

R version 3.4.3 (2017-11-30)

```
library(lme4)
```

```
###Hypothesis 1
```

```
#Baseline Model
```

```
mod0 <- glmer(score ~ (1|item)+(1|person)+(1|school), family=binomial("logit"), data = data)
```

```
summary(mod0)
```

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']

Family: binomial (logit)

Formula: score ~ (1 | item) + (1 | person) + (1 | school)

Data: data

AIC	BIC	logLik	deviance	df.resid
6427.0	6453.9	-3209.5	6419.0	6203

Scaled residuals:

Min	1Q	Median	3Q	Max
-6.7692	-0.5916	-0.2249	0.6210	7.8038

Random effects:

Groups Name	Variance	Std. Dev.
person (Intercept)	0.3866	0.6217
item (Intercept)	2.3422	1.5304
school (Intercept)	0.2466	0.4966

Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.4401	0.2189	-2.011	0.0443 *

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

```
#Model 1: Person variables as fixed effects
```

```
mod1 <- glmer(score ~ CK+RC+PS+ (1|item)+(1|person)+(1|school), family=binomial("logit"), data = data)
```

```
summary(mod1)
```

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']

Family: binomial (logit)

Formula: score ~ CK + RC + PS + (1 | item) + (1 | person) + (1 | school)

Data: data

AIC	BIC	logLik	deviance	df.resid
6349.4	6396.6	-3167.7	6335.4	6200

Scaled residuals:

Min	1Q	Median	3Q	Max
-6.6236	-0.5869	-0.2198	0.6175	8.5475

Random effects:

Groups Name	Variance	Std. Dev.
person (Intercept)	0.2485	0.4985
item (Intercept)	2.3316	1.5270
school (Intercept)	0.0716	0.2676

Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.50263	0.20452	-2.458	0.013986 *
CK	0.17813	0.05123	3.477	0.000507 ***
RC	0.16600	0.04812	3.450	0.000561 ***
PS	0.31297	0.04742	6.600	4.1e-11 ***

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

Correlation of Fixed Effects:

(Intr)	CK	RC	
CK	0.000		
RC	-0.009	-0.104	
PS	-0.038	-0.201	-0.103

```
#Amount of explained variance of persons and school
```

```
1 - VarCorr(mod1)$person[1] /VarCorr(mod0)$person[1]
```

```
[1] 0.3571936
```

```
1 - VarCorr(mod1)$school[1] /VarCorr(mod0)$school[1]
```

```
[1] 0.7097046
```

```

###Hypothesis 2

#Model 2: Person variables are allowed to vary across items

mod2 <- glmer(score ~ CK+RC+PS+(1+CK+RC+PS|item)+(1|person)+(1|school),
              family=binomial("logit"), data = data, control=glmerControl(optimizer = "bobyqa"))

summary(mod2)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
Family: binomial (logit)
Formula: score ~ CK + RC + PS + (1 + CK + RC + PS | item) + (1 | person) + (1 | school)
Data: data
Control: glmerControl(optimizer = "bobyqa")

      AIC      BIC   logLik deviance df.resid
6347.4  6455.1 -3157.7  6315.4    6191

Scaled residuals:
   Min       1Q   Median       3Q      Max
-7.0601 -0.5818 -0.2236  0.6085  8.2135

Random effects:
Groups Name      Variance Std.Dev. Corr
person (Intercept) 0.24647  0.4965
item   (Intercept) 2.34390  1.5310
       CK           0.01484  0.1218  -0.63
       RC           0.03205  0.1790   0.50 -0.29
       PS           0.01717  0.1310   0.16  0.50  0.59
school (Intercept) 0.07408  0.2722
Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:
              Estimate Std. Error z value Pr(>|z|)
(Intercept) -0.49774    0.20554  -2.422 0.015451 *
CK           0.18649    0.05432   3.433 0.000597 ***
RC           0.16810    0.05503   3.055 0.002251 **
PS           0.31222    0.05189   6.017 1.78e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
(Intr) CK      RC
CK -0.174
RC  0.180 -0.127
PS  0.006 -0.119  0.010

#Comparison of model 2 to the model without person variables varying across items

anova(mod2, mod1)
Data: data
Models:
mod1: score ~ CK + RC + PS + (1 | item) + (1 | person) + (1 | school)
mod2: score ~ CK + RC + PS + (1 + CK + RC + PS | item) + (1 | person) +
mod2: (1 | school)
      Df    AIC      BIC   logLik deviance  Chisq Chi Df Pr(>Chisq)
mod1  7 6349.4 6396.6 -3167.7  6335.4
mod2 16 6347.4 6455.1 -3157.7  6315.4 20.085    9  0.01739 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

###Hypothesis 3

#Model 3: Interaction of intrinsic complexity (item indicator) and problem solving (person variable)

```
mod3 <- glmer(score ~ CK+RC+PS*compl+(1+CK+RC+PS|item)+(1|person)+(1|school),
  family=binomial("logit"), data = data, control=glmerControl(optimizer = "bobyqa"))
```

summary(mod3)

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: binomial (logit)
 Formula: score ~ CK + RC + PS * compl + (1 + CK + RC + PS | item) + (1 | person) + (1 | school)
 Data: data
 Control: glmerControl(optimizer = "bobyqa")

AIC	BIC	logLik	deviance	df.resid
6342.2	6463.4	-3153.1	6306.2	6189

Scaled residuals:

Min	1Q	Median	3Q	Max
-7.2437	-0.5823	-0.2220	0.6079	7.5368

Random effects:

Groups	Name	Variance	Std. Dev.	Corr
person	(Intercept)	0.24425	0.49421	
item	(Intercept)	2.15057	1.46648	
	CK	0.00901	0.09492	-0.33
	RC	0.03186	0.17849	0.52 -0.35
	PS	0.01168	0.10806	0.33 -0.40 0.75
school	(Intercept)	0.07287	0.26994	

Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.50268	0.19789	-2.540	0.011078 *
CK	0.17864	0.05330	3.352	0.000803 ***
RC	0.16781	0.05476	3.065	0.002180 **
PS	0.32787	0.05118	6.407	1.49e-10 ***
compl	-0.41796	0.21146	-1.977	0.048090 *
PS: compl	0.11180	0.04697	2.380	0.017303 *

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

Correlation of Fixed Effects:

	(Intr)	CK	RC	PS	compl
CK	-0.070				
RC	0.188	-0.130			
PS	0.037	-0.220	0.014		
compl	0.010	0.049	-0.028	-0.038	
PS: compl	-0.025	0.005	-0.010	0.150	0.033

#Model 4a: Interaction of word frequency (item indicator) and reading comprehension (person variable)

```
mod4a <- glmer(score ~ CK+RC*wordfrequ+PS+(1+RC+PS+CK|item)+(1|person)+(1|school),
  family=binomial("logit"), data = data, control=glmerControl(optimizer = "bobyqa"))
```

summary(mod4a)

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: binomial (logit)
 Formula: score ~ CK + RC * wordfrequ + PS + (1 + RC + PS + CK | item) + (1 | person) + (1 | school)
 Data: data
 Control: glmerControl(optimizer = "bobyqa")

AIC	BIC	logLik	deviance	df.resid
6346.5	6467.7	-3155.3	6310.5	6189

Scaled residuals:

Min	1Q	Median	3Q	Max
-7.5567	-0.5806	-0.2243	0.6099	8.3288

Random effects:

Groups	Name	Variance	Std. Dev.	Corr
person	(Intercept)	0.24741	0.4974	
item	(Intercept)	2.29310	1.5143	
	RC	0.03298	0.1816	0.51
	PS	0.01945	0.1395	0.40 0.63
	CK	0.01997	0.1413	-0.78 -0.34 0.20
school	(Intercept)	0.07466	0.2732	

Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.49845	0.20363	-2.448	0.014372 *
CK	0.18888	0.05500	3.434	0.000595 ***
RC	0.16846	0.05523	3.050	0.002285 **
wordfrequ	0.43902	0.19144	2.293	0.021834 *
PS	0.30824	0.05210	5.916	3.29e-09 ***
RC: wordfrequ	0.01722	0.04214	0.409	0.682777

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

Correlation of Fixed Effects:

	(Intr)	CK	RC	wrdfreq	PS
CK	-0.244				
RC	0.183	-0.134			
wordfrequ	-0.008	0.005	0.008		
PS	0.087	-0.138	0.017	-0.005	
RC: wordfreq	0.009	-0.023	-0.046	0.193	0.029

#Model 4b: Interaction of readability (item indicator) and reading comprehension (person variable)

```
mod4b <- glmer(score ~ CK+RC*readab+PS+(1+CK+RC+PS|item)+(1|person)+(1|school),  
family=binomial("logit"), data = data, control=glmerControl(optimizer = "bobyqa"))
```

summary(mod4b)

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']

Family: binomial (logit)

Formula: score ~ CK + RC * readab + PS + (1 + CK + RC + PS | item) + (1 | person) + (1 | school)

Data: data

Control: glmerControl(optimizer = "bobyqa")

AIC	BIC	logLik	deviance	df.resid
6350.6	6471.8	-3157.3	6314.6	6189

Scaled residuals:

Min	1Q	Median	3Q	Max
-7.0661	-0.5816	-0.2227	0.6071	8.2448

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
person	(Intercept)	0.24609	0.4961	
item	(Intercept)	2.34535	1.5315	
	CK	0.01537	0.1240	-0.67
	RC	0.03056	0.1748	0.52 -0.25
	PS	0.01694	0.1301	0.14 0.50 0.65
school	(Intercept)	0.07392	0.2719	

Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.49888	0.20562	-2.426	0.015254 *
CK	0.18682	0.05435	3.438	0.000587 ***
RC	0.16876	0.05472	3.084	0.002041 **
readab	0.11983	0.19457	0.616	0.537996
PS	0.31332	0.05182	6.047	1.48e-09 ***
RC: readab	-0.01901	0.04092	-0.465	0.642199

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

Correlation of Fixed Effects:

	(Intr)	CK	RC	readab	PS
CK		-0.186			
RC	0.184		-0.119		
readab	-0.010	-0.003	0.001		
PS	-0.001	-0.119	0.018	0.012	
RC: readab	0.002	-0.011	-0.037	0.228	-0.022

#Model 4c: Interaction of number of words (item indicator) and reading comprehension (person variable)

```
mod4c <- glmer(score ~ CK+RC*nbwords+PS+(1+CK+RC+PS|item)+(1|person)+(1|school),  
family=binomial("logit"), data = data, control=glmerControl(optimizer = "bobyqa"))
```

summary(mod4c)

Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']

Family: binomial (logit)

Formula: score ~ CK + RC * nbwords + PS + (1 + CK + RC + PS | item) + (1 | person) + (1 | school)

Data: data

Control: glmerControl(optimizer = "bobyqa")

AIC	BIC	logLik	deviance	df.resid
6349.8	6471.0	-3156.9	6313.8	6189

Scaled residuals:

Min	1Q	Median	3Q	Max
-6.9647	-0.5815	-0.2228	0.6082	8.2892

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
person	(Intercept)	0.24741	0.4974	
item	(Intercept)	2.30049	1.5167	
	CK	0.01436	0.1198	-0.62
	RC	0.03358	0.1832	0.50 -0.30
	PS	0.01729	0.1315	0.09 0.54 0.58
school	(Intercept)	0.07430	0.2726	

Number of obs: 6207, groups: person, 256; item, 64; school, 34

Fixed effects:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.50038	0.20395	-2.453	0.014149 *
CK	0.18557	0.05428	3.419	0.000629 ***
RC	0.16935	0.05536	3.059	0.002222 **
nbwords	-0.20632	0.19483	-1.059	0.289611
PS	0.31382	0.05196	6.040	1.54e-09 ***
RC: nbwords	0.01915	0.04634	0.413	0.679336

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

Correlation of Fixed Effects:

	(Intr)	CK	RC	nbwrds	PS
CK		-0.166			
RC	0.182		-0.128		
nbwords	0.010	0.018	-0.008		
PS	-0.016	-0.117	0.012	-0.029	
RC: nbwords	-0.010	0.007	0.048	0.190	0.000