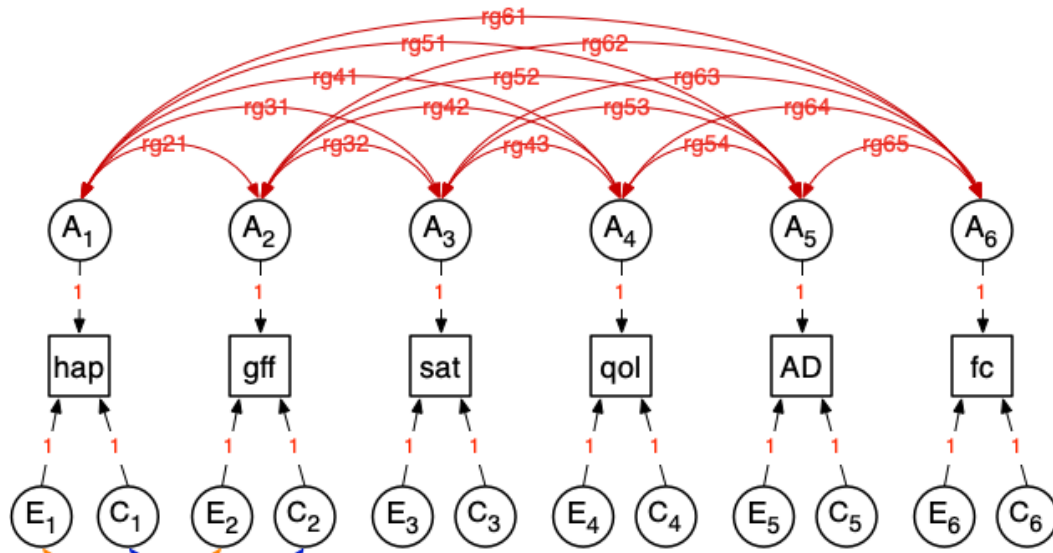


## Session 2: SEM | Study Design | Phenomics - Practical 3

### intro to multivariate twin Modeling using umx

1. Create day2/practical3 directory
2. Copy all files from faculty/hmaes/2021/day2/practical3 to your directory

#### Correlated Factors Model



similar structure for E & C

parameterSpecifications(CF) =function in miFunctions.R

model:top, matrix:A

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	[A_r1c1]	[A_r2c1]	[A_r3c1]	[A_r4c1]	[A_r5c1]	[A_r6c1]
[2,]	[A_r2c1]	[A_r2c2]	[A_r3c2]	[A_r4c2]	[A_r5c2]	[A_r6c2]
[3,]	[A_r3c1]	[A_r3c2]	[A_r3c3]	[A_r4c3]	[A_r5c3]	[A_r6c3]
[4,]	[A_r4c1]	[A_r4c2]	[A_r4c3]	[A_r4c4]	[A_r5c4]	[A_r6c4]
[5,]	[A_r5c1]	[A_r5c2]	[A_r5c3]	[A_r5c4]	[A_r5c5]	[A_r6c5]
[6,]	[A_r6c1]	[A_r6c2]	[A_r6c3]	[A_r6c4]	[A_r6c5]	[A_r6c6]

model:top, matrix:C

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	[C_r1c1]	[C_r2c1]	[C_r3c1]	[C_r4c1]	[C_r5c1]	[C_r6c1]
[2,]	[C_r2c1]	[C_r2c2]	[C_r3c2]	[C_r4c2]	[C_r5c2]	[C_r6c2]
[3,]	[C_r3c1]	[C_r3c2]	[C_r3c3]	[C_r4c3]	[C_r5c3]	[C_r6c3]
[4,]	[C_r4c1]	[C_r4c2]	[C_r4c3]	[C_r4c4]	[C_r5c4]	[C_r6c4]
[5,]	[C_r5c1]	[C_r5c2]	[C_r5c3]	[C_r5c4]	[C_r5c5]	[C_r6c5]
[6,]	[C_r6c1]	[C_r6c2]	[C_r6c3]	[C_r6c4]	[C_r6c5]	[C_r6c6]

model:top, matrix:E

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	[E_r1c1]	[E_r2c1]	[E_r3c1]	[E_r4c1]	[E_r5c1]	[E_r6c1]
[2,]	[E_r2c1]	[E_r2c2]	[E_r3c2]	[E_r4c2]	[E_r5c2]	[E_r6c2]
[3,]	[E_r3c1]	[E_r3c2]	[E_r3c3]	[E_r4c3]	[E_r5c3]	[E_r6c3]
[4,]	[E_r4c1]	[E_r4c2]	[E_r4c3]	[E_r4c4]	[E_r5c4]	[E_r6c4]
[5,]	[E_r5c1]	[E_r5c2]	[E_r5c3]	[E_r5c4]	[E_r5c5]	[E_r6c5]
[6,]	[E_r6c1]	[E_r6c2]	[E_r6c3]	[E_r6c4]	[E_r6c5]	[E_r6c6]

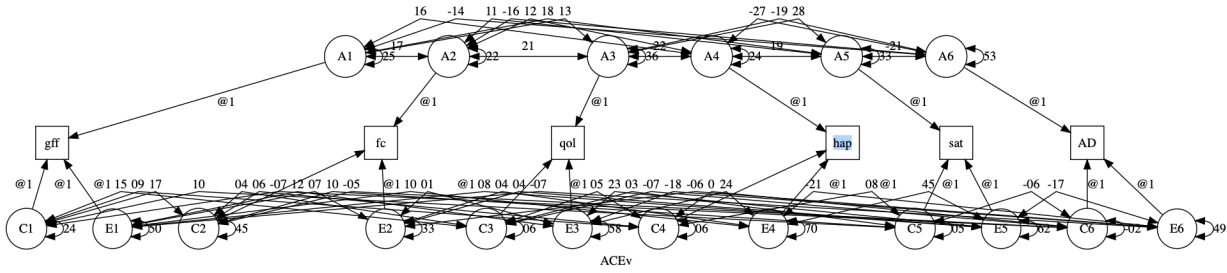


Table: Standardized parameter estimates from a 6-factor Direct variance ACE model. A: additive genetic; C: common environment; E: unique environment.

	A1	A2	A3	A4	A5	A6	C1	C2	C3	C4	C5	C6	E1	E2	E3	E4	E5	E6
lgff	0.252	INA	INA	INA	INA	INA	0.243	INA	INA	INA	INA	INA	0.505	INA	INA	INA	INA	INA
lfc	0.171	0.222	INA	INA	INA	INA	0.166	0.446	INA	INA	INA	INA	0.070	0.332	INA	INA	INA	INA
lqol	0.129	0.215	0.36	INA	INA	INA	0.153	0.036	0.062	INA	INA	INA	0.115	0.008	0.577	INA	INA	INA
lhap	0.164	0.125	0.225	0.239	INA	INA	0.087	0.057	0.052	0.058	INA	INA	0.096	0.038	0.236	0.704	INA	INA
lsat	0.180	0.114	0.285	0.189	0.332	INA	0.104	0.1	0.033	0.085	0.05	INA	0.083	0.035	0.233	0.449	0.618	INA
lAD	-0.142	-0.161	-0.187	-0.267	-0.212	0.532	-0.069	-0.054	-0.072	-0.005	-0.063	-0.022	-0.073	-0.056	-0.177	-0.211	-0.167	0.49

Table: Means (from model\$top\$expMean)

	gff_T1	fc_T1	qol_T1	hap_T1	sat_T1	AD_T1	gff_T2	fc_T2	qol_T2	hap_T2	sat_T2	AD_T2
intercept	38.616	-13.358	7.823	23.033	27.632	4.086	38.616	-13.358	7.823	23.033	27.632	4.086

## Common Pathway Model

```

model:top, matrix:as
  [,1] [,2] [,3] [,4] [,5] [,6]
[1,] [as_r1c1] 0 0 0 0 0
[2,] 0 [as_r2c2] 0 0 0 0
[3,] 0 0 [as_r3c3] 0 0 0
[4,] 0 0 0 [as_r4c4] 0 0
[5,] 0 0 0 0 [as_r5c5] 0
[6,] 0 0 0 0 0 [as_r6c6]

model:top, matrix:cs
  [,1] [,2] [,3] [,4] [,5] [,6]
[1,] [cs_r1c1] 0 0 0 0 0
[2,] 0 [cs_r2c2] 0 0 0 0
[3,] 0 0 [cs_r3c3] 0 0 0
[4,] 0 0 0 [cs_r4c4] 0 0
[5,] 0 0 0 0 [cs_r5c5] 0
[6,] 0 0 0 0 0 [cs_r6c6]

model:top, matrix:es
  [,1] [,2] [,3] [,4] [,5] [,6]
[1,] [es_r1c1] 0 0 0 0 0
[2,] 0 [es_r2c2] 0 0 0 0
[3,] 0 0 [es_r3c3] 0 0 0
[4,] 0 0 0 [es_r4c4] 0 0
[5,] 0 0 0 0 [es_r5c5] 0
[6,] 0 0 0 0 0 [es_r6c6]

model:top, matrix:cp_loadings
  [,1] [,2] [,3]
[1,] [cp_loadings_r1c1] [cp_loadings_r1c2] [cp_loadings_r1c3]
[2,] [cp_loadings_r2c1] [cp_loadings_r2c2] [cp_loadings_r2c3]
[3,] [cp_loadings_r3c1] [cp_loadings_r3c2] [cp_loadings_r3c3]
[4,] [cp_loadings_r4c1] [cp_loadings_r4c2] [cp_loadings_r4c3]
[5,] [cp_loadings_r5c1] [cp_loadings_r5c2] [cp_loadings_r5c3]
[6,] [cp_loadings_r6c1] [cp_loadings_r6c2] [cp_loadings_r6c3]

```

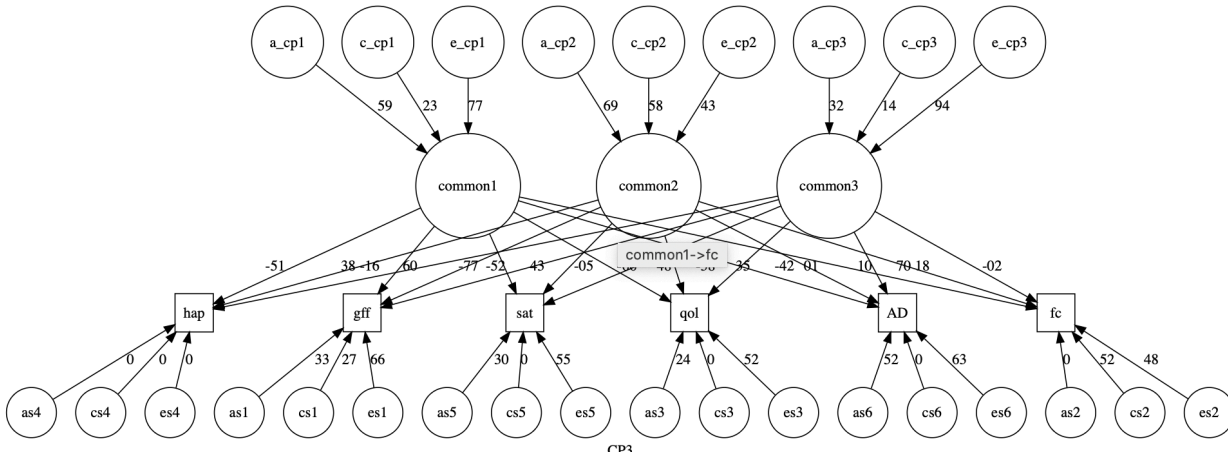


Table: Common Factor Paths

	AI	CI	EI
Common.factor.1	0.593	0.229	0.772
Common.factor.2	0.692	0.580	0.430
Common.factor.3	0.319	0.143	0.937

Table: Loadings of each trait on the Common Factors

	CP1	CP2	CP3
gff	-0.157	0.601	-0.047
fc	0.105	0.703	-0.023
qol	-0.664	0.479	0.008
hap	-0.513	0.377	-0.771
sat	-0.524	0.434	-0.377
AD	0.353	-0.420	0.177

Table: Specific-factor loadings

	gff fc	qol	hap	sat	AD
Specific a	0.331	0.244		0.296	0.525
Specific c	0.271	0.517			
Specific e	0.655	0.476	0.52	0.001	0.555

Table: Means (from model\$top\$expMean)

	gff_T1	fc_T1	qol_T1	hap_T1	sat_T1	AD_T1	gff_T2	fc_T2	qol_T2	hap_T2	sat_T2	AD_T2
intercept	38.615	-13.359	7.822	23.037	27.639	4.092	38.615	-13.359	7.822	23.037	27.639	4.092

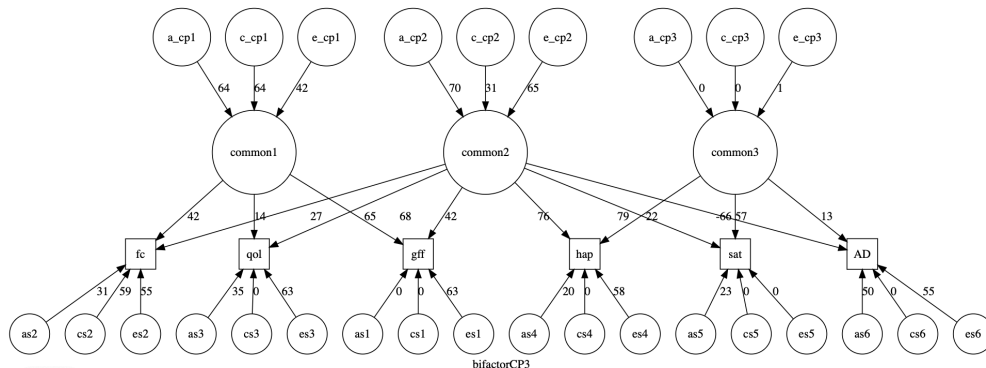
## BiFactor Common Pathway Model

\$labels

```
[,1]
[1,] "cp_loadings_r1c1" "cp_loadings_r1c2" "cp_loadings_r1c3"
[2,] "cp_loadings_r2c1" "cp_loadings_r2c2" "cp_loadings_r2c3"
[3,] "cp_loadings_r3c1" "cp_loadings_r3c2" "cp_loadings_r3c3"
[4,] "cp_loadings_r4c1" "cp_loadings_r4c2" "cp_loadings_r4c3"
[5,] "cp_loadings_r5c1" "cp_loadings_r5c2" "cp_loadings_r5c3"
[6,] "cp_loadings_r6c1" "cp_loadings_r6c2" "cp_loadings_r6c3"
```

\$free

```
[,1] [,2] [,3]
[1,] TRUE TRUE FALSE
[2,] TRUE TRUE FALSE
[3,] TRUE TRUE FALSE
[4,] FALSE TRUE TRUE
[5,] FALSE TRUE TRUE
[6,] FALSE TRUE TRUE
```



## Independent Pathway Model

\$labels

```
[1,] [1,] [2,] [3,]
[1,] "a_cp_r1c1" NA NA
[2,] NA "a_cp_r2c2" NA
[3,] NA NA "a_cp_r3c3"
```

```
$values
[1,] [1,] [2,] [3,]
[1,] 1 0 0
[2,] 0 0 0
[3,] 0 0 0
```

```
$free
[1,] [1,] [2,] [3,]
[1,] TRUE FALSE FALSE
[2,] FALSE FALSE FALSE
[3,] FALSE FALSE FALSE
```

\$labels

```
[1,] [1,] [2,] [3,]
[1,] "c_cp_r1c1" NA NA
[2,] NA "c_cp_r2c2" NA
[3,] NA NA "c_cp_r3c3"
```

```
$values
[1,] [1,] [2,] [3,]
[1,] 0 0 0
[2,] 0 1 0
[3,] 0 0 0
```

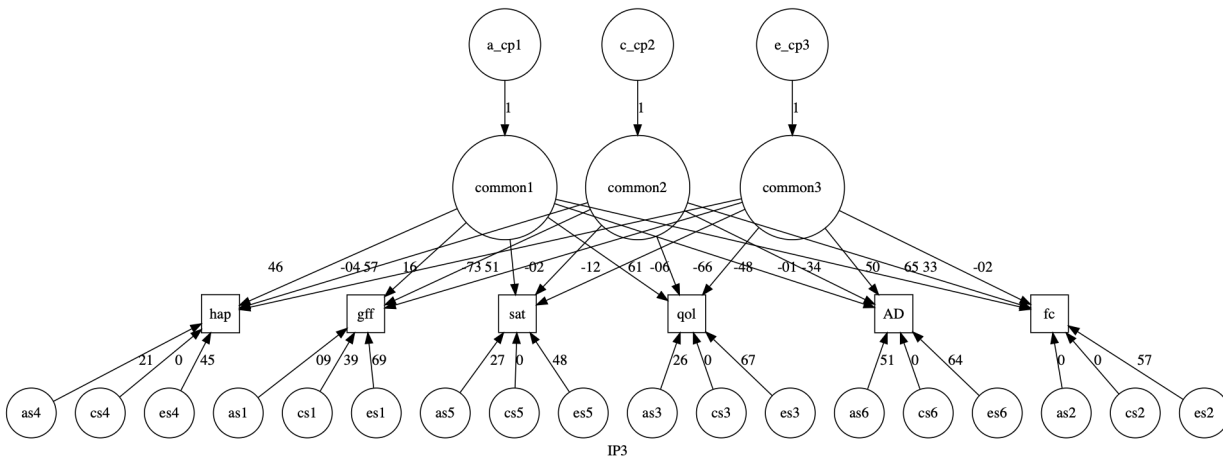
```
$free
[1,] [1,] [2,] [3,]
[1,] FALSE FALSE FALSE
[2,] FALSE TRUE FALSE
[3,] FALSE FALSE FALSE
```

\$labels

```
[1,] [1,] [2,] [3,]
[1,] "e_cp_r1c1" NA NA
[2,] NA "e_cp_r2c2" NA
[3,] NA NA "e_cp_r3c3"
```

```
$values
[1,] [1,] [2,] [3,]
[1,] 0 0 0
[2,] 0 0 0
[3,] 0 0 1
```

```
$free
[1,] [1,] [2,] [3,]
[1,] FALSE FALSE FALSE
[2,] FALSE FALSE FALSE
[3,] FALSE FALSE TRUE
```



## Model Comparisons

Table: Table of Model Comparisons

Model	EPI	Δ Fit	Δ df	lp	AIC	Δ AIC	Compare with Model	Fit units
ACEv	69				150602.81	0		-2lnL
CP3	51	63.669	21	< 0.001	150630.48	27.669	ACEv	-2lnL
bifCP3	45	206.542	27	< 0.001	150761.36	158.542	ACEv	-2lnL
IP3	45	213.897	27	< 0.001	150768.71	165.897	ACEv	-2lnL

```
> omxAkaikeWeights(list(CF,CP3,biCP3,IP3))
  model      AIC      delta AkaikeWeight inConfidenceSet
1  ACEv 150602.81  0.000000 9.9999902e-01 *
2   CP3 150630.48 27.669128 9.8112590e-07
3 bifCP3 150761.36 158.541604 3.7422053e-35
4   IP3 150768.71 165.896779 9.4617559e-37
```

## Genetic Correlations

A,C & E covariance matrices

> CF\$top\$A\$values

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	6.4474191	1.9093695	0.7305842	3.687157	4.642942	-2.8499115
[2,]	1.9093695	1.0811746	0.5294914	1.224419	1.280420	-1.4124644
[3,]	0.7305842	0.5294914	0.4510136	1.120695	1.625685	-0.8327673
[4,]	3.6871566	1.2244190	1.1206948	4.731226	4.297529	-4.7375629
[5,]	4.6429422	1.2804202	1.6256853	4.297529	8.644650	-4.3149053
[6,]	-2.8499115	-1.4124644	-0.8327673	-4.737563	-4.314905	8.4293685

> CF\$top\$C\$values

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	6.2116469	1.85480182	0.86412788	1.96625244	2.6793607	-1.38273487
[2,]	1.8548018	2.16641445	0.08972125	0.55819689	1.1252462	-0.47004033
[3,]	0.8641279	0.08972125	0.07806369	0.25863413	0.1891651	-0.32230630
[4,]	1.9662524	0.55819689	0.25863413	1.14187472	1.9288688	-0.08313271
[5,]	2.6793607	1.12524619	0.18916506	1.92886877	1.3003167	-1.27310473
[6,]	-1.3827349	-0.47004033	-0.32230630	-0.08313271	-1.2731047	-0.34931754

> CF\$top\$E\$values

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	12.9015532	0.77777685	0.65309936	2.1683402	2.1398984	-1.4664052
[2,]	0.7777769	1.61478754	0.02027887	0.3761106	0.3985771	-0.4906921
[3,]	0.6530994	0.02027887	0.72287522	1.1770513	1.3299775	-0.7896577
[4,]	2.1683402	0.37611060	1.17705130	13.9548956	10.1957048	-3.7465664
[5,]	2.1398984	0.39857715	1.32997748	10.1957048	16.1016382	-3.3924335
[6,]	-1.4664052	-0.49069205	-0.78965765	-3.7465664	-3.3924335	7.7499063

A,C & E standardized covariance matrices

> CF\$top\$A\_std\$result

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	0.2522403	0.1712695	0.1291489	0.1637821	0.1799418	-0.1416791
[2,]	0.1712695	0.2223552	0.2146054	0.1247000	0.1137765	-0.1609954
[3,]	0.1291489	0.2146054	0.3602482	0.2249334	0.2846866	-0.1870638
[4,]	0.1637821	0.1247000	0.2249334	0.2386134	0.1891054	-0.2674088
[5,]	0.1799418	0.1137765	0.2846866	0.1891054	0.3318916	-0.2124985
[6,]	-0.1416791	-0.1609954	-0.1870638	-0.2674088	-0.2124985	0.5324947

> CF\$top\$C\_std\$result

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	0.24301629	0.16637479	0.15275604	0.087340200	0.10384126	-0.068740606
[2,]	0.16637479	0.44554641	0.03636445	0.056849115	0.09998796	-0.053576082
[3,]	0.15275604	0.03636445	0.06235355	0.051910175	0.03312619	-0.072399404
[4,]	0.08734020	0.05684911	0.05191018	0.057589013	0.08487655	-0.004692374
[5,]	0.10384126	0.09998796	0.03312619	0.084876549	0.04992270	-0.062697280
[6,]	-0.06874061	-0.05357608	-0.07239940	-0.004692374	-0.06269728	-0.022066866

> CF\$top\$E\_std\$result

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
[1,]	0.50474337	0.069766194	0.115451516	0.09631686	0.08293386	-0.07290015
[2,]	0.06976619	0.332098411	0.008219124	0.03830468	0.03541706	-0.05593000
[3,]	0.11545152	0.008219124	0.577398258	0.23624469	0.23290285	-0.17738016
[4,]	0.09631686	0.038304683	0.236244685	0.70379758	0.44864443	-0.21147262
[5,]	0.08293386	0.035417063	0.232902845	0.44864443	0.61818569	-0.16706902
[6,]	-0.07290015	-0.055930005	-0.177380160	-0.21147262	-0.16706902	0.48957216

### A,C & E correlation matrices

```
> mxEval(cov2cor(A_std),CF$top)
```

```
      [,1]      [,2]      [,3]      [,4]      [,5]      [,6]
[1,] 1.0000000 0.7231845 0.4284326 0.6675930 0.6219087 -0.3865813
[2,] 0.7231845 1.0000000 0.7582565 0.5413714 0.4188234 -0.4678774
[3,] 0.4284326 0.7582565 1.0000000 0.7671949 0.8233186 -0.4271017
[4,] 0.6675930 0.5413714 0.7671949 1.0000000 0.6719830 -0.7501889
[5,] 0.6219087 0.4188234 0.8233186 0.6719830 1.0000000 -0.5054754
[6,] -0.3865813 -0.4678774 -0.4271017 -0.7501889 -0.5054754 1.0000000
```

```
> mxEval(cov2cor(C_std),CF$top)
```

```
      [,1]      [,2]      [,3]      [,4]      [,5] [,6]
[1,] 1.0000000 0.5056190 1.2409381 0.7382895 0.9427645 NaN
[2,] 0.5056190 1.0000000 0.2181725 0.3549012 0.6704281 NaN
[3,] 1.2409381 0.2181725 1.0000000 0.8662676 0.5937339 NaN
[4,] 0.7382895 0.3549012 0.8662676 1.0000000 1.5829561 NaN
[5,] 0.9427645 0.6704281 0.5937339 1.5829561 1.0000000 NaN
[6,]      NaN      NaN      NaN      NaN      NaN 1
```

Warning messages:

1: In sqrt(1/diag(V)) : NaNs produced

2: In cov2cor(c(0.243016292473305, 0.166374794820861, 0.152756042901065, :  
diag(.) had 0 or NA entries; non-finite result is doubtful

```
> mxEval(cov2cor(E_std),CF$top)
```

```
      [,1]      [,2]      [,3]      [,4]      [,5]      [,6]
[1,] 1.0000000 0.17040264 0.21385854 0.1616007 0.14846946 -0.1466509
[2,] 0.1704026 1.00000000 0.01876957 0.0792309 0.07816632 -0.1387085
[3,] 0.2138585 0.01876957 1.00000000 0.3705957 0.38983209 -0.3336253
[4,] 0.1616007 0.07923090 0.37059574 1.0000000 0.68017227 -0.3602649
[5,] 0.1484695 0.07816632 0.38983209 0.6801723 1.00000000 -0.3036883
[6,] -0.1466509 -0.13870851 -0.33362528 -0.3602649 -0.30368832 1.0000000
```