

## Guidance document for running the FBIRT R program with supplemental simulation results

Supplemental materials for the paper: Fox, Klein Entink and Timmers (2013). The Joint Multivariate Modeling of Multiple Mixed Response Sources: Relating Student Performances with Feedback Behavior, *Multivariate Behavioral Research*. This document shows how to run the model using simulated data and subsequently how to analyze the real data presented in the paper.

### Simulation study to show some parameter recovery properties and use of the model and R scripts.

*Note: the results shown here are stored in simu.Rdata. The script "Run FBIRT model.R" contains all the code shown below.*

Source all the functions in the "FBIRT Function Definitions.R" script

```
## Seth path correctly:
```

```
source('~/Supplemental materials/FBIRT Function Definitions.R')
```

```
# Simulate data:
```

```
N <- 400 # define number of test takers
```

```
K <- 25 # define number of items
```

```
rho <- .65 # define correlation parameter that specifies the covariance matrix
```

```
dat <- simfbirt(N,K,rho)
```

```
# Set number of iterations for MCMC algorithm: our advise is 10000 or more.
```

```
iter <- 10000
```

Run the model using the FBIRT Function with the following inputs :

```
## YR = response matrix of dim(N=persons,K=items)
```

```
## YF = feedback use indicator matrix (1=used feedback,0=no feedback) of  
dim(N=persons,K=items)
```

```
## TR = log-response time matrix (time spent on solving an item) of  
dim(N=persons,K=items)
```

```
## TF = log-feedback time matrix (time spent on reading the feedback on an  
item) of dim(N=persons,K=items)
```

```
## iter = number of iterations for the MCMC algorithm
```

```
## guess: optional variable to indicate if guessing parameters should be included  
in the IRT model. Use any number you like, e.g., guess = 1
```

```
out <- FBIRT(dat$YR,dat$YF,dat$TR,dat$TF,iter)
```

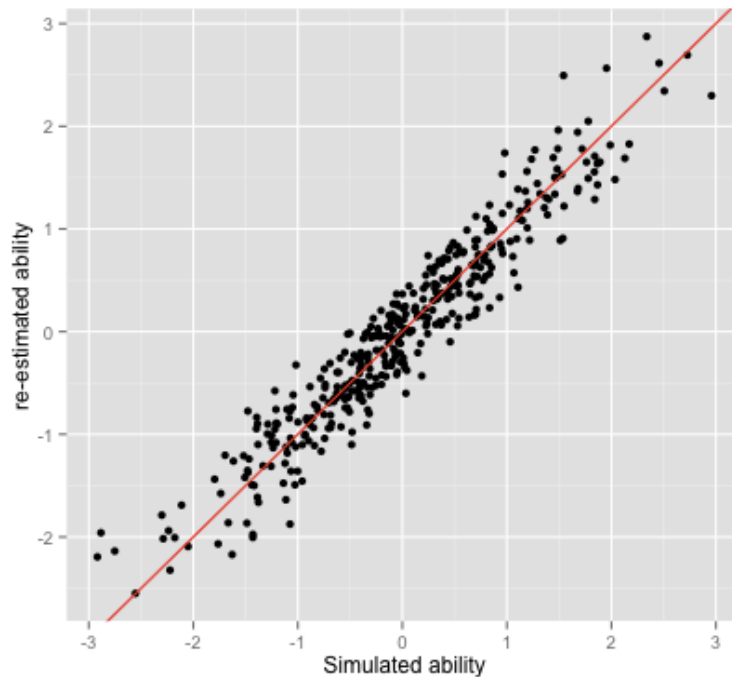
Obtain the person parameter estimates. We give the ability parameter as an example, which corresponds with the first column in "out\$Mtheta". The other person parameters are speed (column 2) feedback trait (column 3) and feedback attention (column 4). The standard deviations are stored in "out\$MTSD", with the same corresponding columns.

```

ability <- data.frame(EAP=out$Mtheta,SD=out$MTSD[,1],SP=dat$theta[,1])
## quick plot of simulated against re-estimated values (EAPs)
library(ggplot2)
qplot(ability$SP,ability$EAP) + xlab("Simulated ability") + ylab("re-estimated
ability") + geom_abline(intercept=0,slope=1, colour=" red")

```

The resulting plot (Figure 1) shows that the posterior means of the re-estimated parameters are close to the simulated values. The red line is the identity line.



**Figure 1: Re-estimated posterior means against simulated values, red line showing the identity line.**

Figure 2 shows that most re-estimated parameters are well within 2 posterior standard deviations from their true, simulated values. Figure 2 below is a bit small in this document, but the real figure can be called in R to show any desired level of detail using the following code:

```

p <- qplot(1:400,ability$EAP-ability$SP) +
geom_pointrange(aes(ymin=ability$EAP-ability$SP-
2*ability$SD,ymax=ability$EAP-ability$SP+2*ability$SD ))
p + ylab("Estimated - True, +/- 2SDs") + xlab("Person")

```

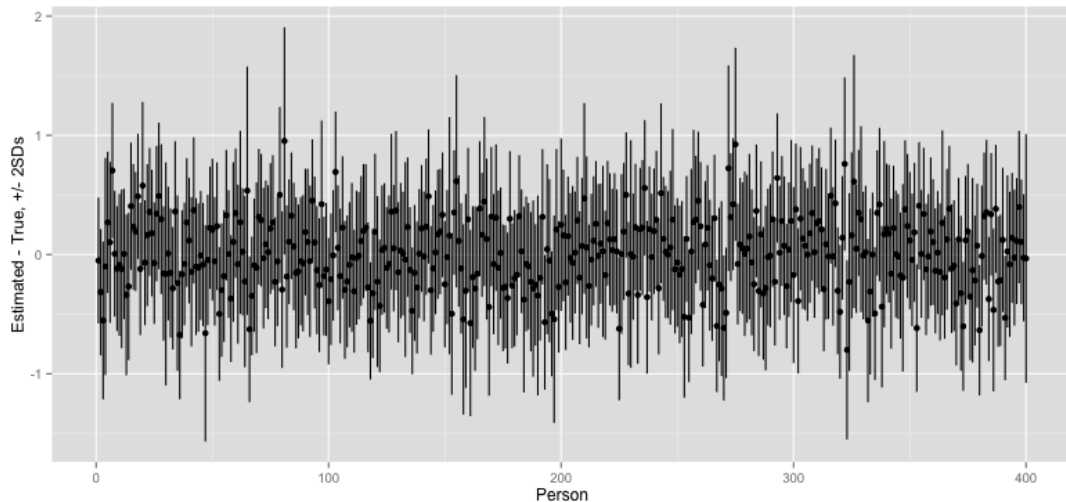
With the following code a numerical evaluation is obtained:

```

> length(which(cbind((ability$EAP-ability$SP-2*ability$SD) < 0 & (ability$EAP-
ability$SP+2*ability$SD) > 0 ) ==TRUE))/N
[1] 0.9575

```

showing that in this simulation at least 95% of the person parameters are within 2 posterior SDs of the true, simulated, values.



**Figure 2: Estimated ability parameters minus simulated values, plus/minus two posterior standard deviations.**

The posterior means of the person-parameter covariance matrix  $\Sigma_P$  can be obtained as follows:

```
> round(colMeans(out$MSP),2)
      [,1] [,2] [,3] [,4]
[1,] 1.07 -0.01 -0.61 0.60
[2,] -0.01 0.97 0.01 -0.04
[3,] -0.61 0.01 0.92 -0.28
[4,] 0.60 -0.04 -0.28 0.95
```

As an example, how to retrieve the posterior means and posterior SDs for the item parameters of the IRT and response time models is shown for the item difficulty below. In the R script the code for all the other item parameters is shown as well:

```
## item difficulty, posterior mean:
round(apply(out$MAB[,2],2,mean),2)
## item difficulty, posterior SD:
round(apply(out$MAB[,2],2,sd),2)
```

### Real data analysis

For the real data analysis in the paper, an adaption to the model code has been made to deal with the block design in the data. All the necessary functions, original data, and some results can be loaded by loading:

- The file RealData.Rdata contains the data, functions and some results. (AB is the matrix containing the item parameter estimates)
- All the functions are defined in FeedbackModel.Miss.R script.
- Output analysis is described in the script Real Data Analysis.R

Observe that the output (stored in modc) contains the same list of results as in the simulation study above. The only difference is that there are two person covariance matrices (SP1 and SP2).