Supplemental Material for
Bi-Factor Structure of the Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition

Marley W. Watkins A. Alexander Beaujean

9 July 2013

Contents

This document provides the syntax for the analyses using all the WPPSI-IV subtests as well the subtests that comprise the Primary Index scores. All data analysis was done using the **R** (version 3.0.1) statistical programming language (R Development Core Team, 2013), using the *lavaan* (version 0.5-13) (Rosseel, 2012) package. Below, we show the WPPSI-IV models and the *lavaan* syntax to fit the models using effects coding. In addition, Tables C and F show the fit statistics for each model using all the subtests as well as just the subtests used for the primary indices.

1 2:6-3:11 Year-Old Group

Coalson and Raiford (2012) performed factor analysis on two sets of variables. The first was with all seven subtests (Receptive Vocabulary, Picture Naming, Block Design, Object Assembly, Picture Memory, and Zoo Locations). The second only included the subtests that contribute to a primary index score, so Picture Naming was omitted. Models using the reduced dataset have *PI* in the name, e.g, `model1PI.model`.

The full covariance matrix for the 2:6-3:11 year-old group comes from Coalson and Raiford (2012, p. 70) and is stored in an **R** objected named `WPPSI2_3.cov` for the following analyses. For an example of how to input a covariance matrix into **R** for the purposes of a confirmatory factor analysis, see Beaujean (2013).

1.1 One first-order factor

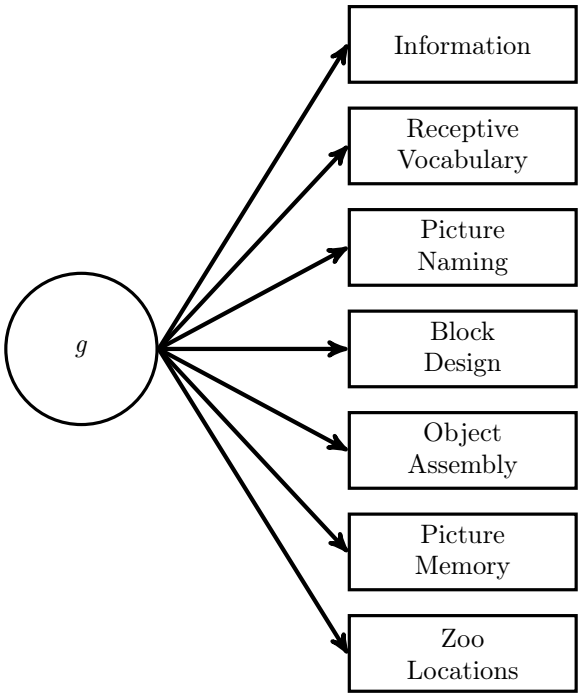

Figure 1: Model with one first-order factor for 2:6-3:11 year-old group. Residual errors not shown.

```
# Model 1: One first-order factor
model1.model <- '
g =~ NA*IN + a*IN + b*RV + c*PN + d*BD + e*OA + f*PM + g*Zl

# For effects coding
a+b+c+d+e+f+g==7
'
model1.fit <- cfa(model1.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600)

model1PI.model <- '
g =~ NA*IN + a*IN + b*RV +  c*BD + d*OA + e*PM + f*Zl

# For effects coding
a+b+c+d+e+f==6
'
model1PI.fit <- cfa(model1PI.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600)
```

1.2 One second-order factor and two first-order factors

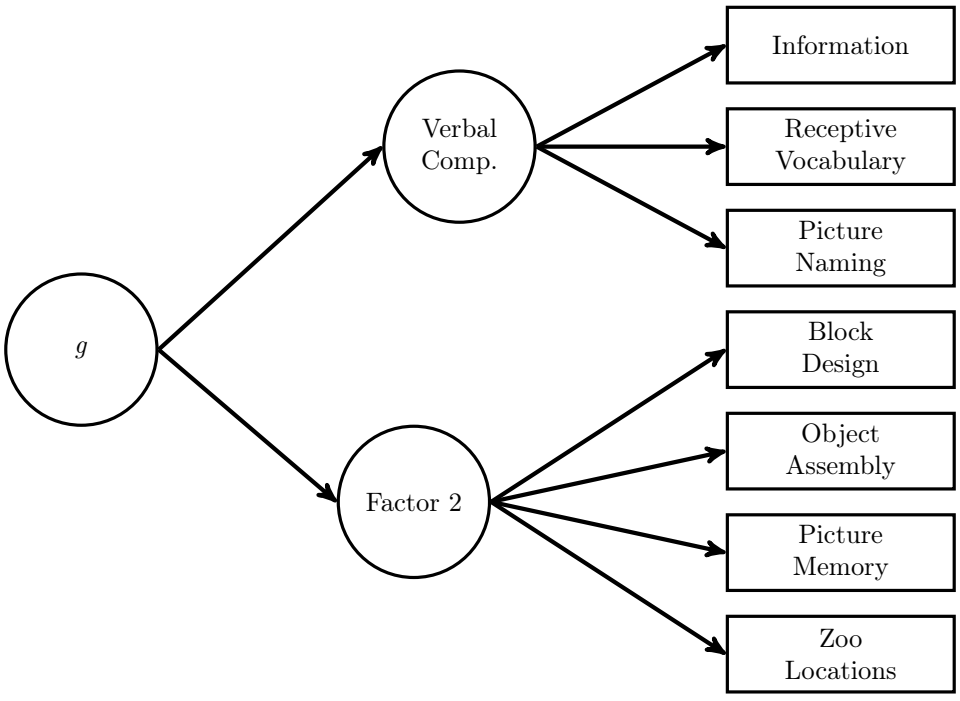

Figure 2: Model with one second-order factor and two first-order factors for 2:6-3:11 Year-Old Group. Residual errors not shown.

```
# Model 2: One second-order factor and two first-order factors
model2.model<-'
F1 =~ NA*IN + a*IN +  b*RV + c*PN
F2 =~ NA*BD + d*BD + e*OA + f*PM + g*Zl
g=~ NA*F1 + h*F1 + i*F2

# For effects coding
a+b+c+d+e+f+g+h+i==9
'
model2.fit<-cfa(model2.model, sample.cov=WPPSI2_3.cov, sample.nobs=600)


model2PI.model<-'
F1 =~ NA*IN + a*IN +  b*RV
F2 =~ NA*BD + c*BD + d*OA + e*PM + f*Zl
g=~ NA*F1 + g*F1 + h*F2

# For effects coding
a+b+c+d+e+f+g+h==8
'
model2PI.fit<-cfa(model2PI.model, sample.cov=WPPSI2_3.cov, sample.nobs=600)
```

1.3 One second-order factor and three first-order factors

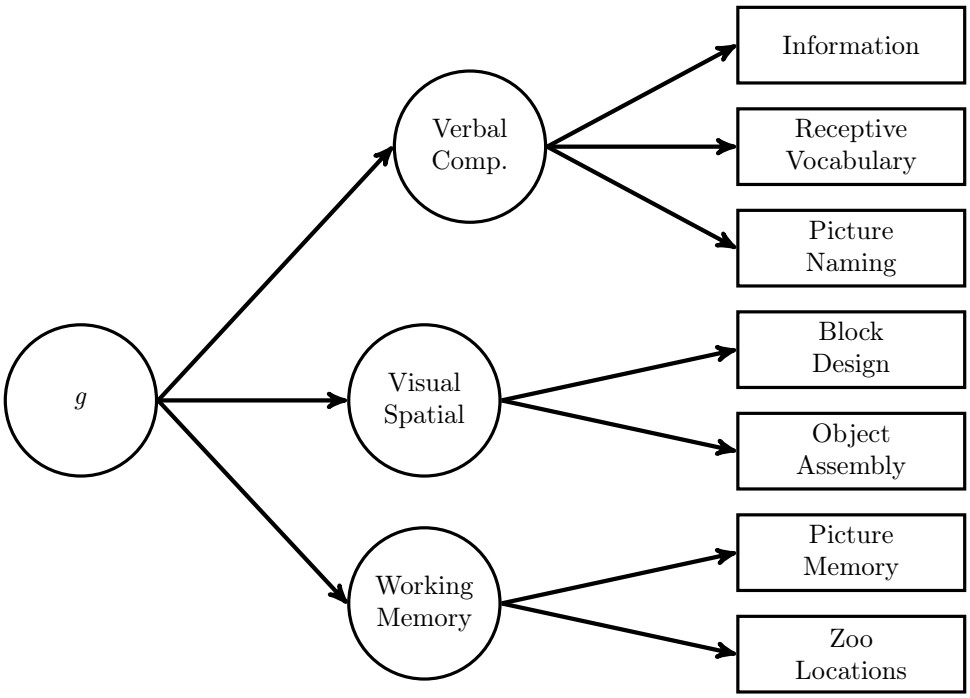

Figure 3: Model with one second-order factor and three first-order factors for 2:6-3:11 Year-Old Group. Residual errors not shown.

```
# Model 3: One second-order factor and three first-order factors
model3.model<-'
VC =~ NA*IN+ a*IN+ b*RV + c*PN
VS =~ NA*BD + d*BD + e*OA
WM =~ NA*PM + f*PM + g*Zl
g=~ NA*VC + h*VC + i*VS + j*WM

# Effects Coding
a+b+c+d+e+f+g+h+i+j==10
'
model3.fit <- cfa(model3.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600)

fitMeasures(model3.fit, fit.indices)


    chisq        df    pvalue       cfi     rmsea      srmr       aic
   25.460     8.000     0.001     0.987     0.060     0.020 20064.669



model3PI.model<-'
VC =~ NA*IN+ a*IN+ b*RV
VS =~ NA*BD + c*BD + d*OA
WM =~ NA*PM + e*PM + f*Zl
g=~ NA*VC + g*VC + h*VS + i*WM

# Effects Coding
a+b+c+d+e+f+g+h+i==9
'
model3PI.fit <- cfa(model3PI.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600)
```

1.4 Bi-factor model

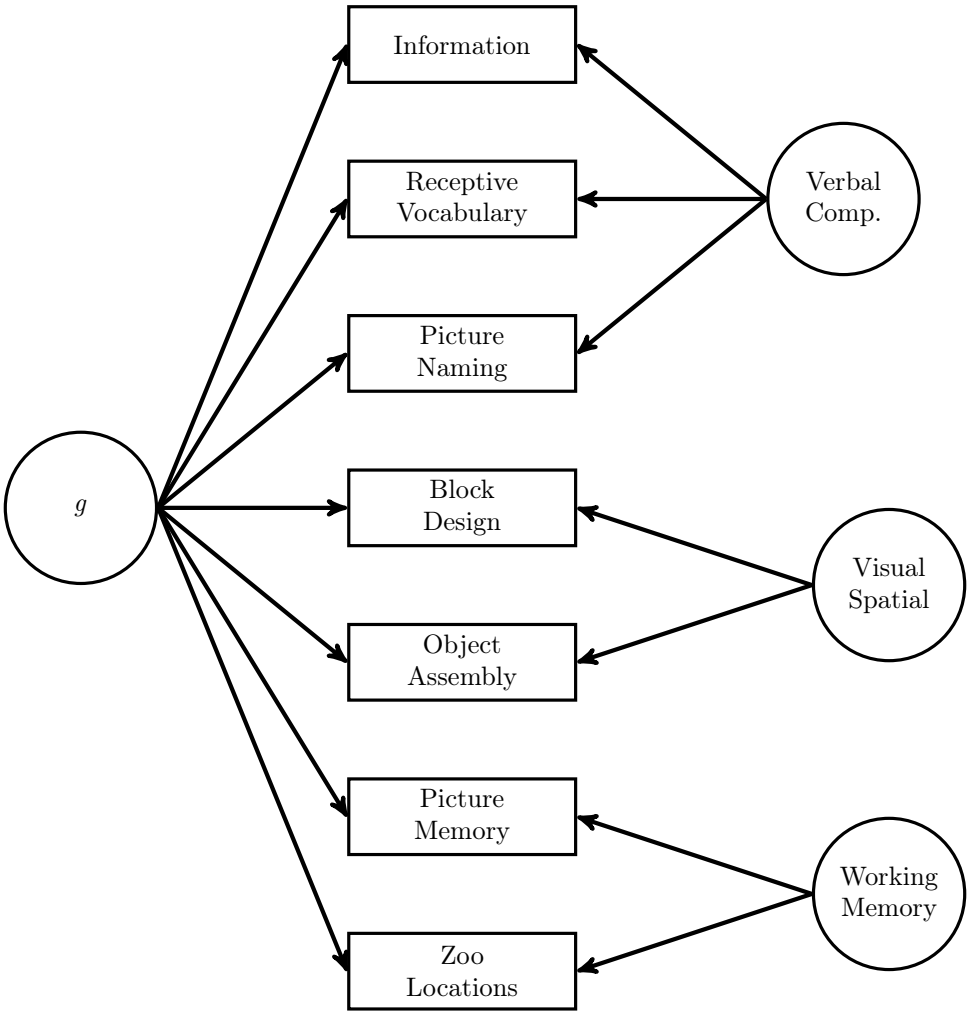

Figure 4: Bi-factor Factor Model for 2:6-3:11 year-old group. Residual errors not shown.

```
# Bi-factor
bifactor.model<-'
g =~ NA*IN + a*IN + b*RV + c*PN + d*BD + e*OA + f*PM + g*Zl
VC =~ NA*IN +h*IN + i*RV + j*PN
VS =~ NA*BD + k*BD + l*OA
WM =~ NA*PM + m*PM + n*Zl

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n==14
'
bifactor.fit<-cfa(bifactor.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600, orthogonal=TRUE)

bifactorPI.model<-'
g =~ NA*IN + a*IN + b*RV + c*BD + d*OA + e*PM + f*Zl
VC =~ NA*IN + g*IN + h*RV
```

```
# Constrain these to be equal for model identification
VS =~ NA*BD + i*BD + i*OA
WM =~ NA*PM + j*PM + j*Zl


# Effects Coding
a+b+c+d+e+f+g+h+i+j==10
'
bifactorPI.fit<-cfa(bifactorPI.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600, orthogonal=TRUE)
```

1.5 No second-order factor and three oblique first-order factors

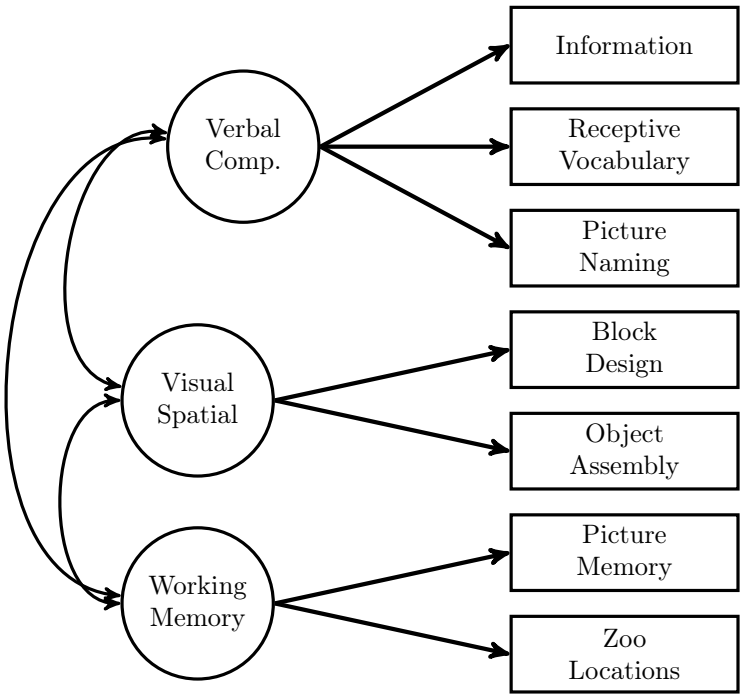

Figure 5: Model with no second-order factor and three oblique first-order factors for 2:6-3:11 year-old group. Residual errors not shown. The correlations among the factors are given in Table A and the variance explained and ω reliability estimates are given in Table B.

```
# Oblique Model--No second-order factor and three first-order factors
oblique.model<-'
VC =~ NA*IN+ a*IN+ b*RV + c*PN
VS =~ NA*BD + d*BD + e*OA
WM =~ NA*PM + f*PM + g*Zl

# Effects Coding
a+b+c+d+e+f+g==7
```

```
'
oblique.fit <- cfa(oblique.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600)

obliquePI.model<-'
VC =~ NA*IN + a*IN+ b*RV
VS =~ NA*BD + c*BD + d*OA
WM =~ NA*PM + e*PM + f*Zl
# Effects Coding
a+b+c+d+e+f==6
'
obliquePI.fit <- cfa(obliquePI.model, sample.cov=WPPSI2_3.cov,
sample.nobs=600)
```

Table A: Correlations among the latent variables for the oblique model for 2:6-3:11 year-old group.

All Subtests				
	Subtest	1	2	3
1.00	Verbal Comp.	1.00	0.81	0.78
2.00	Visual Spatial	0.81	1.00	0.85
3.00	Working Memory	0.78	0.85	1.00
Primary Index Subtests				
	Subtest	1	2	3
1.00	Verbal Comp.	1.00	0.85	0.84
2.00	Visual Spatial	0.85	1.00	0.84
3.00	Working Memory	0.84	0.84	1.00

Table B: Sources of Variance in the Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition Among 600 Children Aged 2:6 to 3:11 Years for the Oblique Mode.

	Ages 2:6-3:11 Years											
	VC		VS		WM		FR		PS			
Subtest	*b*	Var	*b*	Var	*b*	Var	*b*	Var	*b*	Var	h^2	u^2
IN	0.82	67.08									67.08	32.92
RV	0.72	52.27									52.27	47.73
PN	0.80	63.20									63.20	36.80
BD			0.66	43.69							43.69	56.31
OA			0.61	36.60							36.60	63.40
PM					0.70	49.28					49.28	50.72
ZL					0.51	26.32					26.32	73.68
Total		26.1		11.5		10.8						
ω		0.82		0.57		0.54						

Note. *b* = standardized factor loading, Var = % variance explained, h^2 = communality, u^2 = uniqueness, VC = Verbal Comprehension factor, VS = Visual-Spatial factor, WM = Working Memory factor, PS = Processing Speed factor, FR = Fluid Reasoning factor, IN = Information, RV = Receptive Vocabulary, PN = Picture Naming, BD = Block Design, OA = Object Assembly, PM = Picture Memory, ZL = Zoo Locations, ω = omega. ω estimated from the *omega* software program (Watkins, 2013).

Table C: Fit Statistics for the models used for the 2:6-3:11 year-old group data.

Model	χ^2	*df*	*p*	CFI	RMSEA	SRMR	AIC
All Subtests							
Model 1	70.17	14.00	0.00	0.96	0.08	0.04	20097.37
Model 2	31.46	10.00	0.00	0.98	0.06	0.02	20066.66
Model 3	25.46	8.00	0.00	0.99	0.06	0.02	20064.67
Bifactor	13.73	4.00	0.01	0.99	0.06	0.01	20060.94
Oblique	25.46	9.00	0.00	0.99	0.06	0.02	20062.67
Primary Index Subtests							
Model 1	22.19	9.00	0.01	0.99	0.05	0.03	17467.20
Model 2	9.82	5.00	0.08	0.99	0.04	0.02	17462.83
Model 3	2.92	3.00	0.40	1.00	0.00	0.01	17459.93
Bifactor	2.92	2.00	0.23	1.00	0.03	0.01	17461.93
Oblique	2.92	4.00	0.57	1.00	0.00	0.01	17457.93

CFI: comparative fit index; RMSEA: root mean square error of approximation; SRMR: standardized root mean square residual; AIC: Akaike's information criterion.

2 4:0-7:7 Year-Old Group

As with the 2:6-3:11 year-old group, Coalson and Raiford (2012) performed factor analysis on two sets of variables for the 4:0-7:7 year old group. The first was with all fifteen subtests (Information, Similarities, Vocabulary, Comprehension, Receptive Vocabulary, Picture Naming, Block Design, Object Assembly, Matrix Reasoning, Picture Concepts, Picture Memory, Zoo Locations, Bug Search, Cancellation, and Animal Coding). The second only included the subtests that contribute to a primary index score, so Vocabulary, Comprehension, Receptive Vocabulary, Picture Naming, and Animal Coding were omitted. In addition, the for reduced data, models with subfactors within the Verbal Comprehension factor are not estimable. Models using the reduced dataset have *PI* in the name, e.g, `model1PI.model`.

The full covariance matrix for the 4:0-7:7 year-old group comes from Coalson and Raiford (2012, p. 71) and is stored in an **R** objected named `WPPSI4_7.cov` for the following analyses. For an example of how to input a covariance matrix into **R** for the purposes of a confirmatory factor analysis, see Beaujean (2013).

2.1 One first-order factor

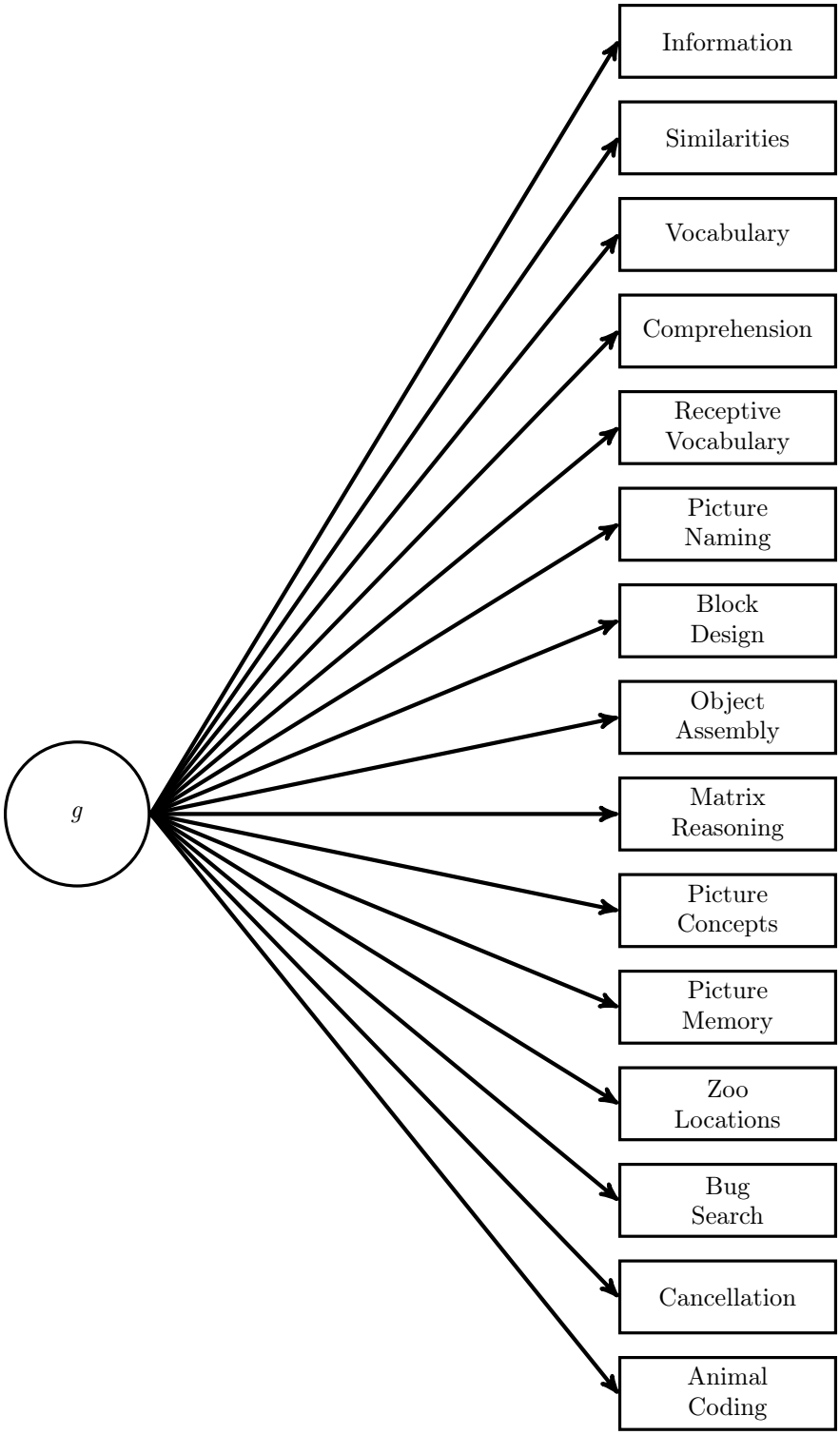

Figure 6: Single first-order factor model for 4:0-7:7 year-old group. Residual errors not shown.

```
#Model 1: One first-order factor
model1.model<-'
g =~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN + g*BD + h*OA + i*MR +
j*PC + k*PM + l*ZL + m*BS + n*CA + o*AC
# Effects Coding
a+b+c+d+e+f+h+i+j+k+l+m+n+o==15
'
model1.fit <- cfa(model1.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)

model1PI.model<-'
g =~ NA*IN + a*IN + b*SI + c*BD + d*OA + e*MR + f*PC + g*PM +
h*ZL + i*BS + j*CA
# Effects Coding
a+b+c+d+e+f+h+i+j==10
'
model1PI.fit <- cfa(model1PI.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)
```

2.2 One second-order factor and two first-order factors

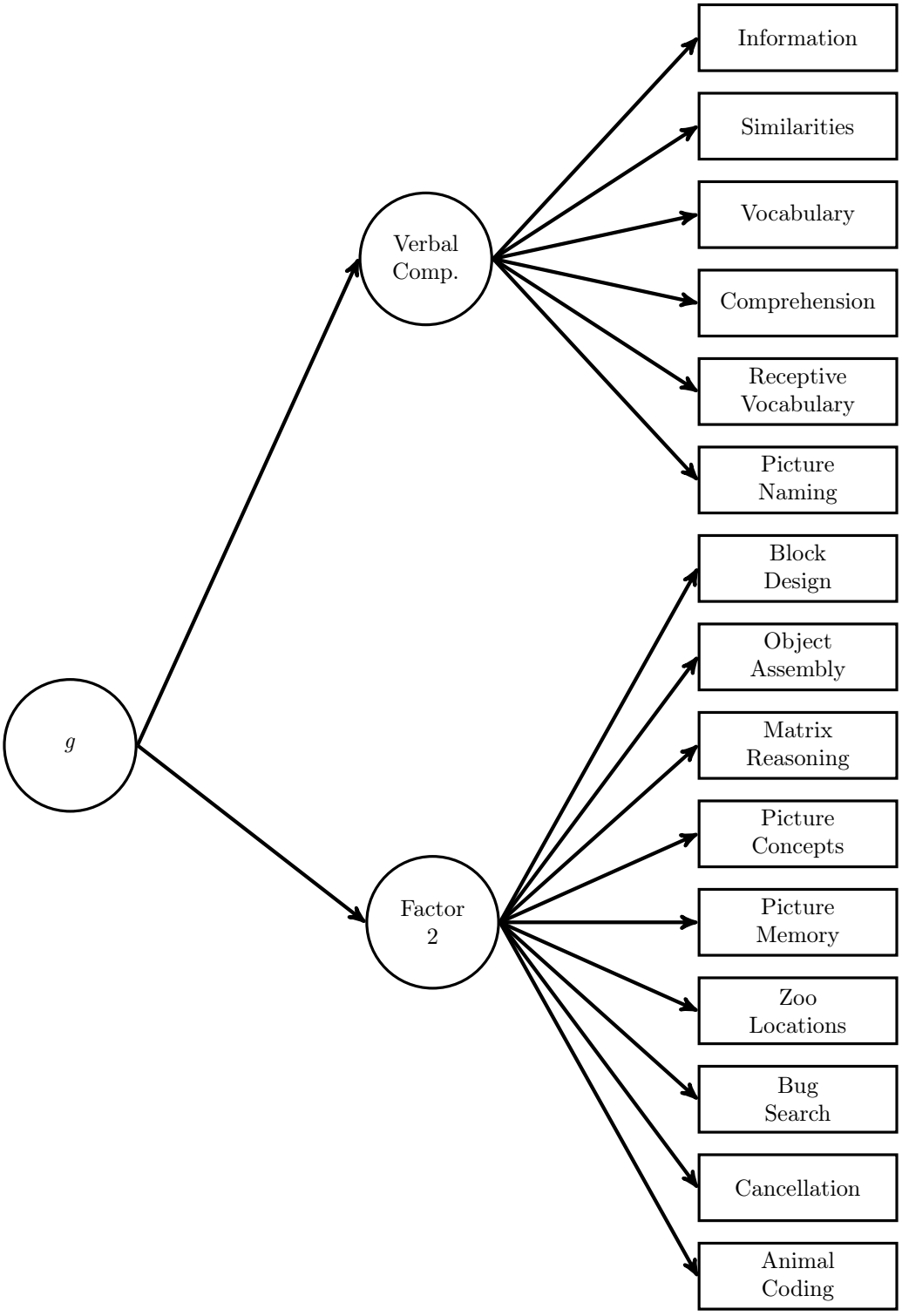

Figure 7: Model with one second-order factor and two first-order factors for 4:0-7:7 year-old group. Residual errors not shown.

```
# Model 2: One second-order factor and two first-order factors
model2.model<-'
VCo =~ NA*IN + a*IN+ b*SI + c*VC + d*CO + e*RV + f*PN
F2 =~ NA*BD + g*BD + h*OA + i*MR + j*PC + k*PM + l*ZL + m*BS + n*CA + o*AC
g =~ NA*VCo + p*VCo + q*F2
# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o+p+q==17
'
model2.fit<-cfa(model2.model, sample.cov=WPPSI4_7.cov, sample.nobs=1100)

model2PI.model<-'
VCo =~ NA*IN + a*IN+ b*SI
F2 =~ NA*BD+ c*BD + d*OA + e*MR + f*PC + g*PM + h*ZL + i*BS + j*CA
g=~NA*VCo + k*VCo + l*F2
# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l==12
'
model2PI.fit<-cfa(model2.model, sample.cov=WPPSI4_7.cov, sample.nobs=1100)
```

2.3 One second-order factor and three first-order factors

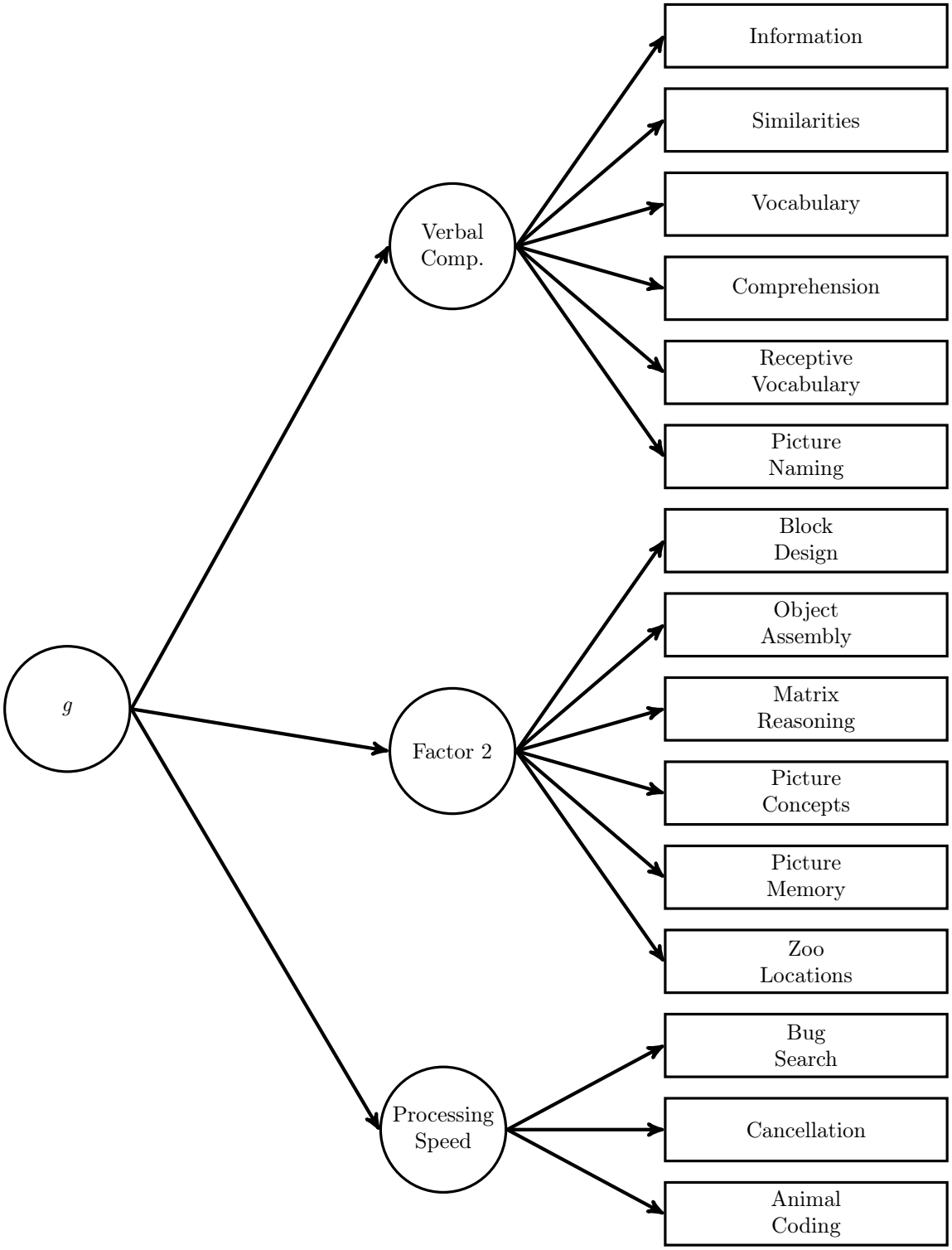

Figure 8: Model with one second-order factor and three first-order factors for 4:0-7:7 year-old group. Residual errors not shown.

```
#Model 3: One second-order factor and three first-order factors
model3.model<-'
VCo=~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN
F2 =~ NA*BD + g*BD + h*OA + i*MR + j*PC + k*PM + l*ZL
PS =~ NA*BS + m*BS + n*CA + o*AC
g =~ NA*VCo + p*VCo + q*F2 + r*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o+p+q+r==18
'
model3.fit <- cfa(model3.model, sample.cov=WPPSI4_7.cov, sample.nobs=1100)

model3PI.model<-'
VCo=~ NA*IN + a*IN + b*SI
F2 =~ NA*BD + c*BD + d*OA + e*MR + f*PC + g*PM + h*ZL
PS =~ NA*BS + i*BS + j*CA
g =~ NA*VCo + k*VCo + l*F2 + m*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m==13
'
model3PI.fit<-cfa(model3PI.model, sample.cov=WPPSI4_7.cov, sample.nobs=1100)
```

2.4 One second-order factor and four first-order factors, version 1

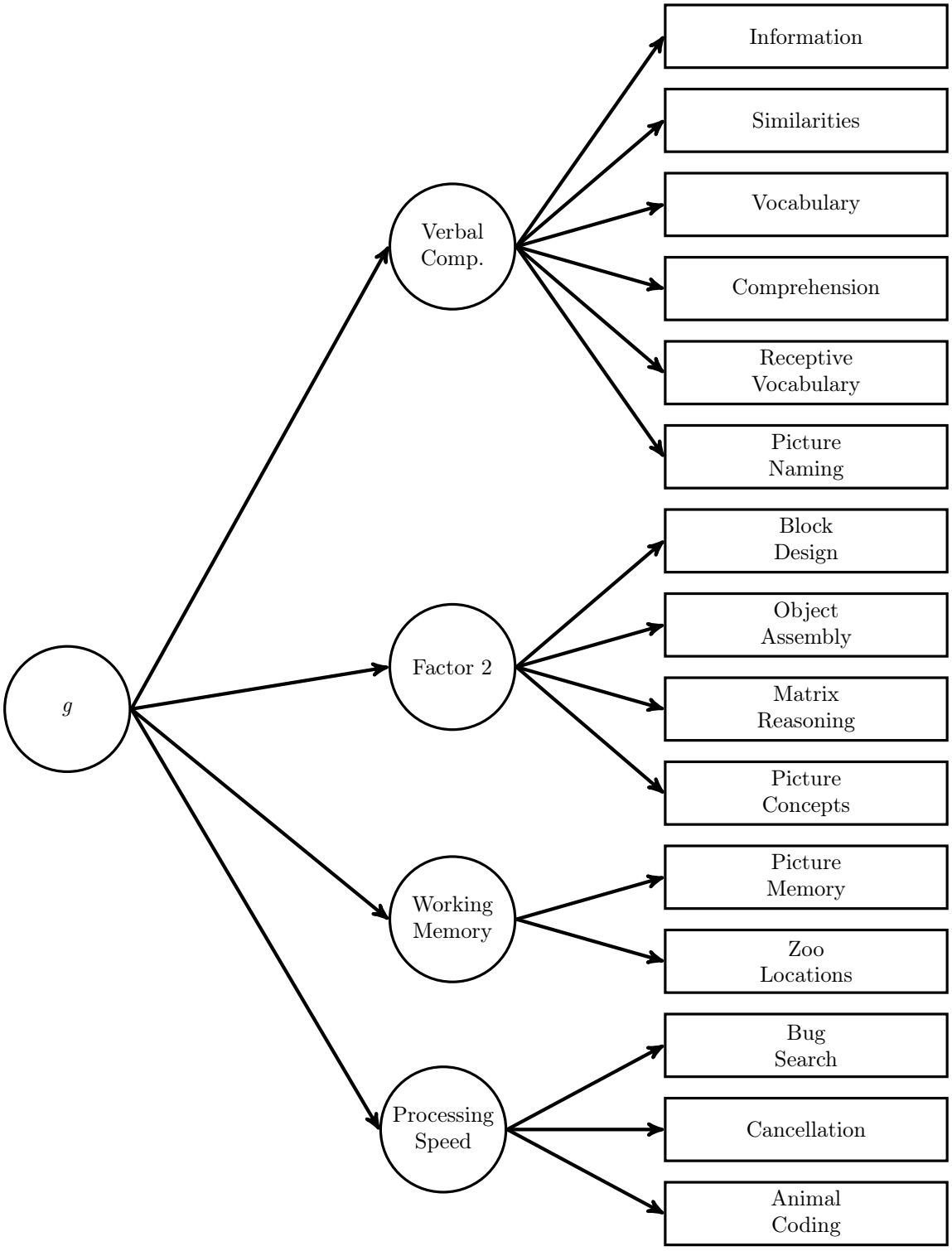

Figure 9: Model with one second-order factor and four first-order factors (version 1) for 4:0-7:7 year-old group. Residual errors not shown.

```
# Model 4a: One second-order factor and four first-order factors, version 1
model4a.model<-'
VCo=~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN
F2 =~ NA*BD + g*BD + h*OA + i*MR + j*PC
WM =~ NA*PM + k*PM + l*ZL
PS =~ NA*BS + m*BS + n*CA + o*AC
g =~ NA*VCo + p*VCo + q*F2 + r*WM + s*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o+p+q+r+s==19
'
model4a.fit<-cfa(model4a.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)

model4aPI.model<-'
VCo=~ NA*IN + a*IN + b*SI
F2 =~ NA*BD + c*BD + d*OA + e*MR + f*PC
WM =~ NA*PM + g*PM + h*ZL
PS =~ NA*BS + i*BS + j*CA
g =~ NA*VCo + k*VCo + l*F2 + m*WM + n*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n==14
'
model4aPI.fit<-cfa(model4aPI.model, sample.cov=WPPSI4_7.cov, sample.nobs=1100)
```

2.5 One second-order factor and four first-order factors, version 2

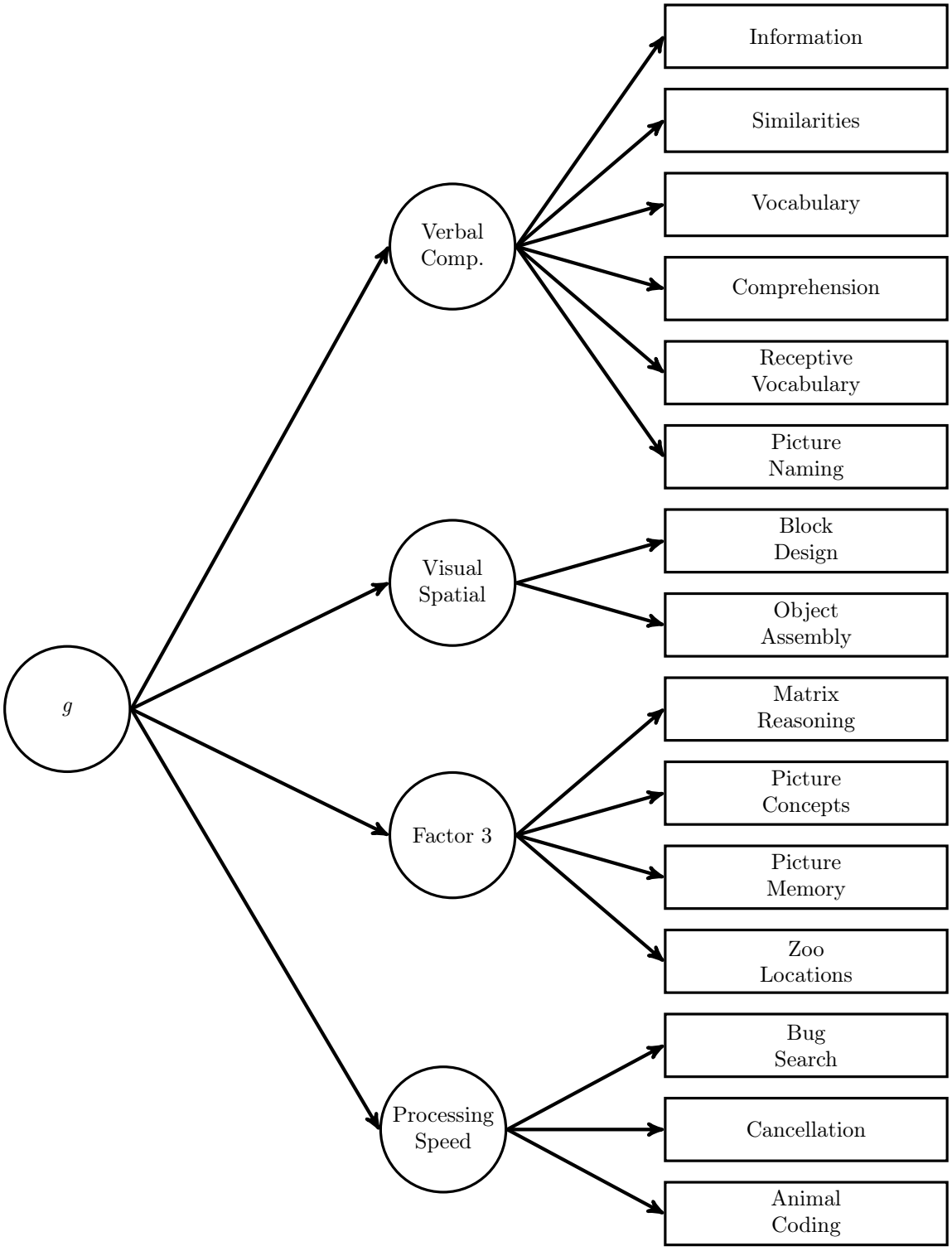

Figure 10: Model with one second-order factor and four first-order factors (version 2) for 4:0-7:7 year-old group. Residual errors not shown.

```
# Model 4b: One second-order factor and four first-order factors, version 2
model4b.model<-'
VCo =~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN
VS =~ NA*BD + g*BD + h*OA
F3 =~ NA*MR + i*MR + j*PC + k*PM + l*ZL
PS =~ NA*BS + m*BS + n*CA + o*AC
g =~ NA*VCo + p*VCo + q*VS + r*F3 + s*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o+p+q+r+s==19
'
model4b.fit<-cfa(model4b.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)

model4bPI.model<-'
VCo =~ NA*IN + a*IN + b*SI
VS =~ NA*BD + c*BD + d*OA
F3 =~ NA*MR + e*MR + f*PC + g*PM + h*ZL
PS =~ NA*BS + i*BS + j*CA
g =~ NA*VCo + k*VCo + l*VS + m*F3 + n*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n==14
'
model4bPI.fit<-cfa(model4bPI.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)
```

2.6 One second-order factor and five first-order factors

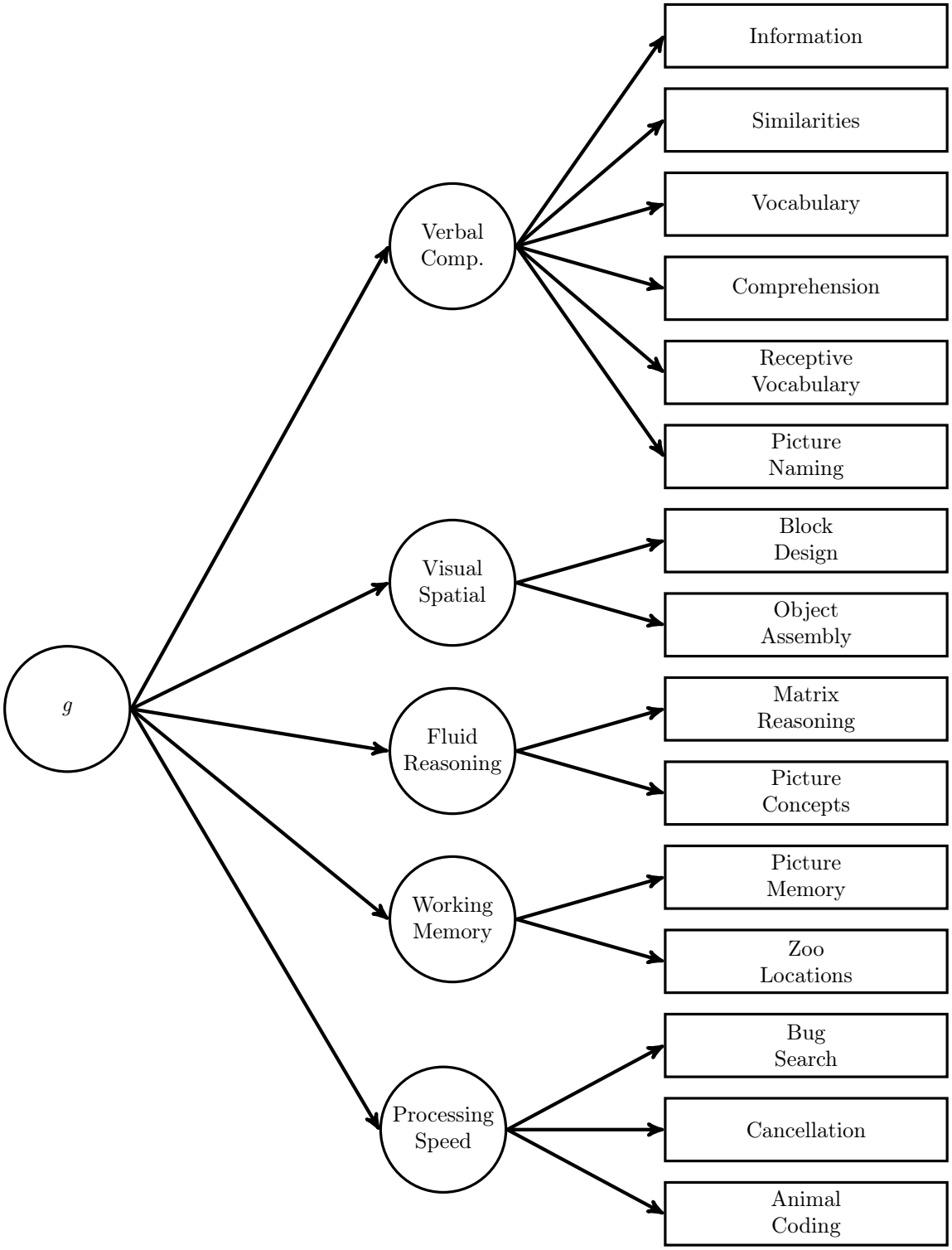

Figure 11: Model with one second-order factor and five first-order factors for 4:0-7:7 year-old group. Residual errors not shown.

```
# Model 5a: One second-order factor and five first-order factors
model5a.model<-'
VCo =~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN
VS =~ NA*BD + g*BD + h*OA
FR =~ NA*MR + i*MR + j*PC
WM =~ NA*PM + k*PM + l*ZL
PS =~ NA*BS + m*BS + n*CA + o*AC
g =~ NA*VCo + p*VCo + q*VS + r*FR + s*WM + t*PS

# Constraint to prevent negative variance
VCo~~u*VCo
u >0

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o+p+q+r+s+t==20
'
model5a.fit<-cfa(model5a.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)

model5aPI.model<-'
VCo =~ NA*IN + a*IN + b*SI
VS =~ NA*BD + c*BD + d*OA
FR =~ NA*MR + e*MR + f*PC
WM =~ NA*PM + g*PM + h*ZL
PS =~ NA*BS + i*BS + j*CA
g =~ NA*VCo + k*VCo + l*VS + m*FR + n*WM + o*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o==15
'
model5aPI.fit<-cfa(model5aPI.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)
```

2.7 One second-order factor, five first-order factors, and two subfactors nested within Verbal Comprehension

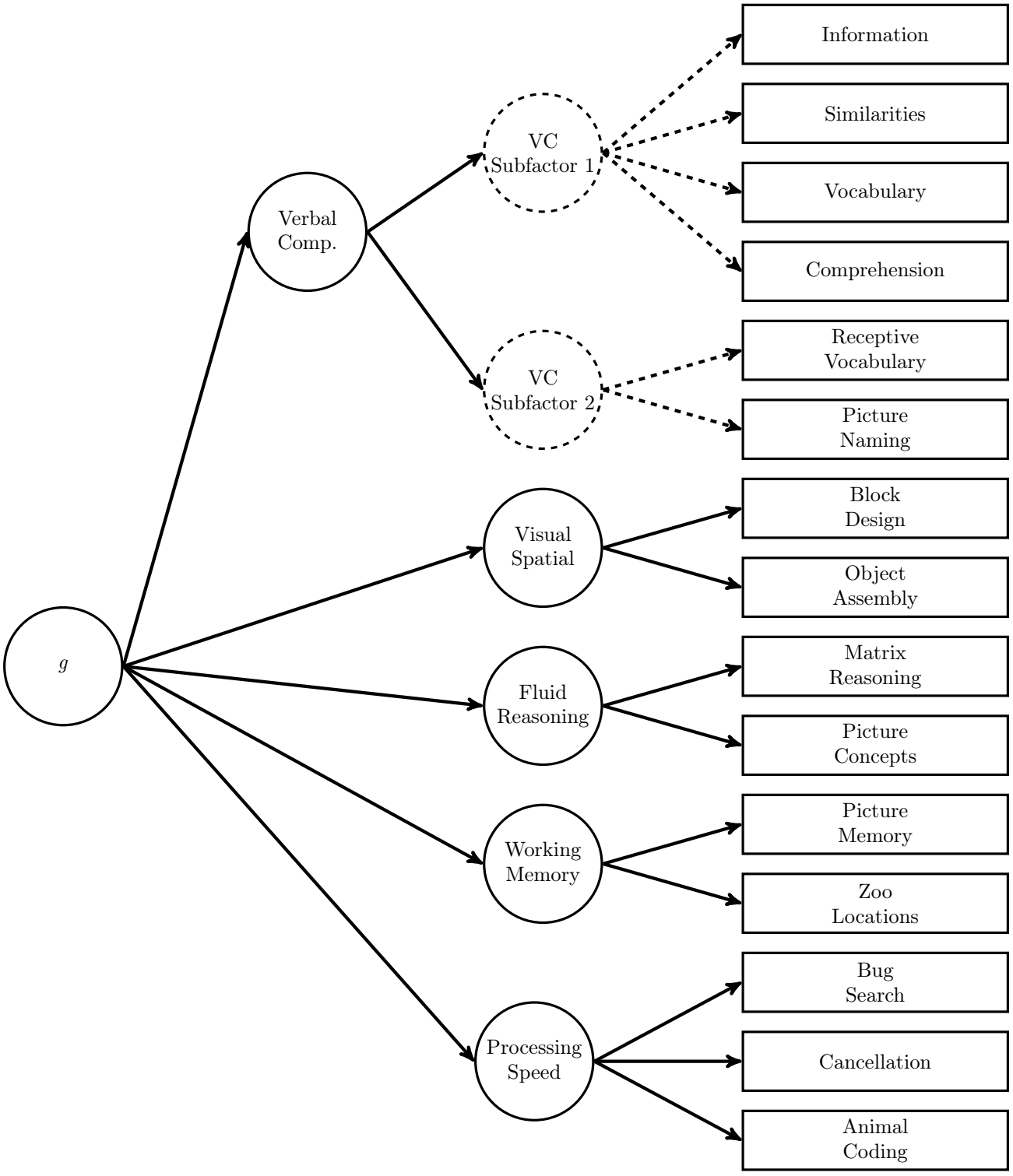

Figure 12: Model with one second-order factor, five first-order factors, and two subfactors nested within Verbal Comprehension for 4:0-7:7 year-old group. Residual errors not shown.

```
# Model 5b: One second-order factor, five first-order factors,
# and two subfactors nested within Verbal Comprehension
model5b.model<-'
VCo1 =~ NA*IN + a*IN+ b*SI + c*VC + d*CO
VCo2 =~ NA*RV+ e*RV + f*PN
VCo =~ NA*VCo1 + g*VCo1 + h*VCo2
VS =~ NA*BD + i*BD + j*OA
FR =~ NA*MR + k*MR + l*PC
WM =~ NA*PM + m*PM + n*ZL
PS =~ NA*BS + o*BS + p*CA + q*AC
g =~ NA*VCo + r*VCo + s*VS + t*FR + u*WM + v*PS

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o+p+q+r+s+t+u+v==22
'
model5b.fit<-cfa(model5b.model, sample.cov=WPPSI4_7.cov, sample.nobs=1100)
```

2.8 Bi-factor model with one Verbal Comprehension factor

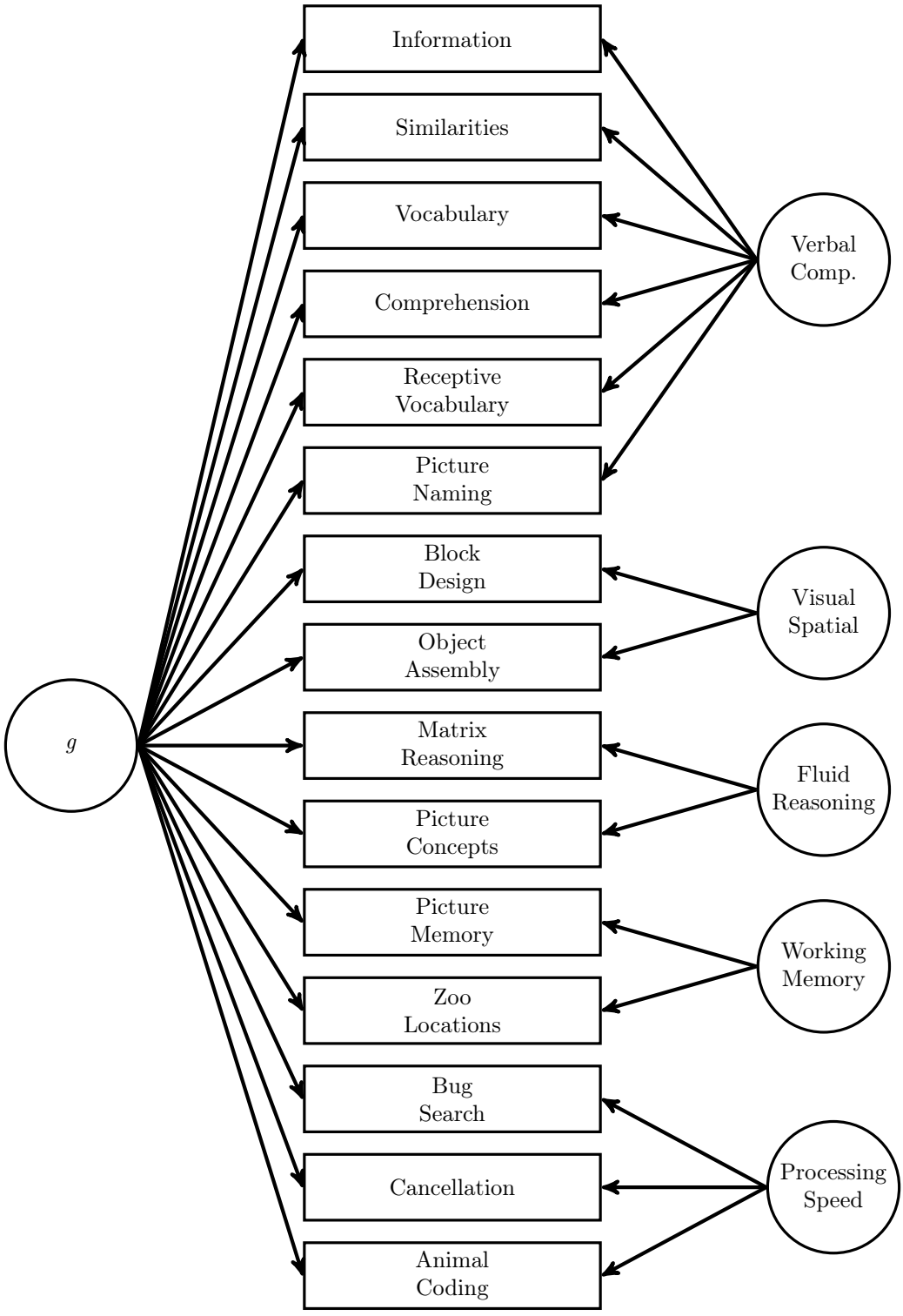

Figure 13: Bi-factor model 1 for 4:0-7:7 year-old group. Residual errors not shown.

```
# Bi-factor model with VCo, PS, VS, FR, and WM domain factors
# No VCo subfactors
biFactor1.model<-'
g =~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN + g*BD + h*OA + i*MR +
j*PC + k*PM + l*ZL + m*BS + n*CA + o*AC
VCo =~ NA*IN + p*IN + q*SI + r*VC + s*CO + t*RV + u*PN
PS =~ NA*BS + w*BS + y*CA + z*AC
VS =~ NA*BD + aa*BD + bb*OA
FR =~ NA*MR + cc*MR + dd*PC
WM =~ NA*PM + ee*PM + ff*ZL

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o==15
p+q+r+s+t+u==6
w+y+z==3
aa+bb==2
cc+dd==2
ee+ff==2
'
biFactor1.fit<-cfa(biFactor1.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100, orthogonal=TRUE)

biFactor1PI.model<-'
g =~ NA*IN + a*IN + b*SI + c*BD + d*OA + e*MR + f*PC + g*PM + h*ZL +
i*BS + j*CA
VCo =~ NA*IN + k*IN + l*SI
PS =~ NA*BS + m*BS + n*CA
VS =~ NA*BD + o*BD + p*OA
FR =~ NA*MR + q*MR + r*PC
WM =~ NA*PM + s*PM + t*ZL

# Effects Coding
a+b+c+d+e+f+g+h+i+j==10
k+l==2
m+n==2
o+o==2
q+r==2
s+t==2
'
biFactor1PI.fit<-cfa(biFactor1PI.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100, orthogonal=TRUE)
```

2.9 Bi-factor model with two Verbal Comprehension subfactors

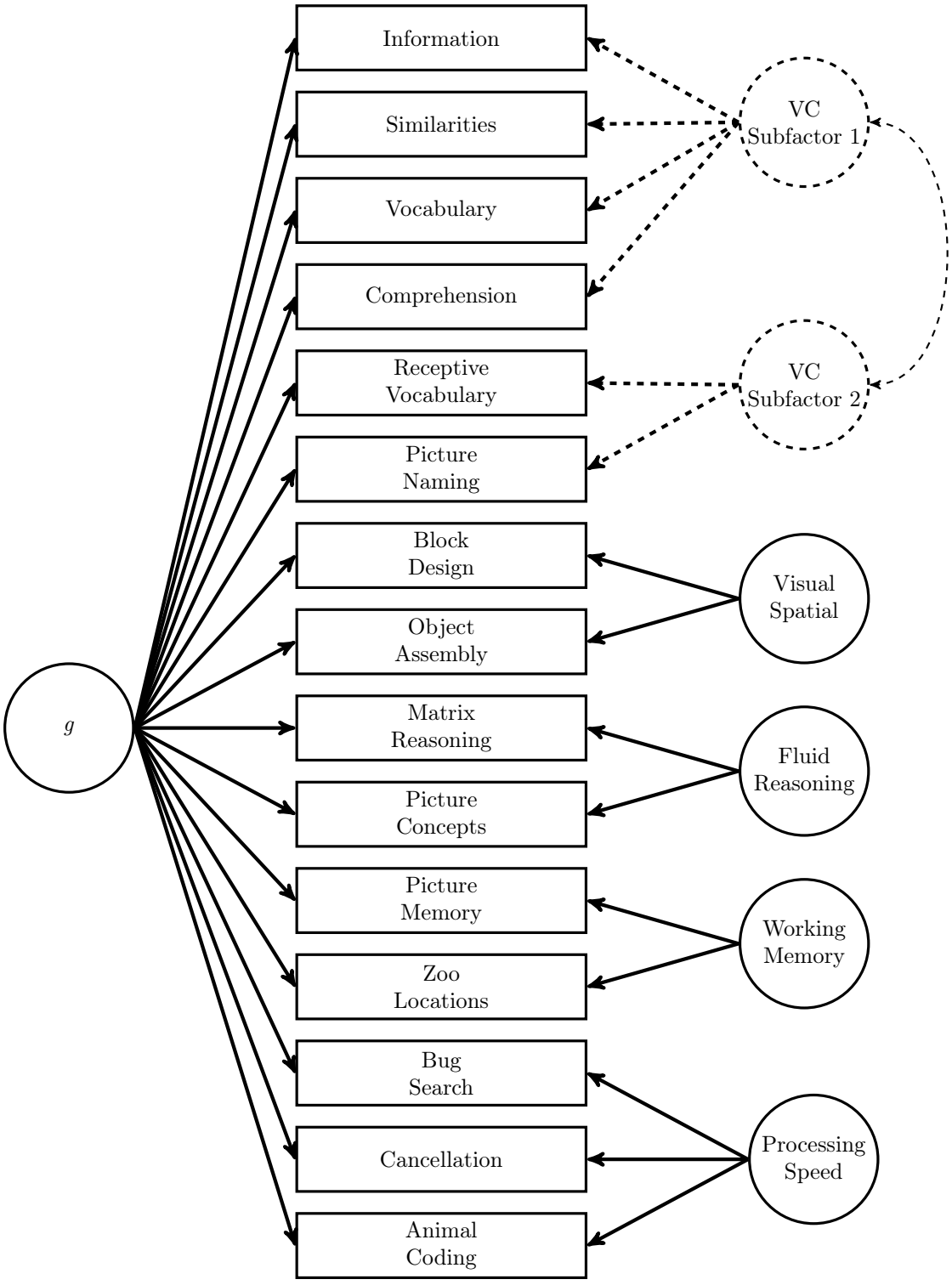

Figure 14: Bi-factor model 2 for 4:0-7:7 year-old group. Residual errors not shown.

```
# Bi factor model with PS, WM, FR, PS and 2 oblique VCo domain factors
# that are allowed to correlate
biFactor2.model<-'
g =~ NA*IN + a*IN + b*SI + c*VC + d*CO + e*RV + f*PN + g*BD + h*OA + i*MR +
 j*PC + k*PM + l*ZL + m*BS + n*CA + o*AC
VCo1 =~ NA*IN + p*IN + q*SI + r*VC + s*CO
VCo2 =~ NA*RV + t*RV + u*PN
PS =~ NA*BS + v*BS + w*CA + y*AC
VS =~ NA*BD + aa*BD + bb*OA
FR =~ NA*MR + cc*MR + dd*PC
WM =~ NA*PM + ee*PM + ff*ZL

g ~~ 0*PS + 0*VCo1 + 0*VCo2 + 0*VS + 0*FR + 0*WM
PS ~~ 0*VCo1 + 0*VCo2 + 0*VS + 0*FR + 0*WM
VCo1 ~~ 0*VS + 0*FR + 0*WM
VCo2 ~~ 0*VS + 0*FR + 0*WM
VS ~~ 0*FR + 0*WM
FR ~~0*WM

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o==15
p+q+r+s==4
t+u==2
v+w+y==3
aa+bb==2
cc+dd==2
ee+ff==2
'
biFactor2.fit<-cfa(biFactor2.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100, control=list(rel.tol=.000001))
```

2.10 No second-order factor and five oblique first-order factors

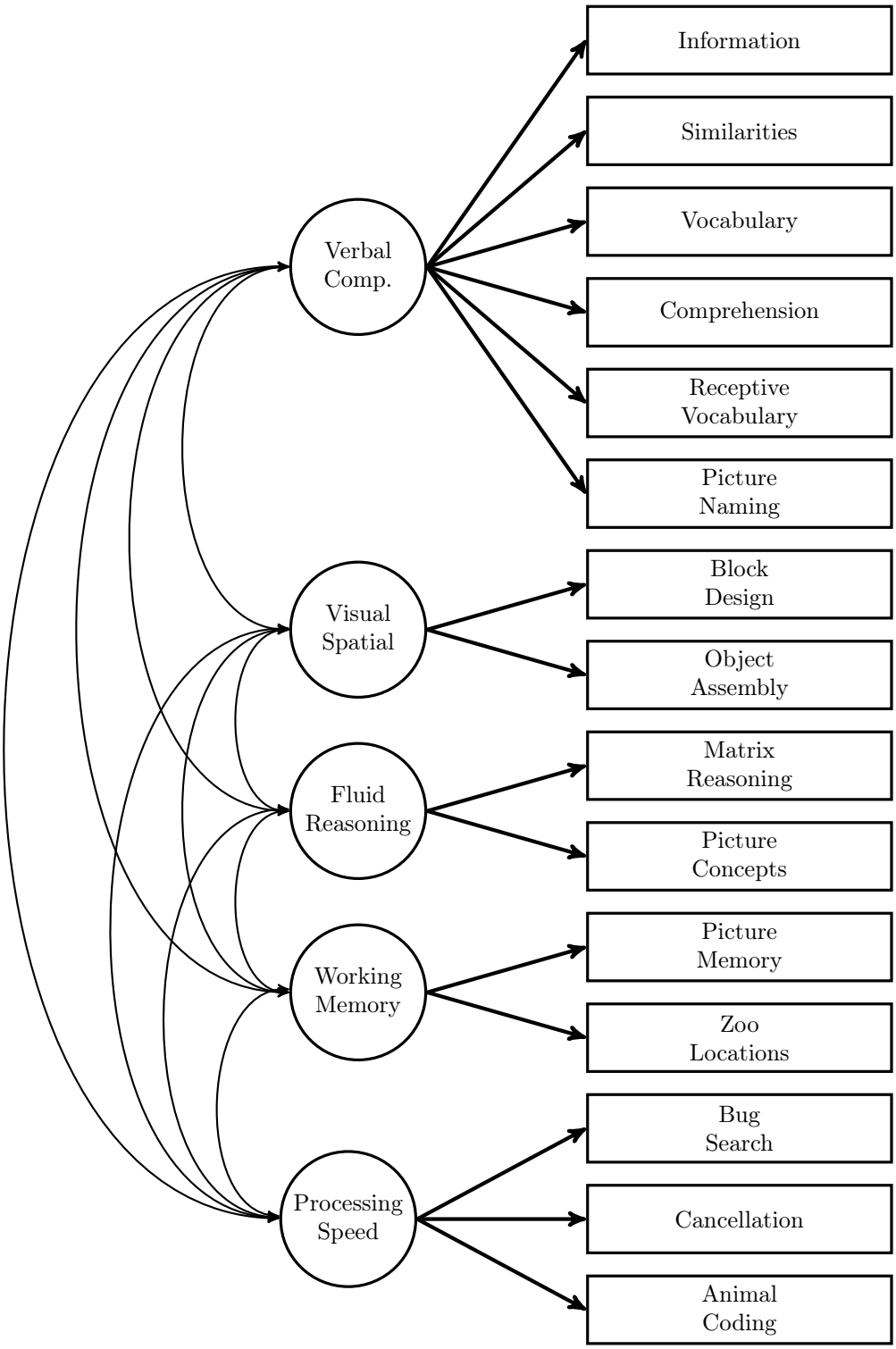

Figure 15: Model with no second-order factors and five oblique first-order factors for 4:0-7:7 year-old group. Residual errors not shown. Correlations among the factors are given in Table D and the variance explained and ω reliability estimates are given in Table E.

```
# Oblique model: No second-order factor and five correlated first-order factors
oblique.model<-'
VCo =~ NA*IN + a*IN+ b*SI + c*VC + d*CO + e*RV + f*PN
VS =~ NA*BD + g*BD + h*OA
FR =~ NA*MR + i*MR + j*PC
WM =~ NA*PM + k*PM + l*ZL
PS =~ NA*BS + m*BS + n*CA + o*AC

# Effects Coding
a+b+c+d+e+f+g+h+i+j+k+l+m+n+o==15
'
oblique.fit<-cfa(oblique.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)

obliquePI.model<-'
VCo =~ NA*IN + a*IN+ b*SI
VS =~ NA*BD + c*BD + d*OA
FR =~ NA*MR + e*MR + f*PC
WM =~ NA*PM + g*PM + h*ZL
PS =~ NA*BS + i*BS + j*CA

# Effects Coding
a+b+c+d+e+f+g+h+i+j==10
'
obliquePI.fit<-cfa(obliquePI.model, sample.cov=WPPSI4_7.cov,
sample.nobs=1100)
```

Table D: Correlations among the latent variables for the oblique model for 4:0-7:7 year-old group.

	All Subtests					
	Subtest	1	2	3	4	5
1.00	Verbal Comp.	1.00	0.77	0.82	0.72	0.60
2.00	Visual Spatial	0.77	1.00	0.88	0.81	0.67
3.00	Fluid Reasoning	0.82	0.88	1.00	0.87	0.69
4.00	Working Memory	0.72	0.81	0.87	1.00	0.76
5.00	Processing Speed	0.60	0.67	0.69	0.76	1.00
	Primary Index Subtests					
	Subtest	1	2	3	4	5
1.00	Verbal Comp.	1.00	0.78	0.81	0.72	0.60
2.00	Visual Spatial	0.78	1.00	0.87	0.81	0.68
3.00	Fluid Reasoning	0.81	0.87	1.00	0.86	0.69
4.00	Working Memory	0.72	0.81	0.86	1.00	0.76
5.00	Processing Speed	0.60	0.68	0.69	0.76	1.00

Table E: Sources of Variance in the Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition Among 1,100 Children Aged 4:00-7:7 Years for the Oblique Mode.

	Ages 2:6-3:11 Years											
	VC		VS		WM		FR		PS			
Subtest	*b*	Var	*b*	Var	*b*	Var	*b*	Var	*b*	Var	h^2	u^2
IN	0.80	63.52									63.52	36.48
SI	0.81	65.93									65.93	34.07
VO	0.79	61.78									61.78	38.22
CO	0.76	57.76									57.76	42.24
RV	0.70	48.72									48.72	51.28
PN	0.75	55.95									55.95	44.05
BD			0.74	54.46							54.46	45.54
OA			0.69	47.75							47.75	52.25
MR							0.72	51.12			51.12	48.88
PC							0.62	37.82			37.82	62.18
PM					0.68	46.10					46.10	53.90
ZL					0.60	36.36					36.36	63.64
BS									0.77	59.75	59.75	40.25
CA									0.60	36.36	36.36	63.64
AC									0.70	48.86	48.86	51.14
Total		23.60		6.80		5.90		5.50		9.70		
ω		0.90		0.68		0.61		0.58		0.74		

Note. *b* = standardized factor loading, Var = % variance explained, h^2 = communality, u^2 = uniqueness, VC = Verbal Comprehension factor, VS = Visual-Spatial factor, WM = Working Memory factor, PS = Processing Speed factor, FR = Fluid Reasoning factor, IN = Information, RV = Receptive Vocabulary, PN = Picture Naming, BD = Block Design, OA = Object Assembly, PM = Picture Memory, ZL = Zoo Locations, SI = Similarities, VO = Vocabulary, CO = Comprehension, MR = Matrix Reasoning, PC = Picture Concepts, BS = Bug Search, CA = Cancellation, AC = Animal Coding, ω = omega. ω estimated from the *omega* software program (Watkins, 2013).

Table F: Fit Statistics for the models used for the 4:0-7:7 year-old group data.

Model	χ^2	*df*	*p*	CFI	RMSEA	SRMR	AIC
All Subtests							
Model 1	950.32	90.00	0.00	0.88	0.09	0.06	76677.51
Model 2	500.34	86.00	0.00	0.94	0.07	0.04	76235.54
Model 3	284.59	84.00	0.00	0.97	0.05	0.03	76023.79
Model 4a	270.11	82.00	0.00	0.97	0.05	0.03	76013.30
Model 4b	263.22	82.00	0.00	0.97	0.04	0.03	76006.42
Model 5a	249.64	80.00	0.00	0.98	0.04	0.03	75996.84
Model 5b	212.03	76.00	0.00	0.98	0.04	0.02	75967.23
Bifactor 1	231.47	75.00	0.00	0.98	0.04	0.02	75998.66
Bifactor 2	191.61	74.00	0.00	0.98	0.04	0.02	75962.81
Oblique	232.23	76.00	0.00	0.98	0.04	0.02	75987.42
Primary Index Subtests							
Model 1	310.52	35.00	0.00	0.92	0.08	0.04	51972.36
Model 2	500.34	86.00	0.00	0.94	0.07	0.04	76235.54
Model 3	104.26	29.00	0.00	0.98	0.05	0.03	51778.10
Model 4a	91.46	27.00	0.00	0.98	0.05	0.02	51769.30
Model 4b	85.55	27.00	0.00	0.98	0.04	0.02	51763.39
Model 5a	70.59	25.00	0.00	0.99	0.04	0.02	51752.43
Bifactor 1	70.59	25.00	0.00	0.99	0.04	0.02	51762.43
Oblique	56.64	21.00	0.00	0.99	0.04	0.02	51746.48

CFI: comparative fit index; RMSEA: root mean square error of approximation; SRMR: standardized root mean square residual; AIC: Akaike's information criterion.

References

Beaujean, A. A. (2013). Factor analysis using R. *Practical Assessment, Research and Evaluation*, *18*(4), 1-11.

Coalson, D. L., & Raiford, S. E. (2012). *Wechsler preschool and primary scale of intelligence technical and Interpretive manual* (4th ed.). San Antonio, TX: The Psychological Corporation.

R Development Core Team. (2013). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing. Available from `http://www.R-project.org`.

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(2), 1-36.

Watkins, M. W. (2013). Omega [Computer software]. Phoenix, AZ: Ed & Psych Associates.