Confirmatory Factor Analysis on the Twin Data: Try One

```
/************ twinfac2.sas ******************/

TITLE2 'Confirmatory  Factor Analysis';

%include 'twinread.sas';

proc calis corr;                    /* Analyze the correlation matrix */
     var progmat reason verbal      /* Name the observed vars */
         headlng headbrd headcir bizyg height weight;
     lineqs
         progmat = lambda1 F1 + e1,
         reason  = lambda2 F1 + e2,
         verbal  = lambda3 F1 + e3,
         headlng = lambda4 F2 + e4,
         headbrd = lambda5 F2 + e5,
         headcir = lambda6 F2 + e6,
         bizyg   = lambda7 F2 + e7,
         height  = lambda8 F2 + e8,
         weight  = lambda9 F2 + e9;
     std     /* Variances (not standard deviations) of exogenous vars */
         F1 F2 = 2 * 1, e1-e9 = 9 * psi:;
     cov F1 F2 = phi12;

/* Notice that psi1-psi9 are being treated as free parameters, even though
   Var(X_j)=1 implies psi_j = 1 - lambda_j^2. MLEs will be just right, to fit
   the ones on the diagonal of the correlation matrix.  For example,
   lambda1-hat = 0.6759, and psi1-hat = 0.54315 = 1-(lambda1-hat)^2  */
```


The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

The 9 Endogenous Variables

Manifest	progmat	reason	verbal	headlng	headbrd	headcir
	bizyg	height	weight			
Latent						

The 11 Exogenous Variables

Manifest						
Latent	F1	F2				
Error	e1	e2	e3	e4	e5	e6
	e7	e8	e9			

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Observations	74	Model Terms	1
Variables	9	Model Matrices	4
Informations	45	Parameters	19

Variable	Mean	Std Dev
progmat	37.98649	8.64203
reason	53.35135	16.51063
verbal	74.72297	24.21764
headlng	186.37838	7.08887
headbrd	146.87838	6.16653
headcir	543.48649	16.59117
bizyg	130.55405	5.88856
height	1651	83.54899
weight	121.70946	21.80848

Correlations

	progmat	reason	verbal	headlng	headbrd
progmat	1.0000	0.5503	0.6136	0.3138	0.1609
reason	0.5503	1.0000	0.7537	0.1582	0.0728
verbal	0.6136	0.7537	1.0000	0.2777	0.1467
headlng	0.3138	0.1582	0.2777	1.0000	0.3002
headbrd	0.1609	0.0728	0.1467	0.3002	1.0000
headcir	0.3314	0.2589	0.3149	0.8336	0.6775
bizyg	0.1843	0.2173	0.2473	0.4541	0.8046
height	0.2840	0.1403	0.2241	0.5915	0.4609
weight	0.2290	0.1452	0.1557	0.5695	0.4942

Correlations

	headcir	bizyg	height	weight
progmat	0.3314	0.1843	0.2840	0.2290
reason	0.2589	0.2173	0.1403	0.1452
verbal	0.3149	0.2473	0.2241	0.1557
headlng	0.8336	0.4541	0.5915	0.5695
headbrd	0.6775	0.8046	0.4609	0.4942
headcir	1.0000	0.7247	0.6115	0.6915
bizyg	0.7247	1.0000	0.6631	0.6570
height	0.6115	0.6631	1.0000	0.6677
weight	0.6915	0.6570	0.6677	1.0000

Determinant 0.000831 Ln -7.092601

NOTE: Some initial estimates computed by instrumental variable method.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Vector of Initial Estimates

	Parameter	Estimate	Type
1	lambda1	0.80267	Matrix Entry: _GAMMA_[1:1]
2	lambda2	0.75550	Matrix Entry: _GAMMA_[2:1]
3	lambda3	0.84070	Matrix Entry: _GAMMA_[3:1]
4	lambda4	0.99696	Matrix Entry: _GAMMA_[4:2]
5	lambda5	0.52745	Matrix Entry: _GAMMA_[5:2]
6	lambda6	1.08009	Matrix Entry: _GAMMA_[6:2]
7	lambda7	0.57605	Matrix Entry: _GAMMA_[7:2]
8	lambda8	0.60346	Matrix Entry: _GAMMA_[8:2]
9	lambda9	0.68732	Matrix Entry: _GAMMA_[9:2]
10	phi12	0.35431	Matrix Entry: _PHI_[2:1]
11	psi1	0.35572	Matrix Entry: _PHI_[3:3]
12	psi2	0.42921	Matrix Entry: _PHI_[4:4]
13	psi3	0.29322	Matrix Entry: _PHI_[5:5]
14	psi4	0.01000	Matrix Entry: _PHI_[6:6]
15	psi5	0.72180	Matrix Entry: _PHI_[7:7]
16	psi6	0.01000	Matrix Entry: _PHI_[8:8]
17	psi7	0.66817	Matrix Entry: _PHI_[9:9]
18	psi8	0.63583	Matrix Entry: _PHI_[10:10]
19	psi9	0.52759	Matrix Entry: _PHI_[11:11]

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Levenberg-Marquardt Optimization

Scaling Update of More (1978)

Parameter Estimates	19
Functions (Observations)	45

Optimization Start

Active Constraints	0	Objective Function	15.817194358
Max Abs Gradient Element	894.29834165	Radius	58849.958394

Iter	Rest arts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	2	0	2.82086	12.9963	19.6725	0	0.0955
2	0	3	0	2.51280	0.3081	4.9467	0	0.146

3	0	5	0	2.00804	0.5048	0.6923	0.00456	0.509
4	0	6	0	1.97594	0.0321	0.6408	0	0.539
5	0	8	0	1.96564	0.0103	0.5409	0.00138	0.351
6	0	9	0	1.96467	0.000964	0.3653	0	0.0876
7	0	10	0	1.96135	0.00332	0.2692	0.00163	0.378
8	0	11	0	1.96104	0.000306	0.1883	0	0.109
9	0	12	0	1.96102	0.000021	0.2240	0	0.0086
10	0	13	0	1.96023	0.000794	0.1198	0.00133	0.353
11	0	14	0	1.96017	0.000056	0.1210	0	0.0713
12	0	15	0	1.95989	0.000278	0.0552	0.00195	0.425
13	0	16	0	1.95987	0.000025	0.0519	0	0.158
14	0	17	0	1.95987	2.716E-6	0.0455	0	0.0200
15	0	18	0	1.95983	0.000040	0.0339	0.00114	0.324
16	0	19	0	1.95982	3.303E-6	0.0267	0	0.0666
17	0	20	0	1.95981	0.000017	0.0160	0.00198	0.427
18	0	21	0	1.95980	1.826E-6	0.0109	0	0.182
19	0	22	0	1.95980	2.169E-7	0.0126	0	0.0265
20	0	23	0	1.95980	2.349E-6	0.00746	0.00102	0.311
21	0	24	0	1.95980	1.859E-7	0.00784	0	0.0568
22	0	25	0	1.95980	1.223E-6	0.00314	0.00222	0.454
23	0	26	0	1.95980	1.234E-7	0.00314	0	0.213
24	0	27	0	1.95980	1.472E-8	0.00255	0	0.0319
25	0	28	0	1.95980	1.21E-7	0.00222	0.00086	0.283
26	0	29	0	1.95980	1.187E-8	0.00168	0	0.0577
27	0	30	0	1.95980	7.558E-8	0.00104	0.00217	0.448
28	0	31	0	1.95980	9.529E-9	0.000606	0	0.249
29	0	32	0	1.95980	1.508E-9	0.000793	0	0.0507
30	0	33	0	1.95980	8.024E-9	0.000445	0.00083	0.290
31	0	34	0	1.95980	8.7E-10	0.000528	0	0.0636
32	0	35	0	1.95980	5.42E-9	0.000166	0.00249	0.486
33	0	36	0	1.95980	6.39E-10	0.000200	0	0.298

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Optimization Results

Iterations	33	Function Calls	37
Jacobian Calls	34	Active Constraints	0
Objective Function	1.9597989957	Max Abs Gradient Element	0.0001998043
Lambda	0	Actual Over Pred Change	0.2982317727
Radius	0.0011727415		

GCONV convergence criterion satisfied.

Predicted Model Matrix

	progmat	reason	verbal	headlng	headbrd
progmat	1.0000	0.5542	0.6186	0.1961	0.1625
reason	0.5542	1.0000	0.7504	0.2379	0.1971
verbal	0.6186	0.7504	1.0000	0.2656	0.2201
headlng	0.1961	0.2379	0.2656	1.0000	0.5641
headbrd	0.1625	0.1971	0.2201	0.5641	1.0000
headcir	0.2328	0.2824	0.3152	0.8080	0.6694
bizyg	0.1791	0.2172	0.2425	0.6215	0.5149
height	0.1560	0.1892	0.2112	0.5413	0.4485
weight	0.1713	0.2078	0.2320	0.5946	0.4926

Predicted Model Matrix

	headcir	bizyg	height	weight
progmat	0.2328	0.1791	0.1560	0.1713
reason	0.2824	0.2172	0.1892	0.2078
verbal	0.3152	0.2425	0.2112	0.2320
headlng	0.8080	0.6215	0.5413	0.5946
headbrd	0.6694	0.5149	0.4485	0.4926
headcir	1.0000	0.7376	0.6424	0.7057
bizyg	0.7376	1.0000	0.4942	0.5428
height	0.6424	0.4942	1.0000	0.4728
weight	0.7057	0.5428	0.4728	1.0000

Determinant 0.005900 Ln -5.132802

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function	1.9598
Goodness of Fit Index (GFI)	0.7411
GFI Adjusted for Degrees of Freedom (AGFI)	0.5518
Root Mean Square Residual (RMR)	0.0882
Parsimonious GFI (Mulaik, 1989)	0.5352
Chi-Square	143.0653
Chi-Square DF	26
Pr > Chi-Square	<.0001
Independence Model Chi-Square	517.76
Independence Model Chi-Square DF	36
RMSEA Estimate	0.2484
RMSEA 90% Lower Confidence Limit	0.2094
RMSEA 90% Upper Confidence Limit	0.2889
ECVI Estimate	2.5630
ECVI 90% Lower Confidence Limit	2.0728
ECVI 90% Upper Confidence Limit	3.1728
Probability of Close Fit	0.0000
Bentler's Comparative Fit Index	0.7570
Normal Theory Reweighted LS Chi-Square	114.7882
Akaike's Information Criterion	91.0653

Bozdogan's (1987) CAIC	5.1596
Schwarz's Bayesian Criterion	31.1596
McDonald's (1989) Centrality	0.4534
Bentler & Bonett's (1980) Non-normed Index	0.6635
Bentler & Bonett's (1980) NFI	0.7237
James, Mulaik, & Brett (1982) Parsimonious NFI	0.5227
Z-Test of Wilson & Hilferty (1931)	8.3720
Bollen (1986) Normed Index Rho1	0.6174
Bollen (1988) Non-normed Index Delta2	0.7619
Hoelter's (1983) Critical N	21

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Estimates

progmat	=	0.6759*F1	+	1.0000 e1
Std Err		0.1091 lambda1		
t Value		6.1948		
reason	=	0.8199*F1	+	1.0000 e2
Std Err		0.1044 lambda2		
t Value		7.8501		
verbal	=	0.9153*F1	+	1.0000 e3
Std Err		0.1009 lambda3		
t Value		9.0674		
headlng	=	0.8251*F2	+	1.0000 e4
Std Err		0.0965 lambda4		
t Value		8.5485		
headbrd	=	0.6836*F2	+	1.0000 e5
Std Err		0.1040 lambda5		
t Value		6.5716		
headcir	=	0.9792*F2	+	1.0000 e6
Std Err		0.0862 lambda6		
t Value		11.3555		
bizyg	=	0.7533*F2	+	1.0000 e7
Std Err		0.1006 lambda7		
t Value		7.4908		
height	=	0.6561*F2	+	1.0000 e8
Std Err		0.1053 lambda8		
t Value		6.2317		
weight	=	0.7206*F2	+	1.0000 e9
Std Err		0.1022 lambda9		
t Value		7.0486		

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
F1		1.00000		
F2		1.00000		
e1	psi1	0.54315	0.10258	5.29
e2	psi2	0.32781	0.08843	3.71
e3	psi3	0.16231	0.09048	1.79
e4	psi4	0.31918	0.05964	5.35
e5	psi5	0.53267	0.09154	5.82
e6	psi6	0.04114	0.03487	1.18
e7	psi7	0.43261	0.07620	5.68
e8	psi8	0.56956	0.09727	5.86
e9	psi9	0.48069	0.08352	5.76

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate	Standard Error	t Value
F1	F2	phi12	0.35170	0.11204	3.14