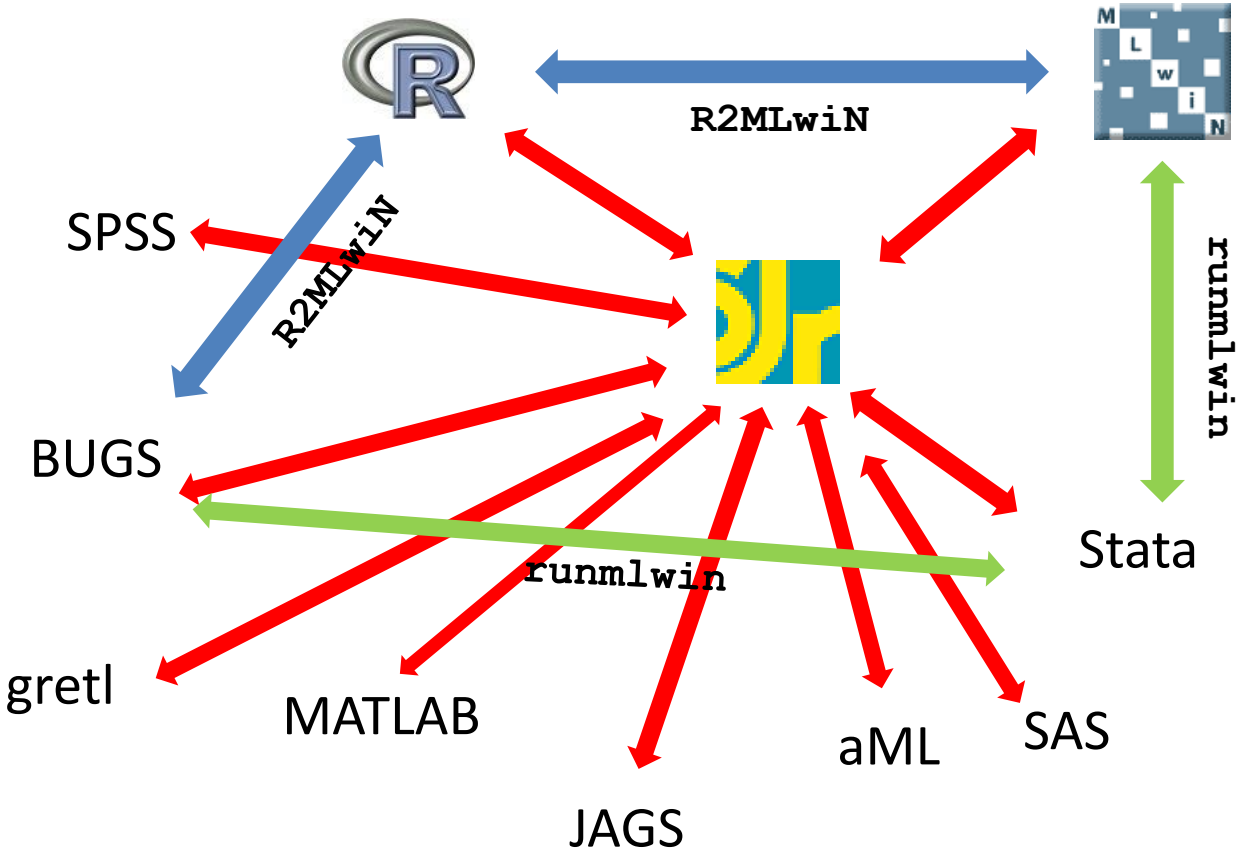

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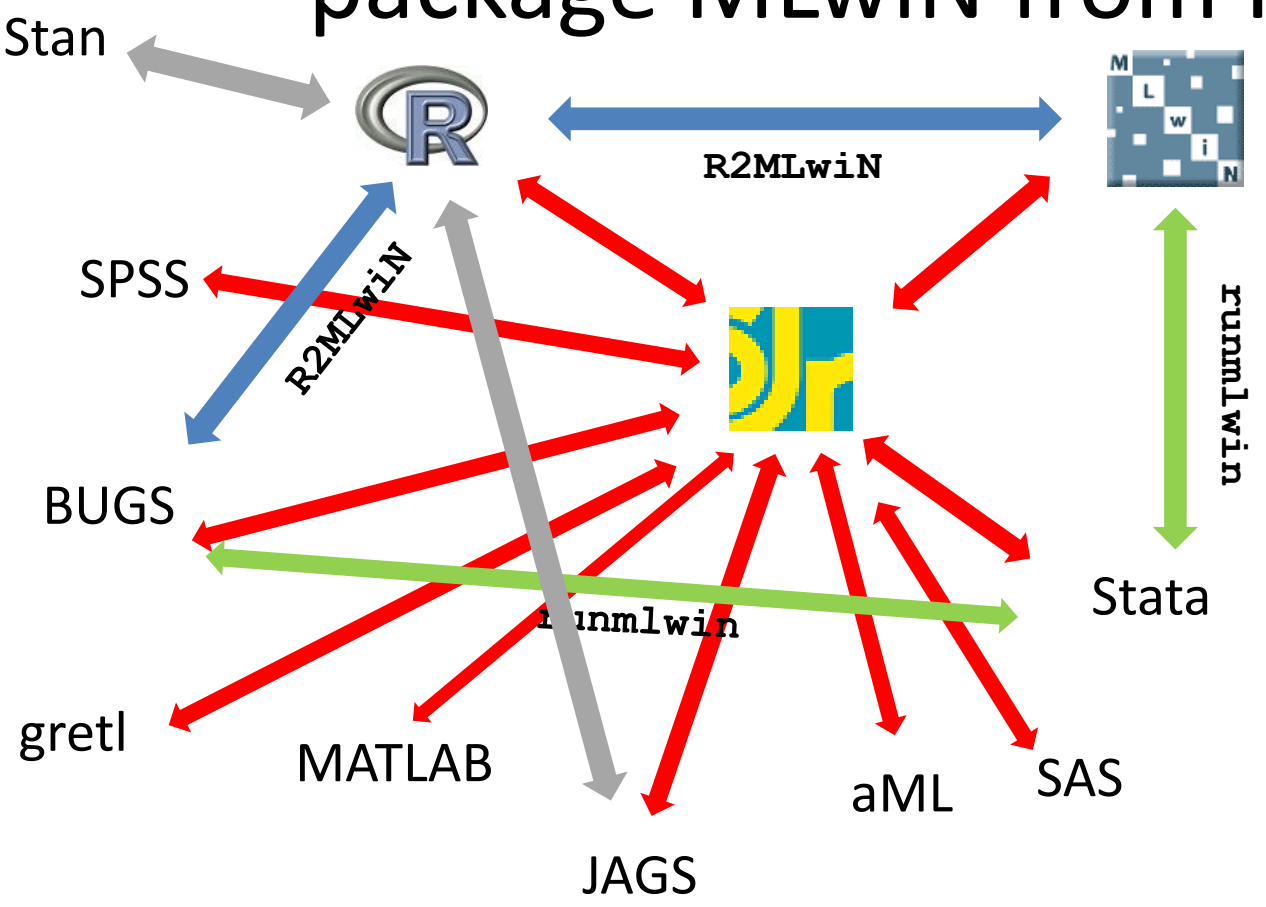

R2MLwiN

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- First released (on CRAN) December 2012
- Most recent release **(0.8-0) March 2015**…

  …this has a number of **new features / syntactical changes**

  …but back-compatibility maintained where possible

R2MLwiN

MLwiN

- Developed & maintained by Centre for Multilevel Modelling (now at Bristol)
- Estimated 18,000 users worldwide
- Large body of supporting documentation, examples, workshops, etc.
- As well as **Windows**, native versions of MLwiN engine for **Mac OS X** and **Linux** now available too

R2MLwiN

MLwiN

- Allows for a variety of response types to be modelled, including:
  - continuous
  - binary
  - count
  - ordinal
  - nominal
  - multivariate combinations (i.e., simultaneous equations)

- Estimation available via:
  - IGLS (iterative generalised least squares), which yields maximum likelihood estimates
  - MCMC (Markov chain Monte Carlo) estimation for Bayesian inference

- Supported data structures:
  - nested, cross-classified and/or multiple membership

- Other features include:
  - fitting of complex level 1 variance (heteroskedastic) models
  - multilevel factor analysis (MCMC only)
  - adjustments for measurement errors in predictors
  - spatial conditional auto regressive (CAR) models
  - autoregressive structures at level 1
  - a selection of MCMC algorithms to increase efficiency.

R2MLwiN

MLwiN

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- Interactive equations window:

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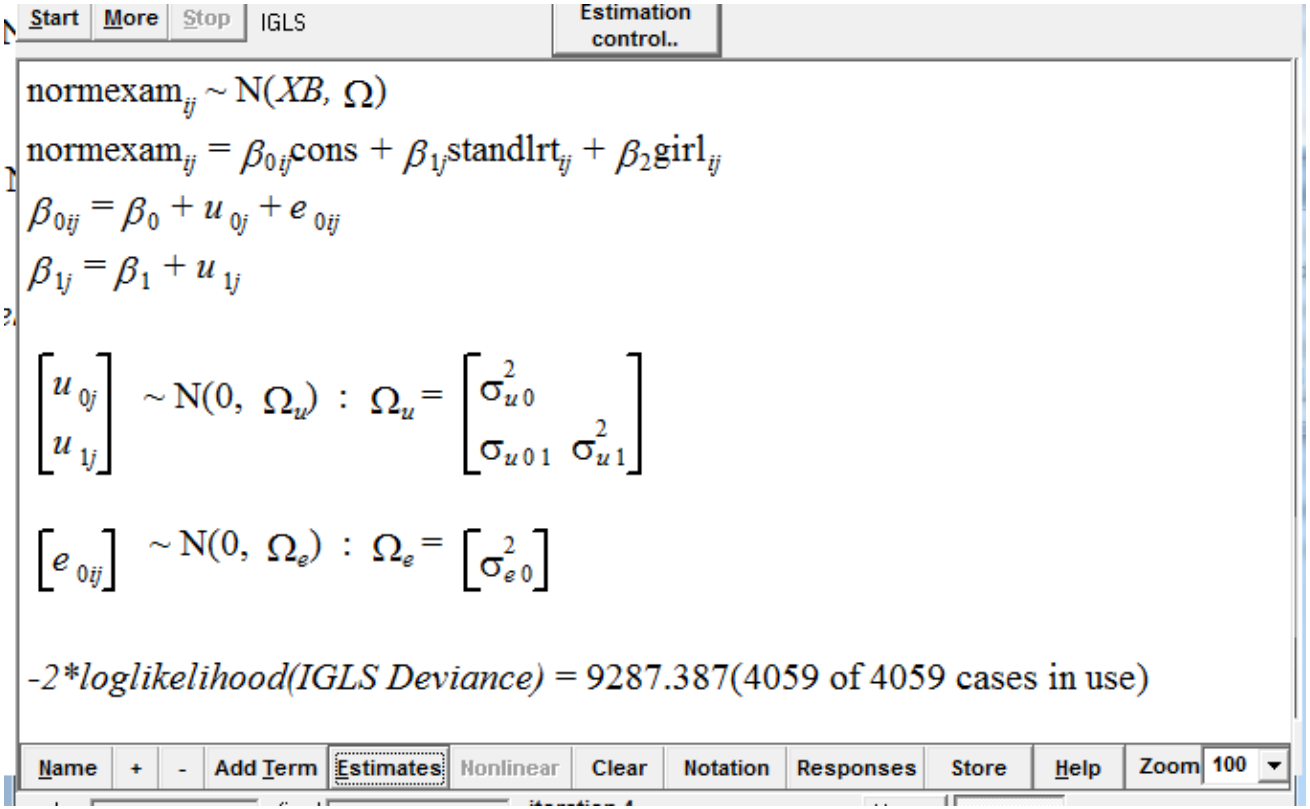

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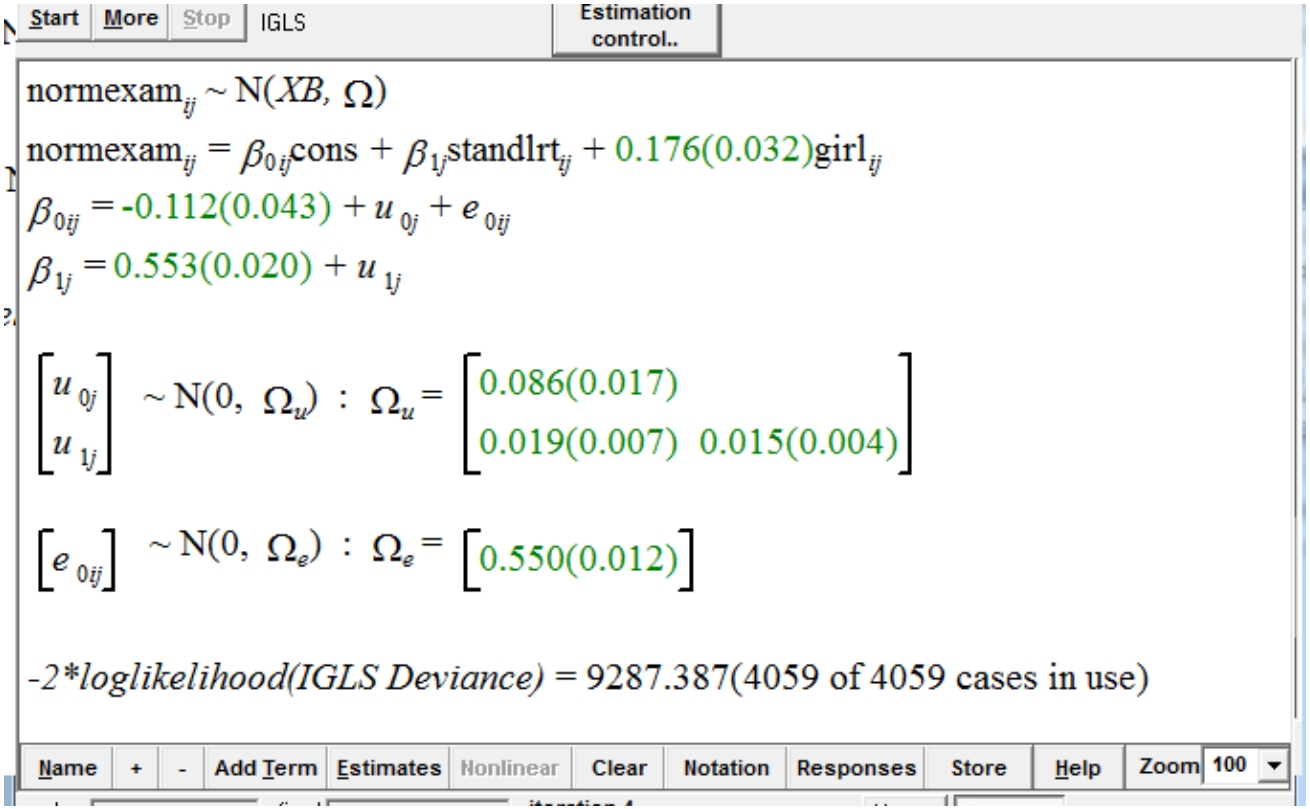

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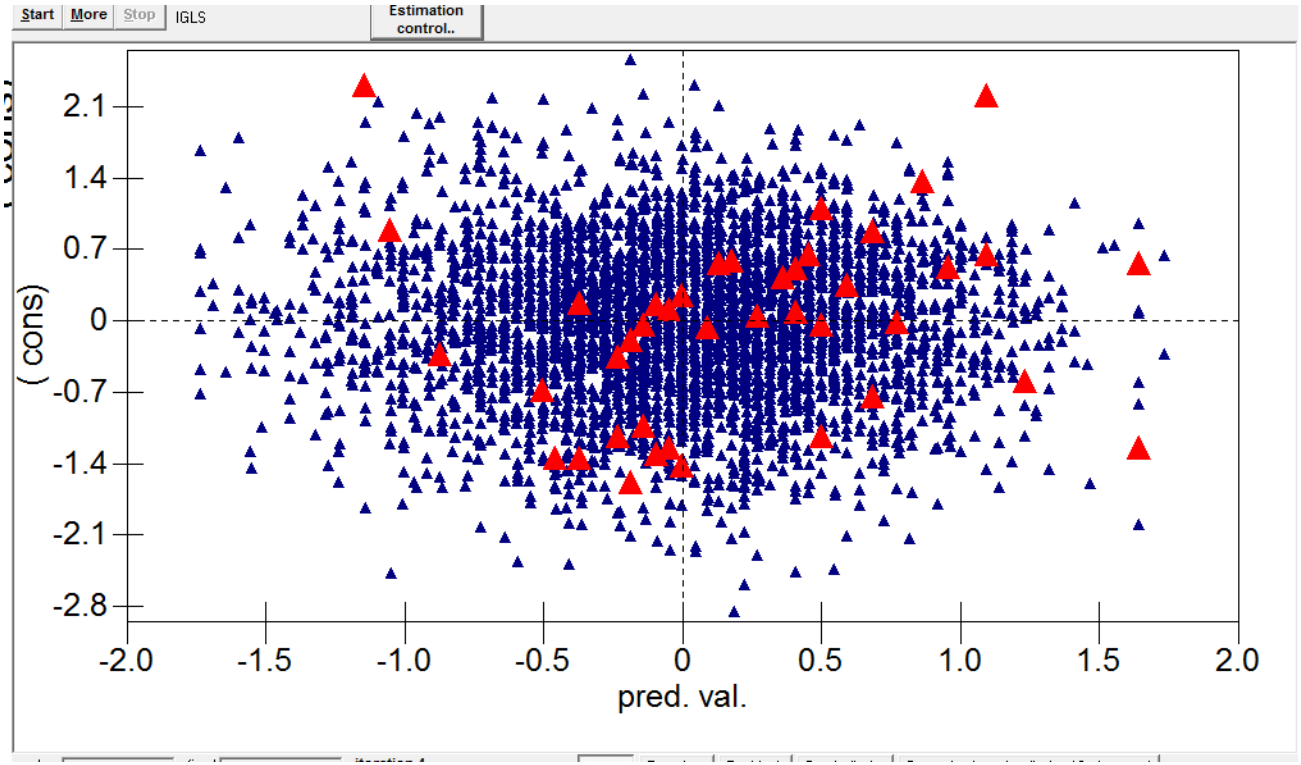
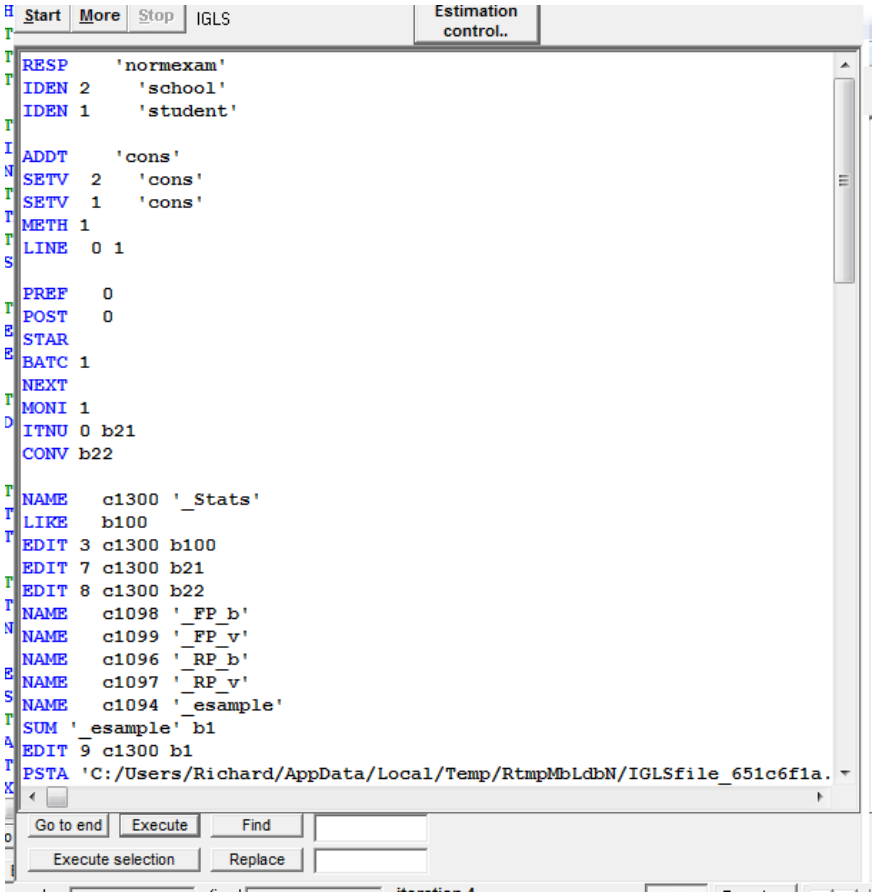


R2MLwiN

MLwiN

- Most users will likely operate MLwiN via GUI
- Macro language can be unwieldy



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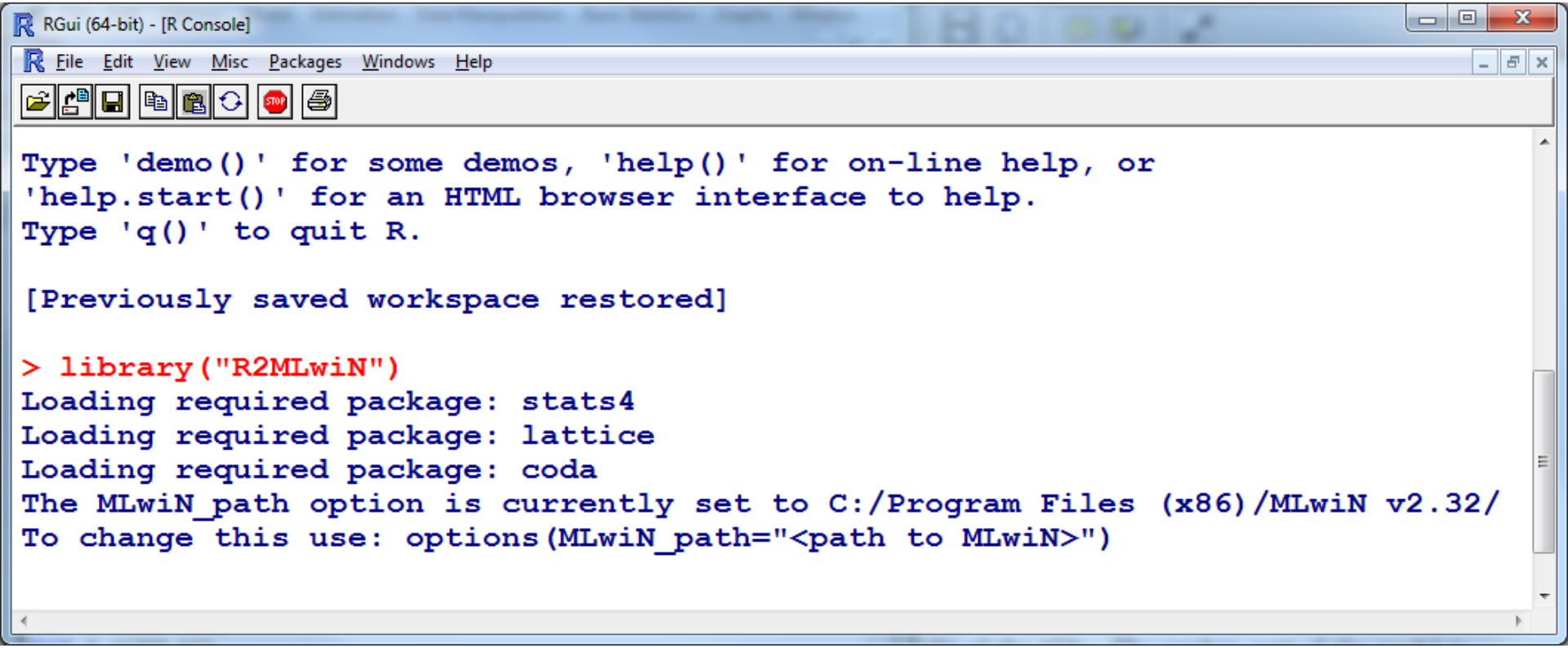
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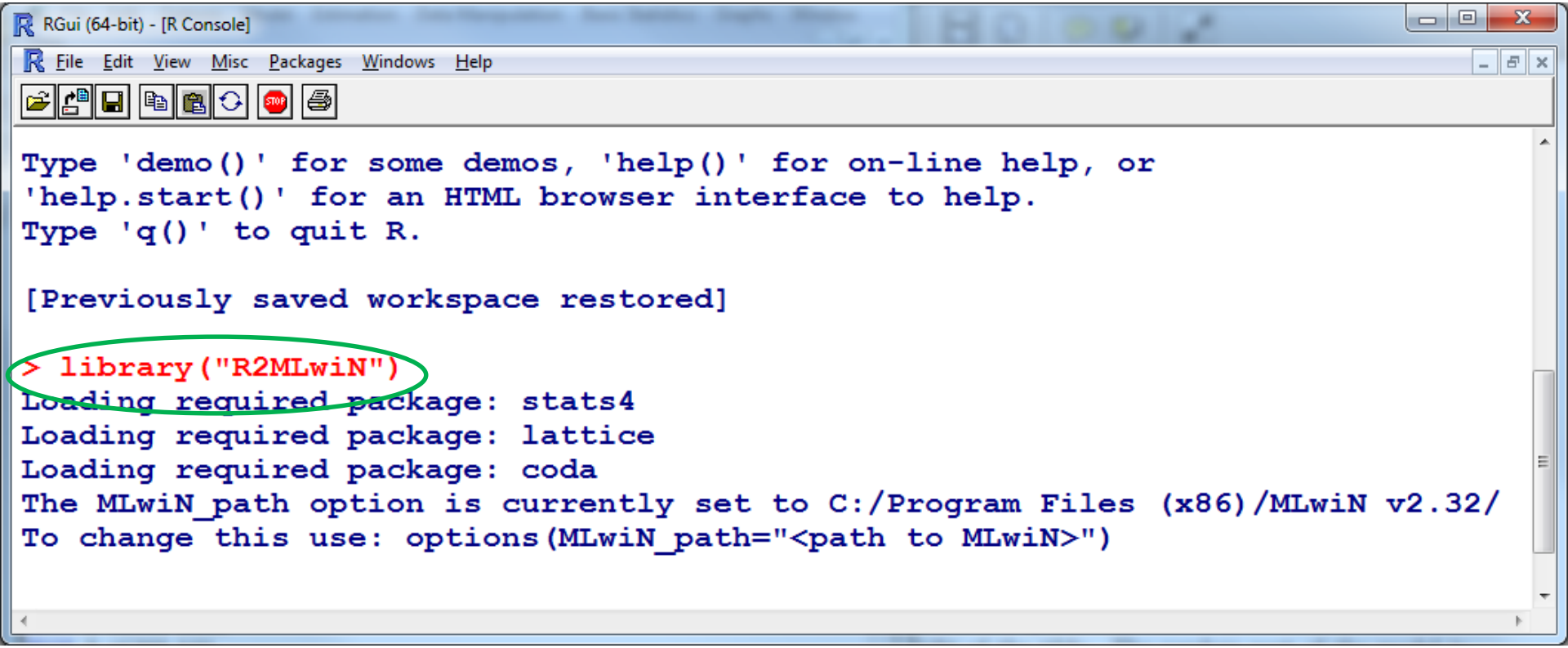
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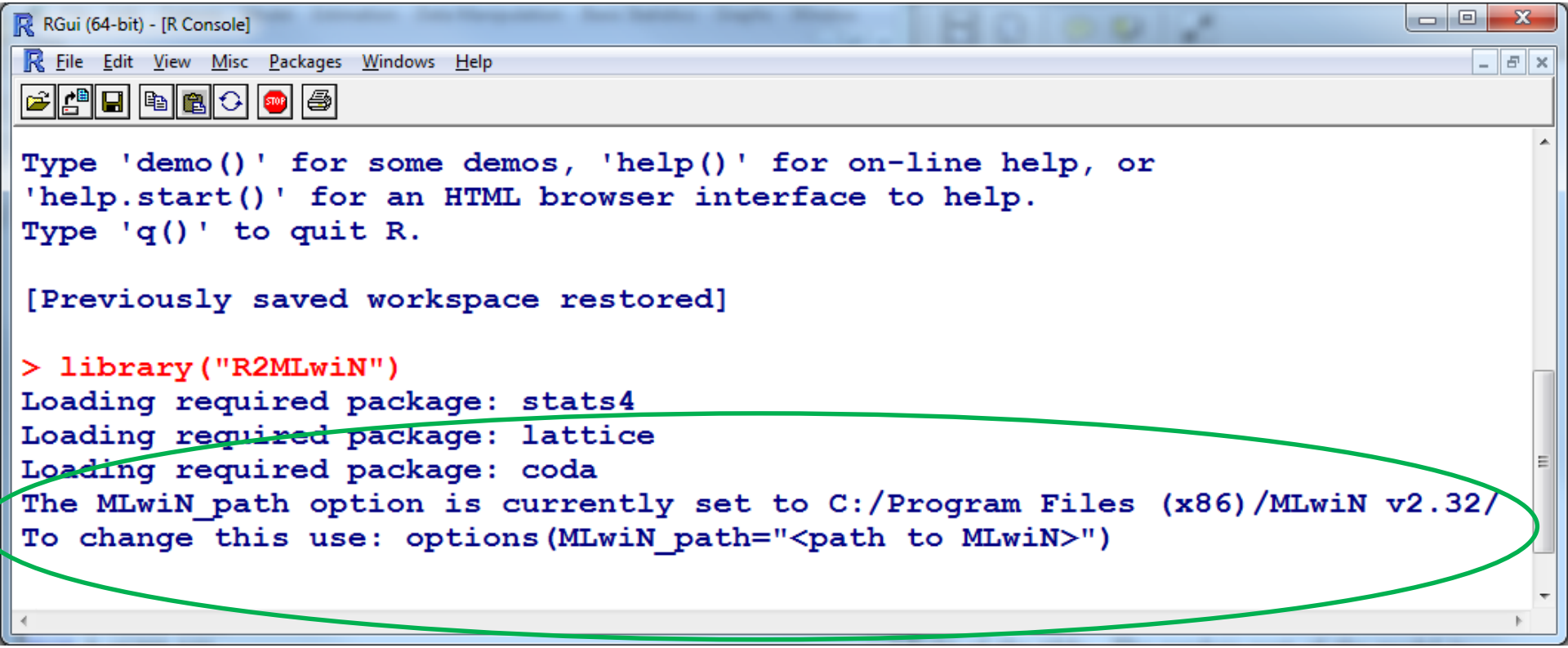
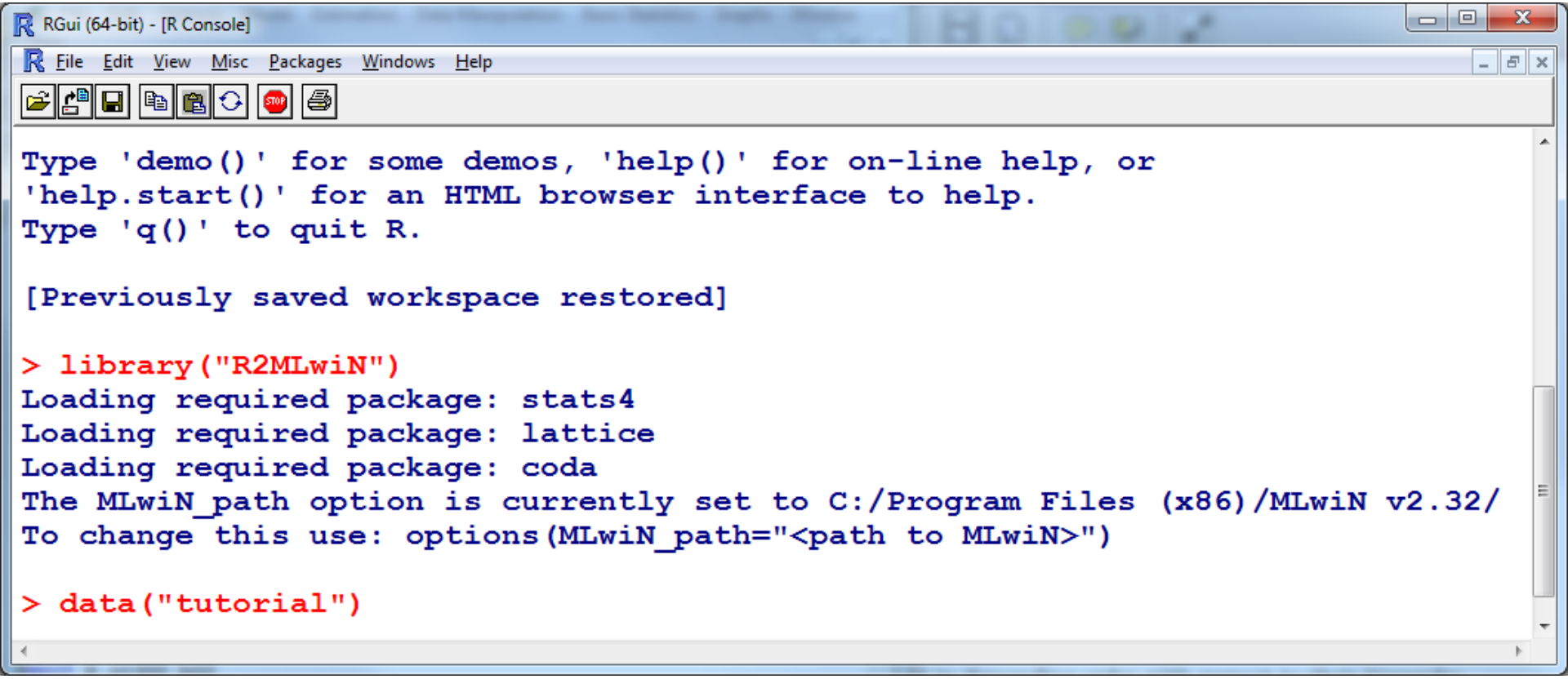


- Tells user where it's expecting to find MLwiN; easy to change path if it's elsewhere

R2MLwiN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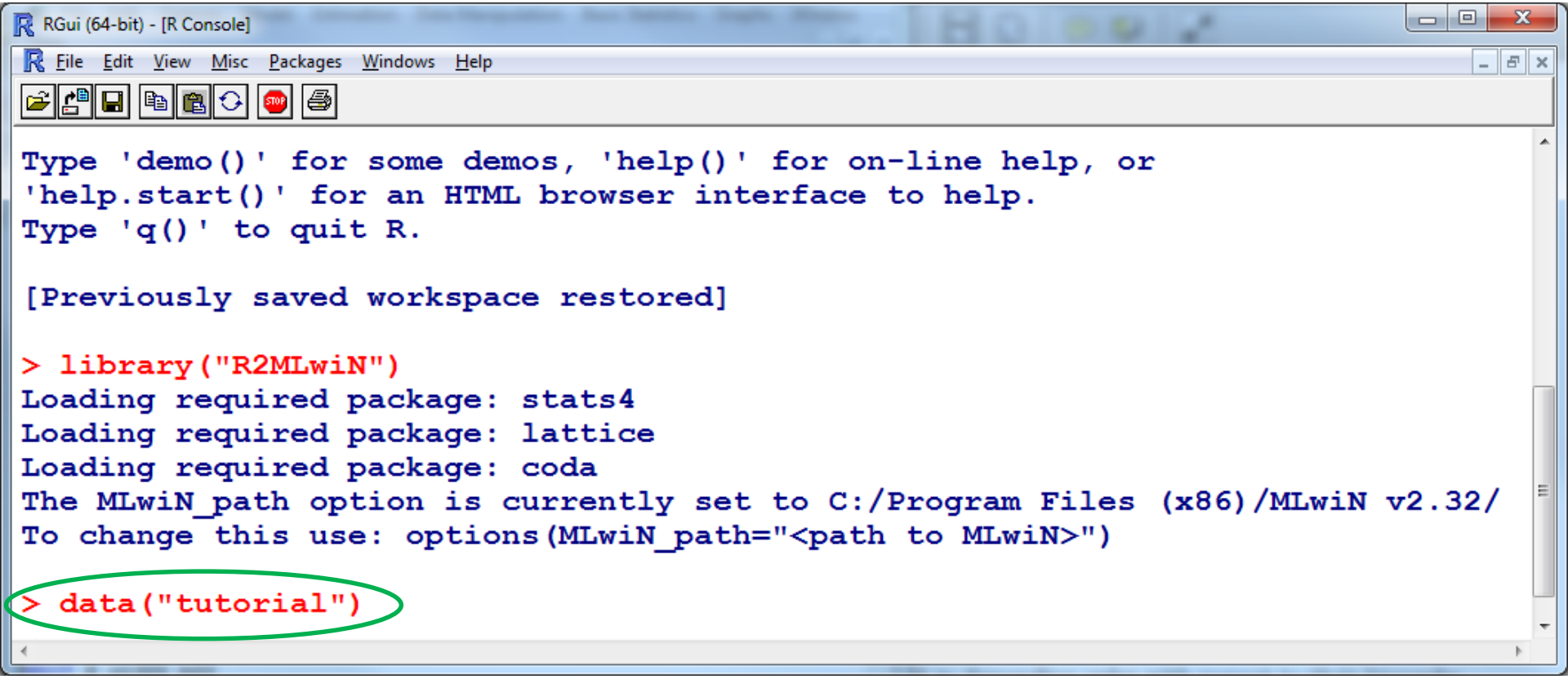
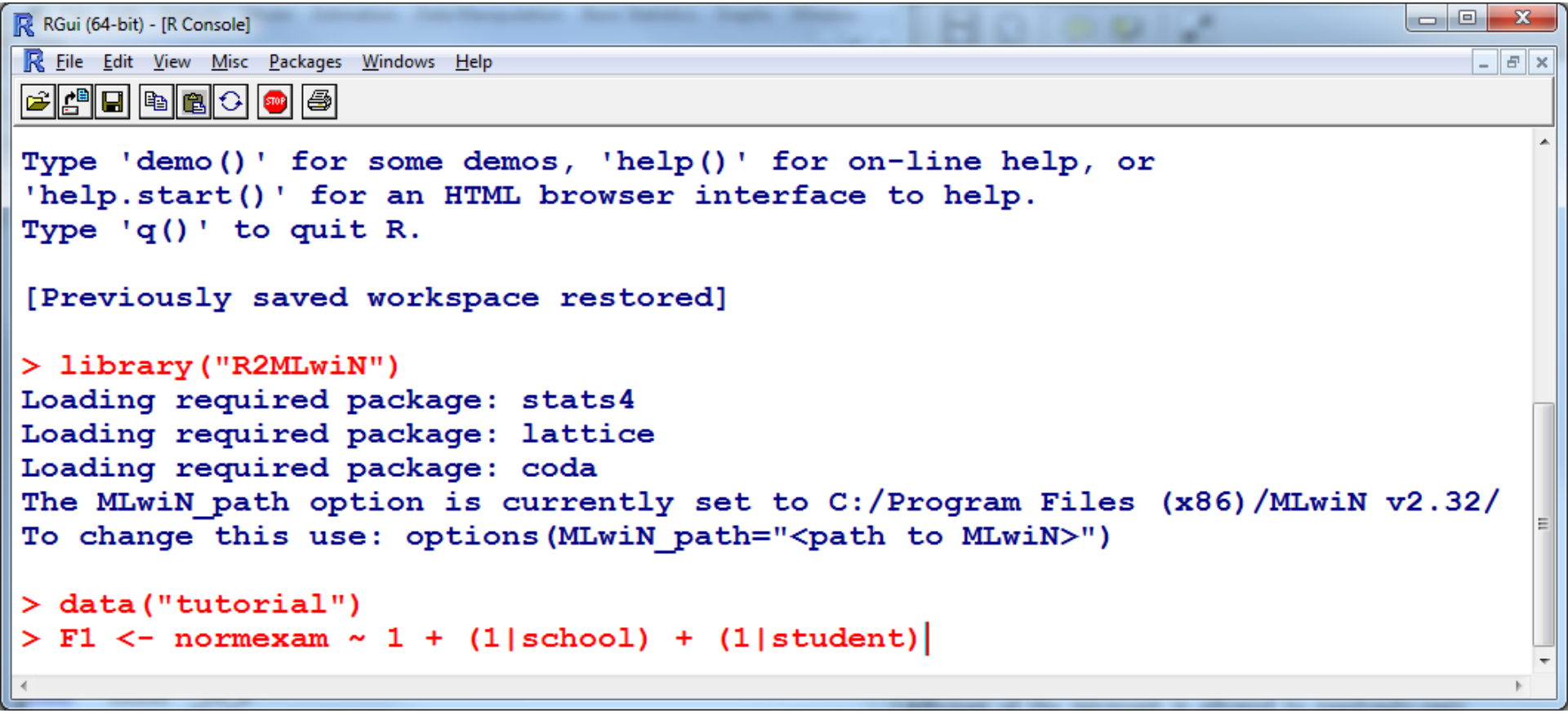


- All sample datasets released with MLwiN available with R2MLwiN

R2MLwiN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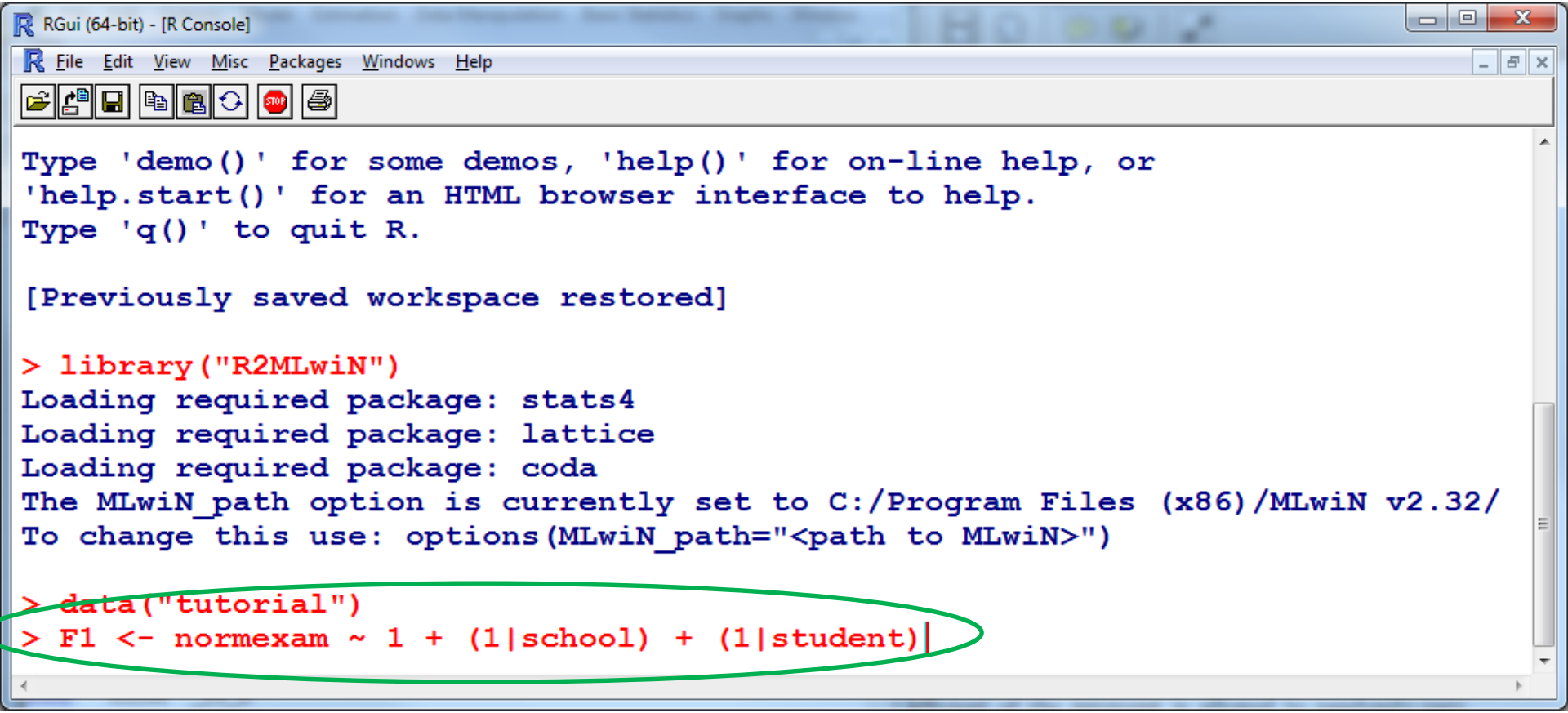
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$$\text{normexam}_{ij} = \beta_0 + u_j + e_{ij}$$

$$u_j \sim \text{N}(0, \sigma_u^2)$$

$$e_{ij} \sim \text{N}(0, \sigma_e^2)$$

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+     (1|student)
```

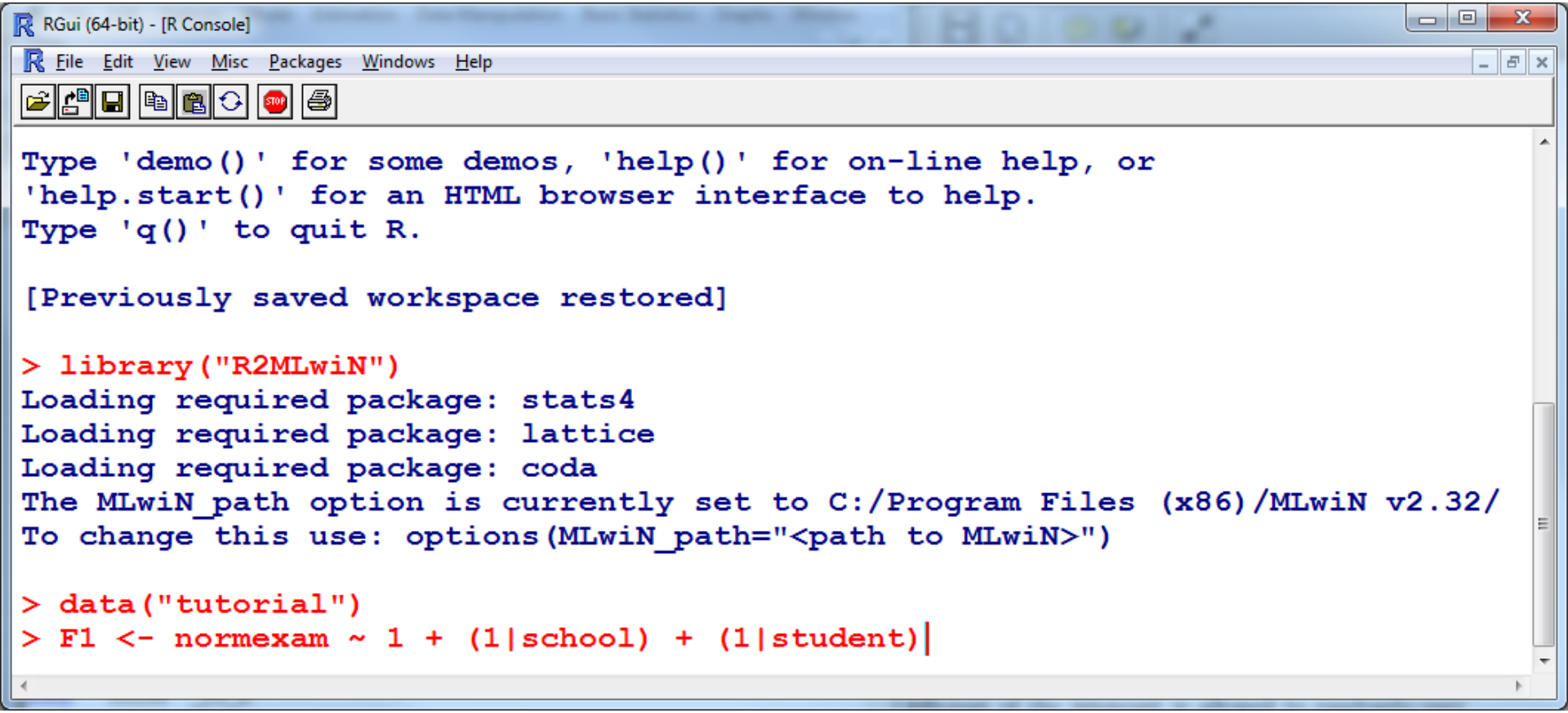
$$\text{normexam}_{ij} = \beta_0 + u_j + e_{ij}$$

$$u_j \sim \text{N}(0, \sigma_u^2)$$

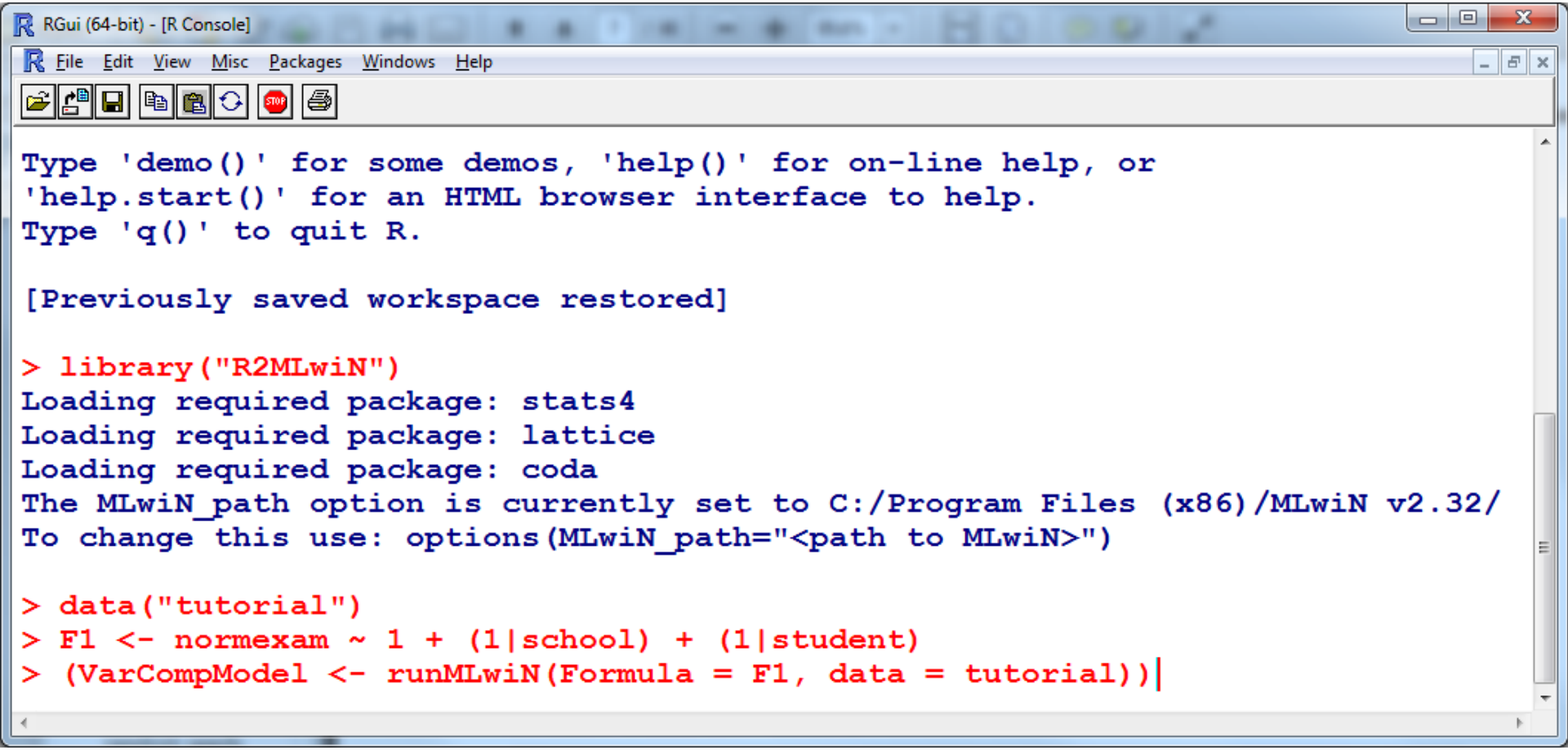
$$e_{ij} \sim \text{N}(0, \sigma_e^2)$$

- Note: need to explicitly add intercept (as in MLwiN)
- Specify random part of model in order of hierarchy

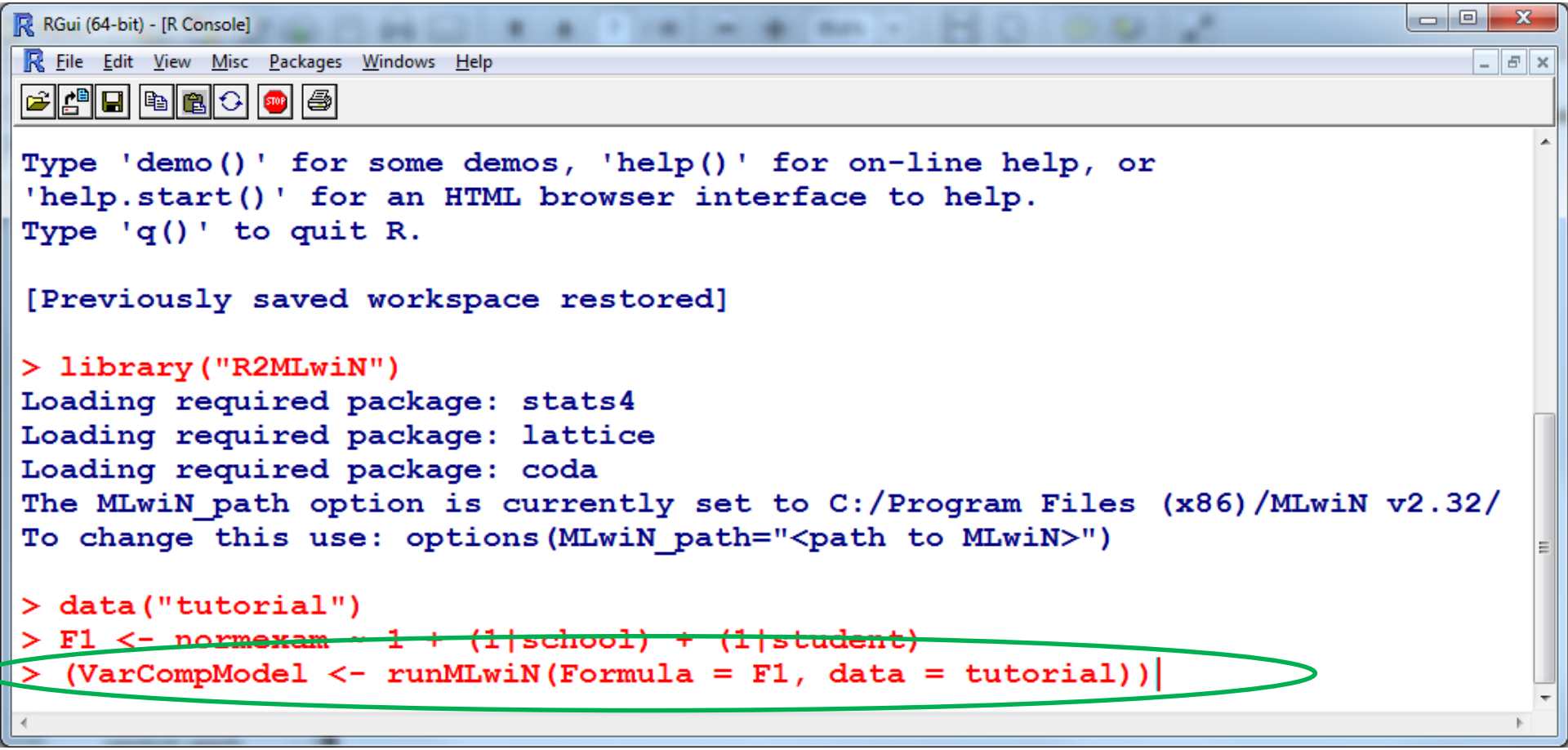
R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
[Previously saved workspace restored]
> library("R2MLwiN")
Loading required package: stats4
Loading required package: lattice
Loading required package: coda
The MLwiN_path option is currently set to C:/Program Files (x86)/MLwiN v2.32/
To change this use: options(MLwiN_path="<path to MLwiN>")
> data("tutorial")
> F1 <- normexam ~ 1 + (1|school) + (1|student)

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
[Previously saved workspace restored]
> library("R2MLwiN")
Loading required package: stats4
Loading required package: lattice
Loading required package: coda
The MLwiN_path option is currently set to C:/Program Files (x86)/MLwiN v2.32/
To change this use: options(MLwiN_path="<path to MLwiN>")
> data("tutorial")
> F1 <- normexam ~ 1 + (1|school) + (1|student)
> (VarCompModel <- runMLwiN(Formula = F1, data = tutorial))

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
[Previously saved workspace restored]
> library("R2MLwiN")
Loading required package: stats4
Loading required package: lattice
Loading required package: coda
The MLwiN_path option is currently set to C:/Program Files (x86)/MLwiN v2.32/
To change this use: options(MLwiN_path="<path to MLwiN>")
> data("tutorial")
> F1 <- normexam ~ 1 + (1|school) + (1|student)
> (VarCompModel <- runMLwiN(Formula = F1, data = tutorial))

R2MLwiN

```
R> F1 <- normexam ~ 1 + (1|school) +
+     (1|student)

R> (VarCompModel <- runMLwiN(
+     Formula = F1, data = tutorial))
```

R2MLwiN

```
R> F1 <- normexam ~ 1 + (1|school) +
+     (1|student)

R> (VarCompModel <- runMLwiN(
+     Formula = F1, data = tutorial))
```

R2MLwiN

```
R> F1 <- normexam ~ 1 + (1|school) +
+     (1|student)

R> (VarCompModel <- runMLwiN(
+     Formula = F1, data = tutorial))
```

runMLwiN function:

1. takes input & creates MLwiN macro file
2. calls MLwiN and executes macro script
3. output is returned to R for post-processing

R2MLwiN

```
R> F1 <- normexam ~ 1 + (1|school) +
+     (1|student)

R> (VarCompModel <- runMLwiN(
+     Formula = F1, data = tutorial))
```

runMLwiN function

- Arguments include:
  - **Formula**
  - **data**
  - **D** …since we don't specify here, using default:

    D = "Normal"
  - **estoptions** …again using default, which is IGLS:

    estoptions = list(EstM = 0)
  - See **?runMLwiN** for full list of arguments

R2MLwiN

```
R> F1 <- normexam ~ 1 + (1|school) +
+     (1|student)

R> (VarCompModel <- runMLwiN(
+     Formula = F1, data = tutorial))
```

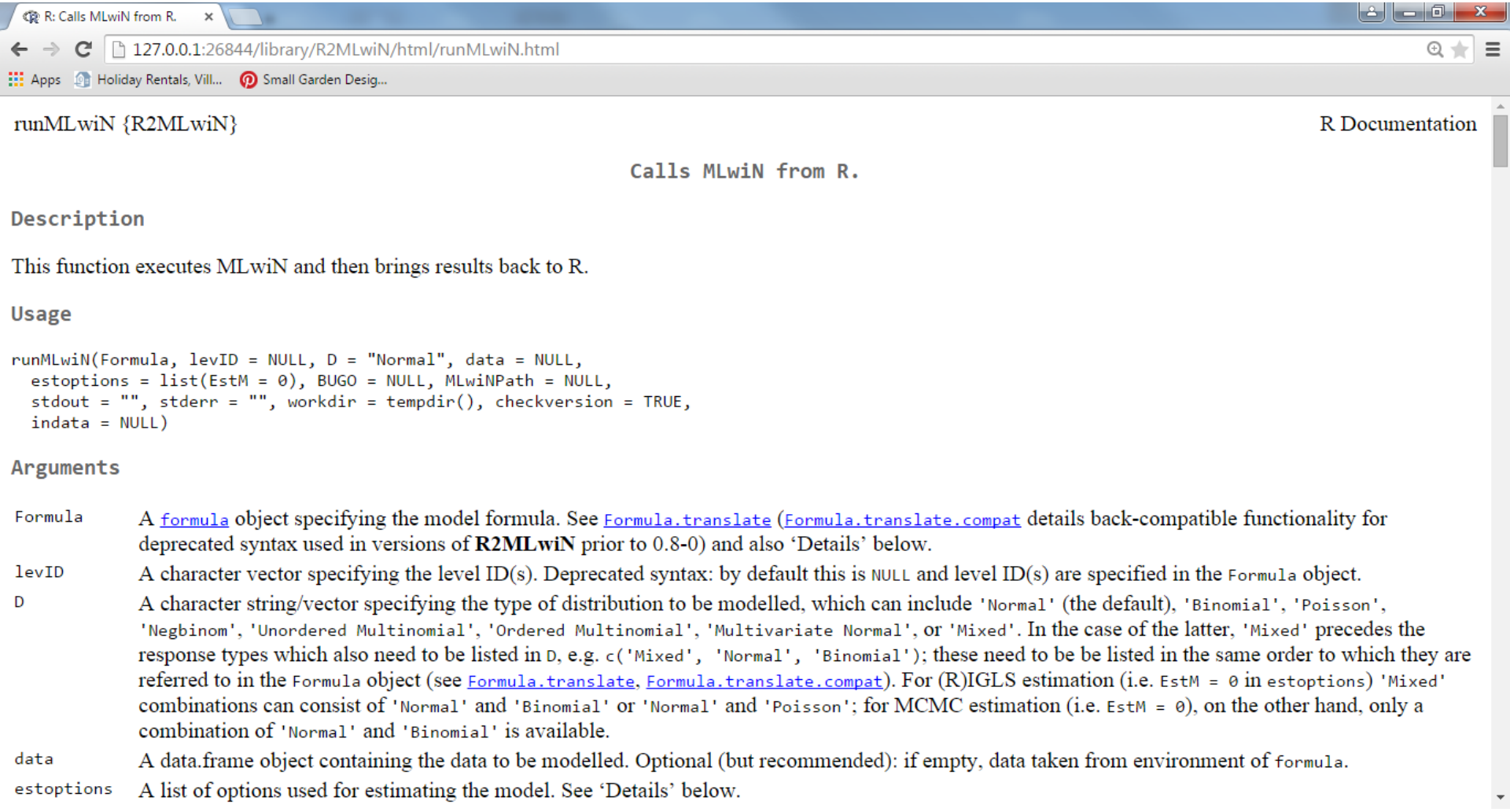
runMLwiN function

- Arguments include:
  - **Formula**
  - **data**
  - **D** …since we don't specify here, using default:

    D = "Normal"
  - **estoptions** …again using default, which is IGLS:

    estoptions = list(EstM = 0)
  - See **?runMLwiN** for full list of arguments

R2MLwiN


R: Calls MLwiN from R.
127.0.0.1:26844/library/R2MLwiN/html/runMLwiN.html
Apps
Holiday Rentals, Vill...
Small Garden Desig...
runMLwiN {R2MLwiN}
R Documentation
Calls MLwiN from R.
Description
This function executes MLwiN and then brings results back to R.
Usage
runMLwiN(Formula, levID = NULL, D = "Normal", data = NULL,
estoptions = list(EstM = 0), BUGO = NULL, MLwiNPath = NULL,
stdout = "", stderr = "", workdir = tempdir(), checkversion = TRUE,
indata = NULL)
Arguments
Formula
A formula object specifying the model formula. See Formula.translate (Formula.translate.compat details back-compatible functionality for deprecated syntax used in versions of R2MLwiN prior to 0.8-0) and also 'Details' below.
levID
A character vector specifying the level ID(s). Deprecated syntax: by default this is NULL and level ID(s) are specified in the Formula object.
D
A character string/vector specifying the type of distribution to be modelled, which can include 'Normal' (the default), 'Binomial', 'Poisson', 'Negbinom', 'Unordered Multinomial', 'Ordered Multinomial', 'Multivariate Normal', or 'Mixed'. In the case of the latter, 'Mixed' precedes the response types which also need to be listed in D, e.g. c('Mixed', 'Normal', 'Binomial'); these need to be be listed in the same order to which they are referred to in the Formula object (see Formula.translate, Formula.translate.compat). For (R)IGLS estimation (i.e. EstM = 0 in estoptions) 'Mixed' combinations can consist of 'Normal' and 'Binomial' or 'Normal' and 'Poisson'; for MCMC estimation (i.e. EstM = 0), on the other hand, only a combination of 'Normal' and 'Binomial' is available.
data
A data.frame object containing the data to be modelled. Optional (but recommended): if empty, data taken from environment of formula.
estoptions
A list of options used for estimating the model. See 'Details' below.

R2MLwiN

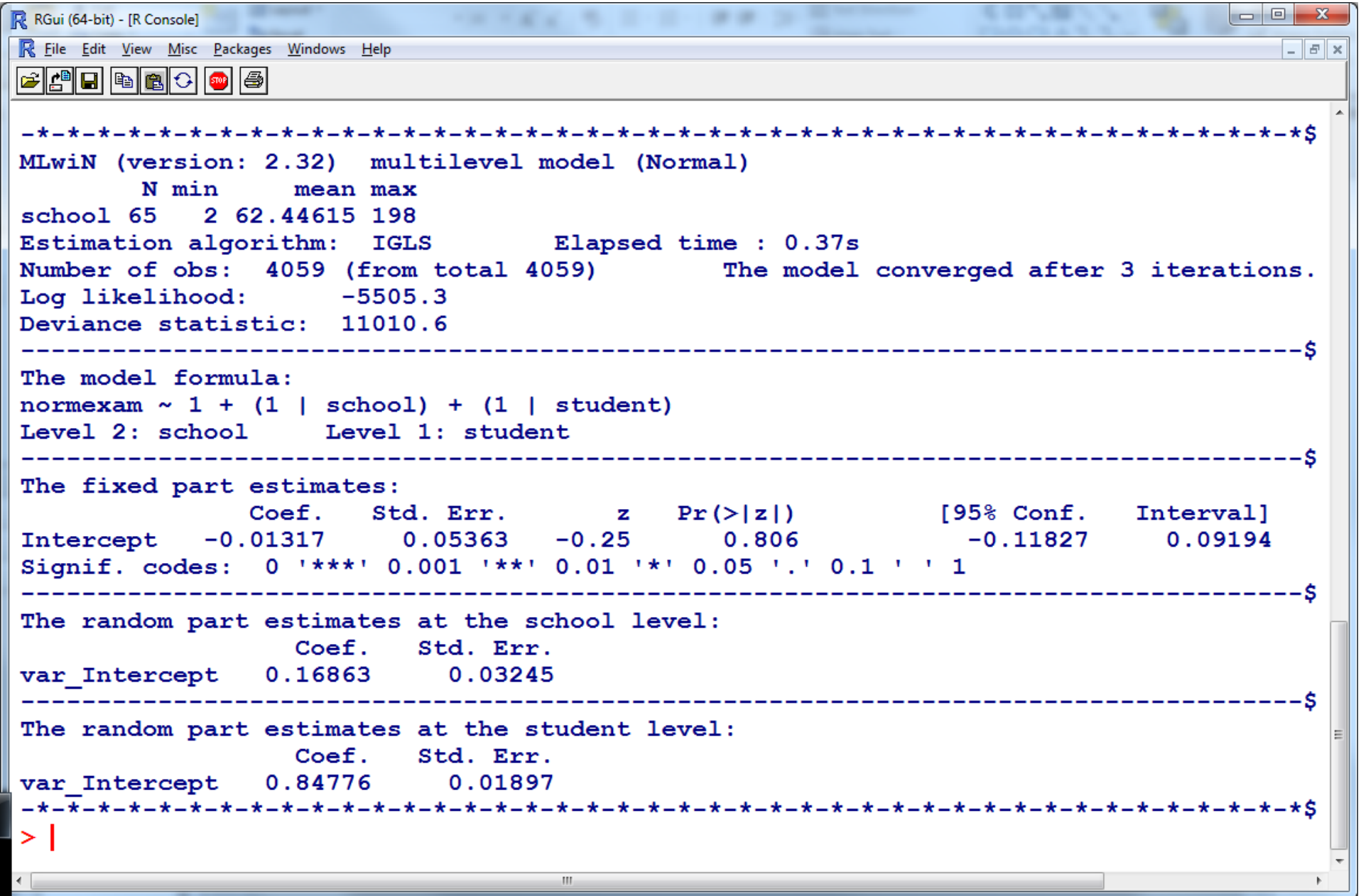
* denotes IGLS only in the table below.

Distribution	Format of `Formula` object	Where `<link>` can equal...
'Normal'	<y1> ~ 1 + <x1> + (1|<L2>) + (1|<L1>) + ...	(identity link assumed)
'Poisson'	<link>(<y1>) ~ 1 + offset(<offs>) + <x1> + (1|<L2>) + ...	log
'Negbinom'*	<link>(<y1>) ~ 1 + offset(<offs>) + (1|<L2>) + ...	log
'Binomial'	<link>(<y1>, <denom>) ~ 1 + <x1> + (1|<L2>) + ...	logit,probit,cloglog
'Unordered Multinomial'	<link>(<y1>, <denom>, <ref_cat>) ~ 1 + <x1> + (1|<L2>) + ...	logit
'Ordered Multinomial'	<link>(<y1>, <denom>, <ref_cat>) ~ 1 + <x1> + <x2>[<common>] + (1[<common>]|<L3>) + (1|<L2>) + ...	logit,probit,cloglog
'Multivariate Normal'	c(<y1>, <y2>, ...) ~ 1 + <x1> + <x2>[<common>] + (1[<common>]|<L3>) + (1|<L2>) + (1|<L1>) + ...	(identity link assumed)
c('Mixed', 'Normal', 'Binomial')	c(<y1>, ..., <link> (<y2>, <denom>), ...) ~ 1 + <x1> + <x2>[<common>] + (1[<common>]|<L3>) + (1|<L2>) + (1|<L1>) + ...	logit*,probit,cloglog*
c('Mixed', 'Normal', 'Poisson')*	c(<y1>, ..., <link>(<y2>, <offset>), ...) ~ 1 + <x1> + <x2>[<common>] + (1[<common>]|<L3>) + (1|<L2>) + (1|<L1>) + ...	log

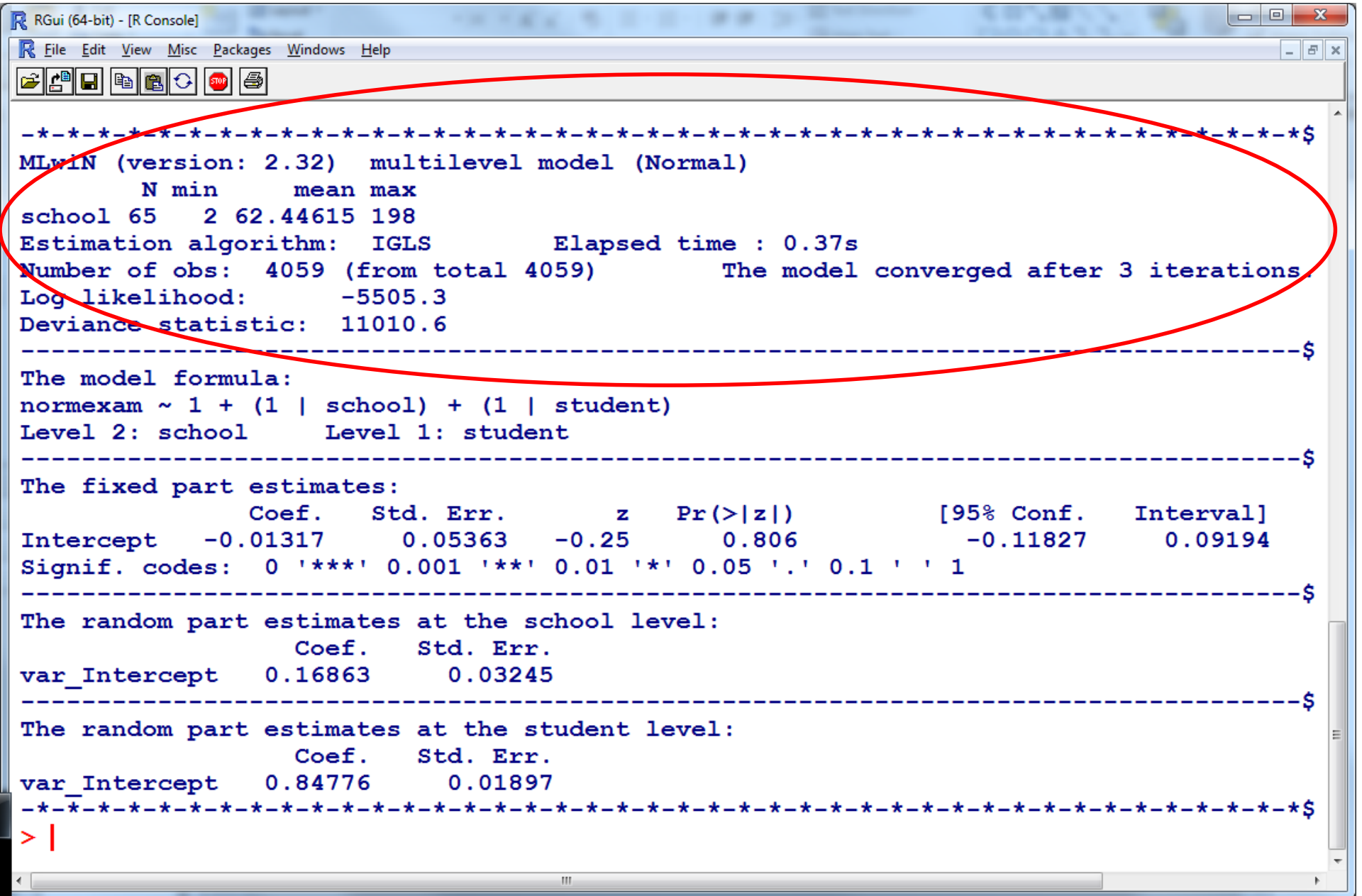
The argument `estoptions` is a list which can contain the following options used for estimating the model:

- `EstM`: specifies estimation method. When `EstM = 0` (default), estimation method is (R)IGLS, otherwise `EstM = 1` specifies MCMC estimation.
- `resi.store`: a logical value indicating whether residuals are to be stored or not. Defaults to `FALSE`.
- `resioptions`: a string vector to specify the various residual options. The `'variance'` option calculates the posterior variances instead of the posterior standard errors; the `'standardised'`, `'leverage'`, `'influence'` and `'deletion'` options calculate standardised, leverage, influence and deletion residuals respectively; the `'sampling'` option calculates the sampling variance covariance matrix for the residuals; the `'norecode'` option prevents residuals with values exceedingly close or equal to zero from being recoded to missing. When `EstM = 1` (i.e. MCMC estimation) `'variance'` is default value, and the only other permissible value is `'standardised'` (else function call stopped with appropriate error message). When `EstM = 0` (i.e. (R)IGLS estimation), `'variance'` cannot be specified together

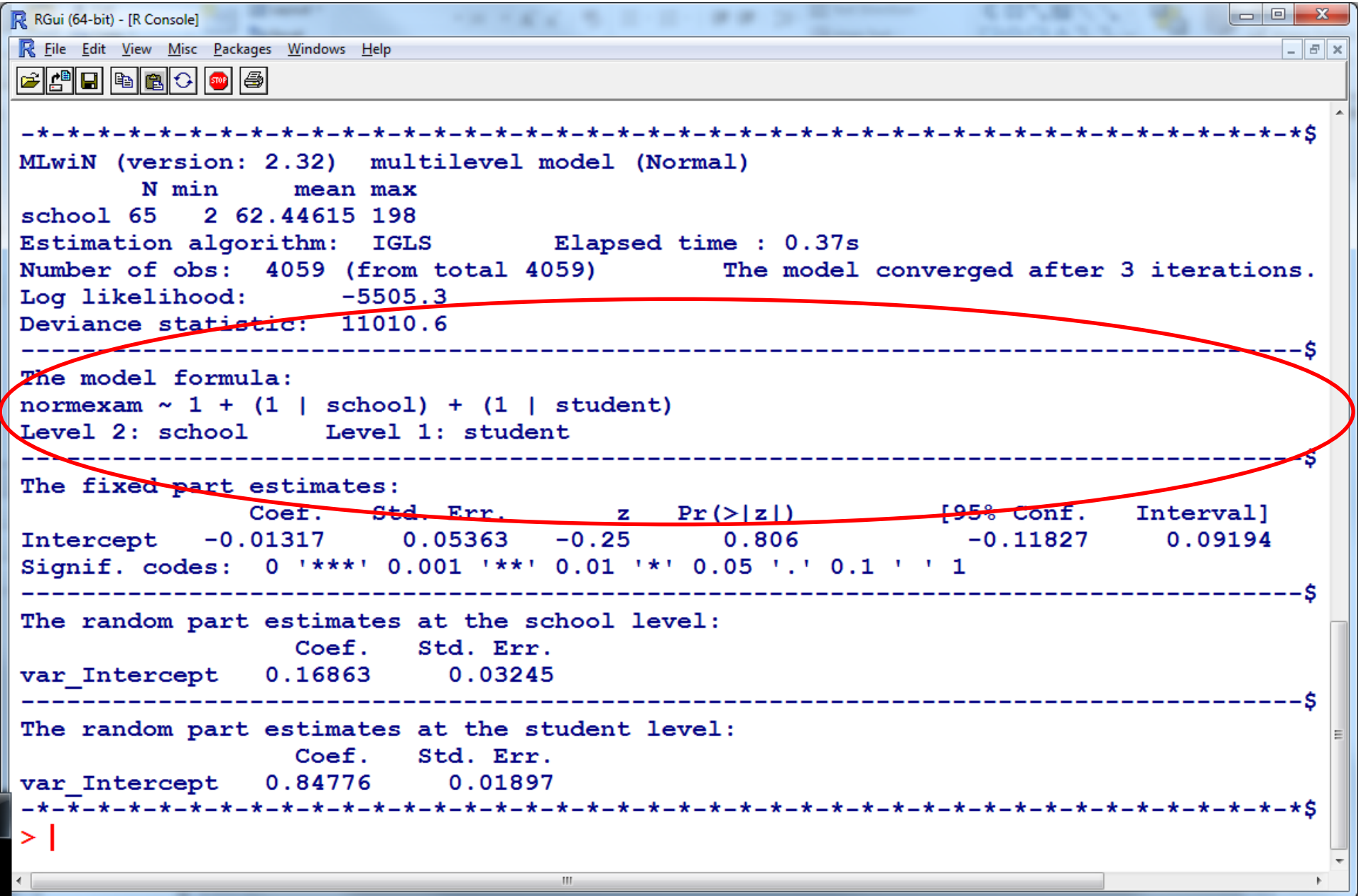
R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
-*$
MLwiN (version: 2.32) multilevel model (Normal)
N min mean max
school 65 2 62.44615 198
Estimation algorithm: IGLS Elapsed time : 0.37s
Number of obs: 4059 (from total 4059) The model converged after 3 iterations.
Log likelihood: -5505.3
Deviance statistic: 11010.6
The model formula:
normexam ~ 1 + (1 | school) + (1 | student)
Level 2: school Level 1: student
The fixed part estimates:
Coef. Std. Err. z Pr(>|z|) [95% Conf. Interval]
Intercept -0.01317 0.05363 -0.25 0.806 -0.11827 0.09194
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
The random part estimates at the school level:
Coef. Std. Err.
var_Intercept 0.16863 0.03245
The random part estimates at the student level:
Coef. Std. Err.
var_Intercept 0.84776 0.01897
> |

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
MLwiN (version: 2.32) multilevel model (Normal)
N min mean max
school 65 2 62.44615 198
Estimation algorithm: IGLS Elapsed time : 0.37s
Number of obs: 4059 (from total 4059) The model converged after 3 iterations.
Log likelihood: -5505.3
Deviance statistic: 11010.6
The model formula:
normexam ~ 1 + (1 | school) + (1 | student)
Level 2: school Level 1: student
The fixed part estimates:
Coef. Std. Err. z Pr(>|z|) [95% Conf. Interval]
Intercept -0.01317 0.05363 -0.25 0.806 -0.11827 0.09194
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
The random part estimates at the school level:
Coef. Std. Err.
var_Intercept 0.16863 0.03245
The random part estimates at the student level:
Coef. Std. Err.
var_Intercept 0.84776 0.01897
> |

R2MLwiN

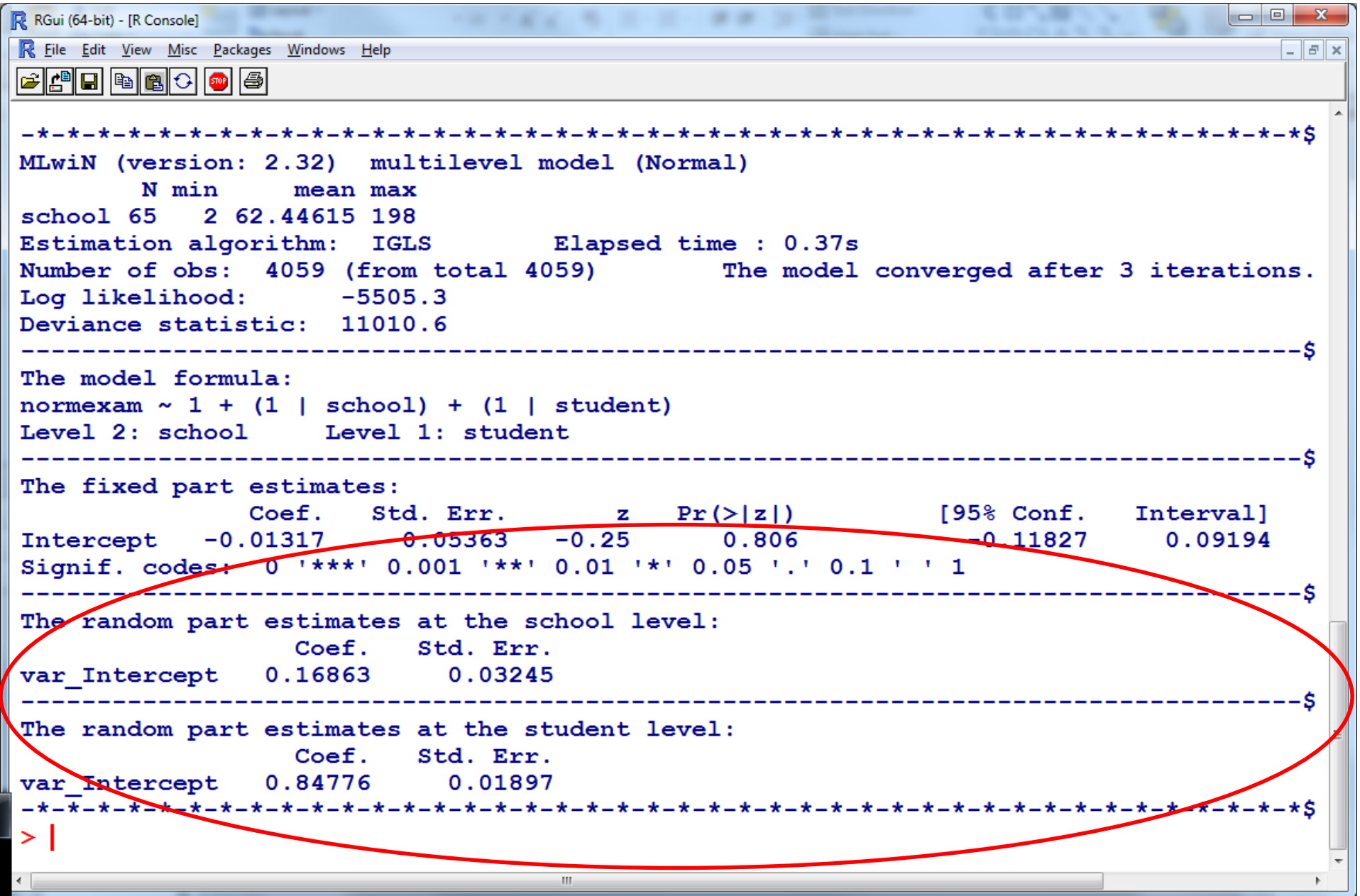

RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
MLwiN (version: 2.32) multilevel model (Normal)
N min mean max
school 65 2 62.44615 198
Estimation algorithm: IGLS Elapsed time : 0.37s
Number of obs: 4059 (from total 4059) The model converged after 3 iterations.
Log likelihood: -5505.3
Deviance statistic: 11010.6
The model formula:
normexam ~ 1 + (1 | school) + (1 | student)
Level 2: school Level 1: student
The fixed part estimates:
Coef. Std. Err. z Pr(>|z|) [95% Conf. Interval]
Intercept -0.01317 0.05363 -0.25 0.806 -0.11827 0.09194
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
The random part estimates at the school level:
Coef. Std. Err.
var_Intercept 0.16863 0.03245
The random part estimates at the student level:
Coef. Std. Err.
var_Intercept 0.84776 0.01897
> |

R2MLwiN

RGui (64-bit) - [R Console]

```
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*$
MLwiN (version: 2.32)  multilevel model (Normal)
        N min     mean max
school 65   2 62.44615 198
Estimation algorithm:  IGLS        Elapsed time : 0.37s
Number of obs:  4059 (from total 4059)        The model converged after 3 iterations.
Log likelihood:      -5505.3
Deviance statistic:  11010.6
---------------------------------------------------------------------------------------$
The model formula:
normexam ~ 1 + (1 | school) + (1 | student)
Level 2: school     Level 1: student
---------------------------------------------------------------------------------------$
The fixed part estimates:
               Coef.   Std. Err.       z   Pr(>|z|)         [95% Conf.   Interval]
Intercept   -0.01317     0.05363   -0.25      0.806         -0.11827     0.09194
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
---------------------------------------------------------------------------------------$
The random part estimates at the school level:
                  Coef.   Std. Err.
var_Intercept   0.16863     0.03245
---------------------------------------------------------------------------------------$
The random part estimates at the student level:
                  Coef.   Std. Err.
var_Intercept   0.84776     0.01897
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*$
> 
```

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
MLwiN (version: 2.32) multilevel model (Normal)
N min mean max
school 65 2 62.44615 198
Estimation algorithm: IGLS Elapsed time : 0.37s
Number of obs: 4059 (from total 4059) The model converged after 3 iterations.
Log likelihood: -5505.3
Deviance statistic: 11010.6
The model formula:
normexam ~ 1 + (1 | school) + (1 | student)
Level 2: school Level 1: student
The fixed part estimates:
Coef. Std. Err. z Pr(>|z|) [95% Conf. Interval]
Intercept -0.01317 0.05363 -0.25 0.806 -0.11827 0.09194
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
The random part estimates at the school level:
Coef. Std. Err.
var_Intercept 0.16863 0.03245
The random part estimates at the student level:
Coef. Std. Err.
var_Intercept 0.84776 0.01897
>

R2MLwiN

```
R> F2 <- normexam ~ 1 + (1|student)
```

R2MLwiN

```
R> F2 <- normexam ~ 1 + (1|student)
R> OneLevelModel <- runMLwiN(
+     Formula = F2, data = tutorial)
```

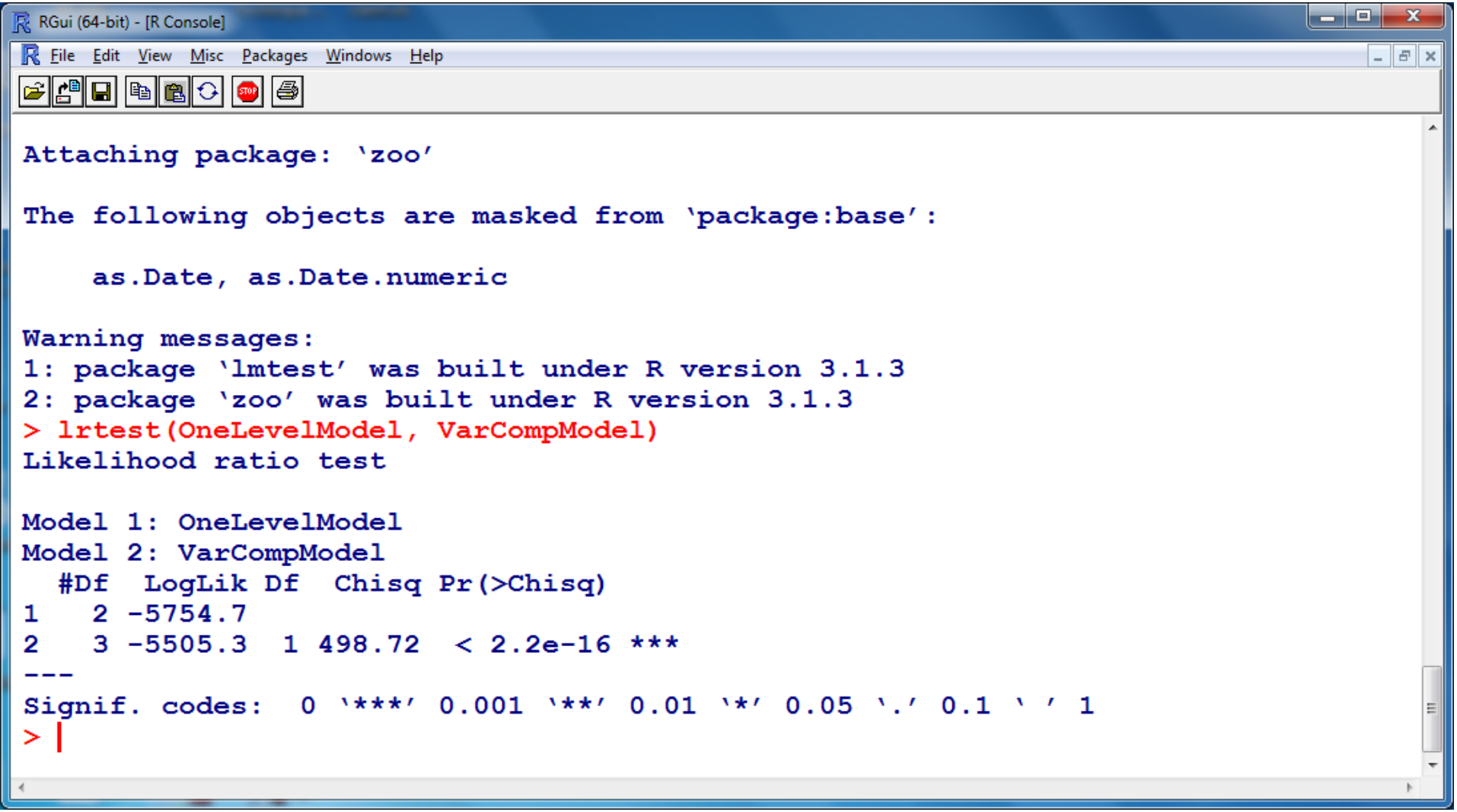
R2MLwiN

```
R> F2 <- normexam ~ 1 + (1|student)
R> OneLevelModel <- runMLwiN(
+    Formula = F2, data = tutorial)
R> library("lmtest")
R> lrtest(OneLevelModel, VarCompModel)
```

Model objects returned by **R2MLwiN** contain some generic S4 methods…

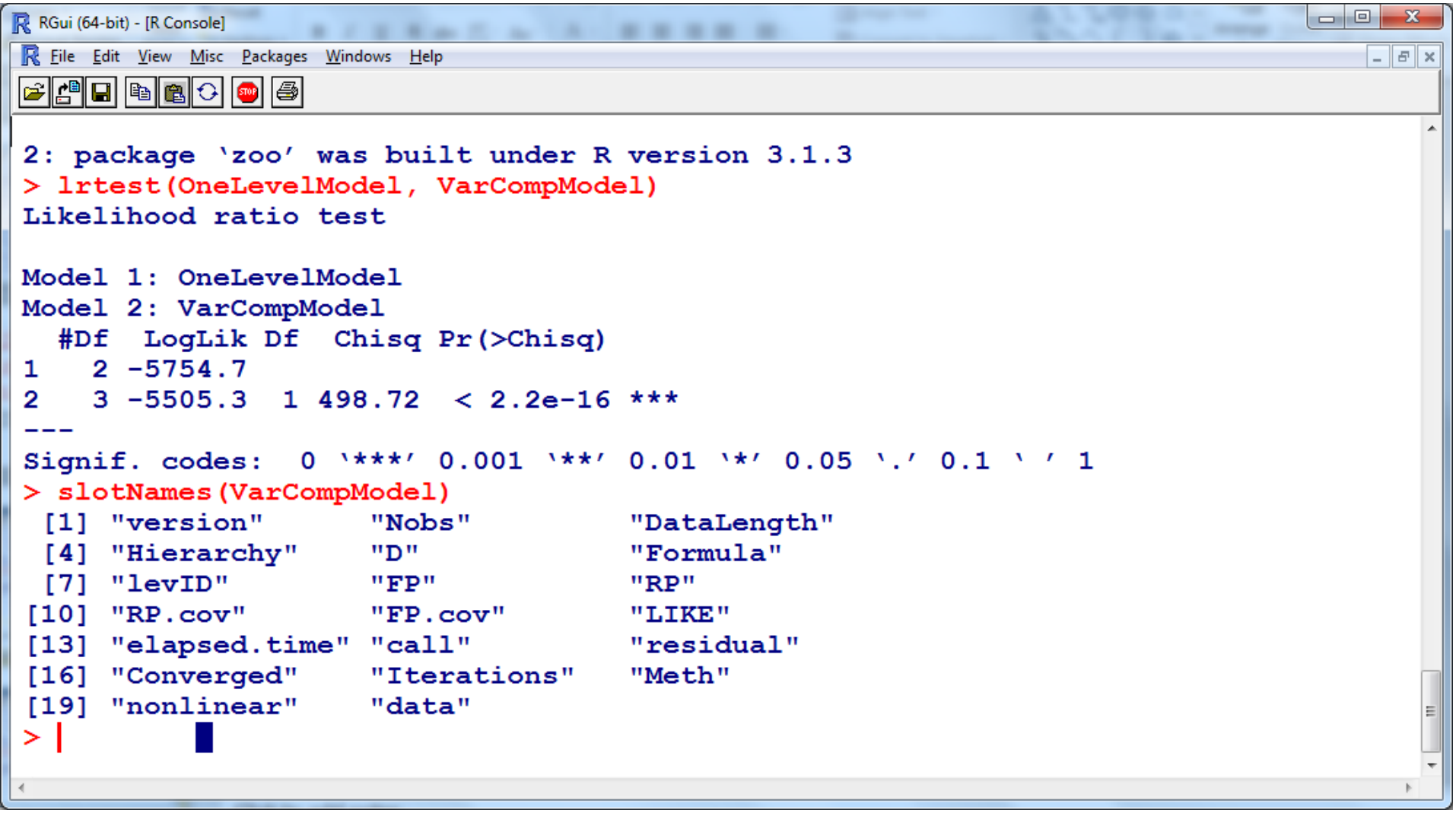
- e.g. has a method for the function **logLik** which allows us to conduct a likelihood ratio test using the **lrtest** function (part of the **lmtest** package)

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
Attaching package: 'zoo'
The following objects are masked from 'package:base':
as.Date, as.Date.numeric
Warning messages:
1: package 'lmtest' was built under R version 3.1.3
2: package 'zoo' was built under R version 3.1.3
> lrtest(OneLevelModel, VarCompModel)
Likelihood ratio test
Model 1: OneLevelModel
Model 2: VarCompModel
#Df LogLik Df Chisq Pr(>Chisq)
1 2 -5754.7
2 3 -5505.3 1 498.72 < 2.2e-16 ***

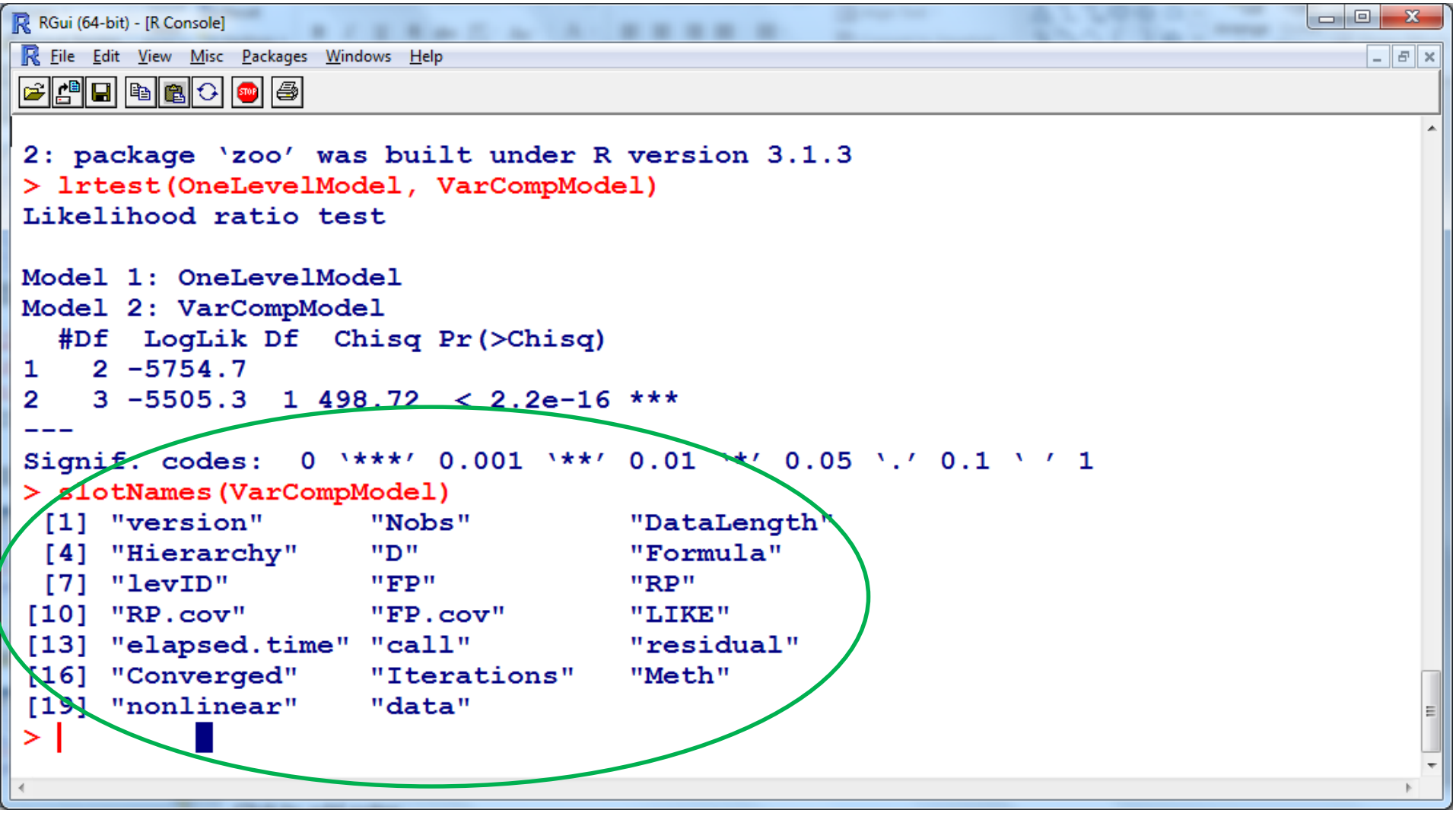
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
2: package 'zoo' was built under R version 3.1.3
> lrtest(OneLevelModel, VarCompModel)
Likelihood ratio test
Model 1: OneLevelModel
Model 2: VarCompModel
#Df LogLik Df Chisq Pr(>Chisq)
1 2 -5754.7
2 3 -5505.3 1 498.72 < 2.2e-16 ***

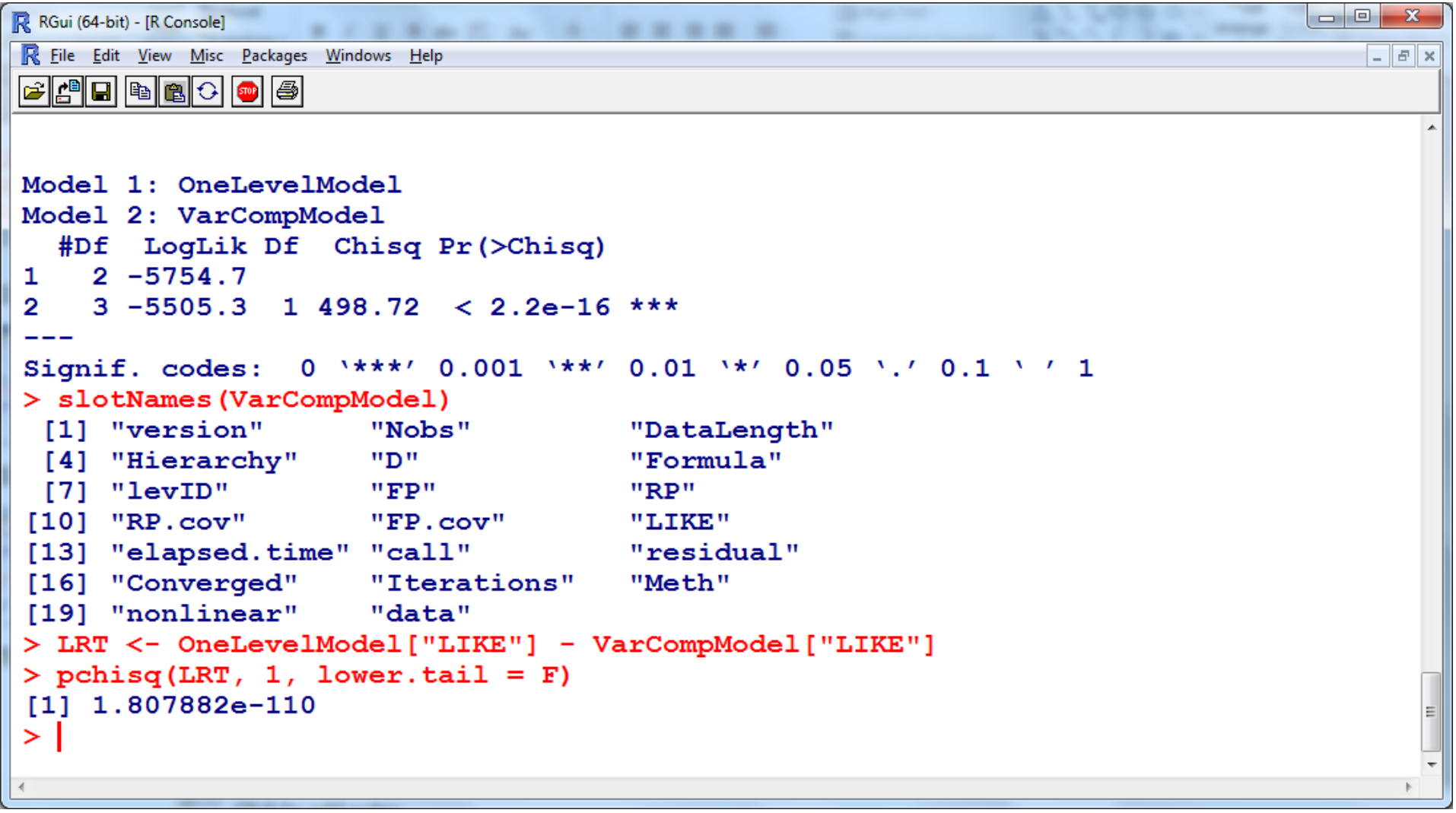
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> slotNames(VarCompModel)
[1] "version" "Nobs" "DataLength"
[4] "Hierarchy" "D" "Formula"
[7] "levID" "FP" "RP"
[10] "RP.cov" "FP.cov" "LIKE"
[13] "elapsed.time" "call" "residual"
[16] "Converged" "Iterations" "Meth"
[19] "nonlinear" "data"
>

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
2: package 'zoo' was built under R version 3.1.3
> lrtest(OneLevelModel, VarCompModel)
Likelihood ratio test
Model 1: OneLevelModel
Model 2: VarCompModel
#Df LogLik Df Chisq Pr(>Chisq)
1 2 -5754.7
2 3 -5505.3 1 498.72 < 2.2e-16 ***

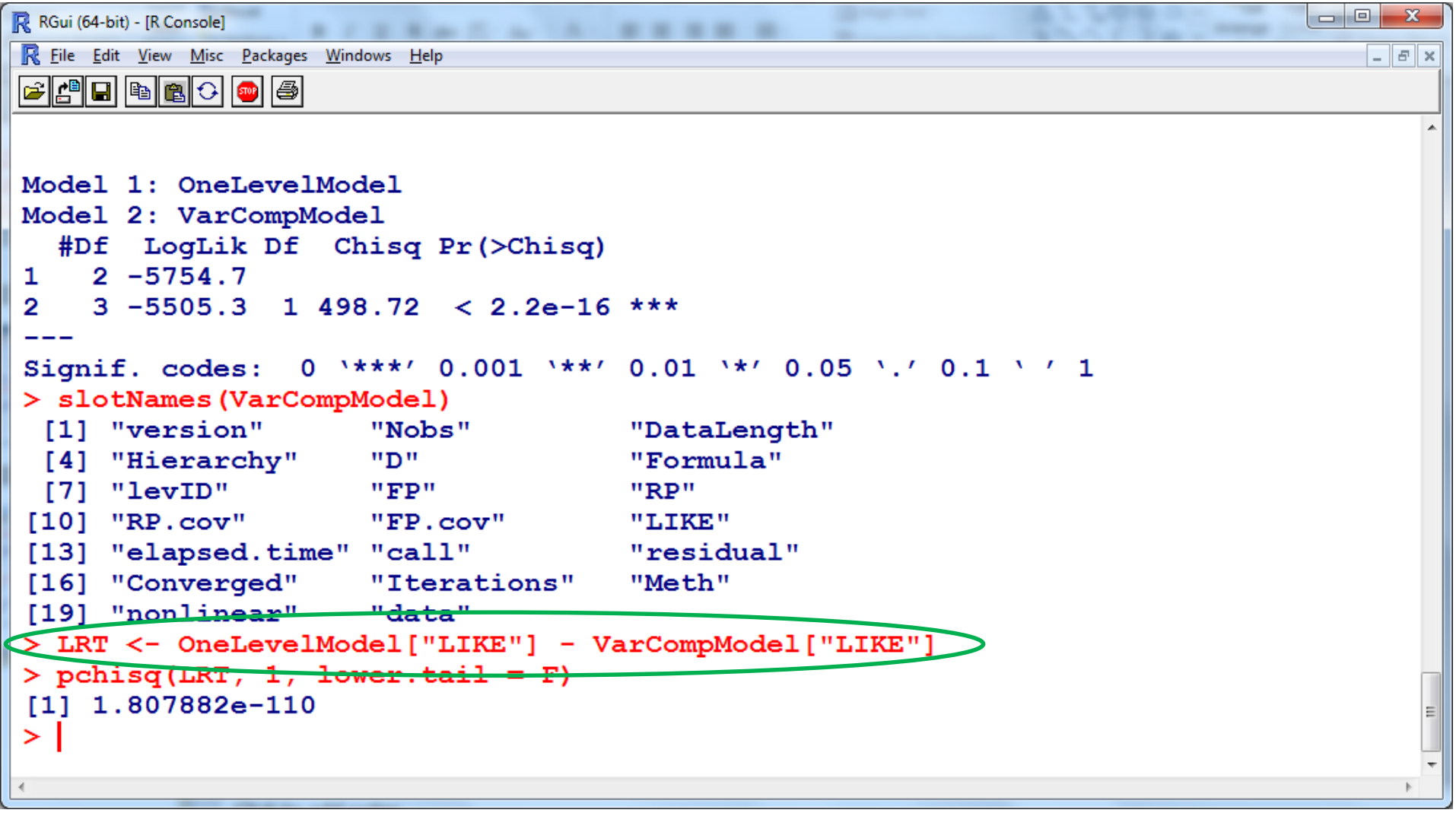
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> slotNames(VarCompModel)
[1] "version" "Nobs" "DataLength"
[4] "Hierarchy" "D" "Formula"
[7] "levID" "FP" "RP"
[10] "RP.cov" "FP.cov" "LIKE"
[13] "elapsed.time" "call" "residual"
[16] "Converged" "Iterations" "Meth"
[19] "nonlinear" "data"
>

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
Model 1: OneLevelModel
Model 2: VarCompModel
#Df LogLik Df Chisq Pr(>Chisq)
1 2 -5754.7
2 3 -5505.3 1 498.72 < 2.2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> slotNames(VarCompModel)
[1] "version" "Nobs" "DataLength"
[4] "Hierarchy" "D" "Formula"
[7] "levID" "FP" "RP"
[10] "RP.cov" "FP.cov" "LIKE"
[13] "elapsed.time" "call" "residual"
[16] "Converged" "Iterations" "Meth"
[19] "nonlinear" "data"
> LRT <- OneLevelModel["LIKE"] - VarCompModel["LIKE"]
> pchisq(LRT, 1, lower.tail = F)
[1] 1.807882e-110
>

R2MLwiN


RGui (64-bit) - [R Console]
File Edit View Misc Packages Windows Help
Model 1: OneLevelModel
Model 2: VarCompModel
#Df LogLik Df Chisq Pr(>Chisq)
1 2 -5754.7
2 3 -5505.3 1 498.72 < 2.2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> slotNames(VarCompModel)
[1] "version" "Nobs" "DataLength"
[4] "Hierarchy" "D" "Formula"
[7] "levID" "FP" "RP"
[10] "RP.cov" "FP.cov" "LIKE"
[13] "elapsed.time" "call" "residual"
[16] "Converged" "Iterations" "Meth"
[19] "nonlinear" "data"
> LRT <- OneLevelModel["LIKE"] - VarCompModel["LIKE"]
> pchisq(LRT, 1, lower.tail = F)
[1] 1.807882e-110
>

R2MLwiN

R2MLwiN

```
R> F3 <- normexam ~ 1 + standlrt +
+     (1 + standlrt | school) + (1 | student)

R> (RandomSlopeModel <- runMLwiN(
+     Formula = F3, estoptions = list(
+     resi.store = TRUE), data = tutorial))
```

R2MLwiN

```
R> F3 <- normexam ~ 1 + standlrt +
+     (1 + standlrt | school) + (1 | student)

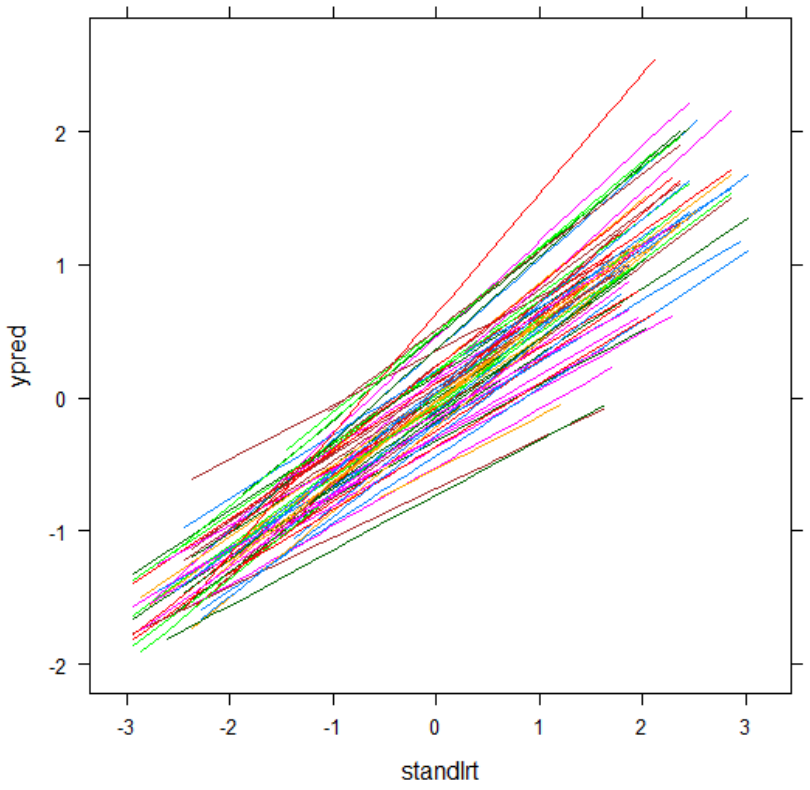
R> (RandomSlopeModel <- runMLwiN(
+     Formula = F3, estoptions = list(
+     resi.store = TRUE), data = tutorial))
```

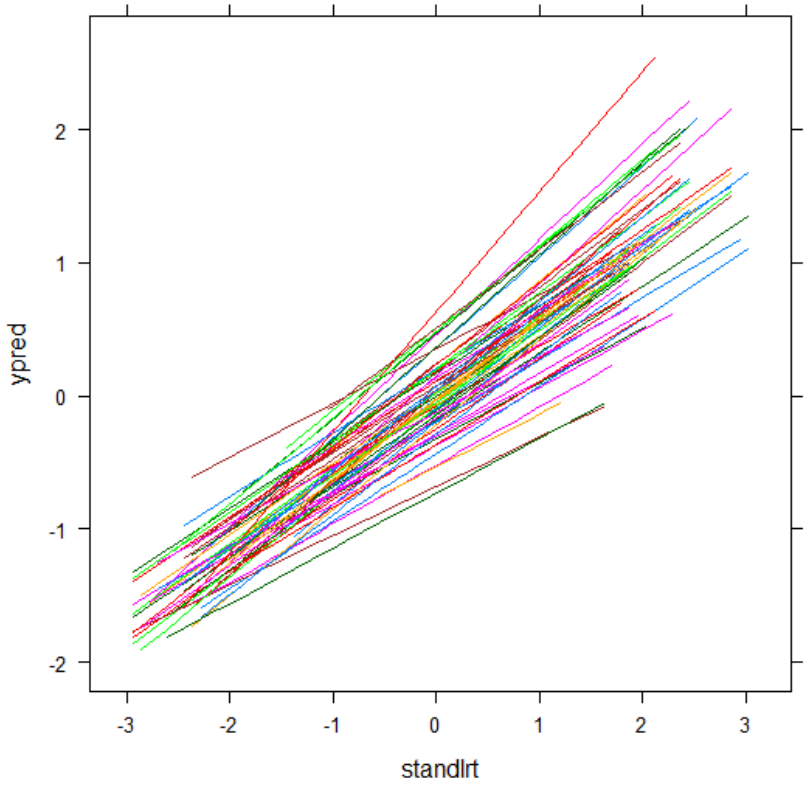
R2MLwiN

```
R> F3 <- normexam ~ 1 + standlrt +
+     (1 + standlrt | school) + (1 | student)

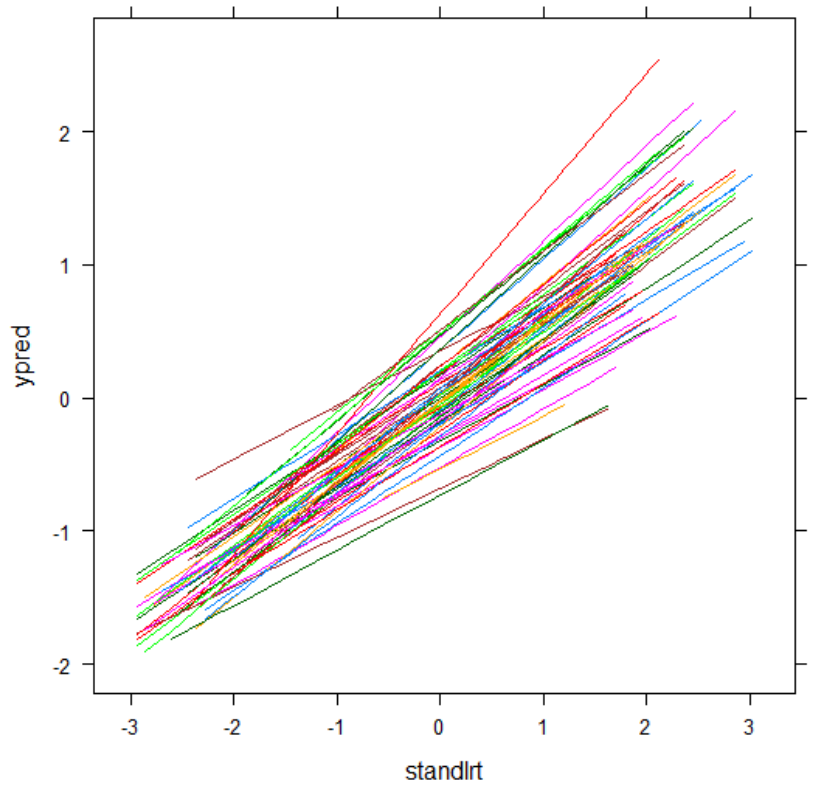
R> (RandomSlopeModel <- runMLwiN(
+     Formula = F3, estoptions = list(
+     resi.store = TRUE), data = tutorial))

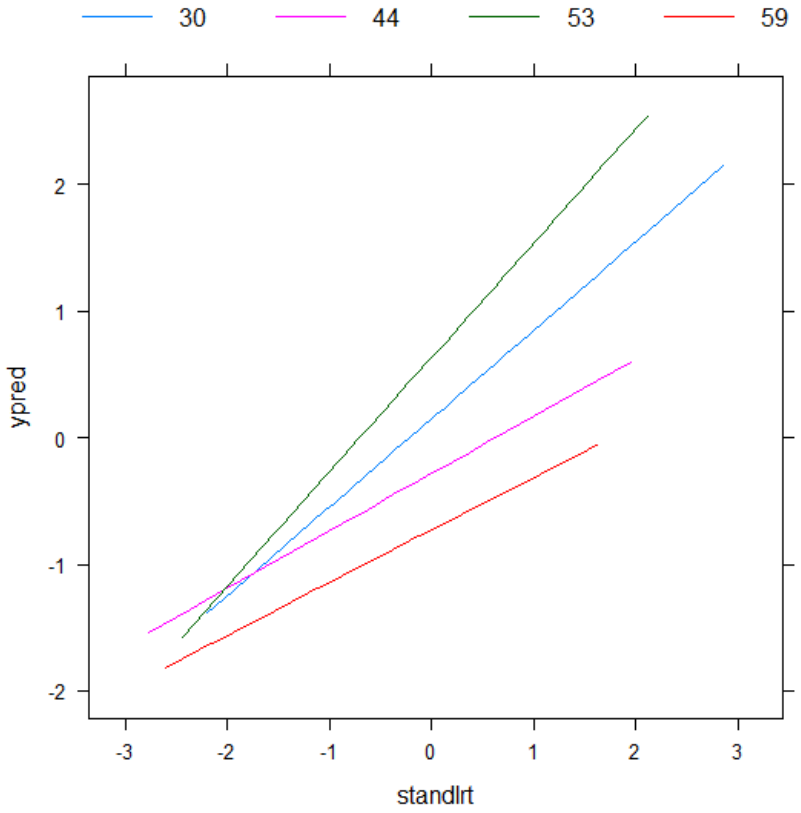
R> predLines(RandomSlopeModel,
+     xname="standlrt", lev = 2, legend = F)
```


ypred
2
1
0
-1
-2
-3
-2
-1
0
1
2
3
standlrt




```
R> predLines(RandomSlopeModel,
+     xname = "standlrt", lev = 2,
+     selected = c(30, 44, 53, 59))
```






```
R> predLines(RandomSlopeModel,
+     xname = "standlrt", lev = 2,
+     selected = c(30, 44, 53, 59))
```

R2MLwiN

```
R> F4 <- normexam ~ 1 + standlrt +
+     (1 + standlrt | school) +
+     (1 + standlrt | student)

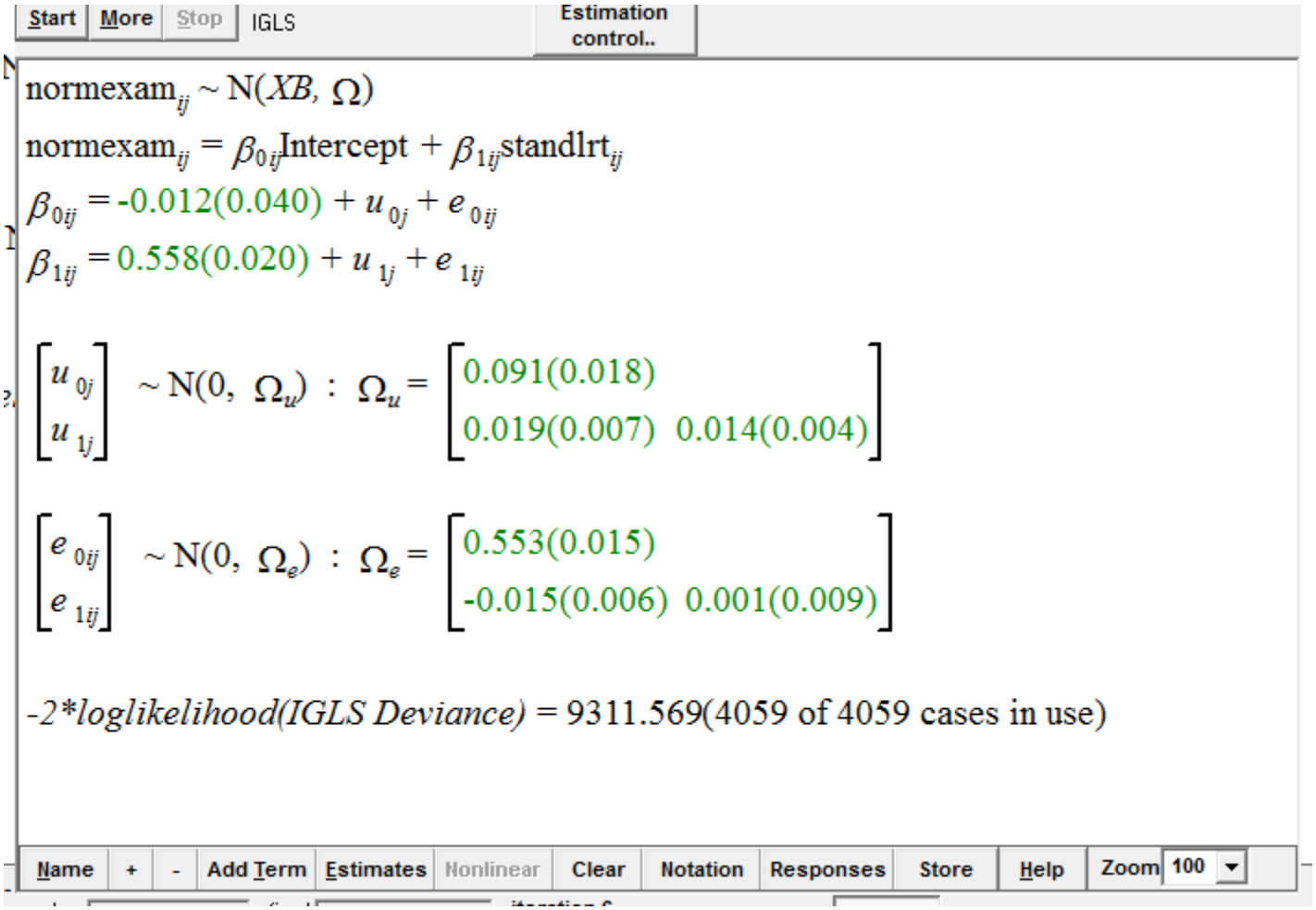
R> ComplexLevOneModel <- runMLwiN(
+     Formula = F4, data = tutorial,
+     estoptions = list(debugmode = TRUE))
```

R2MLwiN

```
R> F4 <- normexam ~ 1 + standlrt +
+     (1 + standlrt | school) +
+     (1 + standlrt | student)

R> ComplexLevOneModel <- runMLwiN(
+     Formula = F4, data = tutorial,
+     estoptions = list(debugmode = TRUE))
```

R2MLwiN


Start
More
Stop
IGLS
Estimation control..
normexam$_{ij}$ ~ N(XB, Ω)
normexam$_{ij}$ = β_{0ij}Intercept + β_{1ij}standlrt$_{ij}$
β_{0ij} = -0.012(0.040) + u_{0j} + e_{0ij}
β_{1ij} = 0.558(0.020) + u_{1j} + e_{1ij}
$\begin{bmatrix} u_{0j} \\ u_{1j} \end{bmatrix}$ ~ N(0, Ω_u) : Ω_u = $\begin{bmatrix} 0.091(0.018) & \\ 0.019(0.007) & 0.014(0.004) \end{bmatrix}$
$\begin{bmatrix} e_{0ij} \\ e_{1ij} \end{bmatrix}$ ~ N(0, Ω_e) : Ω_e = $\begin{bmatrix} 0.553(0.015) & \\ -0.015(0.006) & 0.001(0.009) \end{bmatrix}$
-2*loglikelihood(IGLS Deviance) = 9311.569(4059 of 4059 cases in use)
Name
+
-
Add Term
Estimates
Nonlinear
Clear
Notation
Responses
Store
Help
Zoom
100

R2MLwiN

R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
```

R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
```

R2MLwiN

RGui (64-bit) - [R Console]

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```
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
MLwiN (version: 2.32)  multilevel model (Binomial)
          N min      mean max
district 60   2 32.23333 118
Estimation algorithm:  MCMC      Elapsed time : 11.33s
Number of obs:  1934 (from total 1934)          Number of iter.: 5000          Burn-in: 500
Bayesian Deviance Information Criterion (DIC)
Dbar       D(thetabar)     pD       DIC
2328.716   2272.662   56.054      2384.769
---------------------------------------------------------------------------------------------------
The model formula:
logit(use, cons) ~ 1 + age + lc + urban + (1 + urban | district)
Level 2: district     Level 1: l1id
---------------------------------------------------------------------------------------------------
The fixed part estimates:
                    Coef.    Std. Err.        z      Pr(>|z|)          [95% Cred.    Interval]    ESS
Intercept         -1.71218     0.16771  -10.21    1.828e-24   ***    -2.07668    -1.39602     68
age               -0.02655     0.00821   -3.24     0.001215   **     -0.04252    -0.01035    219
lcOne_child        1.13062     0.16236    6.96    3.327e-12   ***     0.80553     1.44866    155
lcTwo_children     1.36400     0.18341    7.44    1.037e-13   ***     0.99801     1.70792    144
lcThree_plus       1.36138     0.19376    7.03    2.134e-12   ***     0.99136     1.74588     91
urbanUrban         0.80805     0.18466    4.38    1.211e-05   ***     0.43792     1.17175    100
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
---------------------------------------------------------------------------------------------------
The random part estimates at the district level:
                              Coef.    Std. Err.    [95% Cred.    Interval]    ESS
var_Intercept               0.42317     0.13547      0.21589      0.73267    254
cov_Intercept_urbanUrban   -0.43507     0.17899     -0.86104     -0.16201    130
var_urbanUrban              0.72068     0.33219      0.27022      1.51644    100
---------------------------------------------------------------------------------------------------
The random part estimates at the l1id level:
                Coef.    Std. Err.    [95% Cred.    Interval]    ESS
var_bcons_1   1.00000     0.00000      1.00000      1.00000   5000
```

R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
```

R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
R> print(binomialMCMC, z.ratio = FALSE)
```

R2MLwiN

RGui (64-bit) - [R Console]

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```
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
MLwiN (version: 2.32)  multilevel model (Binomial)
          N min      mean max
district 60   2 32.23333 118
Estimation algorithm:  MCMC      Elapsed time : 11.33s
Number of obs:  1934 (from total 1934)          Number of iter.: 5000          Burn-in: 500
Bayesian Deviance Information Criterion (DIC)
Dbar       D(thetabar)    pD      DIC
2328.716   2272.662   56.054     2384.769
--------------------------------------------------------------------------------------------------
The model formula:
logit(use, cons) ~ 1 + age + lc + urban + (1 + urban | district)
Level 2: district     Level 1: l1id
--------------------------------------------------------------------------------------------------
The fixed part estimates:
                    Coef.    Std. Err.  pMCMC(1-sided)  [95% Cred.    Interval]   ESS
Intercept         -1.71218    0.16771               0    -2.07668    -1.39602    68
age               -0.02655    0.00821          0.0004    -0.04252    -0.01035   219
lcOne_child        1.13062    0.16236               0     0.80553     1.44866   155
lcTwo_children     1.36400    0.18341               0     0.99801     1.70792   144
lcThree_plus       1.36138    0.19376               0     0.99136     1.74588    91
urbanUrban         0.80805    0.18466               0     0.43792     1.17175   100
--------------------------------------------------------------------------------------------------
The random part estimates at the district level:
                              Coef.    Std. Err.    [95% Cred.    Interval]    ESS
var_Intercept               0.42317     0.13547      0.21589     0.73267    254
cov_Intercept_urbanUrban   -0.43507     0.17899     -0.86104    -0.16201    130
var_urbanUrban              0.72068     0.33219      0.27022     1.51644    100
--------------------------------------------------------------------------------------------------
The random part estimates at the l1id level:
                Coef.    Std. Err.    [95% Cred.    Interval]     ESS
var_bcons_1   1.00000     0.00000      1.00000      1.00000    5000
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
```

R2MLwiN

RGui (64-bit) - [R Console]

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```
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
MLwiN (version: 2.32)  multilevel model (Binomial)
          N min      mean max
district 60   2 32.23333 118
Estimation algorithm:  MCMC      Elapsed time : 11.33s
Number of obs:  1934 (from total 1934)         Number of iter.: 5000         Burn-in: 500
Bayesian Deviance Information Criterion (DIC)
Dbar       D(thetabar)    pD       DIC
2328.716   2272.662   56.054     2384.769
---------------------------------------------------------------------------------------------------
The model formula:
logit(use, cons) ~ 1 + age + lc + urban + (1 + urban | district)
Level 2: district     Level 1: l1id
---------------------------------------------------------------------------------------------------
The fixed part estimates:
                    Coef.    Std. Err.  pMCMC(1-sided)  [95% Cred.   Interval]   ESS
Intercept         -1.71218     0.16771               0   -2.07668    -1.39602    68
age               -0.02655     0.00821          0.0004   -0.04252    -0.01035   219
lcOne_child        1.13062     0.16236               0    0.80553     1.44866   155
lcTwo_children     1.36400     0.18341               0    0.99801     1.70792   144
lcThree_plus       1.36138     0.19376               0    0.99136     1.74588    91
urbanUrban         0.80805     0.18466               0    0.43792     1.17175   100
---------------------------------------------------------------------------------------------------
The random part estimates at the district level:
                              Coef.    Std. Err.   [95% Cred.   Interval]   ESS
var_Intercept               0.42317     0.13547      0.21589     0.73267   254
cov_Intercept_urbanUrban   -0.43507     0.17899     -0.86104    -0.16201   130
var_urbanUrban              0.72068     0.33219      0.27022     1.51644   100
---------------------------------------------------------------------------------------------------
The random part estimates at the l1id level:
                Coef.    Std. Err.    [95% Cred.    Interval]    ESS
var_bcons_1   1.00000     0.00000      1.00000      1.00000    5000
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
```

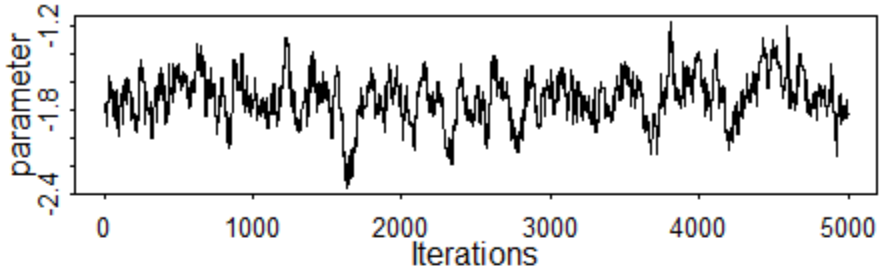
R2MLwiN

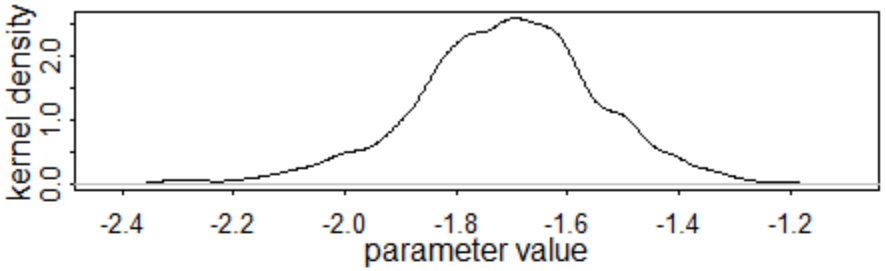
```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
R> print(binomialMCMC, z.ratio = FALSE)
```

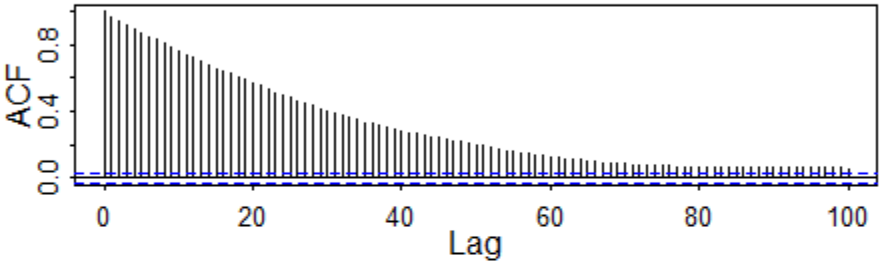
R2MLwiN

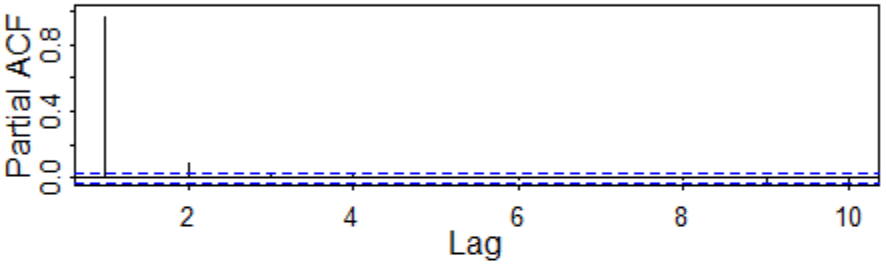
```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
R> print(binomialMCMC, z.ratio = FALSE)
R> sixway(binomialMCMC["chains"]
+     [, "FP_Intercept", drop = FALSE],
+     "beta_0")
```

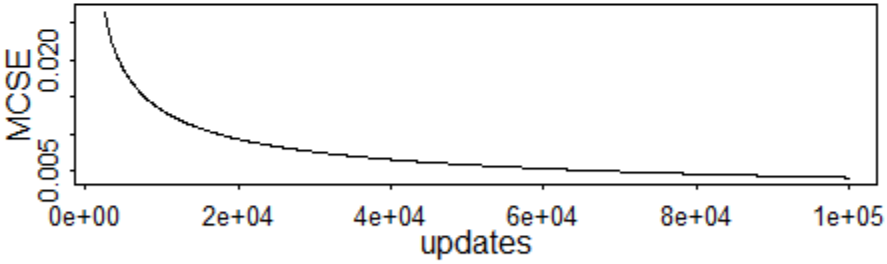
R2MLwiN











Accuracy Diagnostics

Raftery-Lewis (quantile) : Nhat =(66556,47616)

when q=(0.025,0.975), r=0.005 and s=0.95

Brooks-Draper (mean) : Nhat = 2687

when k=2 sigfigs and alpha=0.05

Summary Statistics

param name : beta_0 posterior mean = -1.712 SD = 0.168 mode = -1.696

quantiles : 2.5% = -2.077 5% = -2.005 50% = -1.706 95% = -1.449 97.5% = -1.396

5000 actual iterations storing every 1th iteration. Effective Sample Size (ESS) = 68

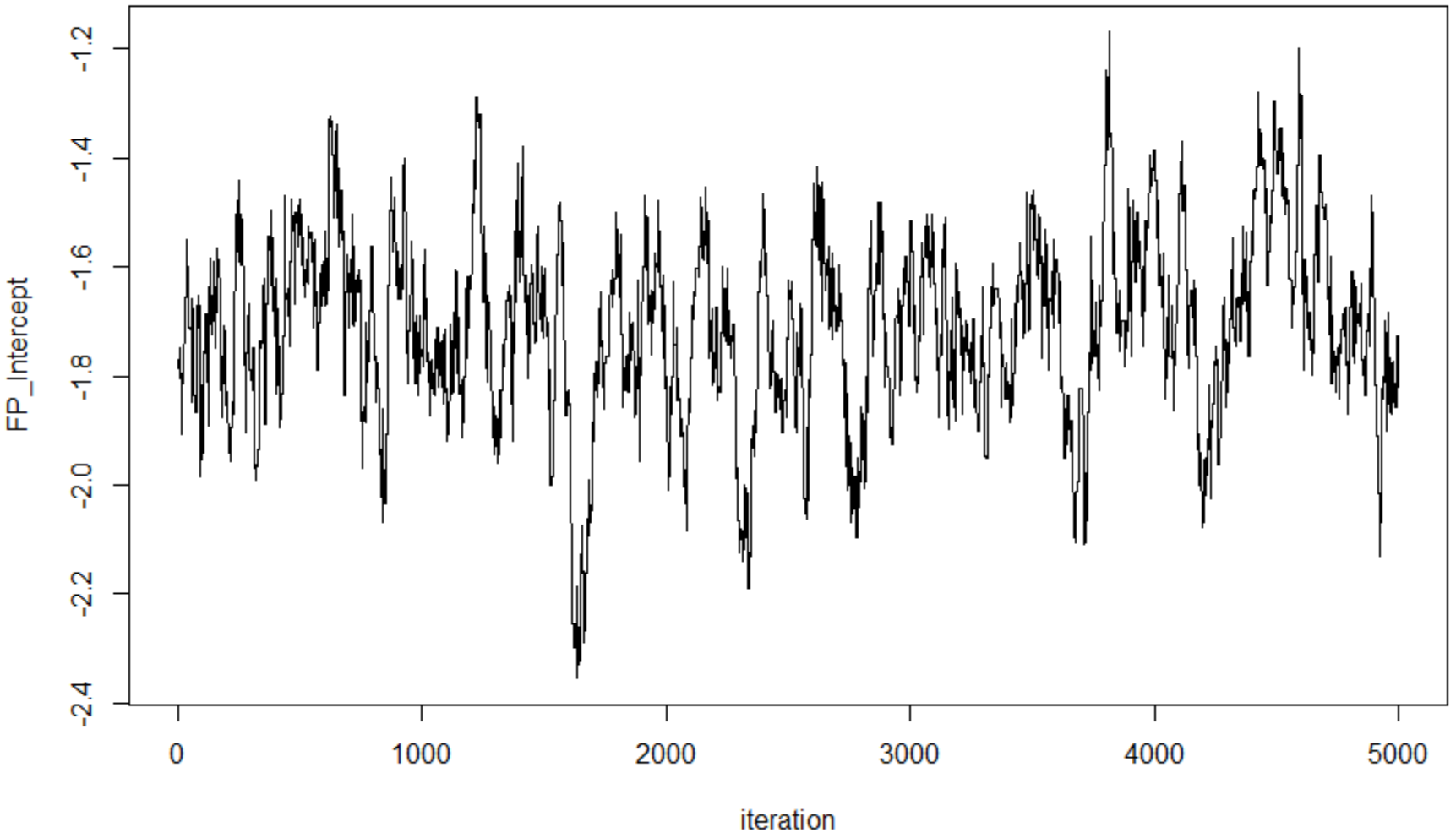
R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
R> print(binomialMCMC, z.ratio = FALSE)
R> sixway(binomialMCMC["chains"]
+     [, "FP_Intercept", drop = FALSE],
+     "beta_0")
```

R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
R> print(binomialMCMC, z.ratio = FALSE)
R> sixway(binomialMCMC["chains"]
+     [, "FP_Intercept", drop = FALSE],
+     "beta_0")
R> trajectories(binomialMCMC["chains"]
+     [, "FP_Intercept", drop = FALSE])
```

R2MLwiN


FP_Intercept
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
-2.4
0
1000
2000
3000
4000
5000
iteration

R2MLwiN

```
R> data("bang1")
R> F5 = logit(use, cons) ~ 1 + age +
+     lc + urban + (1 + urban | district)
R> (binomialMCMC <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1)))
R> print(binomialMCMC, z.ratio = FALSE)
R> sixway(binomialMCMC["chains"]
+     [, "FP_Intercept", drop = FALSE],
+     "beta_0")
R> trajectories(binomialMCMC["chains"]
+     [, "FP_Intercept", drop = FALSE])
```

R2MLwiN

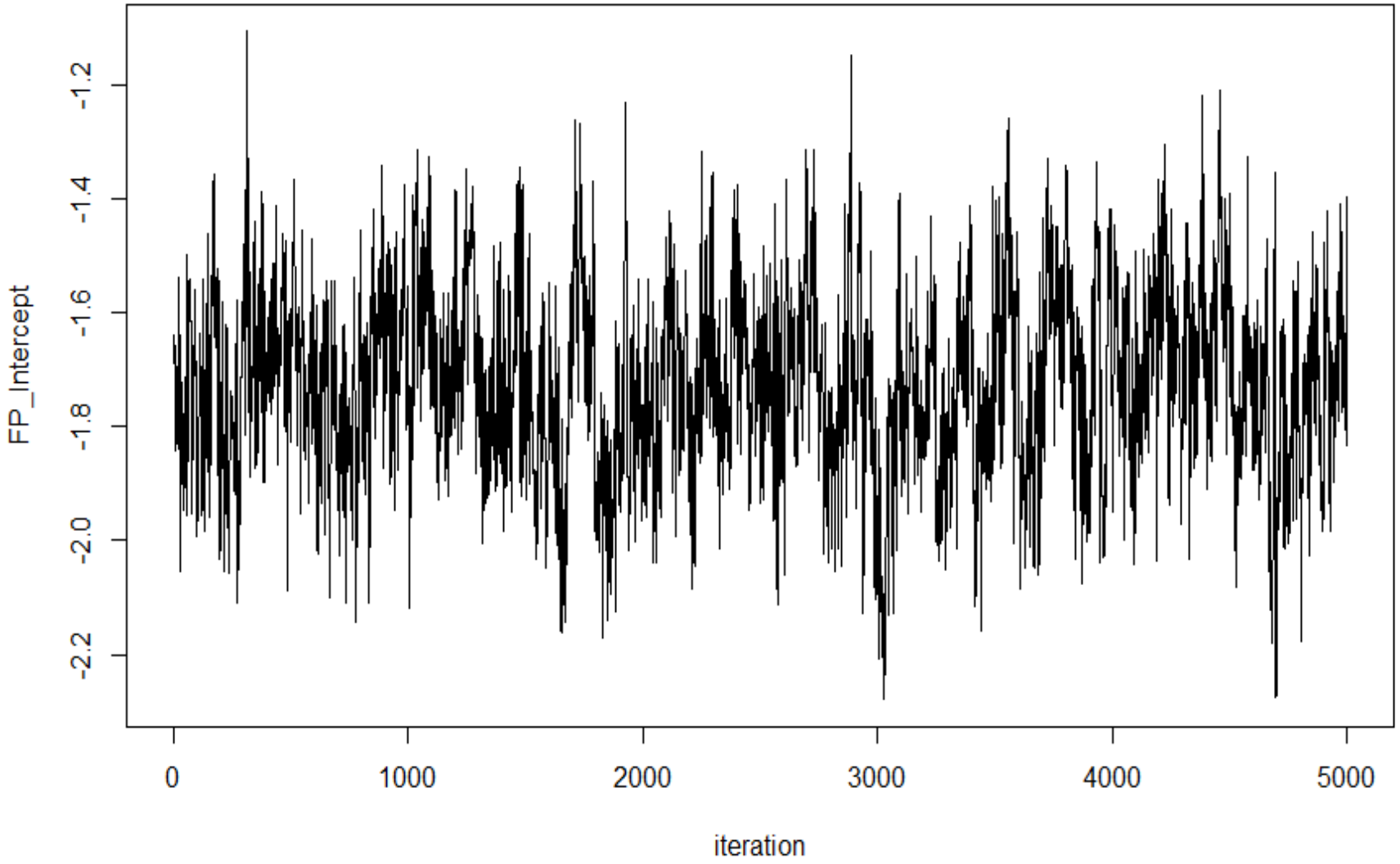
R2MLwiN

```
R> (OrthogbinomialMCMC <- runMLwiN(
+     Formula = F5, D = "Binomial",
+     data = bang1, estoptions = list(EstM = 1,
+      mcmcOptions = list(orth = 1))))
R> trajectories(OrthogbinomialMCMC["chains"]
+     [,"FP_Intercept", drop = FALSE])
```

R2MLwiN

```
R> (OrthogbinomialMCMC <- runMLwiN(
+     Formula = F5, D = "Binomial",
+     data = bang1, estoptions = list(EstM = 1,
+      mcmcOptions = list(orth = 1))))
R> trajectories(OrthogbinomialMCMC["chains"]
+     [,"FP_Intercept", drop = FALSE])
```

R2MLwiN


FP_Intercept
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
0
1000
2000
3000
4000
5000
iteration

R2MLwiN

- As well as using MLwiN's own MCMC estimation engine, R2MLwiN can fit models in WinBUGS / OpenBUGS

R2MLwiN

- As well as using MLwiN's own MCMC estimation engine, R2MLwiN can fit models in WinBUGS / OpenBUGS
- With the aid of the **`rbugs`** package (Yan and Prates 2013), user can employ single **`runMLwiN`** function call to:
  - obtain starting values from an IGLS run in MLwiN,
  - automatically generate necessary BUGS model code, initial values, data files, and script,
  - fit the model in BUGS

R2MLwiN

```
R> WinBUGS <- "C:/WinBUGS14/WinBUGS14.exe"

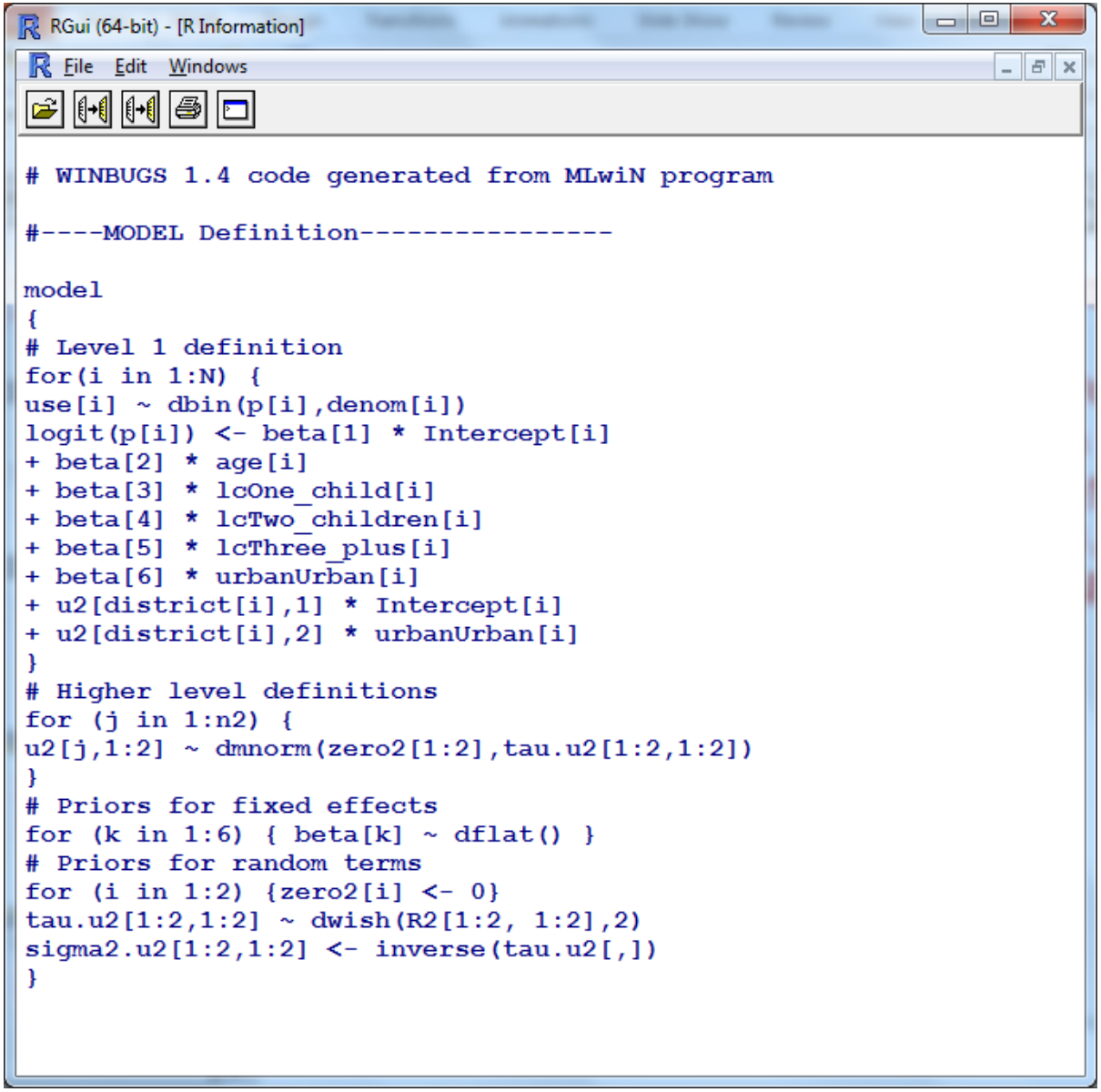
R> BUGSmodel <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1),
+     BUGO = c(version = 4, n.chains = 1,
+     seed = 1, bugs = WinBUGS,
+     OpenBugs = FALSE))
```

R2MLwiN

```
R> WinBUGS <- "C:/WinBUGS14/WinBUGS14.exe"

R> BUGSmodel <- runMLwiN(Formula = F5,
+     D = "Binomial", data = bang1,
+     estoptions = list(EstM = 1),
+     BUGO = c(version = 4, n.chains = 1,
+     seed = 1, bugs = WinBUGS,
+     OpenBugs = FALSE))
```

R2MLwiN


RGui (64-bit) - [R Information]
File Edit Windows
WINBUGS 1.4 code generated from MLwiN program
#----MODEL Definition----------------
model
{
# Level 1 definition
for(i in 1:N) {
use[i] ~ dbin(p[i],denom[i])
logit(p[i]) <- beta[1] * Intercept[i]
+ beta[2] * age[i]
+ beta[3] * lcOne_child[i]
+ beta[4] * lcTwo_children[i]
+ beta[5] * lcThree_plus[i]
+ beta[6] * urbanUrban[i]
+ u2[district[i],1] * Intercept[i]
+ u2[district[i],2] * urbanUrban[i]
}
# Higher level definitions
for (j in 1:n2) {
u2[j,1:2] ~ dmnorm(zero2[1:2],tau.u2[1:2,1:2])
}
# Priors for fixed effects
for (k in 1:6) { beta[k] ~ dflat() }
# Priors for random terms
for (i in 1:2) {zero2[i] <- 0}
tau.u2[1:2,1:2] ~ dwish(R2[1:2, 1:2],2)
sigma2.u2[1:2,1:2] <- inverse(tau.u2[,])
}

R2MLwiN

RGui (64-bit) - [R Console]

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```
u2[60,2]          -0.96108   -0.18080  1.792e-01    0.54900    1.30202

> cc = cbind(binomialMCMC["FP"], OrthogbinomialMCMC["FP"])
> dd = cbind(head(binomialMCMC["RP"], -1),
+            head(OrthogbinomialMCMC["RP"], -1))
> ESS.binMCMC = effectiveSize(binomialMCMC["chains"][,2:10])
> ESS.orthogMCMC = effectiveSize(OrthogbinomialMCMC["chains"][,2:10])
> ESStable = round(rbind(cc, dd), 3)
> BUGSlist <- c(1:6, 8, 9, 11)
> BUGS.Coeff <- round(summary(BUGSmodel)$statistics[BUGSlist, 1], 3)
> BUGS.ESS <- as.data.frame(effectiveSize(BUGSmodel))
> ESStable = cbind(ESStable[, 1], round(ESS.binMCMC), ESStable[, 2],
+                  round(ESS.orthogMCMC), BUGS.Coeff, round(BUGS.ESS[BUGSlist, ]))
> colnames(ESStable) = c("A)Coeff.", "A)ESS", "B)Coeff.",
+                        "B)ESS", "C)Coeff.", "C)ESS")
> cat("NB: A = MLwiN(non-orthog.), B = MLwiN(orthog.), C = WinBUGS\n");
NB: A = MLwiN(non-orthog.), B = MLwiN(orthog.), C = WinBUGS
> ESStable
                           A)Coeff. A)ESS B)Coeff. B)ESS C)Coeff. C)ESS
FP_Intercept                -1.712    68   -1.723   188   -1.726   274
FP_age                      -0.027   219   -0.027  1064   -0.027   884
FP_lcOne_child               1.131   155    1.141   937    1.141   885
FP_lcTwo_children            1.364   144    1.365   931    1.369   668
FP_lcThree_plus              1.361    91    1.366   952    1.368   416
FP_urbanUrban                0.808   100    0.819   108    0.819   445
RP2_var_Intercept            0.423   254    0.416   117    0.423   482
RP2_cov_Intercept_urbanUrban -0.435   130   -0.445    74   -0.437   357
RP2_var_urbanUrban           0.721   100    0.764    87    0.735   282
>
>
```

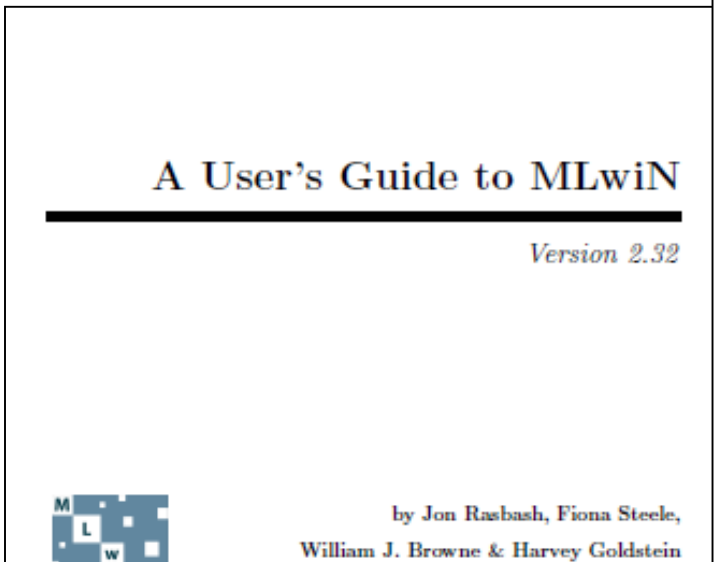
R2MLwiN

As well as usual help files…

…R2MLwiN comes with demos as well…

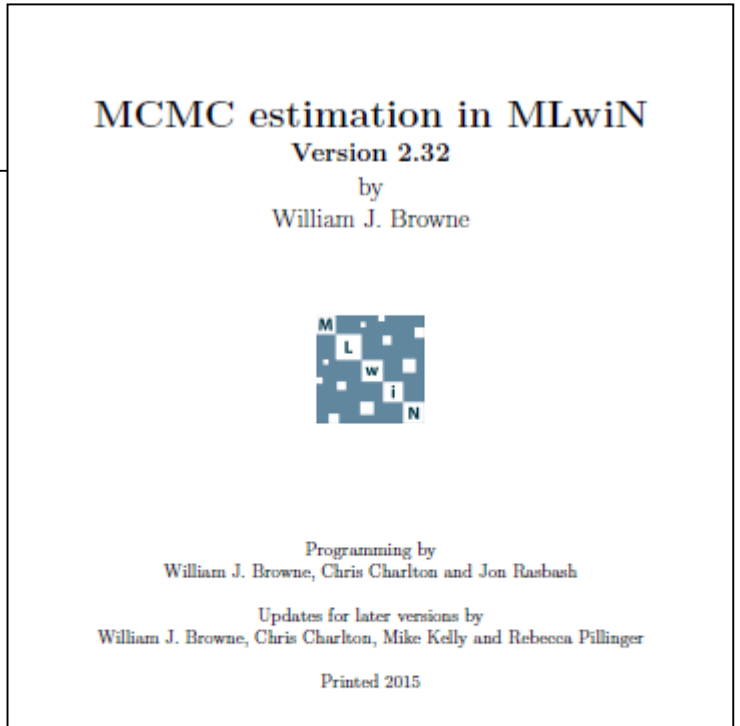
…these replicate all the examples in:

- MLwiN User Manual (IGLS)
- MLwiN MCMC Manual


A User's Guide to MLwiN

Version 2.32

by Jon Rasbash, Fiona Steele,
William J. Browne & Harvey Goldstein


MCMC estimation in MLwiN
Version 2.32
by
William J. Browne

Programming by
William J. Browne, Chris Charlton and Jon Rasbash

Updates for later versions by
William J. Browne, Chris Charlton, Mike Kelly and Rebecca Pillinger

Printed 2015

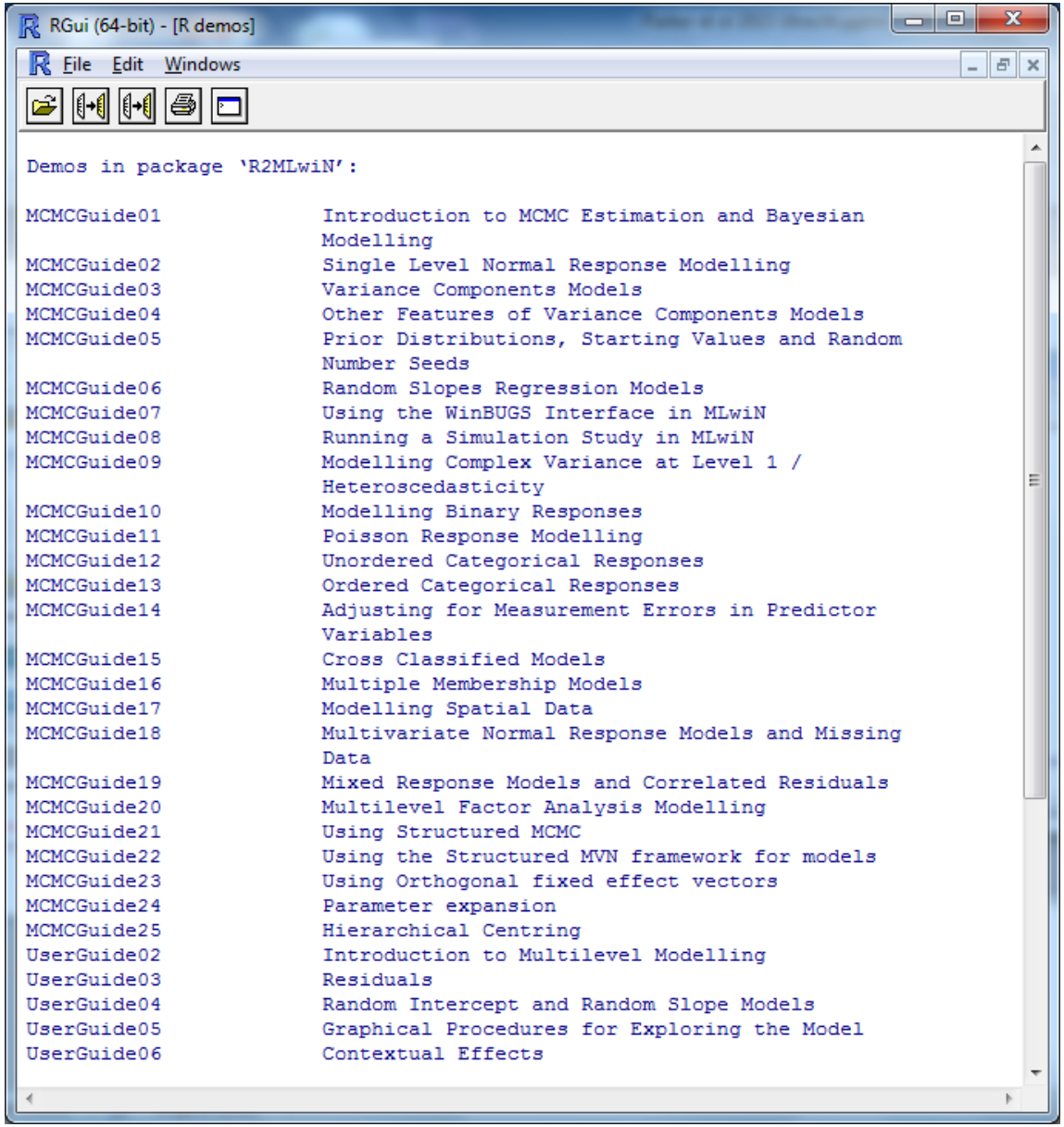
R2MLwiN

R2MLwiN

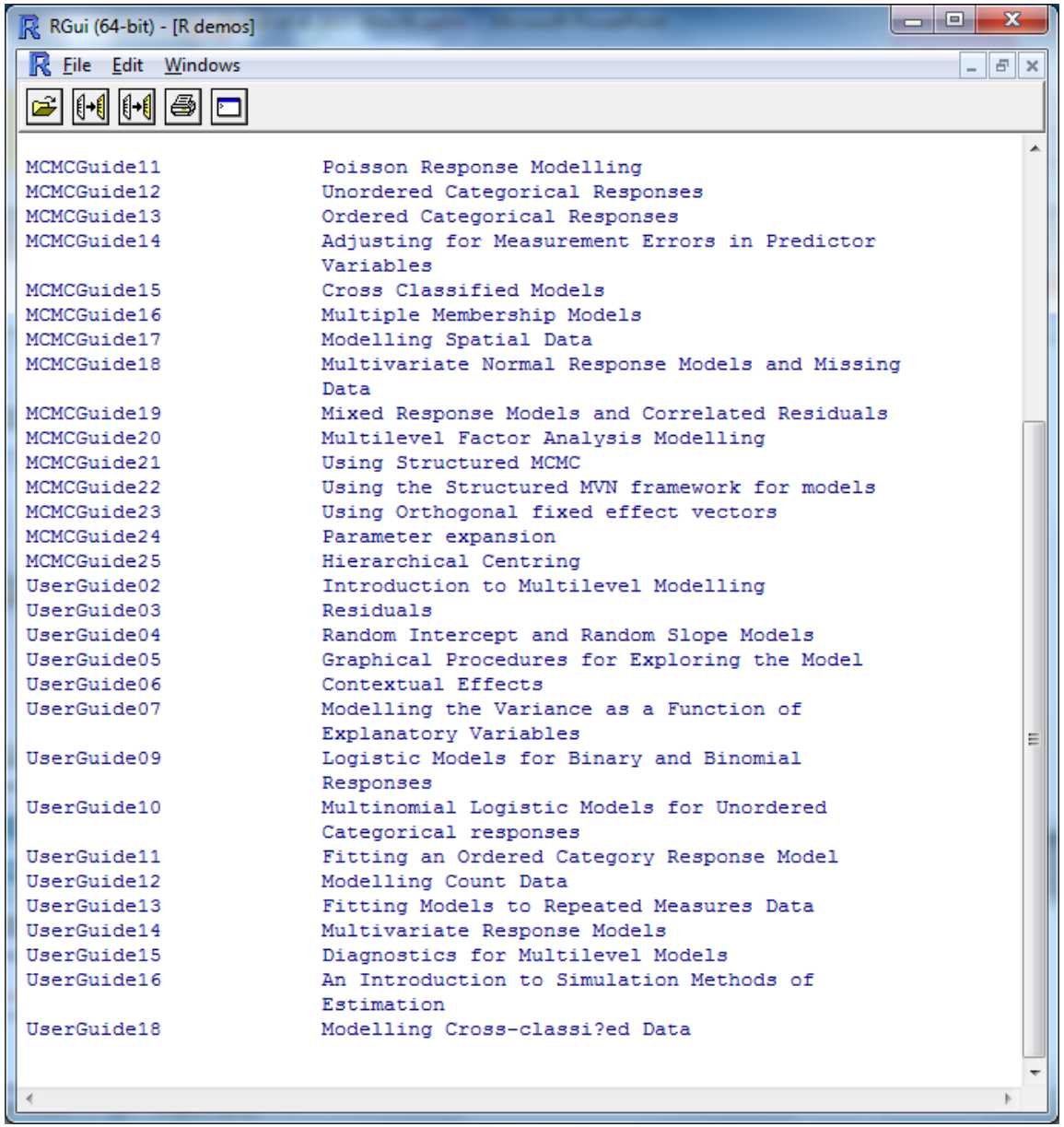
To list demos:

```
R> demo(package = "R2MLwiN")
```

R2MLwiN


RGui (64-bit) - [R demos]
File Edit Windows
Demos in package 'R2MLwiN':
MCMCGuide01 Introduction to MCMC Estimation and Bayesian Modelling
MCMCGuide02 Single Level Normal Response Modelling
MCMCGuide03 Variance Components Models
MCMCGuide04 Other Features of Variance Components Models
MCMCGuide05 Prior Distributions, Starting Values and Random Number Seeds
MCMCGuide06 Random Slopes Regression Models
MCMCGuide07 Using the WinBUGS Interface in MLwiN
MCMCGuide08 Running a Simulation Study in MLwiN
MCMCGuide09 Modelling Complex Variance at Level 1 / Heteroscedasticity
MCMCGuide10 Modelling Binary Responses
MCMCGuide11 Poisson Response Modelling
MCMCGuide12 Unordered Categorical Responses
MCMCGuide13 Ordered Categorical Responses
MCMCGuide14 Adjusting for Measurement Errors in Predictor Variables
MCMCGuide15 Cross Classified Models
MCMCGuide16 Multiple Membership Models
MCMCGuide17 Modelling Spatial Data
MCMCGuide18 Multivariate Normal Response Models and Missing Data
MCMCGuide19 Mixed Response Models and Correlated Residuals
MCMCGuide20 Multilevel Factor Analysis Modelling
MCMCGuide21 Using Structured MCMC
MCMCGuide22 Using the Structured MVN framework for models
MCMCGuide23 Using Orthogonal fixed effect vectors
MCMCGuide24 Parameter expansion
MCMCGuide25 Hierarchical Centring
UserGuide02 Introduction to Multilevel Modelling
UserGuide03 Residuals
UserGuide04 Random Intercept and Random Slope Models
UserGuide05 Graphical Procedures for Exploring the Model
UserGuide06 Contextual Effects

R2MLwiN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MCMCGuide11 Poisson Response Modelling
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MCMCGuide14 Adjusting for Measurement Errors in Predictor Variables
MCMCGuide15 Cross Classified Models
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UserGuide07 Modelling the Variance as a Function of Explanatory Variables
UserGuide09 Logistic Models for Binary and Binomial Responses
UserGuide10 Multinomial Logistic Models for Unordered Categorical responses
UserGuide11 Fitting an Ordered Category Response Model
UserGuide12 Modelling Count Data
UserGuide13 Fitting Models to Repeated Measures Data
UserGuide14 Multivariate Response Models
UserGuide15 Diagnostics for Multilevel Models
UserGuide16 An Introduction to Simulation Methods of Estimation
UserGuide18 Modelling Cross-classi?ed Data

R2MLwiN

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To show demo script:

```
R> file.show(system.file("demo",
"MCMCGuide03.R", package =
"R2MLwiN"))
```

R2MLwiN

RGui (64-bit) - [R Information]

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```
##############################################################################
#     MLwiN MCMC Manual
#
# 3   Variance Components Models . . . . . . . . . . . . . . . . . . . . .35
#
#     Browne, W.J. (2009) MCMC Estimation in MLwiN, v2.13. Centre for
#     Multilevel Modelling, University of Bristol.
##############################################################################
#     R script to replicate all analyses using R2MLwiN
#
#     Zhang, Z., Charlton, C., Parker, R, Leckie, G., and Browne, W.J.
#     Centre for Multilevel Modelling, 2012
#     http://www.bristol.ac.uk/cmm/software/R2MLwiN/
##############################################################################

# 3.1 A 2 level variance components model for the Tutorial dataset . . . .36

library(R2MLwiN)
# MLwiN folder
mlwin <- getOption("MLwiN_path")
while (!file.access(mlwin, mode = 1) == 0) {
  cat("Please specify the root MLwiN folder or the full path to the MLwiN executable:\n")
  mlwin <- scan(what = character(0), sep = "\n")
```

Obtaining R2MLwiN & finding out more:

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…includes link to log files of demo runs

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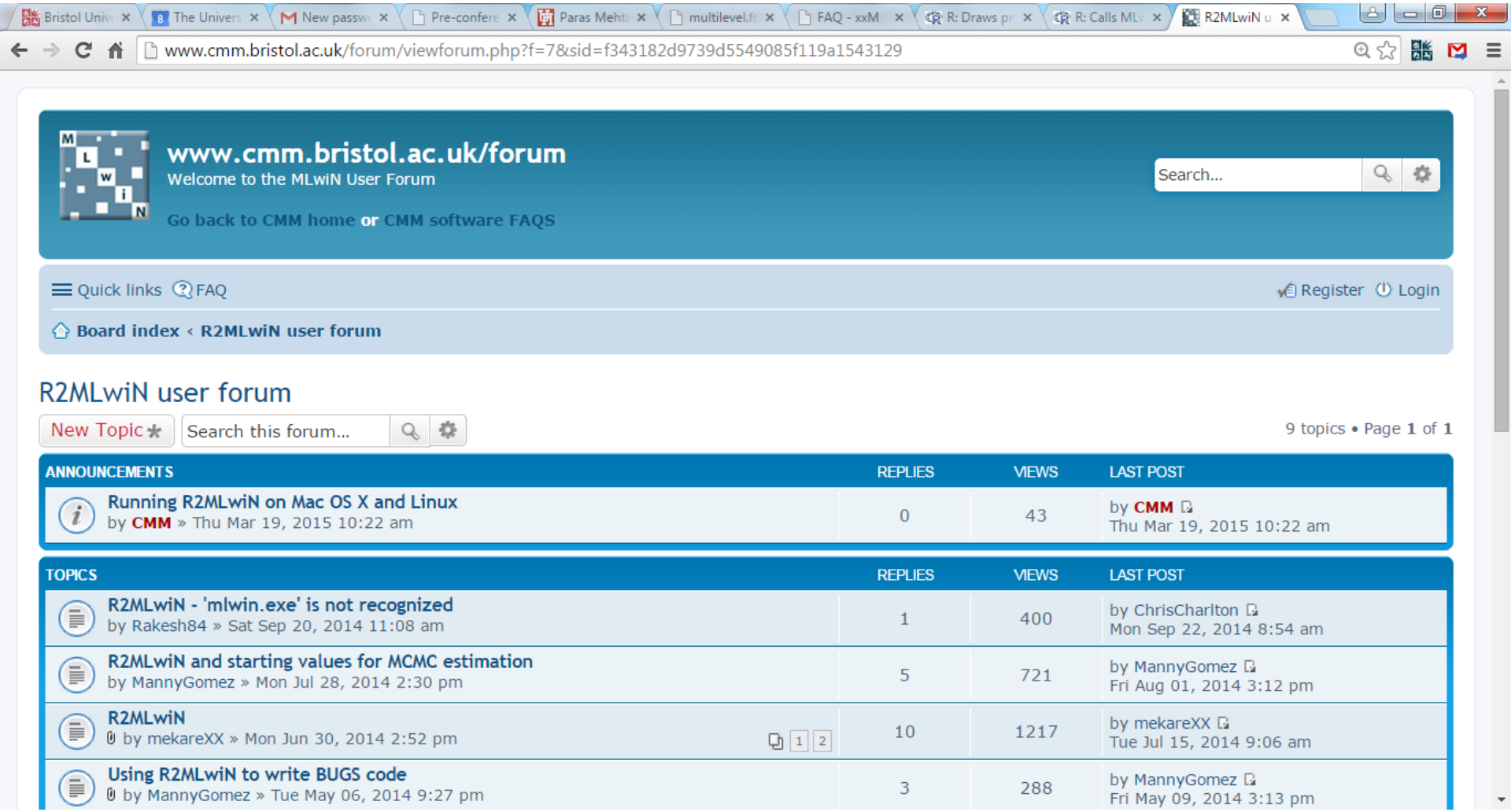

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