# Example 9: Structural Equation Modeling with Latent Variables (or their Observed Variables) (complete syntax and output available electronically for Mplus 8.8; partial for R Lavaan 0.6-12)

These data were adapted from my dissertation work (see references below) in which 152 adults age 63–87 years were measured on visual impairment (distance acuity and five degrees of contrast sensitivity), processing speed, divided visual attention, and selective visual attention (as measured by the Useful Field of View subtests for each), attentional search efficiency (DriverScan), and simulator driving impairment (as measured by six driving performance indicators).

- Hoffman, L., Yang, X., Bovaird, J. A., & Embretson, S. E. (2006). <u>Measuring attention in older adults: Development</u> and psychometric evaluation of DriverScan. *Educational and Psychological Measurement*, *66*, 984-1000.
- Hoffman, L., McDowd, J. M., Atchley, P., & Dubinsky R. A. (2005). <u>The role of visual attention in predicting driving</u> impairment in older adults. *Psychology and Aging*, 20(4), 610-622.

This example will demonstrate how to estimate structural equation models, including models with mediation and latent variable interactions. But because simultaneous estimation of all effects of interest may not always be possible, this example will also show how to generate and use EAP factor score estimates instead. (For a version of this handout that also works with plausible values of factor scores, see Example9c <u>from this previous class</u>.)

# Mplus Code to Read in Data:

TITLE:	SEM Example for Driverscan
DATA:	<pre>FILE = driverscanSEM.csv;  ! FILE is file to be analyzed</pre>
	FORMAT = free; ! Free is default
	<b>TYPE = INDIVIDUAL;</b> ! Individual data is default
VARIABLE:	! Every variable in data set
NAME	S = PersonID sex age75 lncs15 lncs3 lncs6 lncs12 lncs18 far lnps
	lnda lnsa Dscan lane da_task crash stop speed time;
! Ev	ery variable in EACH MODEL
USEV	ARIABLES = (to be changed for each model);
IDVA	RIABLE = PersonID;
MISS	<pre>ING = ALL (-9999); ! Value to denote missing values</pre>
ANALYSIS:	ESTIMATOR = MLR; ! For continuous items whose residuals may not be normal
OUTPUT:	SAMPSTAT ! Sample descriptives to verify data
	MODINDICES (3.84) ! Cheat codes to improve model fit (at $p<.05$ )
	STDYX ! Requests fully standardized solution
	RESIDUAL ! Requests standardized and normalized residuals
	SVALUES; ! Write code with estimated parameters as start values
	TECH4; ! Latent variable correlation matrix
SAVEDATA:	SAVE = FSCORES; FILE = FactorScores.dat; ! Change .dat name by model
	MISSFLAG = 99; ! Missing data item indicator
MODEL:	! (model syntax goes here, to be changed for each model)

We will begin by fitting single-factor measurement models for each latent factor. This is for two reasons: (1) we need to ensure each unidimensional factor fits its indicators, and (2) we will generate the EAP factor scores to use later to demonstrate how to include reliability-corrected factor scores as a replacement for latent variables.

Given MLR estimation, the EAP (expected a posteriori estimate) is the mean of the expected factor score distribution for each person. So anytime factor score SE>0 (and reliability is <1), this means the factor score still has error with it that we should correct for to avoid bias in the structural model parameters...

# Measurement Model 1 for Visual Impairment (including Omega)

```
VARIABLE: ! Every variable in THIS MODEL
             USEVARIABLES = lncs15 lncs3 lncs6 lncs12 lncs18 far;
MODEL: ! Measurement model
  Vision BY far@1
        Incsion incsion incsionIncsion incsion[far* lncs15* lncs3* lncs6* lncs12* lncs18*];! All incerceptefar* lncs15* lncs3* lncs6* lncs12* lncs18* (E1-E6);! Residual variances! Factor M=0, Var=?
  [far* lncs15* lncs3* lncs6* lncs12* lncs18*];
  [Vision@0]; Vision* (Fvar);
MODEL CONSTRAINT: ! TO GET OMEGA
NEW(SumLoad2 SumError SumRCov Omega);
SumLoad2 = (1+L2+L3+L4+L5+L6)**2;
SumError = E1+E2+E3+E4+E5+E6;
SumRCov = 2*(0);
! Omega = true variance / total variance
Omega = SumLoad2*Fvar / (SumLoad2*Fvar+SumError+SumRCov);
MODEL FIT INFORMATION
Number of Free Parameters
                                            18
Loglikelihood
         HO Value
                                      -747.948
         HO Scaling Correction Factor 1.1255
          for MLR
                                      -739.282
         H1 Value
         H1 Scaling Correction Factor 1.1171
          for MLR
Information Criteria
         AKAIKE (AIC)
Bayesian (BIC)
                                     1531.897
                                     1586.327
1529.357
         Sample-Size Adjusted BIC
          (n^* = (n + 2) / 24)
Chi-Square Test of Model Fit
                                        15.752*
         Value
                                         9
         Degrees of Freedom
         P-Value
                                        0.0722
         Scaling Correction Factor
                                        1.1003
          for MLR
RMSEA (Root Mean Square Error Of Approximation)
                        0.070
         Estimate
                                         0.000 0.126
         90 Percent C.I.
         Probability RMSEA <= .05 0.246
CFI/TLI
         CFT
                                          0.973
         TLI
                                          0.955
Chi-Square Test of Model Fit for the Baseline Model
         Value
                                       264.950
         Degrees of Freedom
                                           15
         P-Value
                                        0.0000
SRMR (Standardized Root Mean Square Residual)
                                         0.041
         Value
```

# Measurement Model 1 for Vision:

MODET.	RECITIONS
FIO DEL	TTOOTTO

				Two-Tailed	
	Estimate	S.E.	Est./S.E.	P-Value	
VISION BY					
FAR	1.000	0.000	999.000	999.000	
LNCS15	0.497	0.103	4.815	0.000	
LNCS3	0.594	0.118	5.018	0.000	
LNCS6	0.764	0.136	5.628	0.000	
LNCS12	1.296	0.207	6.277	0.000	
LNCS18	1.504	0.237	6.353	0.000	
Means					
VISION	0.000	0.000	999.000	999.000	
Intercepts					
LNCS15	-3.698	0.035	-105.136	0.000	
LNCS3	-3.938	0.035	-113.273	0.000	
LNCS6	-3 730	0 043	-87 639	0 000	
LNCS12	-2 368	0.046	-36 000	0.000	
LNCS18	-1 406	0.000	-17 389	0.000	
FAR	3 026	0.001	45 130	0.000	
FAI	5.020	0.007	40.100	0.000	
Variances	0.004	0 0 0 7	2 2 2 2	0 001	
VISION	0.224	0.06/	3.333	0.001	For factor score reliability
Desides 1 Tradice					SAMPLE STATISTICS FOR ESTIMATED
Residual Varian	ces 0 100	0 010		0 000	FACTOR SCORES
LNCSIS	0.133	0.018	7.433	0.000	
LNCS3	0.105	0.014	7.451	0.000	Means
LNCS6	0.145	0.028	5.231	0.000	VISION VISION_SE
LNCSIZ	0.282	0.04/	5.94/	0.000	
LNCSI8	0.488	0.062	/.933	0.000	0.000 <b>0.194</b>
FAR	0.460	0.055	8.349	0.000	Courseisses
New/Additional P	arameters				Covariances
SUMLOAD2	31 983	7 564	4 228	0 000	
SUMERROR	1 613	0 102	15 822	0 000	VISION 0.186
SUMBCOV	0 000	0 000	0 000	1 000	224
OMEGA	0.816	0.024	33.851	0.000	$\rho = \frac{.224}{$
	0.010	0.021	00.001	0.000	.224+ .194 <sup>2</sup>
					Factor score reliability uses the
STANDARDIZED MOD	EL RESULTS				factor variance as "true" and the
STDYX Standardiz	ation				$SE^2$ of the factor scores (given just
bibin beandaraiz	401011			Two-Tailed	
	Estimate	SE	Est /S E	P-Value	above) as "error" (because these
VISION BY	DBCINACC	0.1.	100.70.11.	I Varue	factor scores have error in them
FAR	0 572	0 062	9 1 9 0	0 000	anytime reliability is $< 1$ )
LNCS15	0 541	0.002	7 305	0.000	
TWC23	0.541	0.074	10 605	0.000	
TNCSS	0.000	0.002	12 062	0.000	If we were going to sum the
T NCC1 2	0.000	0.057	17 01E	0.000	indicators, omega would have
LINCOLZ	0./00	0.051	14.013 17 202	0.000	been used for reliability instead
отсэли	0./13	0.041	11.293	0.000	

Normalized Residuals for Covariances/Correlations/Residual CorrelationsLNCS15LNCS3LNCS6LNCS12LNCS18

TNCS15	0 000					
THCSID	0.000					
LNCS3	1.651	0.000		Local fit looks go	ood as well…	
LNCS6	-0.045	0.261	0.000			_
LNCS12	-0.455	-0.241	0.021	0.000		
LNCS18	-0.629	-0.458	-0.177	0.353	0.000	
FAR	-0.471	-0.731	-0.062	0.198	0.558	

# Measurement Model 2 for Driving Impairment (including Omega)

```
VARIABLE: ! Every variable in THIS MODEL
             USEVARIABLES = lane da task crash stop speed time;
MODEL:
          ! Measurement model
  Driving BY crash@1
              da task* lane* stop* speed* time* (L2-L6); ! 1 marker loading
  [lane* da task* crash* stop* speed* time*];
                                                          ! All intercepts
  [Driving@0]; Driving* (Fvar);
                                                          ! Factor M=0, Var=?
  speed WITH time* (ResCov);
                                                           ! Residual covariance
MODEL CONSTRAINT: ! TO GET OMEGA
NEW (SumLoad2 SumError SumRCov Omega);
SumLoad2 = (1+L2+L3+L4+L5+L6)**2;
SumError = E1+E2+E3+E4+E5+E6;
SumRCov = 2*(ResCov);
! Omega = true variance / total variance
Omega = SumLoad2*Fvar / (SumLoad2*Fvar+SumError+SumRCov);
*** WARNING
 Data set contains cases with missing on all variables.
                                                      A total of 20 participants were unable to
 These cases were not included in the analysis.
                                                      complete the simulator driving task, so
 Number of cases with missing on all variables: 20
                                                      they are not included in this model...
MODEL FIT INFORMATION
Number of Free Parameters
                                           19
Loglikelihood
         H0 Value
                                      -37.119
        H0 Scaling Correction Factor
                                      1.1566
          for MLR
         H1 Value
                                      -30.710
         H1 Scaling Correction Factor
                                      1.1108
          for MLR
Information Criteria
        Bayesian (BIC)
                                      112.239
                                      167.012
         Sample-Size Adjusted BIC
                                      106.915
          (n^* = (n + 2) / 24)
Chi-Square Test of Model Fit
         Value
                                       12.791*
         Degrees of Freedom
                                            8
                                       0.1192
         P-Value
         Scaling Correction Factor
                                       1.0021
          for MLR
RMSEA (Root Mean Square Error Of Approximation)
                        0.067
         Estimate
         90 Percent C.I.
                                        0.000 0.133
         Probability RMSEA <= .05
                                       0.293
CFI/TLI
         CFI
                                        0.922
         TLI
                                        0.854
Chi-Square Test of Model Fit for the Baseline Model
         Value
                                       76.677
         Degrees of Freedom
                                          15
         P-Value
                                       0.0000
SRMR (Standardized Root Mean Square Residual)
        Value
                                        0.054
```

# Measurement Model 2 for Driving:

MODEL	RESULTS	3

Estimate         S.E.         Fst./S.E.         P-Value           CRASH         1.000         0.003         999.000         999.000           LANE         0.150         0.037         2.608         0.009           STOP         0.147         0.163         2.2408         0.004           STOP         0.447         0.163         2.124         0.004           STOP         0.4422         0.138         3.034         0.002           STOP         0.4422         0.138         3.044         0.004           TIME         0.064         0.043         1.104         0.270           SPEED         WITH         TIME         0.000         0.000         999.000         999.000           Means         0.000         0.000         999.000         999.000         999.000           IANE         0.815         0.013         20.102         0.000           CRASH         0.659         0.033         5.249         0.000           TIME         0.125         0.004         4.619         0.000           CASH         0.027         0.004         4.613         0.000           STOP         0.174         0.031         5.750						Two-Tailed	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $		E:	stimate	S.E.	Est./S.E.	P-Value	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	DRIVING BY						
LARE 0.150 0.057 2.608 0.009 DA_TASK 0.173 0.074 2.345 0.019 STOP 0.347 0.163 2.124 0.034 SPEED 0.042 0.383 3.054 0.002 TIME 0.048 0.043 1.104 0.270 SPEED WITH TIME -0.023 0.004 -5.393 0.000 Means DRIVING 0.000 0.000 999.000 993.000 Intercepts LANE 0.815 0.015 53.293 0.000 CRASH 0.859 0.053 16.292 0.000 STOP 0.205 0.038 5.349 0.000 Variances DRIVING 0.159 0.062 2.574 0.010 Fesidual Variances LANE 0.037 0.004 6.596 0.000 STOP 0.205 0.038 5.349 0.000 Variances DRIVING 0.159 0.062 2.574 0.010 Fesidual Variances LANE 0.027 0.004 6.596 0.000 STOP 0.174 0.028 7.391 0.000 CRASH 0.209 0.055 3.781 0.000 STOP 0.174 0.028 7.391 0.000 STADARDIZED MODEL RESULTS SUMMACR 0.647 0.067 9.627 0.000 SIMMACR 0.647 0.067 9.627 0.000 SIMMACR 0.647 0.076 7.166 0.000 SIMMACR 0.647 0.076 7.166 0.000 SIMMACR 0.647 0.017 5.395 0.000 SIMMACR 0.647 0.117 5.395 0.000 SIMMACR 0.454 0.076 7.166 0.000 SIMMACR 0.454 0.076 7.247 Covariances "Tue" and the SE' of the factor score cliability uses the factor score science defined factor score science for factor s	CRASH		1.000	0.000	999.000	999.000	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	LANE		0.150	0.057	2.608	0.009	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	DA TASK		0.173	0.074	2.348	0.019	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	STOP		0 347	0 163	2 124	0 034	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	SPEED		0 422	0.138	3 054	0.001	
INE       0.048       0.043       1.104       0.270         SPEED       WITH       -0.023       0.004       -5.393       0.000         Means       DRIVING       0.000       0.000       999.000       999.000         Intercepts       IANE       0.815       0.015       53.293       0.000         CRASH       0.859       0.033       15.292       0.000         STMP       0.205       0.033       15.292       0.000         STMP       0.334       15.492       0.000         TIME       0.159       0.062       2.574       0.010         Variances       DATASK       0.027       0.004       6.596       0.000         STMP       0.010       0.028       7.391       0.000       0.000         Variances       DRIVING       0.174       0.031       5.575       0.000         SUMERCR       0.647       0.067       9.627       0.000       0.000         SUMERCR       0.647       0.067       9.627       0.000       0.000         SUMERCR       0.647       0.067       7.166       0.000       0.000         SUMERCR       0.647       0.077       7.166 <t< td=""><td>DIME</td><td></td><td>0.422</td><td>0.130</td><td>1 104</td><td>0.002</td><td></td></t<>	DIME		0.422	0.130	1 104	0.002	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	LIME		0.040	0.045	1.104	0.270	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	ODEED W						
THE       -0.023       0.004       -5.393       0.000         Means DRIVING       0.000       0.000       999.000       999.000         Intercepts LANE       0.815       0.015       53.293       0.000         CRASH       0.859       0.053       16.292       0.000         STOP       0.205       0.038       5.449       0.000         Variances       0.1174       0.004       6.596       0.000         Variances       0.177       0.004       6.596       0.000         STOP       0.210       0.028       7.391       0.000         Variances       0.010       0.001       8.639       0.000         STOP       0.174       0.031       5.781       0.000         STOP       0.174       0.031       8.639       0.000         STADKADD22       4.578       1.185       3.865       0.000         SUMEROR       0.647       0.067       7.166       0.000         STANARDIZED MODEL RESULTS       Two-Tailed       SCore reliability uses the factor scores (given anytime reliability is < 1).	SPEED WI	LTH		0 004		0 000	
Means DRIVING         0.000         0.000         999.000         999.000           Intercepts LANE         0.815         0.015         53.293         0.000           DA TASK         0.256         0.013         20.102         0.000           STOP         0.205         0.038         5.349         0.000           STOP         0.205         0.038         5.349         0.000           Variances         0.159         0.062         2.574         0.010           Residual Variances         0.027         0.004         6.596         0.000           DRIVING         0.159         0.062         2.574         0.010           CRASH         0.207         0.004         6.596         0.000           STME         0.101         0.002         3.781         0.000           TIME         0.010         0.021         5.575         0.000           SUMERCOV         0.647         0.067         9.627         0.000           SUMERCOV         0.647         0.067         9.627         0.000           MERY ADARDIZED MODEL EESULTS         STOP         0.340         0.123         2.767         0.000           STASK         0.467         0.113 <td>TIME</td> <td></td> <td>-0.023</td> <td>0.004</td> <td>-5.393</td> <td>0.000</td> <td></td>	TIME		-0.023	0.004	-5.393	0.000	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $							
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Means						
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	DRIVING		0.000	0.000	999.000	999.000	
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$							
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Intercepts						
$\begin{array}{c c} \mbox{DA} TASK & 0.256 & 0.013 & 20.102 & 0.000 \\ \hline CRSH & 0.859 & 0.053 & 16.292 & 0.000 \\ \mbox{SPEED} & 0.836 & 0.042 & 19.687 & 0.000 \\ \hline TIME & 3.146 & 0.009 & 349.081 & 0.000 \\ \hline Variances & & & & & & & & & & & & \\ \mbox{DA} TASK & 0.17 & 0.004 & 6.596 & 0.000 \\ \mbox{CRSH} & 0.209 & 0.055 & 3.781 & 0.000 \\ \mbox{CRSH} & 0.209 & 0.055 & 3.781 & 0.000 \\ \mbox{STOP} & 0.174 & 0.031 & 5.575 & 0.000 \\ \mbox{STDP} & 0.174 & 0.031 & 5.575 & 0.000 \\ \mbox{STDP} & 0.210 & 0.028 & 7.391 & 0.000 \\ \mbox{SUMERCOV} & 0.010 & 0.001 & 8.639 & 0.000 \\ \mbox{SUMERCOV} & 0.647 & 0.067 & 9.627 & 0.000 \\ \mbox{SUMERCOV} & 0.548 & 0.076 & 7.166 & 0.000 \\ \mbox{SUMERCOV} & 0.548 & 0.076 & 7.166 & 0.000 \\ \mbox{STANDARDIZED MODEL RESULTS} \\ \mbox{STAND} & 0.135 & 0.115 & 2.748 & 0.000 \\ \mbox{AA} & 0.548 & 0.115 & 2.748 & 0.000 \\ \mbox{AA} & 0.123 & 2.767 & 0.000 \\ \mbox{STAND} & 0.135 & 0.115 & 2.748 & 0.000 \\ \mbox{STAND} & 0.135 & 0.145 & 1.275 & 0.202 \\ \mbox{SPEED} & 0.345 & 0.107 & 3.226 & 0.000 \\ \mbox{AA} & 0.128 & 0.145 & 1.275 & 0.202 \\ \mbox{SPEED} & 0.345 & 0.145 & 1.275 & 0.202 \\ \mbox{SPEED} & 0.345 & 0.145 & 1.275 & 0.202 \\ \mbox{SPEED} & 0.345 & 0.000 \\ \mbox{AA} & 0.128 & 0.000 & -5.478 & 0.000 \\ \mbox{AA} & 0.128 & 0.000 & -5.478 & 0.000 \\ \mbox{AA} & 0.128 & 0.000 & -5.478 & 0.000 \\ \mbox{AA} & 0.128 & 0.000 & -5.478 & 0.000 \\ \mbox{AA} & 0.038 & -0.390 & 0.000 \\ \mbox{AA} & 0.047 & 0.030 & 0.000 \\ \mbox{AA} & 0.047 & 0.030 & 0.000 \\ \mbox{AA} & 0.048 & 0.076 & -5.478 & 0.000 \\ \mbox{AA} & 0.028 & -0.390 & 0.000 \\ \mbox{AA} & 0.038 & -0.$	LANE		0.815	0.015	53.293	0.000	
$\begin{array}{cccc} crass & 0.659 & 0.053 & 16.292 & 0.000 \\ stress & 0.205 & 0.038 & 5.349 & 0.000 \\ true & 3.146 & 0.009 & 349.081 & 0.000 \\ \hline \\ variances & 0.027 & 0.042 & 19.687 & 0.000 \\ \hline \\ DRIVING & 0.159 & 0.062 & 2.574 & 0.010 \\ \hline \\ residual Variances & 0.027 & 0.004 & 6.596 & 0.000 \\ DA TASK & 0.017 & 0.004 & 4.613 & 0.000 \\ crass & 0.209 & 0.055 & 3.781 & 0.000 \\ stress & 0.010 & 0.001 & 8.639 & 0.000 \\ stress & 0.010 & 0.001 & 8.639 & 0.000 \\ stress & 0.010 & 0.001 & 8.639 & 0.000 \\ stress & 0.647 & 0.667 & 9.627 & 0.000 \\ stress & 0.647 & 0.667 & 9.627 & 0.000 \\ stress & 0.647 & 0.667 & 9.627 & 0.000 \\ stress & 0.647 & 0.067 & 9.627 & 0.000 \\ stress & 0.647 & 0.067 & 9.627 & 0.000 \\ stress & 0.647 & 0.067 & 9.627 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.657 & 0.117 & 5.596 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.548 & 0.076 & 7.166 & 0.000 \\ stress & 0.315 & 0.112 & 2.767 & 0.000 \\ stress & 0.315 & 0.113 & 2.767 & 0.000 \\ stress & 0.315 & 0.115 & 2.748 & 0.000 \\ stress & 0.315 & 0.115 & 2.748 & 0.000 \\ stress & 0.315 & 0.115 & 2.748 & 0.000 \\ stress & 0.315 & 0.115 & 2.748 & 0.000 \\ stress & 0.315 & 0.115 & 1.275 & 0.202 \\ stress & 0.315 & 0.145 & 1.275 & 0.202 \\ stress & 0.000 \\ true & 0.185 & 0.145 & 1.275 & 0.202 \\ stress & 0.000 \\ true & 0.000 \\ true & 0.000 & -5.478 & 0.000 \\ true & 0.000 \\ true & 0.000 \\ true & 0.000 & -5.478 & 0.000 \\ true & 0.000 \\ true$	DA_TASK		0.256	0.013	20.102	0.000	
STOP       0.205       0.038       5.349       0.000         SPEED       0.836       0.042       19.687       0.000         Variances       DRIVING       0.159       0.062       2.574       0.010         Residual Variances       Ambeind State       0.000       SAMPLE STATISTICS FOR ESTIMA         DA_TASK       0.017       0.004       4.613       0.000         STOP       0.174       0.031       5.575       0.000         STOP       0.174       0.028       7.391       0.000         New/Additional Parameters       SUMERNOR       0.647       0.067       9.627       0.000         SUMERNOR       0.647       0.067       9.627       0.000       Covariances         STDYX standardization       Estimate       S.E.       Est./S.E.       Two-Tailed         DRIVING BY       Estimate       S.E.       Est./S.E.       Two-Tailed       Factor score reliability uses the factor scores (given above) as "error" (because thes factor scores have error in then anytime reliability is < 1).         STME       0.115       2.748       0.000         STOP       0.345       0.107	CRASH		0.859	0.053	16.292	0.000	
SPEED       0.836       0.042       19.687       0.000         Variances       0.000       0.0159       0.062       2.574       0.010         Residual Variances       0.027       0.004       6.596       0.000         DA TASK       0.017       0.004       4.613       0.000         DA TASK       0.017       0.004       4.613       0.000         CRASH       0.207       0.004       4.633       0.000         STOP       0.174       0.031       5.575       0.000         SEED       0.210       0.028       7.391       0.000         SUMLOAD2       4.578       1.185       3.865       0.000         SUMEROR       0.647       0.667       9.627       0.000         OMEGA       0.548       0.076       7.166       0.000         STANDARDIZED MODEL RESULTS       Two-Tailed       DRIVING       Streer" (because thes factor scores reliability uses the factor scores have error in them above) as "error" (because thes factor scores have error in them above) as "error" (because thes factor scores have error in them above) as "error" (because thes factor scores have error in them anytime reliability is < 1).	STOP		0.205	0.038	5.349	0.000	
TIME         3.146         0.009         349.081         0.000           Variances DRIVING         0.159         0.062         2.574         0.010           Residual Variances LANE         0.027         0.004         6.596         0.000           CRASH         0.209         0.055         3.781         0.000           STOP         0.114         0.031         5.575         0.000           TIME         0.010         0.028         7.391         0.000           SUMEDAD2         4.578         1.185         3.865         0.000           SUMEROR         0.647         0.667         9.627         0.000           OMEGA         0.548         0.076         7.166         0.000           STANDARDIZED MODEL RESULTS         Two-Tailed         Factor score reliability uses the factor variance as "true" and the SE <sup>2</sup> of the factor scores (given above) as "error" (because thes factor scores (given above) as "error" (because thes factor scores (given above) as "error" (because thes factor scores have error in then anytime reliability is < 1).           STIVING         DIVING         0.115         2.748         0.000           DRIVING         Batter stande         0.123         2.767         0.000           CRASH         0.457         0.117         5.596 <th< td=""><td>SPEED</td><td></td><td>0.836</td><td>0.042</td><td>19.687</td><td>0.000</td><td></td></th<>	SPEED		0.836	0.042	19.687	0.000	
Variances DRIVING       D.159       0.062       2.574       0.010         Residual Variances LANE       0.027       0.004       6.596       0.000         DA TASK       0.017       0.004       4.613       0.000         DA TASK       0.210       0.028       7.391       0.000         STOP       0.1174       0.028       7.391       0.000         New/Additional Parameters SUMDAD2       0.647       0.667       9.627       0.000         SUMERROR       0.647       0.066       0.000       0.023       DRIVING       0.000         STANDARDIZED MODEL RESULTS STDYX Standardization       Estimate       S.E.       Est./S.E.       Two-Tailed P-Value       Factor score reliability uses the factor variance as "true" and the SE2 of the factor scores (given above) as "error" (because these factor scores have error in then anytime reliability is < 1).	TTME.		3.146	0.009	349.081	0,000	
Variances DRIVING         0.159         0.062         2.574         0.010           Residual Variances LANE         0.027         0.004         6.596         0.000           DA TASK         0.017         0.004         4.613         0.000           CRASH         0.209         0.055         3.781         0.000           STOP         0.174         0.031         5.575         0.000           Mew/Additional Parameters         0.010         0.001         8.639         0.000           New/Additional Parameters         0.548         0.076         7.166         0.000           SUMERCOR         0.647         0.067         7.166         0.000           OMECA         0.548         0.076         7.166         0.000           STANDARDIZED MODEL RESULTS         Two-Tailed         Factor scores (given above) as "error" (because the factor scores (given above) as "error" (because the factor scores (given above) as "error" (because the factor scores have error in then anytime reliability is < 1).	T T1.1T1		0.110	0.000	010.001	0.000	
DRIVING         0.159         0.062         2.574         0.010           Residual Variances           LANE         0.027         0.004         6.596         0.000           DA TASK         0.017         0.004         4.613         0.000           CRASH         0.209         0.055         3.781         0.000           STOP         0.174         0.031         5.575         0.000           SPEED         0.210         0.028         7.391         0.000           New/Additional Parameters         SUMLOAD2         4.578         1.185         3.865         0.000           SUMEROR         0.647         0.067         9.627         0.000         0.09           STANDARDIZED MODEL RESULTS         STDYX standardization         Two-Tailed         P-Value           DRIVING BY         Estimate         S.E.         Est./S.E.         Two-Tailed           DATASK         0.457         0.117         5.596         0.000           STOP         0.315         0.115         2.767         0.000           DA TASK         0.470         0.323         5.76         0.000           STOP         0.315         0.115         2.748	Variances						
INTING       OTOD       Inting       Inting <thinting< th="">       Inting       Inting</thinting<>	DRIVING		0 159	0 062	2 574	0 010	
Residual Variances         LANE       0.027       0.004       6.596       Colope         DA_TASK       0.027       0.004       6.596       Colope         DA_TASK       0.027       0.004       6.596       Colope         DA_TASK       0.027       0.004       6.596       COLOP         DA_TASK       0.027       0.004       6.596       COLOP         STOP       0.174       0.002       TRIVING       DRIVING       DRIVING         MEMADAD2       4.578       1.185       3.865       OLICO         SUMLOAD2       4.578       1.185       3.865       OLICO         SUMLOAD2       4.578       1.185       3.865       OLICO         SUMLOAD2       4.578       1.189       OLICO       OLICO         STADADIJEZE MODEL RESULTS	DICIVING		0.135	0.002	2.071	0.010	
IABL       0.027       0.004       6.596       0.000         DA_TASK       0.017       0.004       4.613       0.000         CRASH       0.209       0.055       3.761       0.000         STOP       0.174       0.031       5.575       0.000         STOP       0.174       0.028       7.391       0.000         TIME       0.010       0.001       8.639       0.000         New/Additional Parameters       SUMLOAD2       4.578       1.185       3.865       0.000         SUMEROR       0.647       0.067       9.627       0.000       0.029         STANDARDIZED MODEL RESULTS       STDYX Standardization       Two-Tailed       P-value         DRIVING BY       Estimate       S.E. Est./S.E.       P-value       S26 of the factor scores (given) above) as "error" (because thes factor scores have error in then anytime reliability is < 1).	Posidual Va	ariancos					For factor score reliability
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	TANE	ar rances	0 027	0 004	6 506	0 000	SAMPLE STATISTICS FOR ESTIMATED
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	LANE DA MACK		0.027	0.004	0.590	0.000	FACTOR SCORES
CRASH       0.209       0.035       3.761       0.000         STOP       0.174       0.031       5.575       0.000         STOP       0.210       0.028       7.391       0.000         TIME       0.010       0.001       8.639       0.000         New/Additional Parameters       0.010       0.007       9.627       0.000         SUMRCOV       -0.046       0.009       -5.393       0.000         OMEGA       0.548       0.076       7.166       0.000         STANDARDIZED MODEL RESULTS       Two-Tailed       Factor score reliability uses the factor scores (given above) as "error" (because thes factor scores (given above) as "error" (because thes factor scores have error in them anytime reliability is < 1).         DRIVING BY       Estimate       S.E.       Est./S.E.       Two-Tailed P-Value         DRIVING BY       CRASH       0.657       0.117       5.596       0.000         DA TASK       0.470       0.132       3.576       0.000         STDED       0.185       0.145       1.275       0.202         SPEED       WITH       TIME       0.494       0.090       -5.478       0.000         Speed       0.359       0.000       Cotal fit looks mostly ok, with one exception	DA_TASK		0.017	0.004	4.613	0.000	Means
STOP       0.1/4       0.031       5.5/5       0.000         SPEED       0.210       0.028       7.391       0.000         New/Additional Parameters       0.010       0.001       8.639       0.000         SUMLOAD2       4.578       1.185       3.865       0.000         SUMRCOV       0.647       0.067       9.627       0.000         SUMRCOV       -0.046       0.009       -5.393       0.000         STDY Standardization       Two-Tailed       P       -159+.2472       =.723       Uh-oh.         STOP       0.340       0.123       2.767       0.000       Starone as "true" and the SE <sup>2</sup> of the factor scores (given above) as "error" (because thes factor scores have error in them anytime reliability is < 1).         SPEED       0.345       0.107       3.226       0.001         SPEED       0.345       0.107       3.226       0.001         SPEED       WITH       TIME       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       SPEED       DA_TASK       CRASH       Co.487       0.000         LANE       0.000       0.000       Cold fit looks mostly ok, with one exception	CRASH		0.209	0.055	3./81	0.000	DRIVING DRIVING SE
SPEED       0.210       0.028       7.391       0.000         TIME       0.010       0.001       8.639       0.000         New/Additional Parameters       0.002       4.578       1.185       3.865       0.000         SUMLROR       0.647       0.667       9.627       0.000 $\overline{DRIVING}$ $\overline{0.09}$ SUMRCOV       -0.046       0.009       -5.393       0.000 $\overline{P}=\frac{.159}{.159+.247^2} = .723$ $Uh-oh.$ STANDARDIZED MODEL RESULTS       Estimate       S.E.       Est./S.E.       Two-Tailed $P-Value$ DRIVING BY       CRASH       0.657       0.117       5.596       0.000 $Dators core reliability uses the factor scores (given above) as "error" (because thes factor scores have error in them above) as "error" (because thes factor scores have error in them above) as "error" (because thes factor scores have error in them anytime reliability is < 1).         SPEED       0.345       0.107       3.226       0.001         SPEED       WITH       TIME       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000       DA_TASK       CRASH       STOP       SPEED$	STOP		0.1/4	0.031	5.5/5	0.000	
TIME       0.010       0.001       8.639       0.000       0.000       0.0247         New/Additional Parameters       SUMLOAD2       4.578       1.185       3.865       0.000       DRIVING       DRIVING       0.09         SUMEROR       0.647       0.067       9.627       0.000       DRIVING       DRIVING       0.09         STANDARDIZED MODEL RESULTS       STOPX Standardization       Two-Tailed       P-Value       Factor score reliability uses the factor scores (given above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them anytime reliability is < 1).	SPEED		0.210	0.028	7.391	0.000	
New/Additional Parameters         SUMLOAD2       4.578       1.185       3.865       0.000         SUMERROR       0.647       0.067       0.000         SUMEROR       0.647       0.000         SUMEROR       0.647       0.000         SUMEROR       0.647       0.000         STANDARDIZED MODEL RESULTS         Two-Tailed         DRIVING BY       Two-Tailed         CRASH       0.657       0.117       5.596       0.000         LANE       0.345       0.117       5.596       0.000         SPEED       0.345       0.117       5.596       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations         SPEED       WITH         TIME       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations         LANE       0.000 </td <td>TIME</td> <td></td> <td>0.010</td> <td>0.001</td> <td>8.639</td> <td>0.000</td> <td>0.000 0.247</td>	TIME		0.010	0.001	8.639	0.000	0.000 0.247
New/Additional Parameters       Description         SUMLOAD2       4.578       1.185       3.865       0.000         SUMEROR       0.647       0.067       9.627       0.000         SUMECOV       -0.046       0.009       -5.393       0.000         OMEGA       0.548       0.076       7.166       0.000         STANDARDIZED MODEL RESULTS       Two-Tailed       P-Value       Factor score reliability uses the factor variance as "true" and the SE <sup>2</sup> of the factor scores (given above) as "error" (because these factor scores have error in them anytime reliability is < 1).							covariances
SUMLDAD2       4.578       1.185       3.865       0.000         SUMEROR       0.647       0.067       9.627       0.000         SUMEROV       -0.046       0.009       -5.393       0.000         OMEGA       0.548       0.076       7.166       0.000         STANDARDIZED MODEL RESULTS       Two-Tailed       Factor score reliability uses the factor variance as "true" and the SE <sup>2</sup> of the factor scores (given jabove) as "error" (because thes above) as "error" (because thes factor scores have error in them anytime reliability is < 1).	New/Additic	onal Parame	eters				
SUMERROR       0.647       0.067       9.627       0.000         SUMRCOV       -0.046       0.009       -5.393       0.000         OMEGA       0.548       0.076       7.166       0.000         STANDARDIZED MODEL RESULTS       STANDARDIZED MODEL RESULTS       Two-Tailed       P-Value         DRIVING BY       Estimate       S.E.       Est./S.E.       P-Value         CRASH       0.657       0.117       5.596       0.000         DA_TASK       0.470       0.132       3.576       0.000         STIME       0.345       0.107       3.226       0.001         TIME       0.485       0.145       1.275       0.202         SPEED       WITH       TIME       DA_TASK       CRASH       STOP         LANE       0.400       -5.478       0.000       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       STOP       STOP         LANE       DA_TASK       -0.487       0.000	SUMLOAD2	2	4.578	1.185	3.865	0.000	DRIVING 0.098
SUMRCOV OMEGA-0.046 0.5480.009 0.076-5.393 7.1660.000 0.000STANDARDIZED MODEL RESULTS STDYX StandardizationFactor score reliability uses the factor variance as "true" and the SE2 of the factor scores (given provided by a series of the factor scores (given provided by	SUMERRON	R	0.647	0.067	9.627	0.000	
OMEGA $0.548$ $0.076$ $7.166$ $0.000$ $p = 159 \pm .247^2 = .7.23$ $011$ $011$ STANDARDIZED MODEL RESULTS STDYX StandardizationTwo-Tailed P-ValueFactor score reliability uses the factor variance as "true" and the SE2 of the factor scores (given above) as "error" (because these factor scores have error in them above) as "error" (because these factor scores have error in them anytime reliability is < 1).	SUMRCOV		-0.046	0.009	-5.393	0.000	$a = \frac{.159}{$
STANDARDIZED MODEL RESULTS         STDYX Standardization         Estimate       S.E. Est./S.E.         DRIVING BY         CRASH       0.657         DA_TASK       0.470         0.345       0.117         STDY       3.576         0.000       STOP         0.185       0.145         1.275       0.202         SPEED       WITH         TIME       -0.494         0.090       -5.478         0.000       Normalized Residuals for Covariances/Correlations/Residual Correlations         LANE       DA_TASK         0.000	OMEGA		0.548	0.076	7.166	0.000	$p = \frac{1}{.159 + .247^2} = .723$ OII OII
STANDARDIZED MODEL RESULTS         STDYX Standardization         Estimate       S.E. Est./S.E.         DRIVING BY         CRASH       0.657         LANE       0.340         0.340       0.123         2.767       0.000         STOP       0.315         0.185       0.107         3.226       0.001         TIME       0.185         0.185       0.145         1.200       -0.494         0.090       -5.478         0.000       STOP         Normalized Residuals for Covariances/Correlations/Residual Correlations         LANE       0.000         CRASH       0.000         LANE       0.000         CRASH       0.000							
STDYX Standardization       Two-Tailed         Estimate       S.E. Est./S.E.       P-Value         DRIVING BY       0.657       0.117       5.596       0.000         LANE       0.340       0.123       2.767       0.006         DA_TASK       0.470       0.132       3.576       0.000         STOP       0.315       0.115       2.748       0.006         SPEED       0.345       0.107       3.226       0.001         TIME       0.185       0.145       1.275       0.202         SPEED       WITH       TIME       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       SPEED       SPEED       SPEED         LANE       0.000       -0.487       0.000       -0.000       -0.000         LANE       0.000       -0.390       0.000       Local fit looks mostly ok, with one exception	STANDARDIZEI	D MODEL RE:	SULTS				Factor score reliability uses the
Two-Tailed P-ValueDRIVING BY CRASH0.6570.1175.5960.000LANE0.3400.1232.7670.006DA_TASK0.4700.1323.5760.000STOP0.3150.1152.7480.006SPEED0.3450.1073.2260.001TIME0.1850.1451.2750.202SPEEDWITH TIME-0.4940.090-5.4780.000Normalized Residuals for Covariances/Correlations/Residual Correlations LANEDA_TASKCRASHSTOPDA_TASK-0.4870.000	STDYX Standa	ardization					factor veriance as "true" and the
EstimateS.E.Est./S.E.P-ValueSE2 of the factor scores (given above) as "error" (because thes factor scores have error in them above) as "error" (because thes factor scores have error in them anytime reliability is < 1).DRIVING BY CRASH0.6570.1175.5960.000LANE0.3400.1232.7670.006DA_TASK0.4700.1323.5760.000STOP0.3150.1152.7480.006SPEED0.3450.1073.2260.001TIME0.1850.1451.2750.202SPEEDWITH TIME-0.4940.090-5.4780.000Normalized Residuals for Covariances/Correlations/Residual Correlations LANEDA_TASKCRASHSTOPDA_TASK-0.4870.000						Two-Tailed	factor variance as true and the
DRIVING BY       above) as "error" (because these factor scores have error in them anytime reliability is < 1).		E	stimate	SE	Est /S E	P-Value	SE <sup>2</sup> of the factor scores (given just
CRASH       0.657       0.117       5.596       0.000         LANE       0.340       0.123       2.767       0.006         DA_TASK       0.470       0.132       3.576       0.000         STOP       0.315       0.115       2.748       0.006         SPEED       0.345       0.107       3.226       0.001         TIME       0.185       0.145       1.275       0.202         SPEED       WITH       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       SPEED       SPEED         LANE       0.000	DRIVING BY	<u> </u>	Definate	0.11.	100.70.11.	I Varac	above) as "error" (because these
LANE       0.340       0.123       2.767       0.006         DA_TASK       0.470       0.132       3.576       0.000         STOP       0.315       0.115       2.748       0.006         SPEED       0.345       0.107       3.226       0.001         TIME       0.185       0.145       1.275       0.202         SPEED       WITH       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       SPEED       SPEED         LANE       0.000       -0.487       0.000       SPEED         LANE       0.000       -0.487       0.000       -0.000	CDACU		0 657	0 117	5 506	0 000	factor coorce have arror in them
LIANNE       0.340       0.123       2.767       0.006       anytime reliability is < 1).	CKADI T AND		0.007	0.112	2.290	0.000	
DA_TASK       0.470       0.132       3.576       0.000       1 <td>LANE</td> <td></td> <td>0.340</td> <td>0.123</td> <td>2./0/</td> <td>0.006</td> <td>anytime reliability is &lt; 1).</td>	LANE		0.340	0.123	2./0/	0.006	anytime reliability is < 1).
STOP       0.315       0.115       2.748       0.006         SPEED       0.345       0.107       3.226       0.001         TIME       0.185       0.145       1.275       0.202         SPEED       WITH       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000       -0.487       0.000            LANE       0.359       -0.390       0.000       Local fit looks mostly ok, with one exception	DA_TASK		0.4/0	0.132	3.5/6	0.000	· · ·
SPEED       0.345       0.107       3.226       0.001         TIME       0.185       0.145       1.275       0.202         SPEED       WITH       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       Correlations       SPEED         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000	STOP		0.315	0.115	2./48	0.006	
TIME       0.185       0.145       1.275       0.202         SPEED       WITH       TIME       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       Correlations       STOP       SPEED         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000	SPEED		0.345	0.107	3.226	0.001	
SPEED       WITH         TIME       -0.494       0.090       -5.478       0.000         Normalized       Residuals       for       Covariances/Correlations/Residual       Correlations         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000	TIME		0.185	0.145	1.275	0.202	
SPEED       WITH         TIME       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       Correlations         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000							
TIME       -0.494       0.090       -5.478       0.000         Normalized Residuals for Covariances/Correlations/Residual Correlations       Crease       Correlations         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000	SPEED WIT	ГН					
Normalized Residuals for Covariances/Correlations/Residual Correlations         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000	TIME		-0.494	0.090	-5.478	0.000	
Normalized Residuals for Covariances/Correlations/Residual Correlations         LANE       DA_TASK       CRASH       STOP       SPEED         LANE       0.000            DA_TASK       -0.487       0.000        Local fit looks mostly ok, with one exception         CRASH       0.359       -0.390       0.000       Local fit looks mostly ok, with one exception							
LANE         DA_TASK         CRASH         STOP         SPEED           LANE         0.000	1	Normalized	Residua	ls for Cova	riances/Cor	relations/Re	esidual Correlations
LANE 0.000 DA_TASK -0.487 0.000 CRASH 0.359 -0.390 0.000		LANE	D	A_TASK	CRASH	STOP	SPEED
LANE 0.000 DA_TASK -0.487 0.000 CRASH 0.359 -0.390 0.000							
DA_TASK -0.487 0.000 Local fit looks mostly ok, with one exception	LANE	0.000			Г		
	DA_TASK	-0.487		0.000		Local fit look	s mostly ok, with one exception
	CRASH	0.359		-0.390	0.000 L		-
STOP 0.769 0.503 -0.004 0.000	STOP	0.769		0.503	-0.004	0.000	)
SPEED 0.458 -0.836 0.471 -0.482 0.000	SPEED	0.458		-0.836	0.471	-0.482	0.000
TIME -1.508 <b>2.067</b> -0.346 -0.545 0.000	TIME	-1.508		2.067	-0.346	-0.545	0.000

# Measurement Model 3 for Attentional Impairment (including Omega)

```
VARIABLE: ! Every variable in THIS MODEL
            USEVARIABLES = lnda lnsa Dscan;
MODEL: ! Measurement model
 Attn BY lnda@1
         lnsa* dscan* (L2-L3); ! 1 marker loading
  [lnda* lnsa* dscan*];
                         ! All intercepts
  lnda* lnsa* dscan* (E1-E3); ! Residual variances
                              ! Factor M=0, Var=?
  [Attn@0]; Attn* (Fvar);
MODEL CONSTRAINT: ! TO GET OMEGA
NEW (SumLoad2 SumError SumRCov Omega);
SumLoad2 = (1+L2+L3)**2;
SumError = E1+E2+E3;
SumRCov = 2*(0);
! Omega = true variance / total variance
Omega = SumLoad2*Fvar / (SumLoad2*Fvar+SumError+SumRCov);
```

Can you guess why I didn't include the model fit results???

# Measurement Model 3 for Attention:

MODEL RESULTS				
	Estimate	SE	Est /S E	Two-Tailed
ATTN BY	Hotridee	0.11.	100.70.11.	1 Varae
LNDA	1.000	0.000	999.000	999.000
LNSA	0.516	0.071	7.275	0.000
DSCAN	1.107	0.139	7.933	0.000
Means				
ATTN	0.000	0.000	999.000	999.000
Intercepts				
LNDA	4.354	0.079	54.825	0.000
LNSA	5.581	0.036	154.256	0.000
DSCAN	-0.012	0.081	-0.154	0.878
Variances				
ATTN	0.443	0.088	5.008	0.000
Residual Varian	ces			
LNDA	0.516	0.068	7.597	0.000
LNSA	0.081	0.017	4.674	0.000
DSCAN	0.449	0.086	5.243	0.000
New/Additional	Parameters			
SUMLOAD2	6.876	0.960	7.165	0.000
SUMERROR	1.045	0.102	10.212	0.000
SUMRCOV	0.000	0.000	0.000	1.000
OMEGA	0.745	0.038	19.728	0.000
STANDARDIZED MOD	EL RESULTS			
STDYX Standardiz	ation			mare medilari
				Two-Talled

Estimate

0.770

0.740

0.680 0.055

0.055

0.056

ATTN BY

LNDA LNSA

DSCAN

S.E. Est./S.E. P-Value

12.275

14.087

13.153 0.000

0.000

0.000

For factor score re	eliability
SAMPLE STATISTICS	FOR ESTIMATED
FACTOR SCORES	
Means	
ATTN	ATTN_SE
0.000	0.313
Covariances	
ATTN	0.345
$\rho = \frac{.443}{.443 + .313^2} = .83$	19

Factor score reliability uses the factor variance as "true" and the  $SE^2$  of the factor scores (given just above) as "error" (because these factor scores have error in them anytime reliability is < 1).

Now we are ready to test the model of interest, **Model 4a** as shown below (drawn by Mplus, made prettier by me). We'll begin with a **saturated structural model** that has main effects of the latent variables only. This model uses directed arrows and covariances among the latent variables (but bivariate relations instead of unique relations will be provided by the model-estimated latent variable covariance matrix in the output).



<pre>! Structural model with all possible main effects Vision Attn Pspeed Driving ON Age75* (Age1-Age4); ! Age&gt; outcomes Attn Pspeed Driving ON Vision* (Vis1-Vis3): ! Vision&gt; outcomes</pre>								
Attn I	WITH Pspeed*;	· <u>]</u>	eed1 Attn1)		! Res cov for Attn and Pspeed			
DIIVI					· rspeed, Attin > Driving			
<pre>MODEL CONSTRAINT: ! Example of how to request indirect effects NEW(AgeVis AgeSpeed AgeAttn); AgeVis = Age1*Vis3; ! Indirect effect of age to vision to driving AgeSpeed = Age3*Speed1; ! Indirect effect of age to processing speed to driving AgeAttn = Age2*Attn1; ! Indirect effect of age to attention to driving</pre>								
MODEL FIT Number of Loglikeli	INFORMATION Free Parameters hood H0 Value H0 Scaling Corr for MLR H1 Value H1 Scaling Corr for MLR	ection Factor	58 -1310.811 1.1063 -1238.221 1.0405					
Informati	on Criteria Akaike (AIC) Bayesian (BIC) Sample-Size Adj (n* = (n + 2)	usted BIC / 24)	2737.622 2913.007 2729.438					
Chi-Squar	e Test of Model Value Degrees of Free P-Value Scaling Correct for MLR	Fit edom ion Factor	144.331* 110 0.0156 1.0059	k .	Overall model fit is good enough according to RMSEA and SRMR (how much worse is our $H_0$ model than the perfect saturated $H_1$ model), but maybe a little lacking according to CFI and TLI (how much better is our $H_0$ model against the			
RMSEA (Ro	ot Mean Square E Estimate 90 Percent C.I. Probability RMS	Crror Of Appro	0.045 0.021 0.635	0.064	worst possible null model of no covariances). But any misfit must be due to the cross-factor measurement model (i.e., covariances of			
CFI/TLI SRMR (Sta	CFI TLI ndardized Root M	lean Square Re	0.936 0.921 esidual)		indicators from different factors not predicted accurately) <b>because our structural model is</b> <b>saturated</b> —every possible direct relationship among the latent variables has been included.			
IINSTANDAR	Value	ILTS (TRIINCATE	0.063	L				
MEASUREME	Estin NT MODEL RESULTS	ate S.H GIVEN FIRST	E. Est./S.E. (BY STATEMENT	Two-Tail P-Valu <b>IS)</b>	ed e			
FAR LNCS1 LNCS3 LNCS6 LNCS1 LNCS1	5 0. 5 0. 0. 2 1. 8 1.	000         0.00           481         0.09           584         0.12           759         0.13           265         0.20           491         0.23	999.000           99         4.837           15         5.076           36         5.583           03         6.248           32         6.416	999.00 0.00 0.00 0.00 0.00	0 0 0 0 0 0			
DRIVING CRASH LANE DA_TA STOP SPEED TIME	BY 1. 0. SK 0. 0. 0.	000         0.00           161         0.00           197         0.00           381         0.10           418         0.10           097         0.05	00         999.000           56         2.444           55         3.022           54         2.330           54         2.540           53         1.819	999.00 0.01 0.02 0.01 0.06	0 5 3 0 1 9			
ATTN LNDA LNSA DSCAN	BY 1. 0. 1.	000 0.00 491 0.00 192 0.1	00 999.000 51 8.000 70 7.022	999.00 0.00 0.00	0 0 0			

PSPEED BY LNPS 1.000 0.000 999.000 999.000

#### REGRESSION PATHS GIVEN NEXT (ON STATEMENTS)

ATTN	ON				
VIS	ION	0.287	0.137	2.095	0.036
PSPEED	ON				
VIS	ION	0.167	0.100	1.658	0.097
DDTUTNO	ON				
DRIVING	ON				
VIS	ION	-0.089	0.109	-0.814	0.415
PSPI	EED	0.114	0.083	1.387	0.165
ATT	V	0.365	0.127	2.884	0.004
VISION	ON				
AGE	75	0.024	0.011	2.187	0.029
ATTN	ON				
AGE	75	0.059	0.014	4.393	0.000
PSPEED	ON				
AGE	75	0.008	0.008	0.988	0.323
DRIVING	ON				
AGE	75	0.001	0.011	0.119	0.905

# COVARIANCES GIVEN LAST (WITH STATEMENTS)

A'1''1'N	M T .T.H				
PSP:	EED	0.061	0.027	2.292	0.022
SPEED	WITH				
TIM	E	-0.025	0.004	-5.512	0.000

#### INDIRECT EFFECTS REQUESTED USING MODEL CONSTRAINT

New/Additional	Parameters			
AGEVIS	-0.002	0.003	-0.830	0.406
AGESPEED	0.001	0.001	0.764	0.445
AGEATTN	0.022	0.009	2.507	0.012

STANDARDIZED MODEL RESULTS (TRUNCATED FOR SPACE) STDYX Standardization

				Two-Tailed
	Estimate	S.E.	Est./S.E.	P-Value
VISION BY				
FAR	0.580	0.062	9.424	0.000
LNCS15	0.531	0.076	6.999	0.000
LNCS3	0.653	0.061	10.646	0.000
LNCS6	0.694	0.059	11.851	0.000
LNCS12	0.749	0.051	14.647	0.000
LNCS18	0.717	0.042	17.024	0.000
DRIVING BY				
CRASH	0.575	0.107	5.378	0.000
LANE	0.319	0.130	2.446	0.014
DA TASK	0.470	0.100	4.694	0.000
STOP	0.302	0.115	2.630	0.009
SPEED	0.298	0.102	2.911	0.004
TIME	0.325	0.132	2.470	0.014
ATTN BY				
LNDA	0.672	0.058	11.501	0.000
LNSA	0.724	0.053	13.543	0.000
DSCAN	0.787	0.045	17.608	0.000
PSPEED BY				
LNPS	1.000	0.000	999.000	999.000
DRIVING ON				
VISION	-0.122	0.148	-0.826	0.409
PSPEED	0.164	0.120	1.368	0.171
ATTN	0.690	0.149	4.617	0.000
PSPEED ON				
VISION	0.160	0.094	1.715	0.086
ATTN ON				
VISION	0.209	0.096	2.191	0.028
DRIVING ON				
AGE75	0.017	0.148	0.118	0.906
VISION ON				
AGE75	0.224	0.087	2.582	0.010
ATTN ON				
AGE75	0.413	0.081	5.085	0.000
PSPEED ON				
AGE75	0.074	0.075	0.986	0.324
ATTN WITH				
PSPEED	0.221	0.088	2.523	0.012
SPEED WITH				
TIME	-0.544	0.090	-6.061	0.000

Left: The ON statements among the latent variables describe the standardized (correlation metric) unique relations of each latent predictor for the same latent outcome.

Below: The estimated latent variable correlation matrix describes the bivariate relations among the latent predictors and outcomes instead. It's useful to understand both types of relations in describing the results (that way you can differentiate what is not related *bivariately* from what is not related *any more* after controlling for something else).

ESTIMATED CORRELATION MATRIX FOR LATENT VARIABLES							
	VISION	DRIVING	ATTN	PSPEED			
VISION	1.000						
DRIVING	0.119	1.000					
ATTN	0.302	0.705	1.000				
PSPEED	0.177	0.331	0.270	1.000			
AGE75	0.224	0.325	0.459	0.110			

Latent				Two-Ta	ailed
Variable	Estimate	S.E.	Est./S.E.	P-Va	alue
VISION	0.050	0.039	1.291	0	.197
DRIVING	0.532	0.151	3.526	0	.000
ATTN	0.253	0.077	3.264	0	.001
PSPEED	0.037	0.032	1.129	0	.259
! Reduced a	structural model	4b (n	o age or	visio	on> driving)
Vision A	ttn Pspeed ON Age	e75*	(Age2-Age	4)	<pre>! Age&gt; outcomes, not driving</pre>
A	ttn Pspeed ON Vi	sion*	(Vis2-Vis	3);	! Vision> outcomes, not driving
Attn WITH	H Pspeed*;				! Res cov for Attn and Pspeed
Driving (	ON Pspeed* Attn*	(Spe	ed1 Attn1	);	! Pspeed, Attn> Driving
MODEL ETH THE					Did constraining these two structured noths to 0
Number of Fre	e Parameters		56		
Loglikelihood	e fafameters		50		make the model worse?
НО	Value		-1311.286		Rescaled $-2\Delta LL(2) = 0.646$ , $p = .72$ , so no
НO	Scaling Correction F	actor	1.0933		
f	or MLR				This model comparison is the appropriate way to
Hl	Value		-1238.221		test changes to the structural model whose job is
Hl	Scaling Correction F	actor	1.0405		to reproduce the equationed emeng the letent
f	or MLR				to reproduce the covariance among the latent
Information C	riteria				factors and any observed predictors (but not
Aka	ike (AIC)		2734.572		among any observed predictors themselves).
Bay	esian (BIC)		2903.909		
Sam	ple-Size Adjusted BI	С	2726.670		Bolying on good global model fit (which will mostly
(	$n^* = (n + 2) / 24)$				Relying on good global model in (which will mostly
Chi-Square Te	st of Model Fit				reflect the measurement models) is not sufficient
Val	ue		144.090*		to say a structural model fits. Instead, one should
Deg	rees of Freedom		112		compare any overidentified structural model (with
P-V	alue		0.0221		paths missing) to the saturated structural model to
Sca	ling Correction Fact	or	1.0142		patris missing) to the saturated structural model to
I (D M	or MLR				see if the fit is "not worse". One might compute a
RMSEA (ROOL M	imate	AbbroxI			new version of the H1 model that reflects a
ESC 90	Percent C T		0.043	0 063	saturated structural model (and a new null model
90 Pro	bability DMGEA <- 0	5	0.018	0.005	that reflects an independent structural model) to be
CFT/TT.T	DADITICY NUDER (0	5	0.091		used in computing structural model fit indices
CEL CEL			0.940		
СГ I ФТ.Т			0 927		
SRMR (Standar	dized Root Mean Squa	re Resi	dual)		We will continue with a saturated structural model
Val	ue		0.063		in the model variants that follow

R-SOUARE

What if we wanted to test a latent variable interaction? Model 5a (same measurement model as in Model 4a, including a full structural model with additions shown below)

Note that latent variable interactions can only be model predictors (and they cannot have covariances) Latent variable interactions do not appear to be possible within R lavaan (or I couldn't find it if so)

```
ANALYSIS: ESTIMATOR = MLR; ! For continuous items whose residuals may not be normal
            TYPE = RANDOM; ALGORITHM = INTEGRATION; ! New estimation options needed
! Full structural model
  Vision Attn Pspeed Driving ON Age75* (Age1-Age4); ! Age --> outcomes
         Attn Pspeed Driving ON Vision* (Vis1-Vis3); ! Vision --> outcomes
  Attn WITH Pspeed*;
                                                        ! Res cov for Attn and Pspeed
  Driving ON Pspeed* Attn* (Speed1 Attn1);
                                                        ! Pspeed, Attn --> Driving
! Interaction between two latent variables (would be same if one variable was observed)
 VisAttn | Vision XWITH Attn; ! VisAttn = new latent variable interaction
                                    ! Latent variable interaction --> Driving
  Driving ON VisAttn* (VxA);
MODEL CONSTRAINT: ! Original latent factor variance of attn = .443, of vision = .224
NEW (V4low V4high A4low A4high);
 V4low = Vis3 - VxA*SQRT(.443); ! Vision slope for -1SD attn
 V4high = Vis3 + VxA*SQRT(.443); ! Vision slope for +1SD attn
A4low = Attn1 - VxA*SQRT(.224); ! Attn slope for -1SD vision
  A4high = Attn1 + VxA*SQRT(.224); ! Attn slope for -+1SD vision
```

MODEL FIT INFORMATION					
Number of Free Parameters 59					
Loglikelihood		_			
HO Value	-1310.261	.			
H0 Scaling Correction Factor	1.1066				
for MLR					
Information Criteria					
Akaike (AIC)	2738.522				
Bayesian (BIC)	2916.931				
Sample-Size Adjusted BIC	2730.197				
$(n^* = (n + 2) / 24)$					

The absolute model fit indices have disappeared once we've used numeric integration (no  $H_1$  saturated covariance matrix to come back to anymore). STDYX disappears for the same reason.

# New structural model output only-note that the VisAttn interaction is related only to driving:

### UNSTANDARDIZED MODEL RESULTS

					Two-Tailed	
		Estimate	S.E.	Est./S.E.	P-Value	
ATTN	ON					
VISION		0.305	0.142	2.140	0.032	
PSPEED	ON					
VISION		0.168	0.101	1.662	0.096	
DRIVING	ON					
VISION		-0.106	0.114	-0.924	0.355	simple vision slope at attn=0
PSPEED		0.118	0.083	1.423	0.155	
ATTN		0.363	0.130	2.785	0.005	simple attn slope at vision=0
VISATT	N	0.139	0.142	0.978	0.328	n.s. interaction
VISION	ON					
AGE75		0.024	0.011	2.188	0.029	
ATTN	ON					
AGE75		0.059	0.014	4.399	0.000	
PSPEED	ON					
AGE75		0.008	0.008	0.982	0.326	
DRIVING	ON					
AGE75		0.002	0.011	0.135	0.892	
ATTN W	ITH					
PSPEED		0.060	0.027	2.222	0.026	
New/Additi	onal E	Parameters				
V4LOW		-0.198	0.167	-1.181	0.237	simple vision slope at attn=-1SD
V4HIGH		0.013	0.126	-0.105	0.916	simple vision slope at attn=+1SD
A4LOW		0.297	0.139	2.134	0.033	simple attn slope at vision=-1SD
A4HIGH		0.428	0.153	2.793	0.005	simple attn slope at vision=+1SD

#### STDYX Standardization

		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
ATTIN VISION	ON	0.220	0.099	2.233	0.026
PSPEED VISION	ON	0.160	0.093	1.720	0.085
DRIVING VISION PSPEED ATTN VISATTN	ON	-0.145 0.170 0.692 0.125	0.155 0.120 0.152 0.126	-0.939 1.417 4.564 0.999	0.348 0.157 0.000 0.318
VISION AGE75	ON	0.227	0.088	2.594	0.009
ATTN AGE75	ON	0.413	0.081	5.071	0.000
PSPEED AGE75	ON	0.074	0.075	0.981	0.327
DRIVING AGE75	ON	0.020	0.151	0.133	0.894
ATTN W PSPEED	ITH	0.217	0.088	2.448	0.014

What would have happened if we used the mean of each person's factor score distribution from the single-factor models as observed constructs instead (i.e., replaced the latent circles with observed boxes)? Let's compare two possible ways of doing this—with or without reliability correction.

```
TITLE: SEM Example for Driverscan using Single Factor Scores;
DATA:
                                     ! EAP factor scores merged into original data
 FILE = SEMfactorscores.csv;
  TYPE = INDIVIDUAL; FORMAT = FREE; ! Defaults
VARIABLE:
! List of ALL variables in data file
  NAMES = PersonID sex age75 lncs15 lncs3 lncs6 lncs12 lncs18 far lnps
          1nda 1nsa Dscan 1ane da task crash stop speed time
          VisFact DrivFact AttnFact; ! New factor scores
! Variables to be analyzed in this model
 USEVARIABLE = age75 lnps VisFact DrivFact AttnFact;
! Missing data identifier
 MISSING = ALL (-9999);
! ID variable;
  IDVARIABLE = PersonID;
ANALYSIS:
           ESTIMATOR = MLR:
            TYPE = RANDOM; ALGORITHM = INTEGRATION;
                                                      ! New estimation options for latent interaction
OUTPUT:
            STDYX RESIDUAL; ! Standardized model, local fit
            SAMPSTAT;
                                ! Get descriptive stats for variables
```

Model 5b: Using Reliability-Corrected Single Factor Scores (and Latent Interaction)

```
MODEL.
! Measurement models for "factors" (factor mean=0 used to do centering)
! "Res" labels used to Incorporate factor score unreliability
 Vision BY VisFact@1; Vision*; VisFact* (ResVis); [Vision@0 VisFact*];
                                  AttnFact* (ResAttn); [Attn@0
  Attn
         BY AttnFact@1; Attn*;
                                                                  AttnFact*];
 Pspeed BY lnps@1; Pspeed*; lnps*
                                           (ResPspd); [Pspeed@0 lnps*];
  Driving BY DrivFact@1; Driving*; DrivFact* (ResDriv); [Driving@0 DrivFact*];
  VisAttn | Vision XWITH Attn; ! Latent interaction term (to address unreliability)
! Structural model among "factors"
  Vision Attn Pspeed Driving ON Age75* (Age1-Age4); ! Age --> outcomes
        Attn Pspeed Driving ON Vision* (Vis1-Vis3); ! Vision --> outcomes
 Attn WITH Pspeed*;
                                                      ! Res cov for Attn and Pspeed
  Driving ON Pspeed* Attn* (Speed1 Attn1);
                                                     ! Pspeed, Attn --> Driving
  Driving ON VisAttn* (VxA);
                                                      ! Interaction --> Driving
MODEL CONSTRAINT: ! Factor score variance of attn = .345, of vision = .186
NEW (V4low V4high A4low A4high);
  V4low = Vis3 - VxA*SQRT(.345);
                                  ! Vision slope for -1SD attn
 V4high = Vis3 + VxA*SQRT(.345); ! Vision slope for +1SD attn
  A4low = Attn1 - VxA*SQRT(.186); ! Attn slope for -1SD vision
 A4high = Attn1 + VxA*SQRT(.186); ! Attn slope for -+1SD vision
! (1-Reliability)*(factorvar+(SE*SE)) to fix residual variances to "error" variance
  ResVis =(1-.856)*(0.224+(.194*.194));
  ResAttn=(1-.819)*(0.443+(.313*.313));
  ResPspd=0; ! Processing speed assumed perfectly reliable
  ResDriv=(1-.723)*(0.159+(.247*.247));
! Processing speed assumed perfectly reliable
```

Model 5c: Using Uncorrected Single Factor Scores (Reliability=1 for all; changes to code below)

```
VARIABLE: ! Variables to be analyzed in this model
USEVARIABLE = age75 lnps VisFact DrivFact AttnFact VisAttn;
DEFINE: VisAttn = VisFact * AttnFact; ! Interaction is now an observed variable instead of latent
ANALYSIS: ESTIMATOR = MLR; ! Integration no longer needed
MODEL: ! All measurement and structural model code is the same as 5b after removing latent interaction
!VisAttn | Vision XWITH Attn; ! Latent interaction term removed (is now observed)
MODEL CONSTRAINT:
! Residual variances as "error" variances now ALL fixed to 0
ResVis=0;
ResAttn=0;
ResAttn=0;
ResPspd=0;
ResDriv=0;
```

# Model fit is acceptable for Model 5c (DF=3), but not available for Model 5b (given latent interaction)

	Estimates			Stand	ard Erro	ors	P-	P-Values		
	5a	5b	5c	5a	5b	5c	5a	5b	5c	
MODEL	SEM	CF	UF	SEM	CF	UF	SEM	CF	UF	
Age>										
VISION	.227	.232	.203	.088	.086	.077	.009	.007	.008	
ATTN	.413	.418	.362	.081	.086	.073	.000	.000	.000	
PSPEED	.074	.073	.081	.075	.076	.074	.327	.337	.275	
DRIVING	.020	069	.046	.151	.160	.082	.894	.665	.576	
Vision>										
PSPEED	.160	.162	.144	.093	.091	.081	.085	.076	.077	
ATTN	.220	.246	.170	.099	.105	.075	.026	.019	.022	
ATTN<>PSPEED	.217	.230	.198	.088	.093	.073	.014	.014	.007	
DRIVING <										
PSPEED	.170	.150	.129	.120	.144	.081	.157	.299	.110	
VISION	145	172	035	.155	.190	.087	.348	.364	.686	
ATTN	.692	.934	.415	.152	.187	.082	.000	.000	.000	
VISATTN	.125	.189	.028	.126	.155	.073	.318	.223	.705	
R2 Latent										
Variable										
VISION	.052	.054	.041	.040	.040	.031	.195	.179	.186	
ATTN	.260	.283	.185	.081	.091	.060	.001	.002	.002	
PSPEED	.037	.037	.032	.032	.032	.027	.258	.245	.237	
DRIVING	.551	.872	.226	.147	.248	.061	.000	.000	.000	

What about the results? Let's compare the standardized solution across our 3 options:



From our informal comparison of methods, it looks like reliability-corrected version (model 5b) of the full SEM model 5a appears to do a better job of reproducing parameter estimates (left figure) and standard errors (right figure) than the uncorrected version (model 5c). Note that a single estimate of reliability cannot be used as demonstrated here when factors are created using IRT/IFA, in which reliability is trait-specific instead (although it may be possible to trick Mplus into doing so, I'm not aware of any work on this).

For an example SEM results section, see Hoffman et al. (2005) reference given on page 1.