Instructional Online Supplement to

“Extending Applications of Generalizability Theory-Based Bifactor Model Designs”

Walter P. Vispoel, Hyeryung Lee,

Tingting Chen, and Hyeri Hong

Contents

1. Data Preparation

Examples used in this supplement represent two-occasion results for Open-mindedness domain (composite) and facet (subscale) scores from the updated Big Five Inventory (BFI-2; Soto & John, 2017). Following essential data cleaning, the dataset as well as relevant R libraries are loaded. All item variables are renamed with the labels 'T1_' for Occasion 1 and 'T2_' for Occasion 2. When using the *lavaan* (Rosseel, 2012) and *semTools* (Jorgensen et al., 2022) packages in *R* to perform Generalizability theory (GT; Cronbach et al., 1963) analyses, data must be arranged in a wide format that has a column for each variable. Sample code is provided below for using these packages for GT analyses, including estimation of G and D coefficients, proportions of measurement error, and respective Monte Carlo confidence intervals. The original dataset (`bfi2_open_389.csv`) was analyzed using the code provided in this supplement. A smaller set of 200 randomly selected cases (`BFI2_Openmindedness_Random_200.csv`) from the original dataset is available as additional Supplemental Material to enable readers to apply the illustrated code to a different dataset.

```
library(lavaan)
library(semTools)

bfi2_open <- read.csv("bfi2_open_389.csv", header = T)
```

2. Bifactor Model

The following code specifies the $p \times i \times o$ bifactor model, which is used to obtain variance partitioning and scale viability indices.

```
model<-'

# General factor
general =~NA*T1_5+lmd1*T1_5+lmd1*T1_20+lmd1*T1_35+lmd1*T1_50
      +lmd1*T2_5+lmd1*T2_20+lmd1*T2_35+lmd1*T2_50+
      lmd2*T1_15+lmd2*T1_30+lmd2*T1_45+lmd2*T1_60
      +lmd2*T2_15+lmd2*T2_30+lmd2*T2_45+lmd2*T2_60+
      lmd3*T1_10+lmd3*T1_25+lmd3*T1_40+lmd3*T1_55
      +lmd3*T2_10+lmd3*T2_25+lmd3*T2_40+lmd3*T2_55

# Group factors
F1 =~ NA*T1_5+dlt1*T1_5+dlt1*T1_20+dlt1*T1_35+dlt1*T1_50
      +dlt1*T2_5+dlt1*T2_20+dlt1*T2_35+dlt1*T2_50
F2 =~ NA*T1_15+dlt2*T1_15+dlt2*T1_30+dlt2*T1_45+dlt2*T1_60
      +dlt2*T2_15+dlt2*T2_30+dlt2*T2_45+dlt2*T2_60
F3 =~ NA*T1_10+dlt3*T1_10+dlt3*T1_25+dlt3*T1_40+dlt3*T1_55
      +dlt3*T2_10+dlt3*T2_25+dlt3*T2_40+dlt3*T2_55

# Occasion factors
OCC1 =~ NA*T1_5+sgm1*T1_5+sgm1*T1_20+sgm1*T1_35+sgm1*T1_50
+sgm2*T1_15+sgm2*T1_30+sgm2*T1_45+sgm2*T1_60
```

```
+sgm3*T1_10+sgm3*T1_25+sgm3*T1_40+sgm3*T1_55
OCC2 =~ NA*T2_5+sgm1*T2_5+sgm1*T2_20+sgm1*T2_35+sgm1*T2_50
+sgm2*T2_15+sgm2*T2_30+sgm2*T2_45+sgm2*T2_60
+sgm3*T2_10+sgm3*T2_25+sgm3*T2_40+sgm3*T2_55
# Item factors
ITEM1 =~ 1*T1_5 + 1*T2_5
ITEM2 =~ 1*T1_20 + 1*T2_20
ITEM3 =~ 1*T1_35 + 1*T2_35
ITEM4 =~ 1*T1_50 + 1*T2_50
ITEM5 =~ 1*T1_10 + 1*T2_10
ITEM6 =~ 1*T1_25 + 1*T2_25
ITEM7 =~ 1*T1_40 + 1*T2_40
ITEM8 =~ 1*T1_55 + 1*T2_55
ITEM9 =~ 1*T1_15 + 1*T2_15
ITEM10=~ 1*T1_30 + 1*T2_30
ITEM11=~ 1*T1_45 + 1*T2_45
ITEM12=~ 1*T1_60 + 1*T2_60

# General, group, and occasion variances
general~~1*general
F1~~1*F1
F2~~1*F2
F3~~1*F3
OCC1~~1*OCC1
OCC2~~1*OCC2

## p x i interaction variance
  ITEM1 ~~ S_pi1*ITEM1
  ITEM2 ~~ S_pi1*ITEM2
  ITEM3 ~~ S_pi1*ITEM3
  ITEM4 ~~ S_pi1*ITEM4
  ITEM5 ~~ S_pi3*ITEM5
  ITEM6 ~~ S_pi3*ITEM6
  ITEM7 ~~ S_pi3*ITEM7
  ITEM8 ~~ S_pi3*ITEM8
  ITEM9 ~~ S_pi2*ITEM9
  ITEM10 ~~ S_pi2*ITEM10
  ITEM11 ~~ S_pi2*ITEM11
  ITEM12 ~~ S_pi2*ITEM12

## p x i x o interaction variance (+ error)
T1_5~~e_var1*T1_5
T1_20~~e_var1*T1_20
T1_35~~e_var1*T1_35
T1_50~~e_var1*T1_50
T1_10~~e_var3*T1_10
T1_25~~e_var3*T1_25
T1_40~~e_var3*T1_40
T1_55~~e_var3*T1_55
T1_15~~e_var2*T1_15
```

```
T1_30~~e_var2*T1_30
T1_45~~e_var2*T1_45
T1_60~~e_var2*T1_60
T2_5~~e_var1*T2_5
T2_20~~e_var1*T2_20
T2_35~~e_var1*T2_35
T2_50~~e_var1*T2_50
T2_10~~e_var3*T2_10
T2_25~~e_var3*T2_25
T2_40~~e_var3*T2_40
T2_55~~e_var3*T2_55
T2_15~~e_var2*T2_15
T2_30~~e_var2*T2_30
T2_45~~e_var2*T2_45
T2_60~~e_var2*T2_60

## Factor mean
general ~ Mu*1
F1 ~ Mu1*1
F2 ~ Mu2*1
F3 ~ Mu3*1
OCC1 ~ mu_o1*1
OCC2 ~ mu_o2*1
ITEM1 ~ mu_i1*1
ITEM2 ~ mu_i2*1
ITEM3 ~ mu_i3*1
ITEM4 ~ mu_i4*1
ITEM5 ~ mu_i5*1
ITEM6 ~ mu_i6*1
ITEM7 ~ mu_i7*1
ITEM8 ~ mu_i8*1
ITEM9 ~ mu_i9*1
ITEM10 ~ mu_i10*1
ITEM11 ~ mu_i11*1
ITEM12 ~ mu_i12*1


## Residual
T1_5 ~ mu11*1
T1_20 ~ mu12*1
T1_35 ~ mu13*1
T1_50 ~ mu14*1
T1_10 ~ mu15*1
T1_25 ~ mu16*1
T1_40 ~ mu17*1
T1_55 ~ mu18*1
T1_15 ~ mu19*1
T1_30 ~ mu110*1
T1_45 ~ mu111*1
T1_60 ~ mu112*1
```

```
T2_5 ~ mu21*1
T2_20 ~ mu22*1
T2_35 ~ mu23*1
T2_50 ~ mu24*1
T2_10 ~ mu25*1
T2_25 ~ mu26*1
T2_40 ~ mu27*1
T2_55 ~ mu28*1
T2_15 ~ mu29*1
T2_30 ~ mu210*1
T2_45 ~ mu211*1
T2_60 ~ mu212*1


## Effects coding identification constraints for model mean structure
mu212 ==-1*(mu11 + mu12 + mu13 + mu14 +mu21 + mu22 + mu23 +mu24+
              mu15 + mu16 + mu17 + mu18 +mu25 + mu26 + mu27 + mu28 +
              mu19 + mu110 + mu111 + mu112+ mu29 + mu210 + mu211)

mu24 == -1*(mu11 + mu12 + mu13 + mu14 +mu21 + mu22 + mu23)
mu28 == -1*(mu15 + mu16 + mu17 + mu18 +mu25 + mu26 + mu27)
mu212 == -1*(mu19 + mu110 + mu111 + mu112+ mu29 + mu210 + mu211)

mu14  == -1*(mu11 + mu12 + mu13)
mu18  == -1*(mu15 + mu16 + mu17)
mu112  == -1*(mu19 + mu110 + mu111)
mu24 == -1*(mu21 + mu22 + mu23)
mu28  == -1*(mu25 + mu26 + mu27)
mu212  == -1*(mu29 + mu210 + mu211)

mu112  == -1*(mu11 + mu12 + mu13+mu14+ mu15 +
mu16 + mu17+mu18 +mu19 + mu110 + mu111)
mu212  == -1*(mu21 + mu22 + mu23+mu24+ mu25 +
mu26 + mu27+mu28 +mu29 + mu210 + mu211)

mu21 == -1*mu11
mu22 == -1*mu12
mu23 == -1*mu13
mu24 == -1*mu14
mu25 == -1*mu15
mu26 == -1*mu16
mu27 == -1*mu17
mu28 == -1*mu18
mu29 == -1*mu19
mu210 == -1*mu110
mu211 == -1*mu111
mu212 == -1*mu112
mu_i4 == -1*(mu_i1 + mu_i2 + mu_i3)
mu_i8 == -1*(mu_i5 + mu_i6 + mu_i7)
mu_i12 == -1*(mu_i9 + mu_i10 + mu_i11)
```

```
mu_o2 == -1*(mu_o1)

## Item (i) variance
S_i1 := (mu_i1^2 + mu_i2^2 + mu_i3^2 + mu_i4^2) / 3
S_i2 := (mu_i9^2 + mu_i10^2 + mu_i11^2 + mu_i12^2) / 3
S_i3 := (mu_i5^2 + mu_i6^2 +mu_i7^2 + mu_i8^2) / 3

## i x o interaction variance
S_io1:= (mu11^2 + mu12^2 + mu13^2 + mu14^2 + mu21^2 + mu22^2 + mu23^2 + mu24^
2)/7
S_io2:= (mu19^2 + mu110^2 + mu111^2 + mu112^2 + mu29^2 + mu210^2 + mu211^2 +
mu212^2)/7
S_io3:= (mu15^2 + mu16^2+ mu17^2+ mu18^2+ mu25^2 + mu26^2+ mu27^2+ mu28^2)/7

## Occasion (o) variance
S_o:= (mu_o1^2 + mu_o2^2 ) / 1
'
```

3. Variance Partitioning and Scale Viability

To obtain the results of variance partitioning and scale viability indices for the preceding bifactor model, the following formula code should be used as a model argument for the *lavaan* function. Within the formula code for each design, the number of occasions and items can be adjusted for alternative designs.

3.1 *p* × *i* × *o* Design

```
cal<-'
## Specify the number of occasions and items per subscale
occ := 2
item := 4

## G Coefficients and Proportions of Measurement Error

# Composite level
total_var_g:= (lmd1 + lmd2 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) +
(S_pi1 + S_pi2 + S_pi3)/item + ((sgm1 + sgm2 + sgm3)^2)/occ + (e_var1 + e_var
2 + e_var3)/(item*occ)
G_coef := ((lmd1 + lmd3 + lmd3)^2+ (dlt1^2 + dlt2^2 + dlt3^2))/total_var_g
gen := ((lmd1 + lmd3 + lmd3)^2)/total_var_g
grp := (dlt1^2 + dlt2^2 + dlt3^2)/total_var_g
sfe := ((S_pi1 + S_pi2 + S_pi3)/item)/total_var_g
te := ((sgm1 + sgm2 + sgm3)^2/occ)/total_var_g
rre := ((e_var1 + e_var2 + e_var3)/(item*occ))/total_var_g
toterror:= sfe + te + rre

# Subscale level: Aesthetic Sensitivity
total_var_g1 := dlt1^2 + lmd1^2 + S_pi1/item + sgm1^2/occ + e_var1/(item*occ)
g1 := (dlt1^2+lmd1^2)/total_var_g1
```

```
gen1 := lmd1^2/total_var_g1
grp1 := dlt1^2/total_var_g1
sfe1 := (S_pi1/item)/total_var_g1
te1 := (sgm1^2/occ)/total_var_g1
rre1 := (e_var1/(item*occ))/total_var_g1
totale1 := sfe1 + te1 + rre1

# Subscale level: Creative Imagination
total_var_g2 := dlt2^2 + lmd2^2 + S_pi2/item + sgm2^2/occ + e_var2/(item*occ)
g2 := (dlt2^2+lmd3^2)/total_var_g2
gen2 := lmd2^2/total_var_g2
grp2 := dlt2^2/total_var_g2
sfe2 := (S_pi2/item)/total_var_g2
te2 := (sgm2^2/occ)/total_var_g2
rre2 := (e_var2/(item*occ))/total_var_g2
totale2 := sfe2 + te2 + rre2

# Subscale level: Intellectual Curiosity
total_var_g3 := dlt3^2 + lmd3^2 + S_pi3/item + sgm3^2/occ + e_var3/(item*occ)
g3 := (dlt3^2+lmd3^2)/total_var_g3
gen3 := lmd3^2/total_var_g3
grp3 := dlt3^2/total_var_g3
sfe3 := (S_pi3/item)/total_var_g3
te3 := (sgm3^2/occ)/total_var_g3
rre3 := (e_var3/(item*occ))/total_var_g3
totale3 := sfe3 + te3 + rre3

## Global D Coefficients and Proportions of Measurement Error


# Composite level
total_var_d:= total_var_g + (S_i1 + S_i2 + S_i3)/item  + 3*S_o/occ + (S_io1 +
S_io2 + S_io3)/(item*occ)
D_coef := ((lmd1 + lmd2 + lmd3)^2+ (dlt1^2 + dlt2^2 + dlt3^2))/total_var_d
gen_d := ((lmd1 + lmd2 + lmd3)^2)/total_var_d
grp_d := (dlt1^2 + dlt2^2 + dlt3^2)/total_var_d
sfe_d := ((S_pi1 + S_pi2 + S_pi3)/item)/total_var_d
te_d := ((sgm1 + sgm2 + sgm3)^2/occ)/total_var_d
rre_d := ((e_var1 + e_var2 + e_var3)/(item*occ))/total_var_d
i_d := ((S_i1 + S_i2 + S_i3)/item)/total_var_d
o_d:= (3*S_o/occ)/total_var_d
io_d := ((S_io1 + S_io2 + S_io3)/(item*occ))/total_var_d

# Subscale level: Aesthetic Sensitivity
total_var_d1 := total_var_g1 + S_i1/item + S_o/occ + S_io1/(item*occ)
d1 := (dlt1^2+lmd1^2)/total_var_d1
gen1_d := lmd1^2/total_var_d1
grp1_d := dlt1^2/total_var_d1
sfe1_d := (S_pi1/item)/total_var_d1
te1_d := (sgm1^2/occ)/total_var_d1
rre1_d := (e_var1/(item*occ))/total_var_d1
```

```
i_1_d := (S_i1/item)/total_var_d1
o_1_d := (S_o/occ)/total_var_d1
io_1_d := (S_io1/(item*occ))/total_var_d1

# Subscale level: Creative Imagination
total_var_d2 := total_var_g2 + S_i2/item + S_o/occ + S_io2/(item*occ)
d2 := (dlt2^2+lmd2^2)/total_var_d2
gen2_d := lmd2^2/total_var_d2
grp2_d := dlt2^2/total_var_d2
sfe2_d := (S_pi2/item)/total_var_d2
te2_d := (sgm2^2/occ)/total_var_d2
rre2_d := (e_var2/(item*occ))/total_var_d2
i_2_d := (S_i2/item)/total_var_d2
o_2_d := (S_o/occ)/total_var_d2
io_2_d := (S_io2/(item*occ))/total_var_d2

# Subscale level: Intellectual Curiosity
total_var_d3 := total_var_g3 + S_i3/item + S_o/occ + S_io3/(item*occ)
d3 := (dlt3^2+lmd3^2)/total_var_d3
gen3_d := lmd3^2/total_var_d3
grp3_d := dlt3^2/total_var_d3
sfe3_d := (S_pi3/item)/total_var_d3
te3_d := (sgm3^2/occ)/total_var_d3
rre3_d := (e_var3/(item*occ))/total_var_d3
i_3_d := (S_i3/item)/total_var_d3
o_3_d := (S_o/occ)/total_var_d3
io_3_d := (S_io3/(item*occ))/total_var_d3


## Common and Unique Explained Variance Ratios

# Composite level
ECV:= (lmd1 + lmd2 + lmd3)^2/((lmd1 + lmd2 + lmd3)^2 +dlt1^2 +dlt2^2 +dlt3^2)
EUV:= (dlt1^2 + dlt2^2 + dlt3^2)/(dlt1^2 + dlt2^2 + dlt3^2+(lmd1 + lmd2 + lmd
3)^2)
ECV_div_EUV := ECV/EUV

# Subscale level: Aesthetic Sensitivity
ECV1 :=lmd1^2/(dlt1^2+lmd1^2)
EUV1 := dlt1^2/(dlt1^2+lmd1^2)
ECV_div_EUV1 := ECV1/EUV1

# Subscale level: Creative Imagination
ECV2 :=lmd2^2/(dlt2^2+lmd2^2)
EUV2 := dlt2^2/(dlt2^2+lmd2^2)
ECV_div_EUV2 := ECV2/EUV2

# Subscale level: Intellectual Curiosity
ECV3 :=lmd3^2/(dlt3^2+lmd3^2)
EUV3 := dlt3^2/(dlt3^2+lmd3^2)
```

```
ECV_div_EUV3 := ECV3/EUV3


## Subscale Value-Added Ratios
Var.X1 :=(gen_var1*item^2 + grp_var1*item^2 + po_var1*item^2/occ+
pi_var1*item + pio_var1*item/occ)*g1
Var.X2 :=(gen_var2*item^2 + grp_var2*item^2 + po_var2*item^2/occ+
pi_var2*item + pio_var2*item/occ)*g2
Var.X3 :=(gen_var3*item^2 + grp_var3*item^2 + po_var3*item^2/occ+
pi_var3*item + pio_var3*item/occ)*g3
Var.Z :=(9*gen_var*item^2 + 9*grp_var*item^2 + 9*po_var*item^2/occ+
9*pi_var*item + 9*pio_var*item/occ)*G_coef
prmse1 := (G_coef*(Var.X1+(0.350824883+(0.022494348+0.025949365)/occ+0.316268
17)*item^2)^2)/(Var.X1*Var.Z)
prmse2 := (G_coef*(Var.X2+(0.31626817+(0.025949365+0.04450095)/occ+0.305734)*
item^2)^2)/(Var.X2*Var.Z)
prmse3 := (G_coef*(Var.X3+(0.350824883+(0.022494348+0.04450095)/occ+0.305734)
*item^2)^2)/(Var.X3*Var.Z)
var1 := g1/prmse1
var2 := g2/prmse2
var3 := g3/prmse3'
Results <- lavaan(model = c(model, cal), orthogonal = "TRUE",
                  data =bfi2_open, estimator= "ULS")

monte<-monteCarloCI(Results, level=0.95)
monte

## G Coefficients and Proportions of Measurement Error
##                   est ci.lower ci.upper
## total_var_g     3.880    3.833    3.940
## G_coef          0.849    0.834    0.864
## gen             0.750    0.730    0.766
## grp             0.100    0.090    0.113
## sfe             0.073    0.067    0.079
## te              0.040    0.027    0.056
## rre             0.037    0.033    0.040
## toterror        0.151    0.136    0.166
## total_var_g1    0.785    0.769    0.803
## g1              0.779    0.758    0.796
## gen1            0.453    0.413    0.492
## grp1            0.326    0.288    0.363
## sfe1            0.139    0.121    0.156
## te1             0.013    0.003    0.031
## rre1            0.069    0.059    0.080
## totale1         0.221    0.204    0.242
## total_var_g2    0.546    0.530    0.565
## g2              0.716    0.677    0.751
## gen2            0.503    0.461    0.543
## grp2            0.213    0.166    0.263
## sfe2            0.150    0.124    0.176
```

```
## te2            0.051    0.024    0.086
## rre2           0.083    0.066    0.099
## totale2        0.284    0.249    0.323
## total_var_g3   0.511    0.499    0.541
## g3             0.701    0.667    0.735
## gen3           0.671    0.597    0.714
## grp3           0.030    0.000    0.115
## sfe3           0.182    0.152    0.208
## te3            0.032    0.011    0.063
## rre3           0.085    0.067    0.101
## totale3        0.299    0.265    0.333

## Global D Coefficients and Proportions of Measurement Error
##                  est ci.lower ci.upper
## total_var_d    3.930    3.887    4.016
## D_coef         0.839    0.819    0.852
## gen_d          0.740    0.718    0.755
## grp_d          0.099    0.089    0.111
## sfe_d          0.072    0.066    0.078
## te_d           0.040    0.027    0.055
## rre_d          0.036    0.033    0.040
## i_d            0.012    0.010    0.014
## o_d            0.001    0.000    0.016
## io_d           0.000    0.000    0.000
## total_var_d1   0.805    0.789    0.832
## d1             0.759    0.731    0.776
## gen1_d         0.442    0.400    0.478
## grp1_d         0.318    0.279    0.353
## sfe1_d         0.135    0.117    0.152
## te1_d          0.013    0.003    0.030
## rre1_d         0.068    0.057    0.078
## i_1_d          0.023    0.017    0.030
## o_1_d          0.002    0.000    0.025
## io_1_d         0.000    0.000    0.001
## total_var_d2   0.551    0.536    0.578
## d2             0.710    0.663    0.742
## gen2_d         0.498    0.453    0.536
## grp2_d         0.211    0.163    0.260
## sfe2_d         0.149    0.122    0.174
## te2_d          0.050    0.024    0.085
## rre2_d         0.082    0.065    0.098
## i_2_d          0.006    0.003    0.012
## o_2_d          0.003    0.000    0.036
## io_2_d         0.000    0.000    0.001
## total_var_d3   0.536    0.524    0.574
## d3             0.668    0.628    0.701
## gen3_d         0.640    0.565    0.679
## grp3_d         0.029    0.000    0.109
## sfe3_d         0.174    0.144    0.197
## te3_d          0.030    0.010    0.060
```

```
## rre3_d         0.081    0.064    0.096
## i_3_d          0.044    0.033    0.055
## o_3_d          0.003    0.000    0.037
## io_3_d         0.000    0.000    0.001


## Common and Unique Explained Variance Ratios
##                  est ci.lower ci.upper
## ECV            0.882    0.867    0.894
## EUV            0.118    0.106    0.133
## ECV_div_EUV    7.509    6.530    8.424
## ECV1           0.582    0.534    0.630
## EUV1           0.418    0.370    0.466
## ECV_div_EUV1   1.391    1.144    1.700
## ECV2           0.702    0.641    0.762
## EUV2           0.298    0.238    0.359
## ECV_div_EUV2   2.357    1.785    3.204
## ECV3           0.957    0.840    1.000
## EUV3           0.043    0.000    0.160
## ECV_div_EUV3 22.170    5.233 2105.898


## Subscale Value-Added Ratios
##                  est ci.lower ci.upper
## prmse1         0.715    0.715    0.717
## prmse2         0.724    0.716    0.735
## prmse3         0.790    0.779    0.804
## var1           1.088    1.057    1.114
## var2           0.989    0.921    1.048
## var3           0.887    0.829    0.944
```

3.2 Restricted *p* × *i* Design

```
cal_res_pi<-'
## Specify the number of items per subscale
item := 4

## G Coefficients, Global D Coefficients, and Proportions of Measurement Error
# Composite level
total_var_gi:= (lmd1 + lmd2 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) +
(S_pi1 + S_pi2 + S_pi3)/item + ((sgm1 + sgm2 + sgm3)^2) + (e_var1 + e_var2 +
e_var3)/item
gcoef_pi := ((lmd1 + lmd2 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) + ((sgm1 + s
gm2 + sgm3)^2))/total_var_gi
gen_pi := ((lmd1 + lmd2 + lmd3)^2 + ((sgm1 + sgm2 + sgm3)^2))/total_var_gi
grp_pi := (((sgm1 + sgm2 + sgm3)^2))/total_var_gi
err_pi := ((S_pi1 + S_pi2 + S_pi3)/item+(e_var1 + e_var2 + e_var3)/item)/tota
l_var_gi
total_var_di:= total_var_gi + (S_i1 + S_i2 + S_i3)/item  + (S_io1 + S_io2 + S
```

```
_io3)/item
dcoef_pi := ((lmd1 + lmd2 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) + ((sgm1 + s
gm2 + sgm3)^2))/total_var_di


# Subscale level: Aesthetic Sensitivity
gcoef_pi_s1 := (lmd1^2 + dlt1^2 + sgm1^2)/(lmd1^2 + dlt1^2 + sgm1^2 + S_pi1/i
tem + e_var1/item)
gen_pi_s1 := lmd1^2 /(lmd1^2 + dlt1^2 + sgm1^2 + S_pi1/item + e_var1/item)
grp_pi_s1 := dlt1^2 /(lmd1^2 + dlt1^2 + sgm1^2 + S_pi1/item + e_var1/item)
err_pi_s1 := (S_pi1/item + e_var1/item)/(lmd1^2 + dlt1^2 + sgm1^2 + S_pi1/ite
m + e_var1/item)
dcoef_pi_s1 := (lmd1^2 + dlt1^2 + sgm1^2)/(lmd1^2 + dlt1^2 + sgm1^2 + (S_pi1+
e_var1+S_i1+S_io1)/item)


# Subscale level: Creative Imagination
gcoef_pi_s2 := (lmd2^2 + dlt2^2 + sgm2^2)/(lmd2^2 + dlt2^2 + sgm2^2 + S_pi2/i
tem + e_var2/item)
gen_pi_s2 := lmd3^2 /(lmd2^2 + dlt2^2 + sgm2^2 + S_pi2/item + e_var2/item)
grp_pi_s2 := dlt2^2 /(lmd2^2 + dlt2^2 + sgm2^2 + S_pi2/item + e_var2/item)
err_pi_s2 := (S_pi2/item + e_var2/item)/(lmd2^2 + dlt2^2 + sgm2^2 + S_pi2/ite
m + e_var2/item)
dcoef_pi_s2 := (lmd2^2 + dlt2^2 + sgm2^2)/(lmd2^2 + dlt2^2 + sgm2^2 + (S_pi2+
e_var2+S_i2+S_io2)/item)

# Subscale level: Intellectual Curiosity
gcoef_pi_s3 := (lmd3^2 + dlt3^2 + sgm3^2)/(lmd3^2 + dlt3^2 + sgm3^2 + S_pi3/i
tem + e_var3/item)
gen_pi_s3 := lmd3^2 /(lmd3^2 + dlt3^2 + sgm3^2 + S_pi3/item + e_var3/item)
grp_pi_s3 := dlt3^2 /(lmd3^2 + dlt3^2 + sgm3^2 + S_pi3/item + e_var3/item)
err_pi_s3 := (S_pi3/item + e_var3/item)/(lmd3^2 + dlt3^2 + sgm3^2 + S_pi3/ite
m + e_var3/item)
dcoef_pi_s3 := (lmd3^2 + dlt3^2 + sgm3^2)/(lmd3^2 + dlt3^2 + sgm3^2 + (S_pi3+
e_var3+S_i3+S_io3)/item)

## Common and Unique Explained Variance Ratios
# Composite level
ECV_pi := (lmd1 + lmd2 + lmd3)^2/((lmd1 + lmd2 + lmd3)^2+dlt1^2 + dlt2^2 + dl
t3^2)
EUV_pi := (dlt1^2 + dlt2^2 + dlt3^2)/((lmd1 + lmd2 + lmd3)^2+dlt1^2 + dlt2^2
+ dlt3^2)
ECV_div_EUV_pi := ECV_pi/EUV_pi

# Subscale level: Aesthetic Sensitivity
ECV_pi_s1 := lmd1^2/(lmd1^2+dlt1^2)
EUV_pi_s1 := dlt1^2/(lmd1^2+dlt1^2)
ECV_div_EUV_pi_s1 := ECV_pi_s1/EUV_pi_s1

# Subscale level: Creative Imagination
ECV_pi_s2 := lmd2^2 / (lmd2^2+dlt2^2)
```

```
EUV_pi_s2 := dlt2^2 / (lmd2^2+dlt2^2)
ECV_div_EUV_pi_s2 := ECV_pi_s2/EUV_pi_s2

# Subscale level: Intellectual Curiosity
ECV_pi_s3 := lmd3^2/(lmd3^2+dlt3^2)
EUV_pi_s3 := dlt3^2/(lmd3^2+dlt3^2)
ECV_div_EUV_pi_s3 := ECV_pi_s3/EUV_pi_s3


## Subscale value-added ratios
Var.X1 :=(lmd1^2*item^2 + dlt1^2*item^2 + (sgm1^2*item^2)/occ+
S_pi1*item + e_var1*item/occ)*gcoef_pi_s1
Var.X2 :=(lmd2^2*item^2 + dlt2^2*item^2 + (sgm2^2*item^2)/occ+
S_pi2*item + e_var2*item/occ)*gcoef_pi_s2
Var.X3 :=(lmd3^2*item^2 + dlt3^2*item^2 + (sgm3^2*item^2)/occ+
S_pi3*item + e_var3*item/occ)*gcoef_pi_s3
Var.Z :=(((lmd1 + lmd2 + lmd3)^2)*item^2 + (dlt1^2 + dlt2^2 + dlt3^2)*item^2
+(S_pi1 + S_pi2 + S_pi3)*item + (((sgm1 + sgm2 + sgm3)^2)*item^2)/occ + (e_va
r1 + e_var2 + e_var3)*item/occ)*gcoef_pi
prmse1 := (gcoef_pi*(Var.X1+(0.350824883+(0.022494348+0.025949365)/occ+0.3162
6817)*item^2)^2)/(Var.X1*Var.Z)
prmse2 := (gcoef_pi*(Var.X2+(0.31626817+(0.025949365+0.04450095)/occ+0.30573
4)*item^2)^2)/(Var.X2*Var.Z)
prmse3 := (gcoef_pi*(Var.X3+(0.350824883+(0.022494348+0.04450095)/occ+0.30573
4)*item^2)^2)/(Var.X3*Var.Z)
var1 := gcoef_pi_s1/prmse1
var2 := gcoef_pi_s2/prmse2
var3 := gcoef_pi_s3/prmse3'

Results <- lavaan(model = c(model, cal_res_pi), orthogonal = "TRUE",
                  data =bfi2_open, estimator= "ULS")

monte<-monteCarloCI(Results, level=0.95)
monte

## G Coefficients, Global D Coefficients, and Proportions of Measurement Error
###                       est    ci.lower ci.upper
## total_var_gi         4.180    4.117    4.265
## total_var_di         4.226    4.164    4.313
## gcoef_pi             0.864    0.859    0.869
## gen_pi               0.771    0.759    0.781
## grp_pi               0.075    0.052    0.102
## err_pi               0.136    0.131    0.141
## dcoef_pi             0.854    0.849    0.860
## gcoef_pi_s1          0.744    0.730    0.759
## gen_pi_s1            0.418    0.379    0.456
## grp_pi_s1            0.301    0.266    0.335
## err_pi_s1            0.256    0.241    0.270
## dcoef_pi_s1          0.728    0.713    0.743
## gcoef_pi_s2          0.722    0.700    0.745
```

```
## gen_pi_s2           0.444    0.402    0.482
## grp_pi_s2           0.188    0.145    0.234
## err_pi_s2           0.278    0.255    0.300
## dcoef_pi_s2         0.717    0.695    0.740
## gcoef_pi_s3         0.685    0.665    0.713
## gen_pi_s3           0.601    0.531    0.646
## grp_pi_s3           0.027    0.000    0.104
## err_pi_s3           0.315    0.287    0.335
## dcoef_pi_s3         0.657    0.637    0.686


## Common and Unique Explained Variance Ratios
##                       est ci.lower ci.upper
## ECV_pi              0.882    0.867    0.894
## EUV_pi              0.118    0.106    0.133
## ECV_div_EUV_pi      7.509    6.532    8.421
## ECV_pi_s1           0.582    0.533    0.630
## EUV_pi_s1           0.418    0.370    0.467
## ECV_div_EUV_pi_s1   1.391    1.143    1.701
## ECV_pi_s2           0.702    0.641    0.762
## EUV_pi_s2           0.298    0.238    0.359
## ECV_div_EUV_pi_s2   2.357    1.784    3.202
## ECV_pi_s3           0.957    0.839    1.000
## EUV_pi_s3           0.043    0.000    0.161
## ECV_div_EUV_pi_s3 22.170    5.218 2050.789

## Subscale Value-Added Ratios
## prmse1              0.687    0.673    0.699
## prmse2              0.695    0.676    0.711
## prmse3              0.760    0.731    0.778
## var1                1.082    1.052    1.119
## var2                1.038    0.991    1.095
## var3                0.901    0.859    0.971
```

3.3 Restricted $p \times o$ Design

```
cal_res_po<-'
## Specify the number of occasions per subscale
occ := 2

## G Coefficients, Global D Coefficients, and Proportions of Measurement Error
# Composite level
total_var_go:= (lmd1 + lmd2 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) +
(S_pi1 + S_pi2 + S_pi3)/item + ((sgm1 + sgm2 + sgm3)^2)/occ +
(e_var1 + e_var2 + e_var3)/(occ*item)
total_var_do:= total_var_go + 3*S_o/occ  + (S_io1 + S_io2 + S_io3)/(occ*item)
gcoef_po := ((lmd1 + lmd3 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) +
(S_pi1 + S_pi2 + S_pi3)/item)/total_var_go
gen_po := ((lmd1 + lmd2 + lmd3)^2 + ((sgm1 + sgm2 + sgm3)^2))/total_var_go
grp_po := (((sgm1 + sgm2 + sgm3)^2))/total_var_go
err_po := (((sgm1 + sgm2 + sgm3)^2)/occ + (e_var1 + e_var2 + e_var3)/(occ*ite
m))/total_var_go
dcoef_po := ((lmd1 + lmd2 + lmd3)^2 + (dlt1^2 + dlt2^2 + dlt3^2) + ((sgm1 + s
gm2 + sgm3)^2))/total_var_do


# Subscale level: Aesthetic Sensitivity
gcoef_po_s1 := (lmd1^2 + dlt1^2 + S_pi1/item)/(lmd1^2 + dlt1^2 + (sgm1^2)/occ
 + S_pi1/item + e_var1/(item*occ))
gen_po_s1 := lmd1^2 /(lmd1^2 + dlt1^2 + (sgm1^2)/occ + S_pi1/item + e_var1/(i
tem*occ))
grp_po_s1 := dlt1^2 /(lmd1^2 + dlt1^2 + (sgm1^2)/occ + S_pi1/item + e_var1/(i
tem*occ))
err_po_s1 := ((sgm1^2)/occ + e_var1/(item*occ))/(lmd1^2 + dlt1^2 + (sgm1^2)/o
cc +S_pi1/item + e_var1/(item*occ))
dcoef_po_s1 := (lmd1^2 + dlt1^2 + (sgm1^2)/occ)/(lmd1^2 + dlt1^2 + (sgm1^2)/o
cc + S_pi1/item + e_var1/(item*occ) + S_o/occ + S_io1/(item*occ))


# Subscale level: Creative Imagination
gcoef_po_s2 := (lmd2^2 + dlt2^2 + S_pi2/item)/(lmd2^2 + dlt2^2 + (sgm2^2)/occ
 + S_pi2/item + e_var2/(item*occ))
gen_po_s2 := (lmd2^2) /(lmd2^2 + dlt2^2 + (sgm2^2)/occ + S_pi2/item + e_var2/
(item*occ))
grp_po_s2 := (dlt2^2) /(lmd2^2 + dlt2^2 + (sgm2^2)/occ + S_pi2/item + e_var2/
(item*occ))
err_po_s2 := ((sgm2^2)/occ + e_var2/(item*occ))/(lmd2^2 + dlt2^2 + (sgm2^2)/o
cc +S_pi2/item + e_var2/(item*occ))
dcoef_po_s2 := (lmd2^2 + dlt2^2 + (sgm2^2)/occ)/(lmd2^2 + dlt2^2 + (sgm2^2)/o
cc + S_pi2/item + e_var2/(item*occ) + S_o/occ + S_io2/(item*occ))


# Subscale level: Intellectual Curiosity
gcoef_po_s3 := (lmd3^2 + dlt3^2 + S_pi3/item)/(lmd3^2 + dlt3^2 + (sgm3^2)/occ
 + S_pi3/item + e_var3/(item*occ))
```

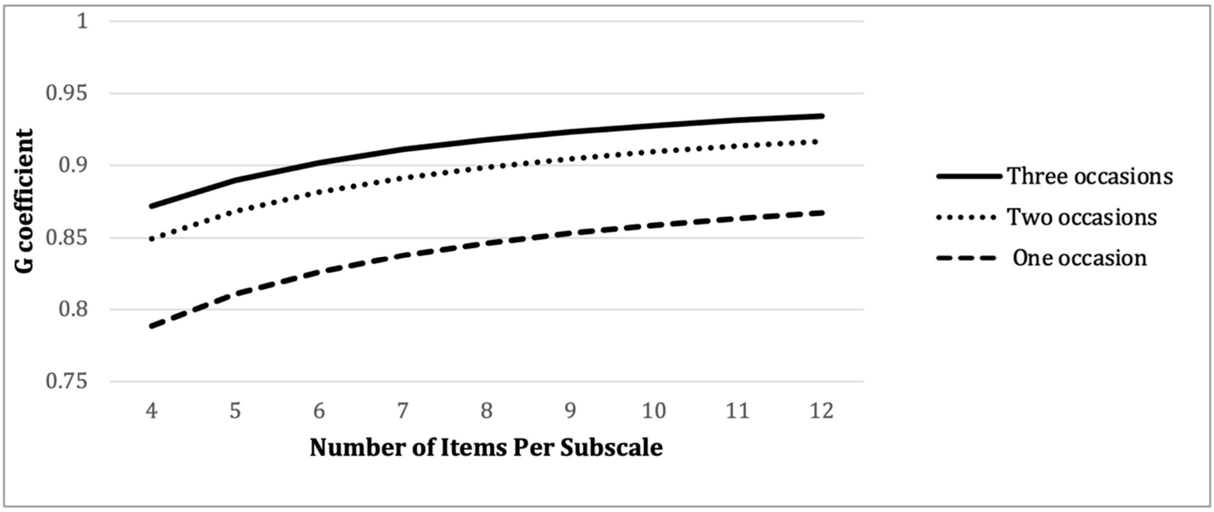
```
gen_po_s3 := (lmd3^2) /(lmd3^2 + dlt3^2 + (sgm3^2)/occ + S_pi3/item + e_var3/
(item*occ))
grp_po_s3 := (dlt3^2) /(lmd3^2 + dlt3^2 + (sgm3^2)/occ + S_pi3/item + e_var3/
(item*occ))
err_po_s3 := ((sgm3^2)/occ + e_var3/(item*occ))/(lmd3^2 + dlt3^2 + (sgm3^2)/o
cc + S_pi3/item + e_var3/(item*occ))
dcoef_po_s3 := (lmd3^2 + dlt3^2 + (sgm3^2)/occ)/(lmd3^2 + dlt3^2 + (sgm3^2)/o
cc + S_pi3/item + e_var3/(item*occ) + S_o/occ + S_io3/(item*occ))


## Common and Unique Explained Variance Ratios
ECV_po := (lmd1 + lmd2 + lmd3)^2/((lmd1 + lmd2 + lmd3)^2+dlt1^2 + dlt2^2 + dl
t3^2)
EUV_po := (dlt1^2 + dlt2^2 + dlt3^2)/((lmd1 + lmd2 + lmd3)^2+dlt1^2 + dlt2^2
+ dlt3^2)
ECV_div_EUV_po := ECV_po/EUV_po
ECV_po_s1 := lmd1^2/(lmd1^2+dlt1^2)
EUV_po_s1 := dlt1^2/(lmd1^2+dlt1^2)
ECV_div_EUV_po_s1 := ECV_po_s1/EUV_po_s1
ECV_po_s2 := (lmd2^2)/(lmd2^2+dlt2^2)
EUV_po_s2 := (dlt2^2)/(lmd2^2+dlt2^2)
ECV_div_EUV_po_s2 := (ECV_po_s2)/(EUV_po_s2)
ECV_po_s3 := (lmd3^2)/(lmd3^2+dlt3^2)
EUV_po_s3 := (dlt3^2)/(lmd3^2+dlt3^2)
ECV_div_EUV_po_s3 := (ECV_po_s3)/(EUV_po_s3)

## Subscale Value-Added ratios
Var.X1 :=(lmd1^2*item^2 + dlt1^2*item^2 + (sgm1^2*item^2)/occ+
S_pi1*item + e_var1*item/occ)*gcoef_po_s1
Var.X2 :=(lmd2^2*item^2 + dlt2^2*item^2 + (sgm2^2*item^2)/occ+
S_pi2*item + e_var2*item/occ)*gcoef_po_s2
Var.X3 :=(lmd3^2*item^2 + dlt3^2*item^2 + (sgm3^2*item^2)/occ+
S_pi3*item + e_var3*item/occ)*gcoef_po_s3
Var.Z :=(((lmd1 + lmd2 + lmd3)^2)*item^2 + (dlt1^2 + dlt2^2 + dlt3^2)*item^2
+(S_pi1 + S_pi2 + S_pi3)*item + (((sgm1 + sgm2 + sgm3)^2)*item^2)/occ +
(e_var1 + e_var2 + e_var3)*item/occ)*gcoef_po
prmse1 := (gcoef_po*((Var.X1+(0.350824883+(0.022494348+0.025949365)/
occ+0.31626817)*item^2)^2))/(Var.X1*Var.Z)
prmse2 := (gcoef_po*((Var.X2+(0.31626817+(0.025949365+0.04450095)/
occ+0.305734)*item^2)^2))/(Var.X2*Var.Z)
prmse3 := (gcoef_po*((Var.X3+(0.350824883+(0.022494348+0.04450095)/
occ+0.305734)*item^2)^2))/(Var.X3*Var.Z)
var1 := gcoef_po_s1/ prmse1
var2 := gcoef_po_s2/ prmse2
var3 := gcoef_po_s3/ prmse3
'

Results <- lavaan(model = c(model, cal_res_po), orthogonal = "TRUE",
                  data =bfi2_open, estimator= "ULS")
```

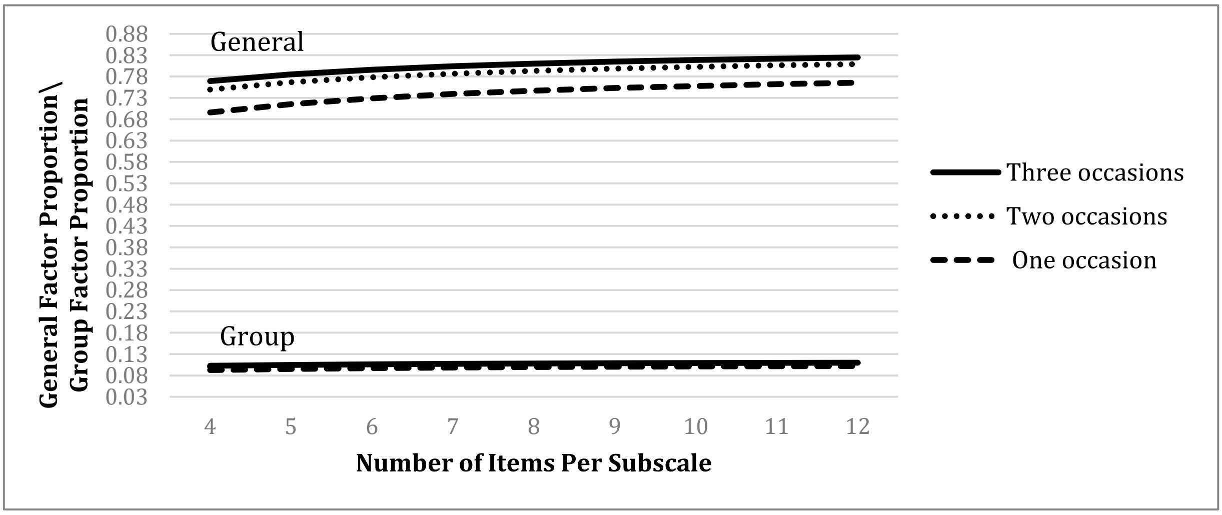
```
monte<-monteCarloCI(Results, level=0.95)
monte

## G Coefficients, Global D Coefficients, and Proportions of Measurement Error
##                       est ci.lower ci.upper
## total_var_go        3.880    3.833    3.940
## total_var_do        3.885    3.841    3.969
## gcoef_po            0.923    0.908    0.935
## gen_po              0.831    0.813    0.848
## grp_po              0.081    0.055    0.112
## err_po              0.077    0.065    0.092
## dcoef_po            0.929    0.910    0.945
## gcoef_po_s1         0.917    0.901    0.930
## gen_po_s1           0.453    0.413    0.492
## grp_po_s1           0.326    0.288    0.363
## err_po_s1           0.083    0.070    0.099
## dcoef_po_s1         0.790    0.768    0.803
## gcoef_po_s2         0.866    0.835    0.891
## gen_po_s2           0.503    0.461    0.543
## grp_po_s2           0.213    0.166    0.263
## err_po_s2           0.134    0.109    0.165
## dcoef_po_s2         0.765    0.733    0.783
## gcoef_po_s3         0.883    0.855    0.906
## gen_po_s3           0.671    0.597    0.714
## grp_po_s3           0.030    0.000    0.115
## err_po_s3           0.117    0.094    0.145
## dcoef_po_s3         0.731    0.700    0.754


## Common and Unique Explained Variance Ratios
##                       est ci.lower ci.upper
## ECV_po              0.882    0.867    0.894
## EUV_po              0.118    0.106    0.133
## ECV_div_EUV_po      7.509    6.536    8.422
## ECV_po_s1           0.582    0.534    0.629
## EUV_po_s1           0.418    0.371    0.466
## ECV_div_EUV_po_s1   1.391    1.144    1.701
## ECV_po_s2           0.702    0.641    0.762
## EUV_po_s2           0.298    0.238    0.359
## ECV_div_EUV_po_s2   2.357    1.786    3.203
## ECV_po_s3           0.957    0.840    1.000
## EUV_po_s3           0.043    0.000    0.160
## ECV_div_EUV_po_s3  22.170    5.265 2027.910


## Subscale Value-Added Ratios
##                       est ci.lower ci.upper
## prmse1              0.713    0.702    0.722
## prmse2              0.696    0.683    0.707
## prmse3              0.744    0.726    0.756
```

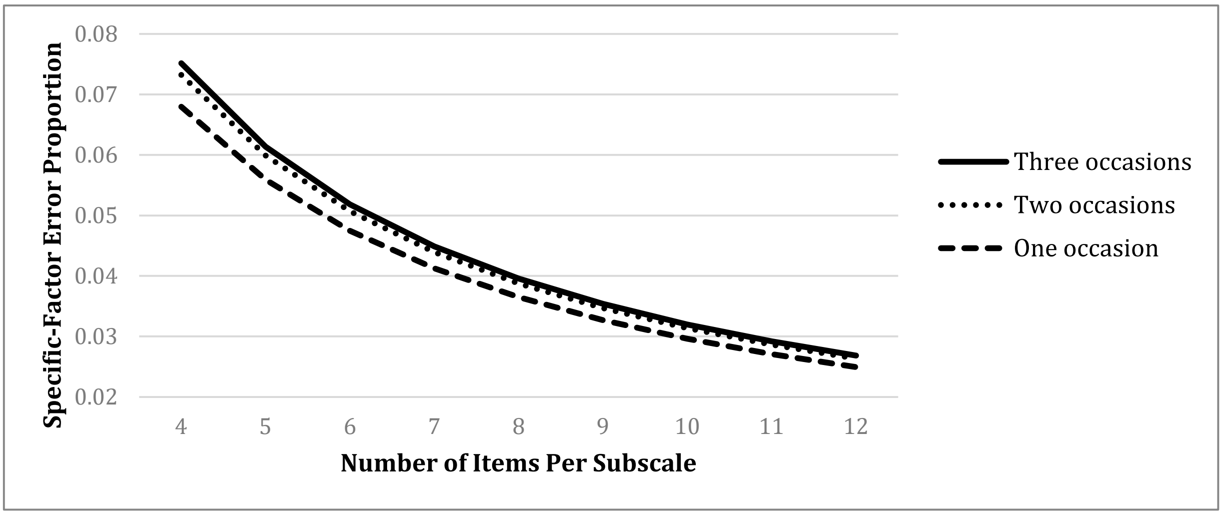
```
## var1                   1.287     1.259     1.314
## var2                   1.245     1.190     1.296
## var3                   1.187     1.139     1.239
```

4. Prophecy Graphs for BFI-2 Open-mindedness Composite and Subscale Scores

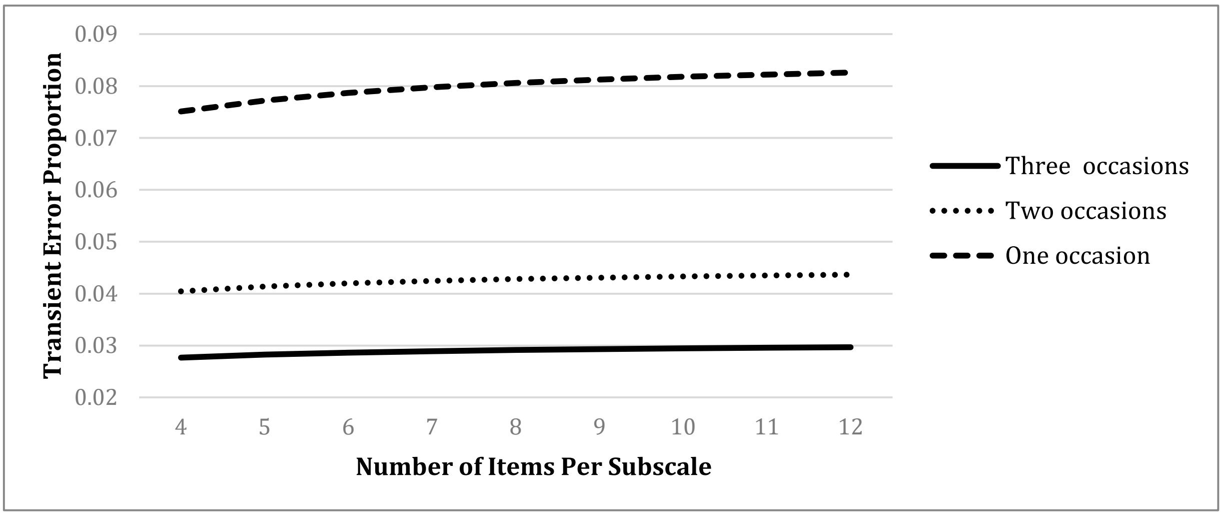
Figure S4.1 Prophecy graphs for Composite Score: Open-mindedness



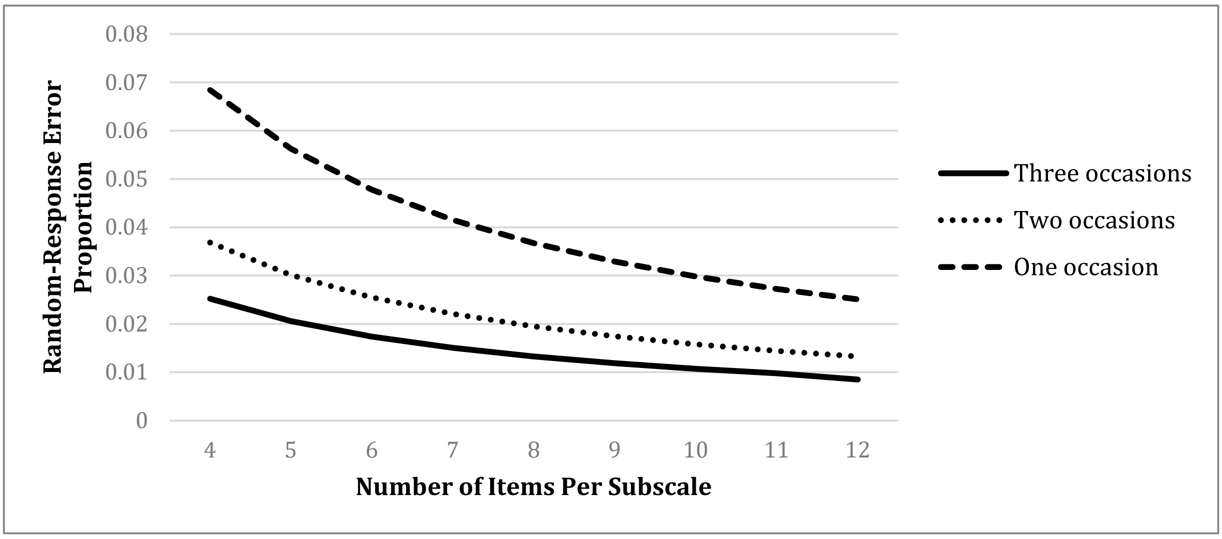




Specific-Factor Error Proportion
0.08
0.07
0.06
0.05
0.04
0.03
0.02
4
5
6
7
8
9
10
11
12
Number of Items Per Subscale
Three occasions
Two occasions
One occasion



Transient Error Proportion
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
4
5
6
7
8
9
10
11
12
Number of Items Per Subscale
Three occasions
Two occasions
One occasion



Random-Response Error Proportion
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
4
5
6
7
8
9
10
11
12
Number of Items Per Subscale
Three occasions
Two occasions
One occasion

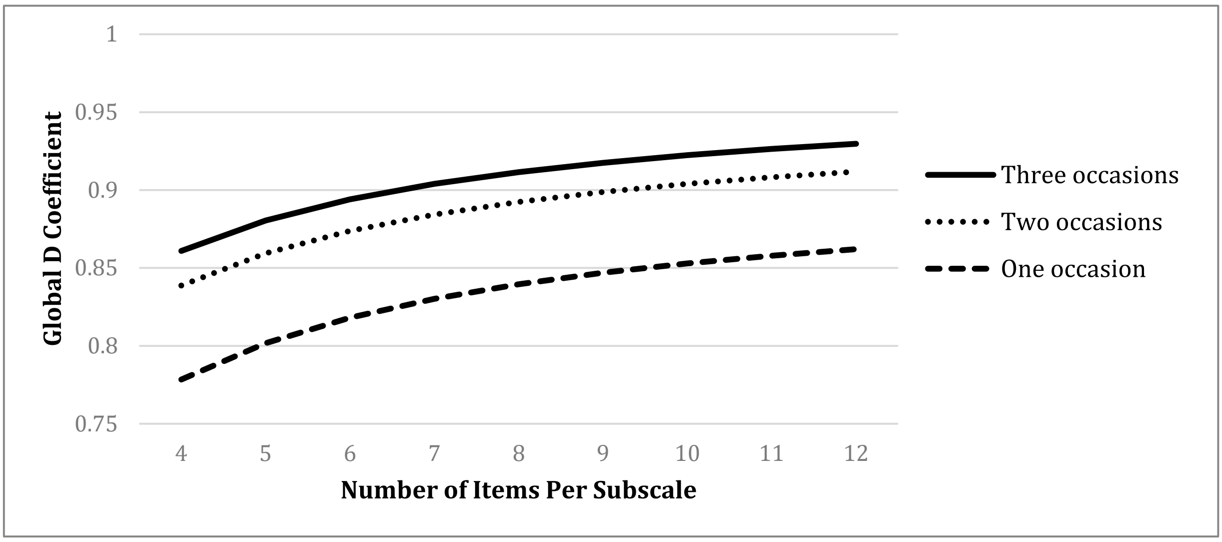
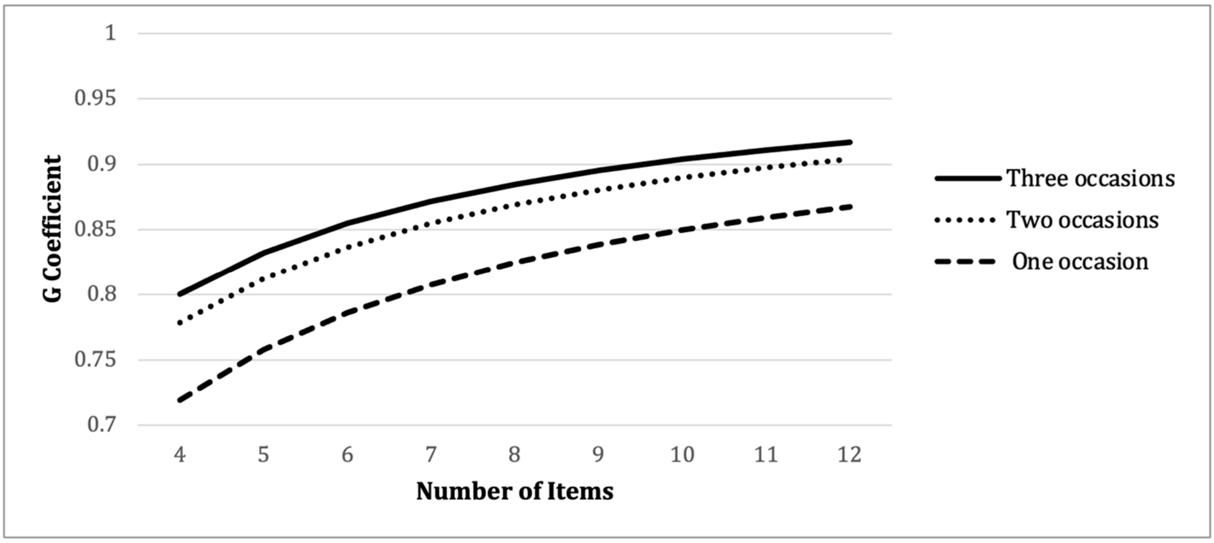
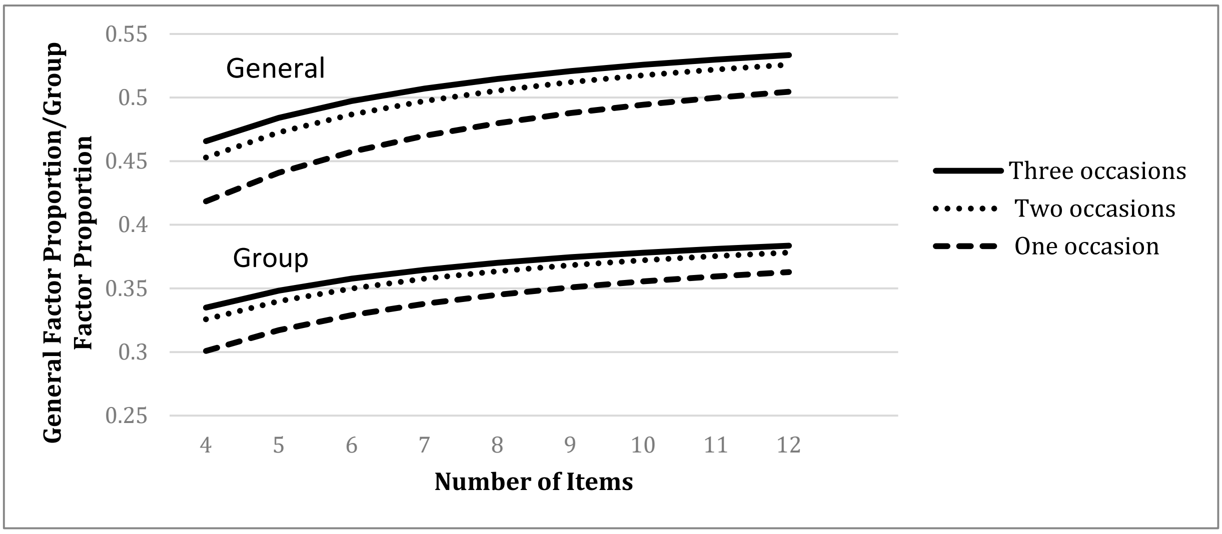
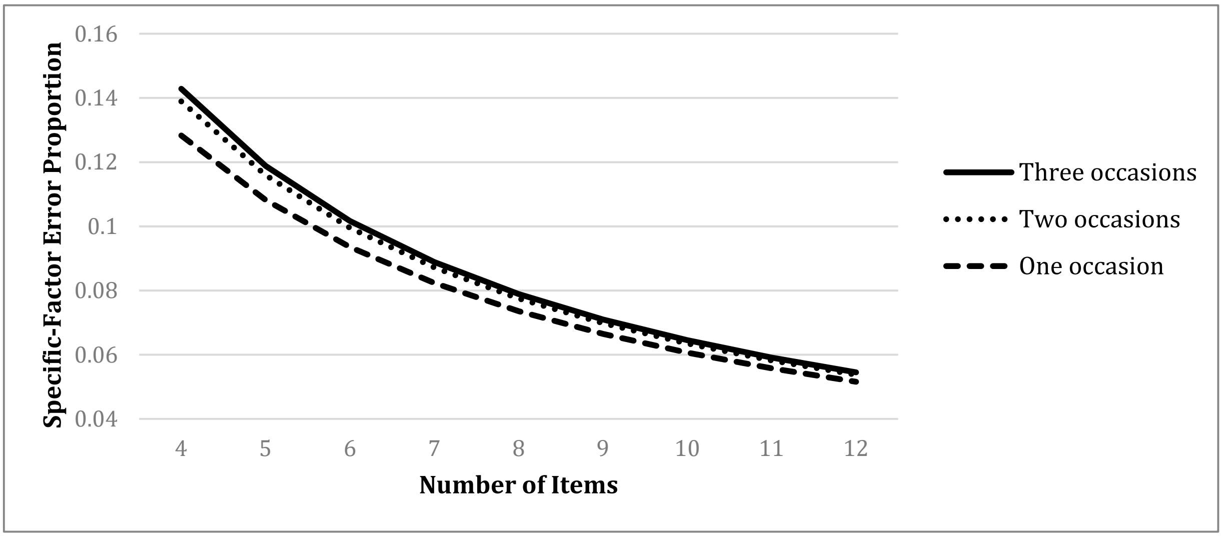
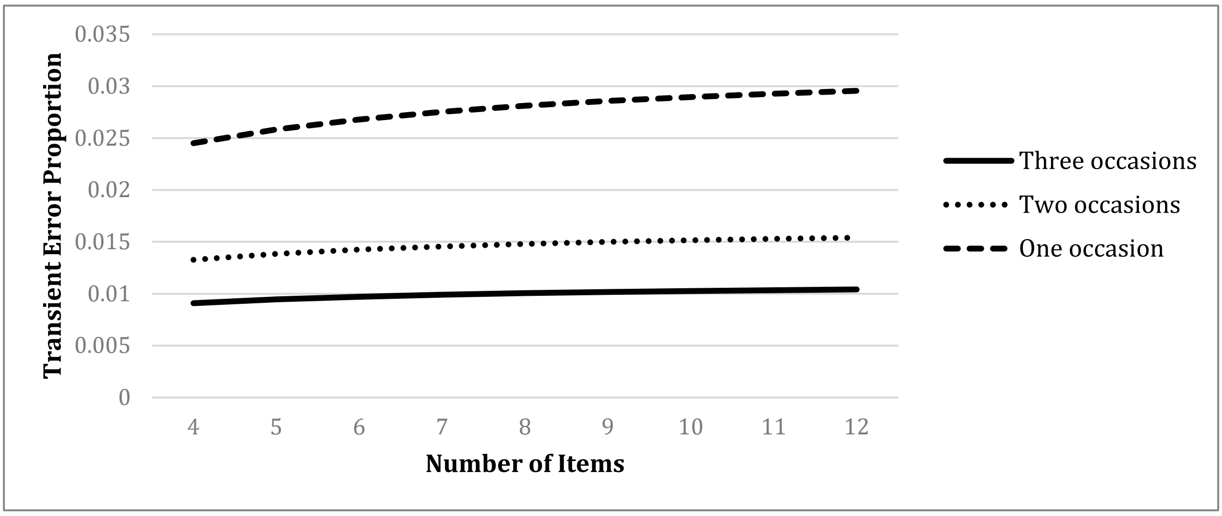


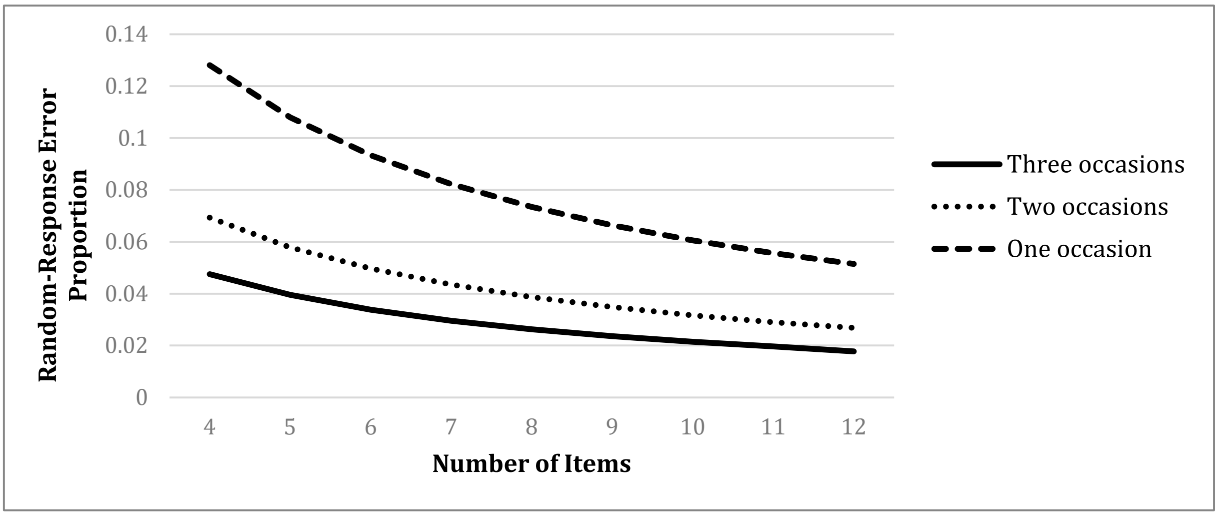
Figure S4.2 Prophecy Graphs for Subscale Score: Aesthetic Sensitivity

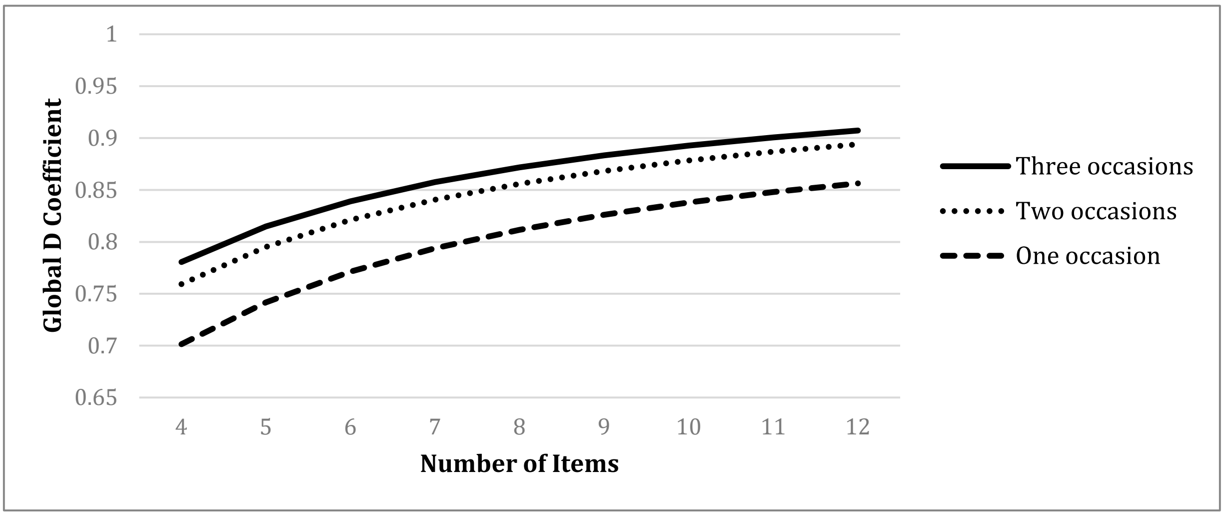



General
Group
General Factor Proportion/Group Factor Proportion
Number of Items
Three occasions
Two occasions
One occasion


Specific-Factor Error Proportion
Number of Items
Three occasions
Two occasions
One occasion


Transient Error Proportion
Number of Items
Three occasions
Two occasions
One occasion


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Random-Response Error Proportion
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion


1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
Global D Coefficient
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion

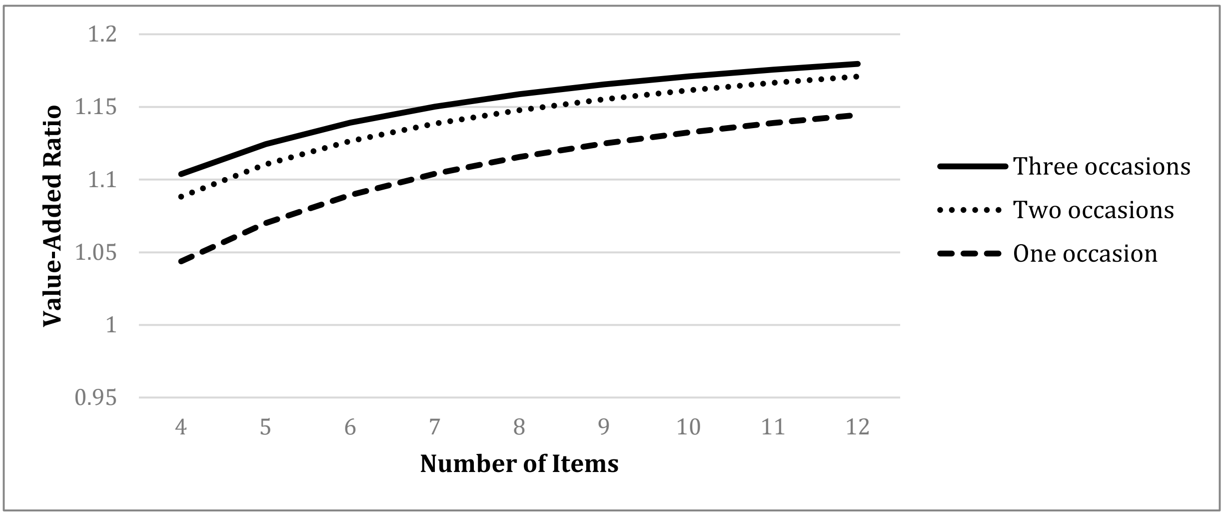
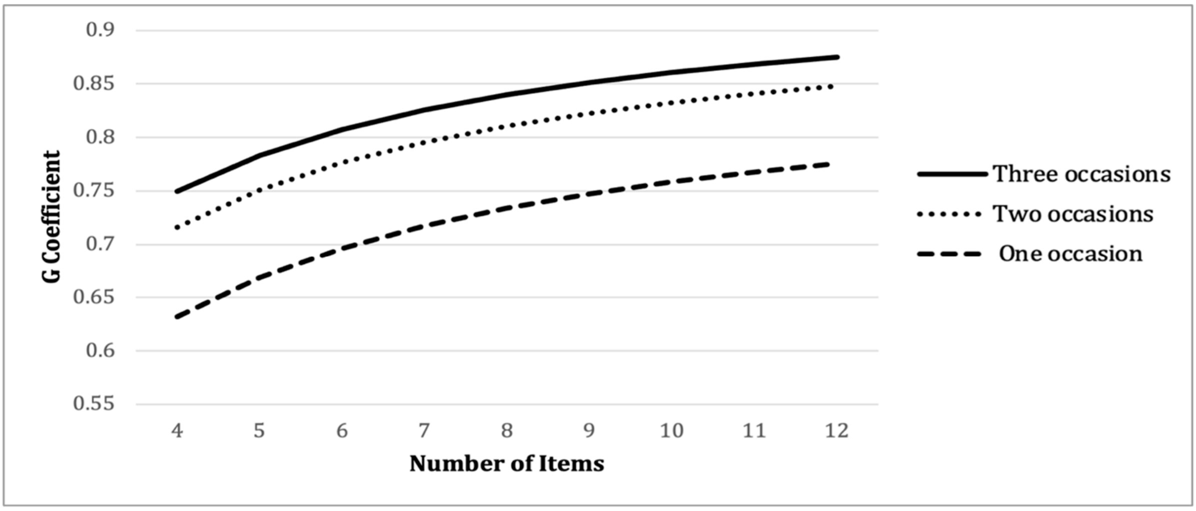
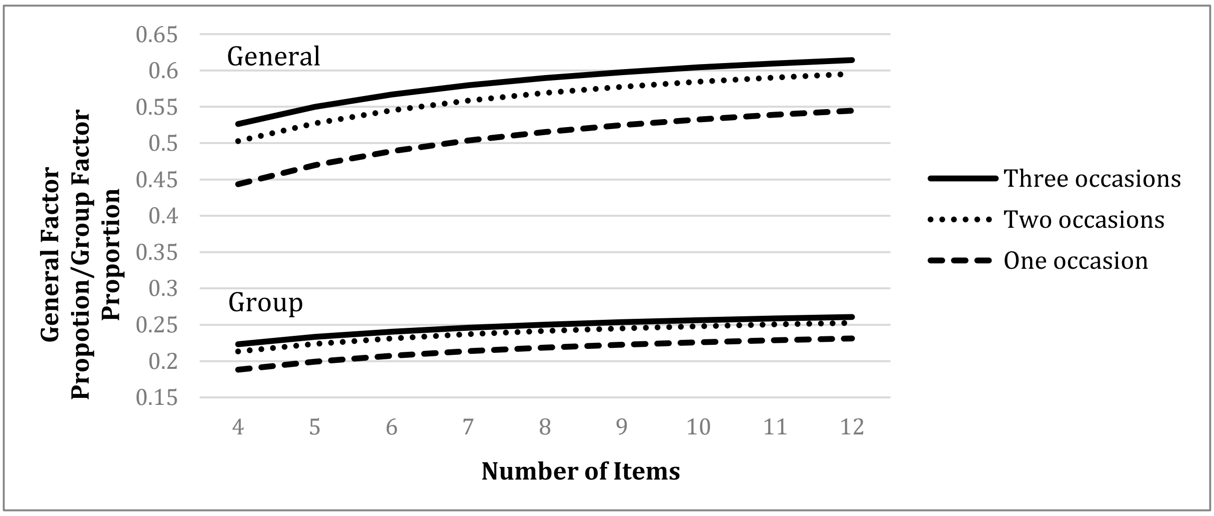
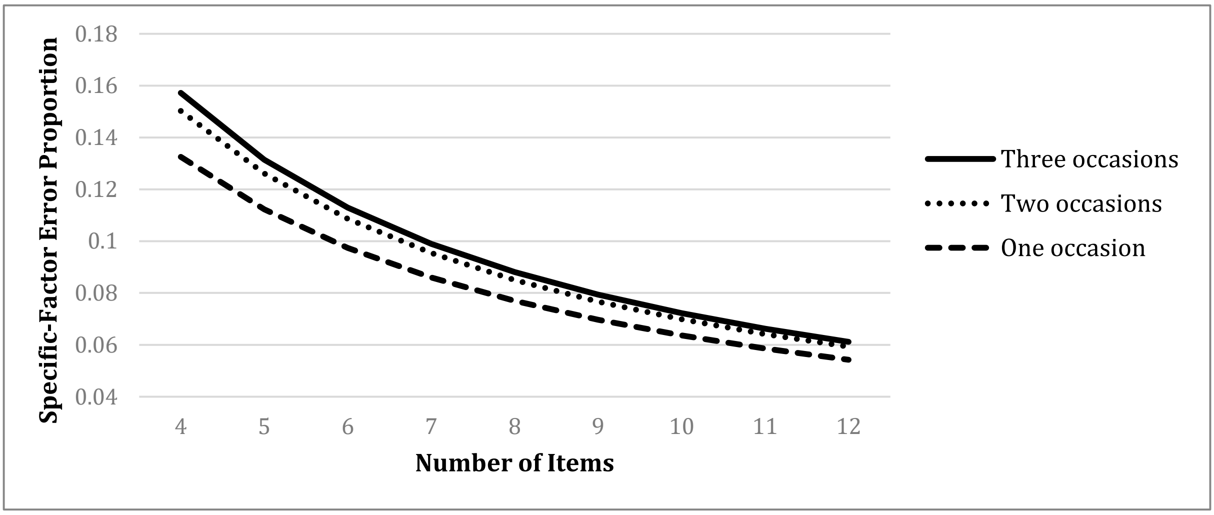
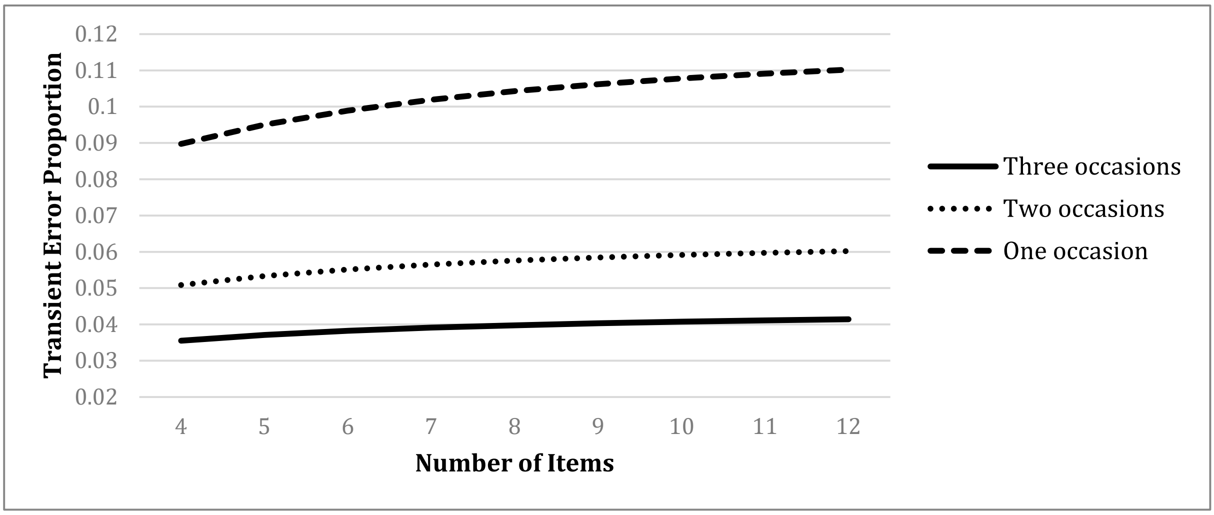

1.2
1.15
1.1
1.05
1
0.95
Value-Added Ratio
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion

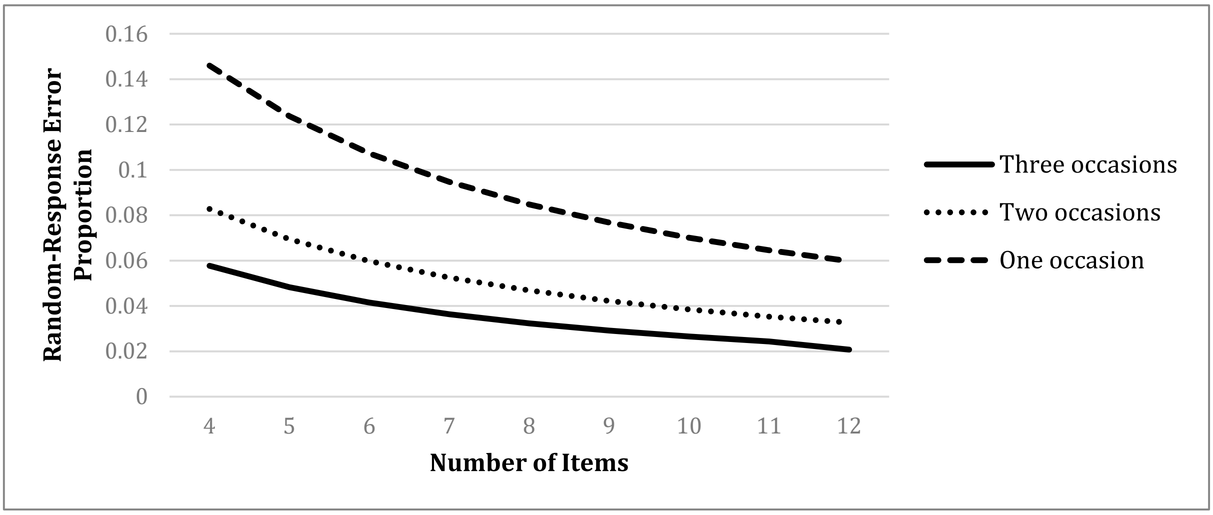
Figure S4.3 Prophecy Graphs for Subscale Score: Creative Imagination

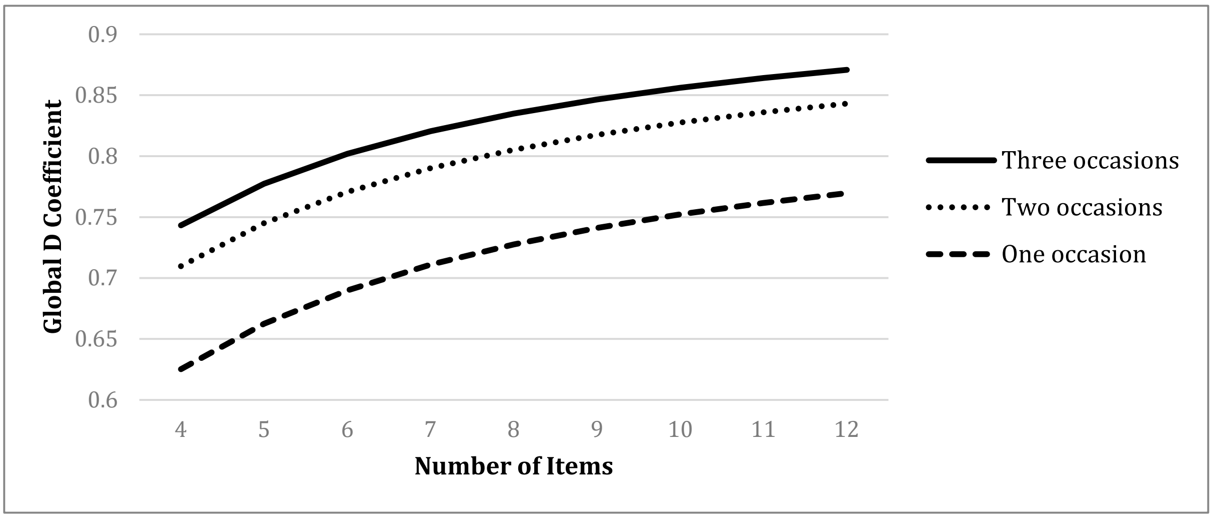







0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
Transient Error Proportion
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion


0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Random-Response Error Proportion
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion


0.9
0.85
0.8
0.75
0.7
0.65
0.6
Global D Coefficient
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion

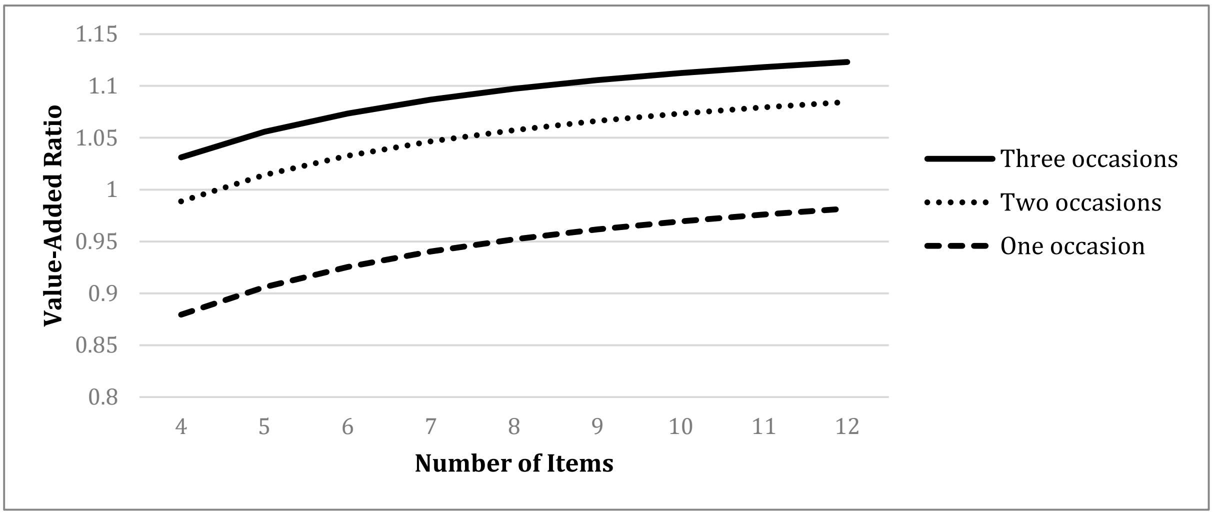
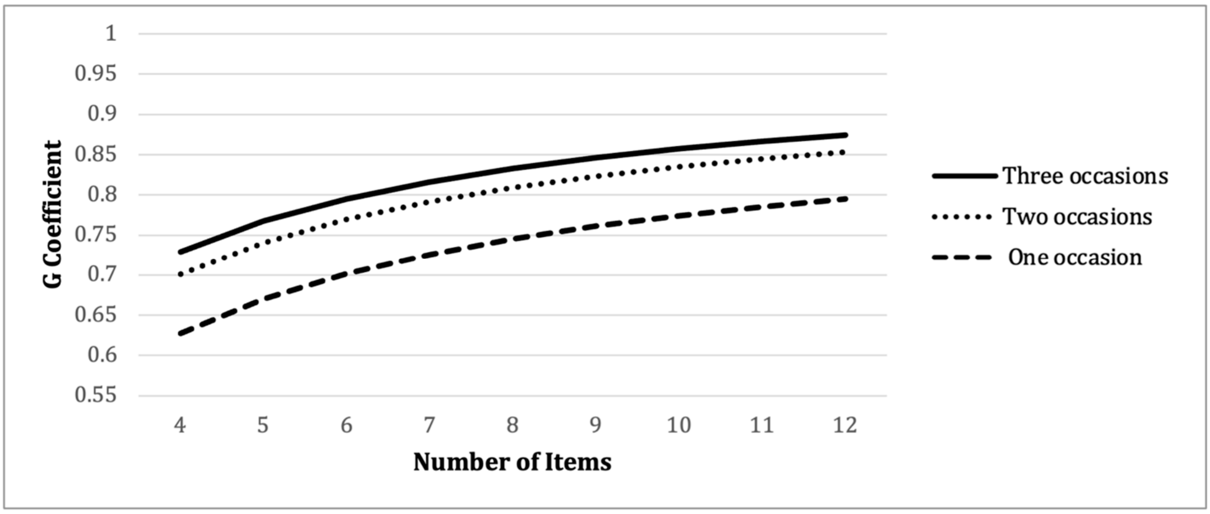
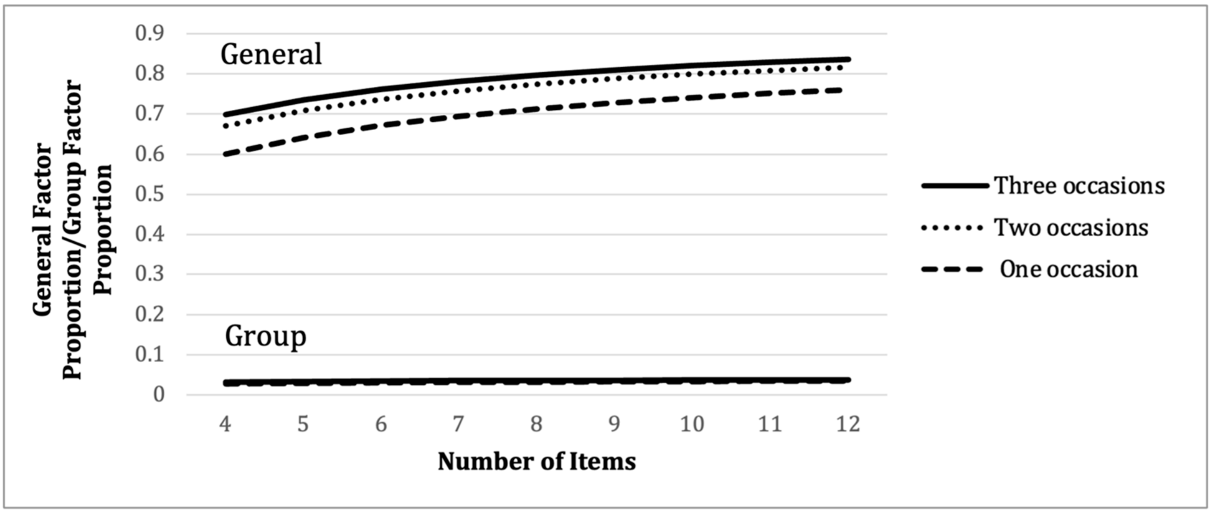
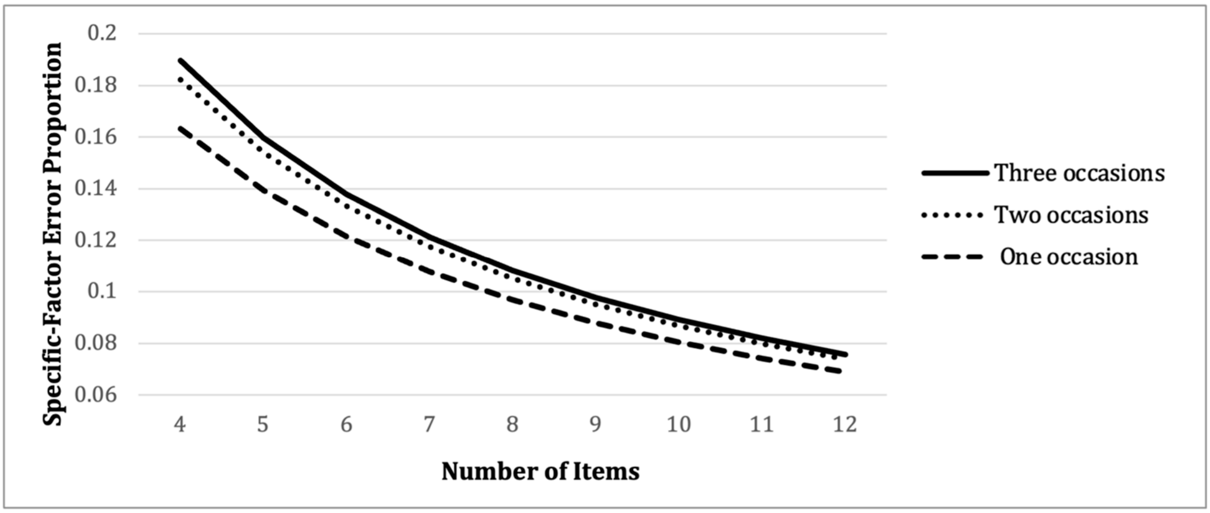
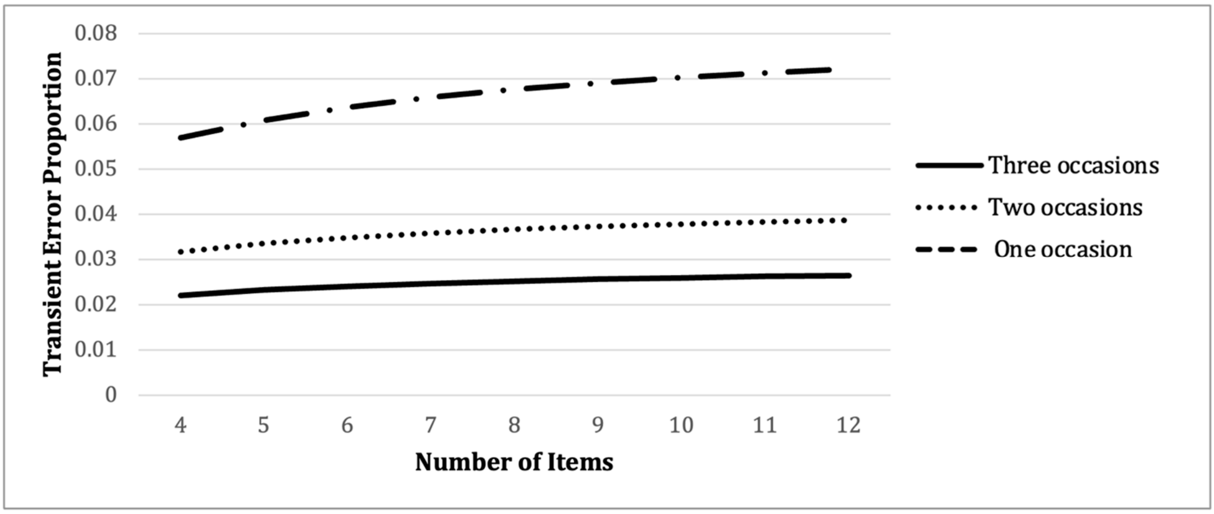


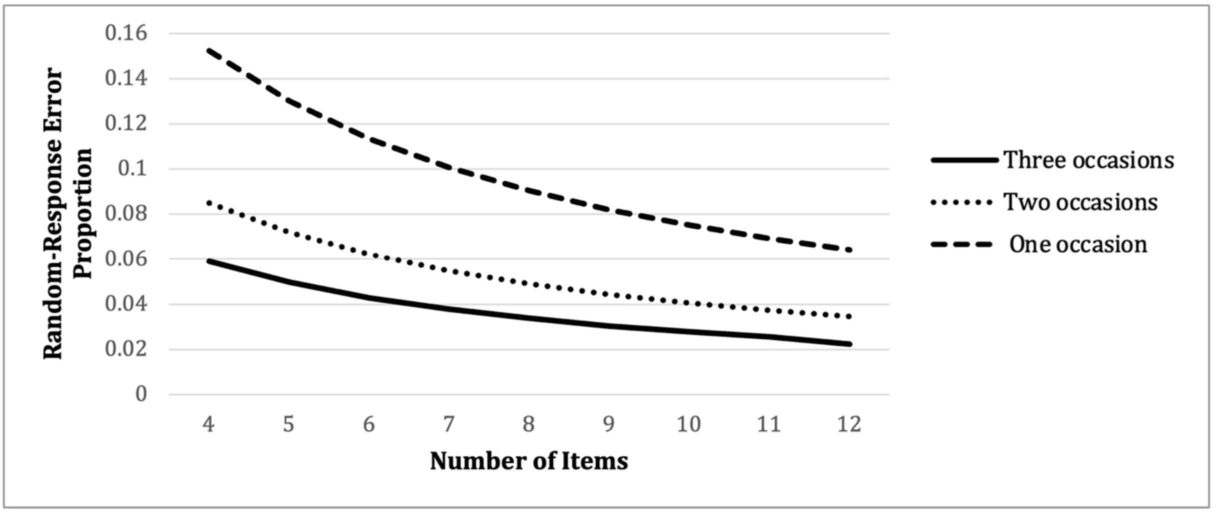
Figure S4.4 Prophecy Graphs for Subscale Score: Intellectual Curiosity

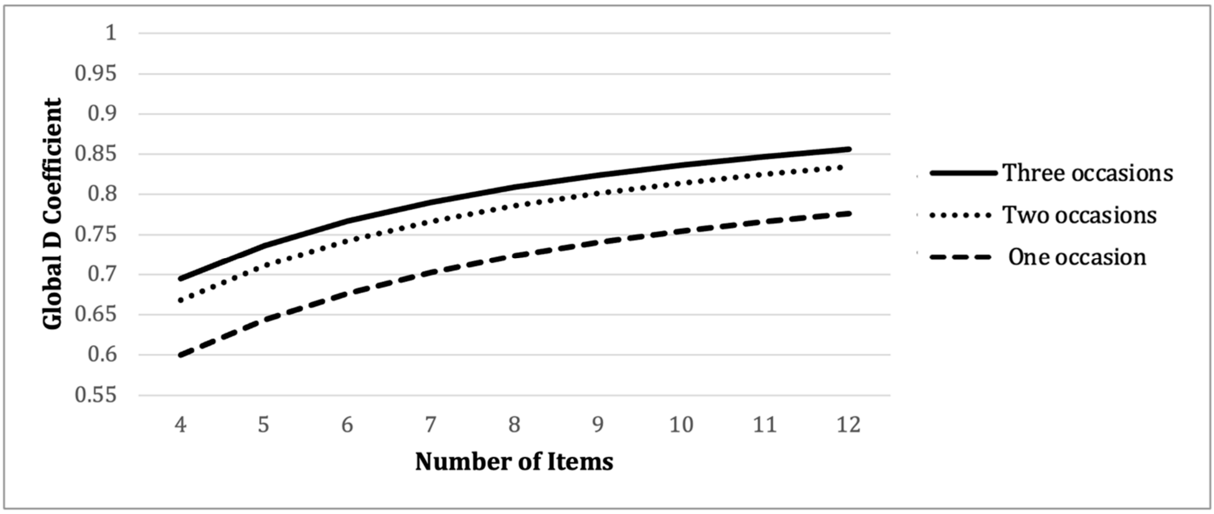


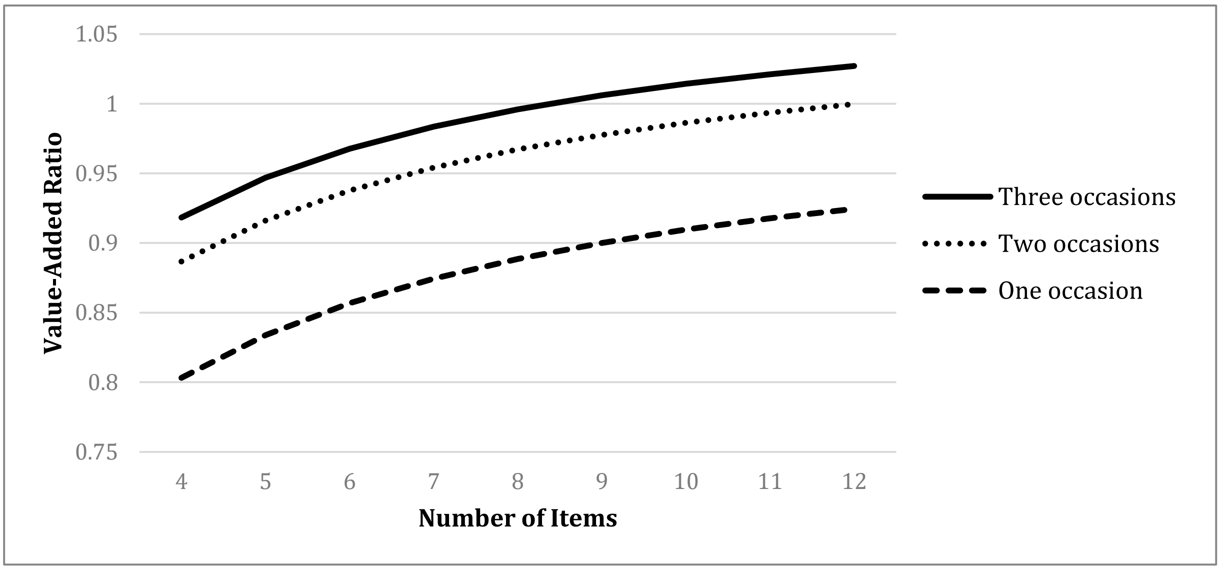

General
Group
General Factor Proportion/Group Factor Proportion
Number of Items
Three occasions
Two occasions
One occasion


Specific-Factor Error Proportion
Number of Items
Three occasions
Two occasions
One occasion


Transient Error Proportion
Number of Items
Three occasions
Two occasions
One occasion


0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Random-Response Error Proportion
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion


1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
Global D Coefficient
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion


1.05
1
0.95
0.9
0.85
0.8
0.75
Value-Added Ratio
4
5
6
7
8
9
10
11
12
Number of Items
Three occasions
Two occasions
One occasion

Abbreviations used throughout the supplement

GT: Generalizability theory

BFI-2: Big Five Inventory Form 2

G_COEF : G coefficient

SFE : Specific-factor error

TE: Transient error

RRE: Random-response error

Tot_E: Total error

PRMSE : Proportional reduction in mean squared error

VAR: Value-added ratio

References

Cronbach, L. J., Rajaratnam, N. & Gleser, G. C. (1963). Theory of generalizability: A liberalization of reliability theory. *British Journal of Statistical Psychology*, *16*(2), 137-163. https://doi.org/1.1111/j.2044-8317.1963.tb00206.x

Jorgensen, T. D., Pornprasertmanit, S., Schoemann, A. M., & Rosseel, Y. (2022). *semTools: Useful tools for structural equation modeling*. R package version 0.5-6. Retrieved from https://CRAN.R-project.org/package=semTools

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*(2), 1-36. https//doi.org/10.18637/jss.v048.i02

Soto, C. J., & John, O. P. (2017). The next Big Five Inventory (BFI-2): Developing and assessing a hierarchical model with 15 facets to enhance bandwidth, fidelity, and predictive power. *Journal of Personality and Social Psychology, 113*(1), 117–143. https://doi.org/ 1.1037/pspp0000096