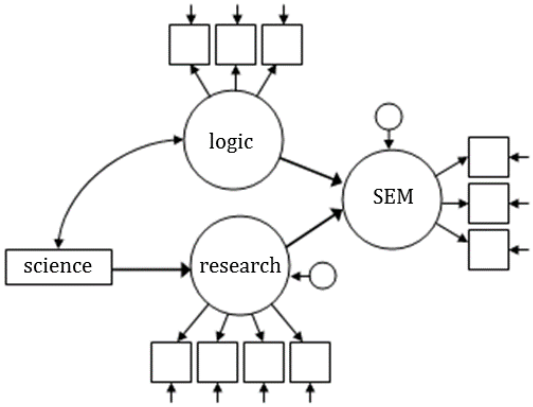


Intro to SEM

with examples from Stata and Mplus

Christiane Grill Nate Breznau

Mannheim Centre for European Social Research
Social Science Data Lab

29.11.2017

What is SEM

- **Structural** – human built, constructed
- **Equation**
  - a logical statement (“=”)
  - a mathematical statement (5x=2y)
  - statistical in some way

What is SEM

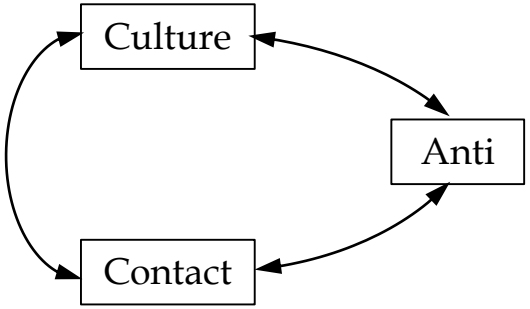
- **Structural** – human built, constructed
- **Equation**
  - a logical statement (“=”)
  - a mathematical statement (5x=2y)
  - statistical in some way
- **Structural Equation** – one equation dependent on others
- **Models** – descriptions of theory in mathematical terms

What is SEM

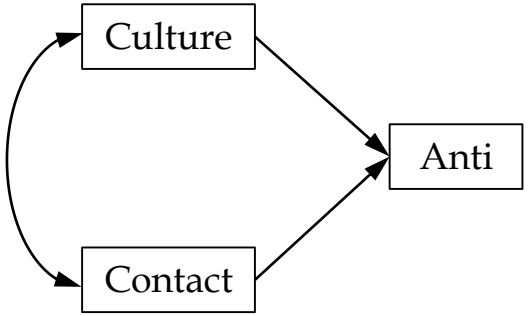
Anti-immigrant attitudes
Culture: value of cultural diversity
Contact with immigrants

Model 1. Same Variables. Alternative Models.

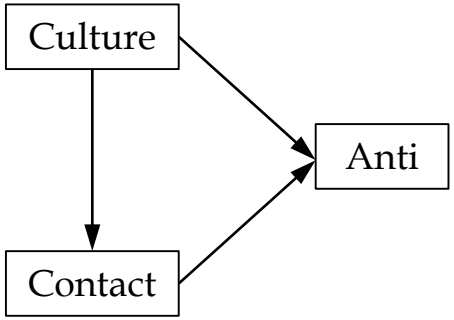
(a)



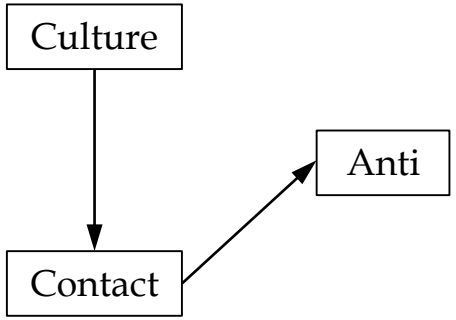
(b)



(c)



(d)

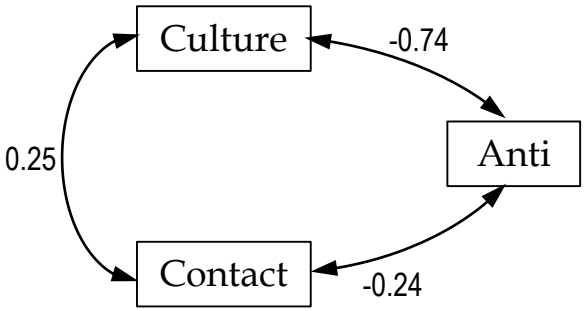


What is SEM

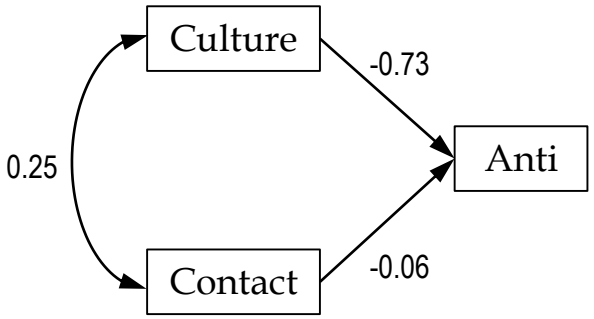
Model 1. Same Variables. Alternative Models.

Anti-immigrant attitudes
Culture: value of cultural diversity
Contact with immigrants

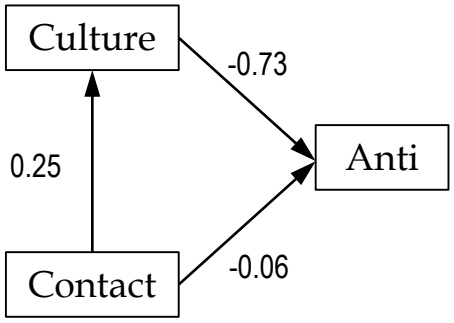
(a)



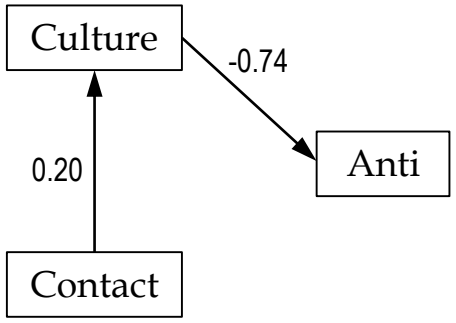
(b)



(c)



(d)



Mplus Code: M1a; M1b; M1c; M1d

What is SEM

Model 1. Same Variables. Alternative Models.

Anti-immigrant attitudes
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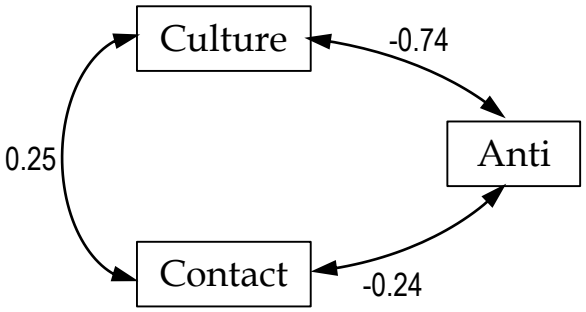
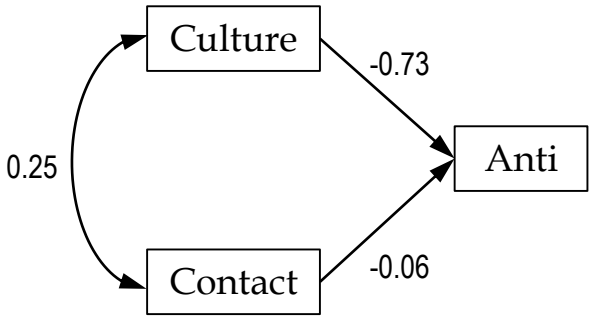
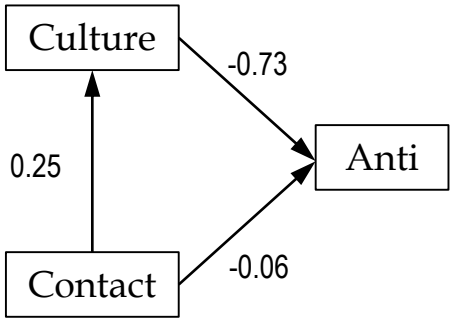
(a)



(b)

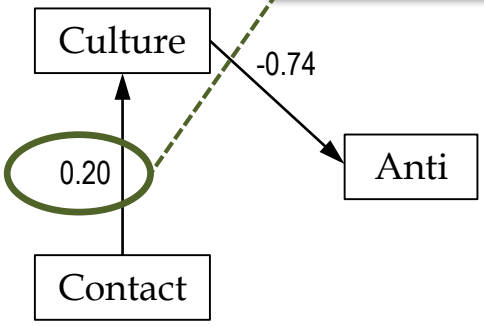


(c)



(d)

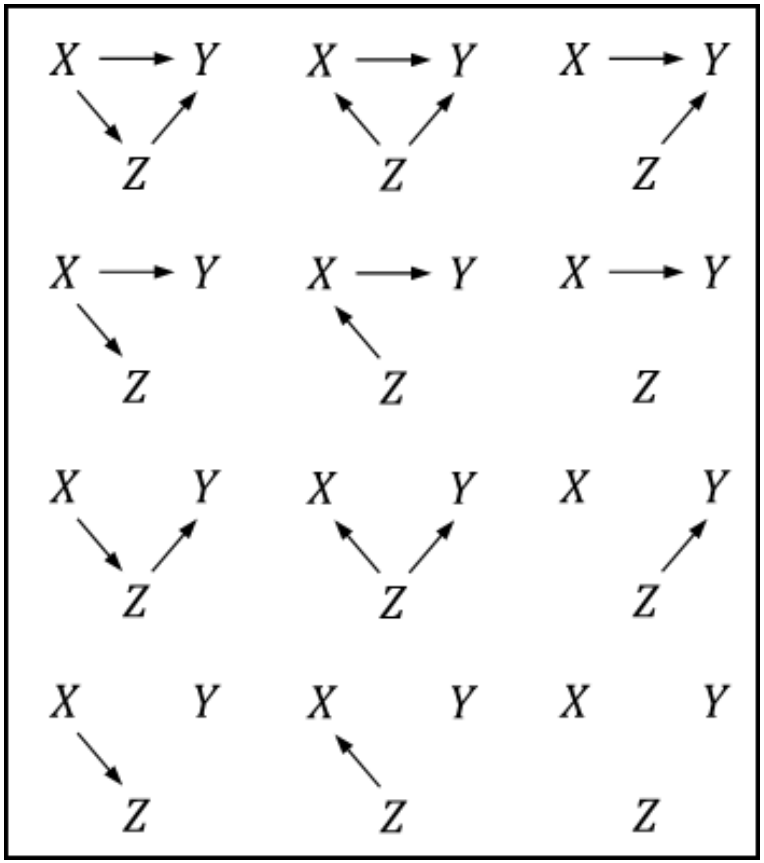
Structural coefficient!
E(Culture)|Contact, Contact ⊥ Anti



Code: fig1a; fig1b; fig1c; fig1d

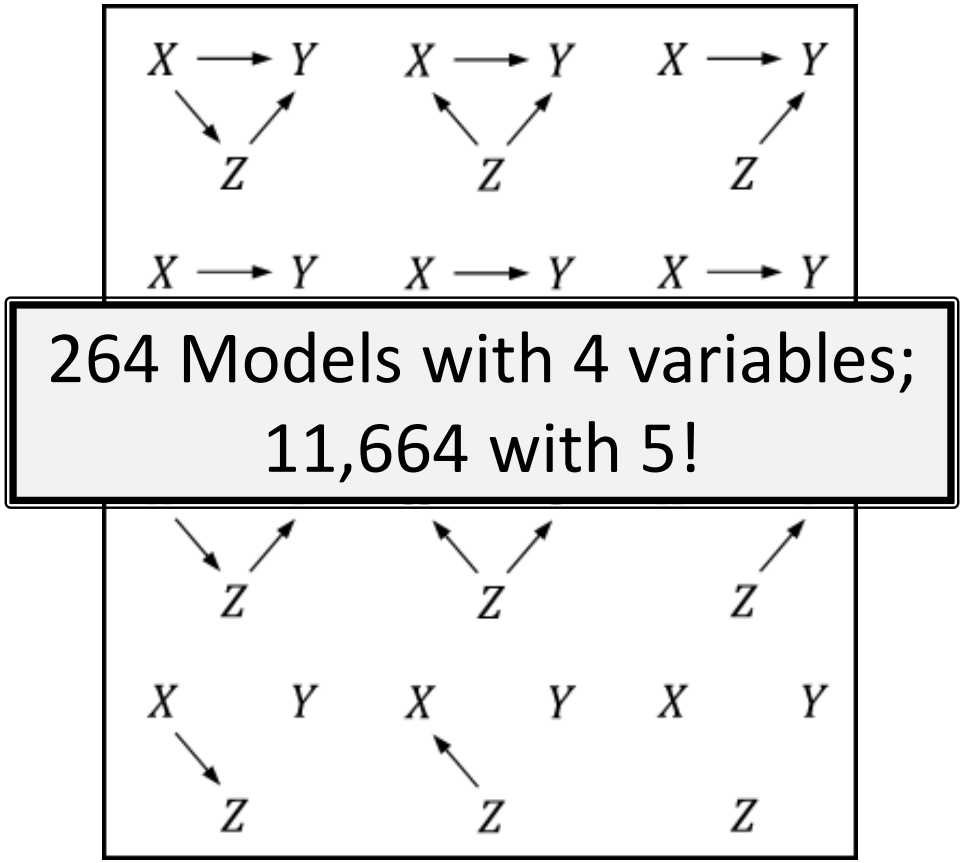
What is SEM

Figure 2. Twelve Alternative Path Models for one Outcome (Y) and two Inputs (X, Z)



What is SEM

Figure 2. Twelve Alternative Path Models for one Outcome (Y) and two Inputs (X, Z)



Surprising but True. SEM…

- …is analysis of covariance structures
- …does not minimize error terms
- …cannot identify causality
- …requires qualitative assumptions
- …'s structural coefficients ≠ regression coefficients
- …*any* model can eventually fit the data perfectly

(Bollen 1989; Bollen and Pearl 2013)

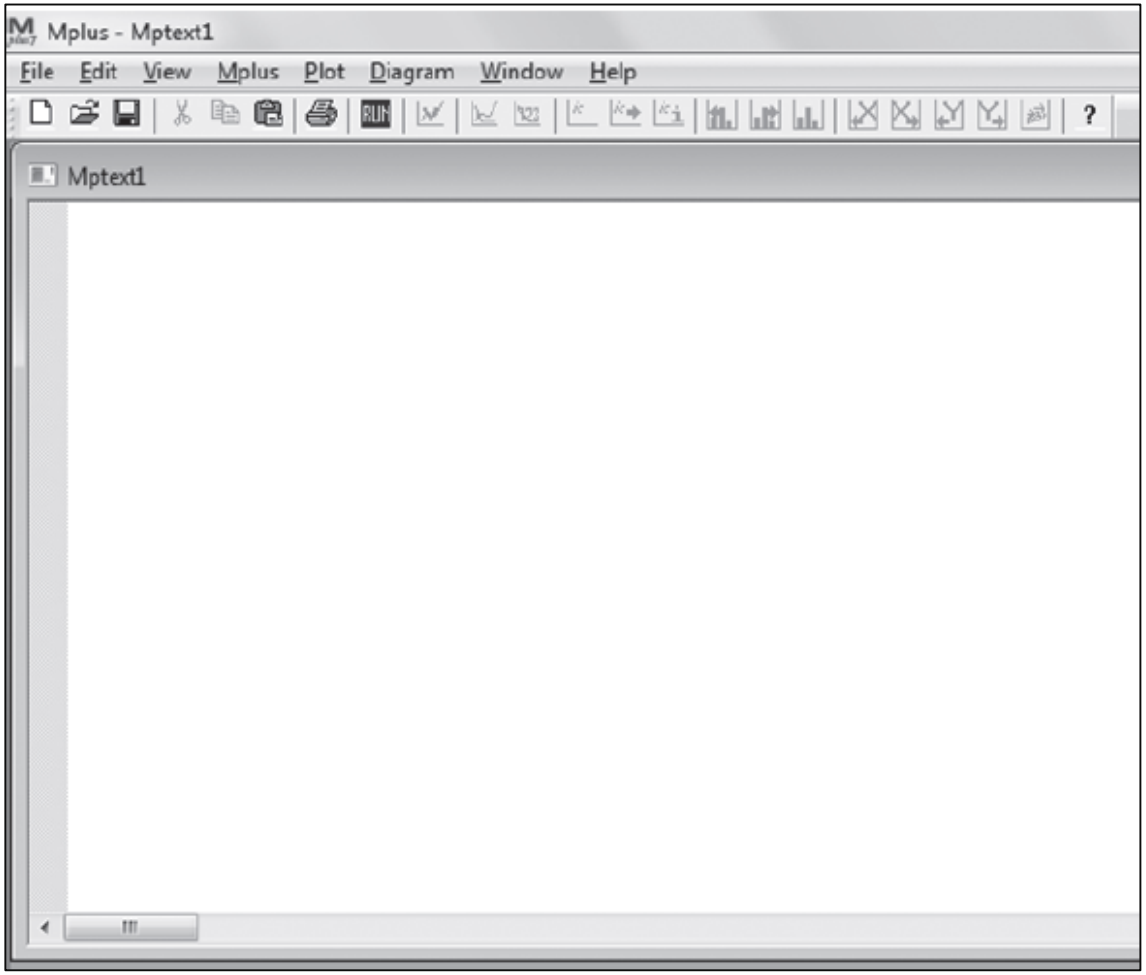
MPLUS


Mplus
THURSDAY
NOVEMBER 23, 2017
HOME ORDER CONTACT US LOGIN MPLUS DISCUSSION
MPLUS
Mplus at a Glance
General Description
Mplus Programs
Pricing
Version History
System Requirements
Platforms
FAQ
MPLUS DEMO VERSION
TRAINING
Short Courses
Short Course Videos and Handouts
Web Training
DOCUMENTATION
Mplus User's Guide
Mplus Diagrammer
Technical Appendices
Mplus Web Notes
User's Guide Examples
Mplus Book
Mplus Book Examples
Mplus Book Errata
ANALYSES/RESEARCH
Mplus Examples
Papers
Last updated: November 21, 2017
Mplus Version 8 Available Now!!!
Latest News
• Mplus Version 8 is now available. Mplus Version 8 includes corrections to minor problems that have been found since the release of Version 7.4 in November 2015 and the following new features listed on our Version History page. Registered users who purchased Mplus within the last year and those with a current Mplus Upgrade and Support Contract can download Version 8 at no cost by logging into their customer account.
Mplus Papers
Using Special Mplus Features
Mplus Demo Version
The Mplus Demo version is available for download at no cost. Click here to download the demo. The demo version contains all of the capabilities of the regular version of Mplus and is only limited by the number of observed variables that can be used in an analysis.
Student Pricing for Mplus Version 8
Special student pricing is available for Mplus. The student version of the program is identical to the regular version. Click here for more information.
Mplus Version 8 User's Guide and Examples
Click here for the Mplus
and to download the in
the Mplus User's Guide
www.statmodel.com

MPLUS

- Mplus editor
- Mplus input file: *.inp
- Mplus output file: *.out
- Input data file: *.dat
  - Define missings!

- Other software runs Mplus
  - runmplus (Stata)
  - MplusAutomation (R)



MPLUS Syntax

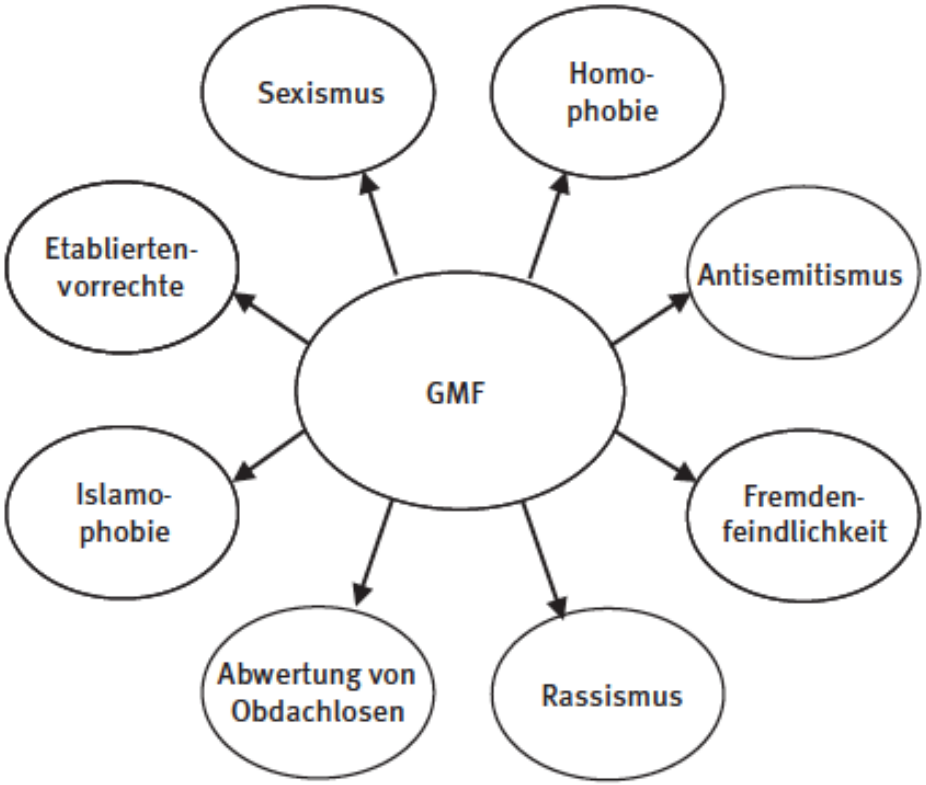
Command block	Options
DATA	FILE IS
	FORMAT IS
	TYPE IS
VARIABLE	NAMES ARE
	USEVARIABLES
	USEOBSERVATIONS
	CATEGORICAL, COUNT etc.
DEFINE	

Command block	Options
ANALYSIS	TYPE IS
	ESTIMATOR IS
MODEL	BY
	ON
	WITH
OUTPUT	STDYX
	RESIDUAL
	MODINDICES
	CINTERVAL

MPLUS Syntax

```
TITLE:      Einlesen des Datensatzes "GMF05_Querschnitt_CFA.dat"

DATA:       FILE IS GMF05_Querschnitt_CFA.dat;

VARIABLE:   NAMES ARE qcp_ser he01hq4 sx03q4r sx04q4r he01oq4r
            he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
            ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r
            ka05q4r zu01q4k;

            USEVARIABLES ARE he01hq4 sx03q4r sx04q4r he01oq4r
            he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
            ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r
            ka05q4r zu01q4k;

            MISSING ARE he01oq4r he02oq4r (99) zu01q4k (9 99);

ANALYSIS:   TYPE IS BASIC;
```

Factor Analysis



(Kleinke et al 2017: Figure 2.1)

Factor Analysis

Element von GMF (in Klammern der Name der latenten Variablen in Mplus)	Indikatoren
Sexismus (sexism)	sx03q4r, sx04q4r
Homophobie (homoph)	he01hq4, he02hq4r
Antisemitismus (antisem)	as01q4r, as02q4r
Fremdenfeindlichkeit (fremdenf)	ff04dq4r, ff08dq4r
Rassismus (rass)	ra01q4r, ra03q4r
Abwertung von Obdachlosen (obdachl)	he01oq4r, he02oq4r
Islamophobie (islamph)	he05mq4r, he12mq4r
Etabliertenvorrechte (etabl)	ev03q4r, ev04q4r

Factor Analysis

Exploratory Factor Analysis	Confirmatory Factor Analysis
no theoretical model Number of factors are extracted by statistical criteri a Factors are usually uncorrelated Matrix of factor loadings are estimated without restrictions	theoretical model Number of factors are restricted before the analysis Factors are usually correlated Matrix of factor loadings are estimated with restrictions

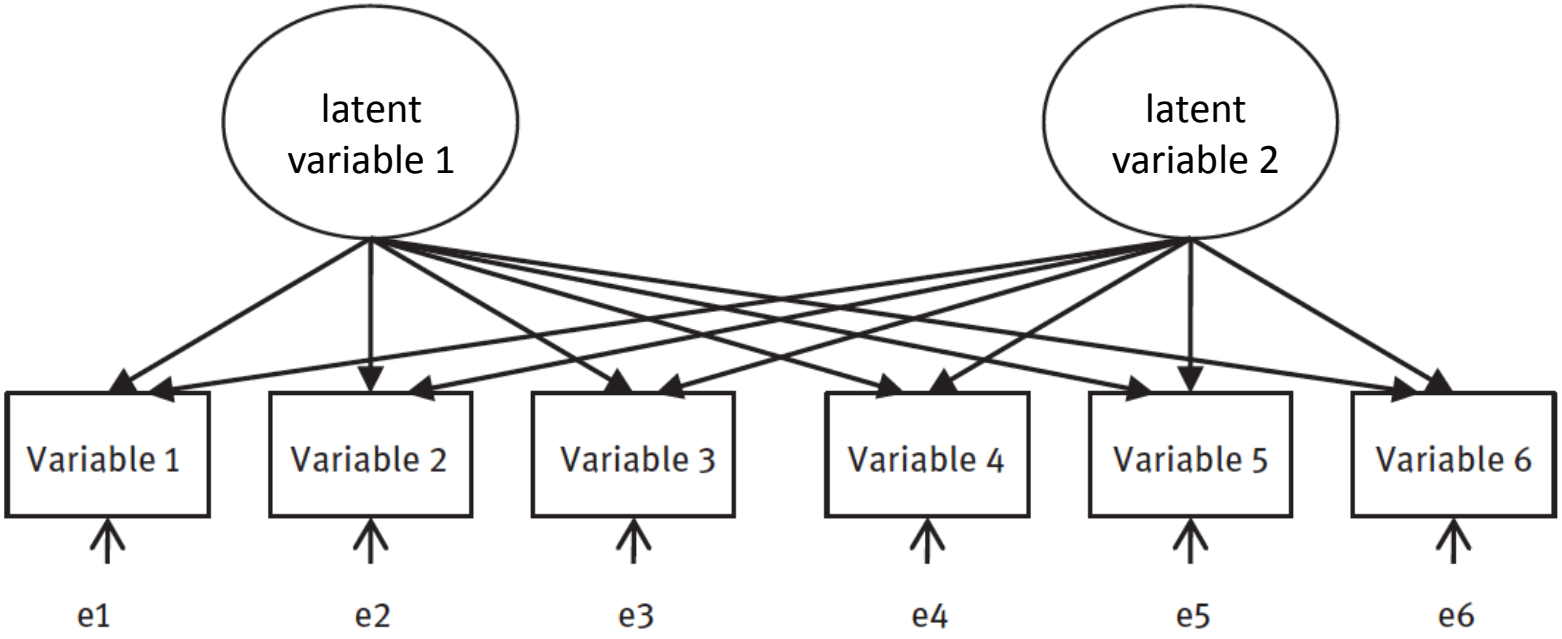
Exploratory Factor Analysis

- Exploratory factor analysis (EFA) is used to determine the number of continuous latent variables that are needed to explain the correlations among a set of observed variables.
- The continuous latent variables are referred to as factors, and the observed variables are referred to as factor indicators (manifest variables). In EFA, factor indicators can be continuous, censored, binary, ordered categorical (ordinal), counts, or combinations of these variable types.

Exploratory Factor Analysis

- Two main questions can be answered with exploratory factor analysis:
- How many factors are needed to explain the associations between the measurements (manifest variables)?
- How strong are the relationships between the factors and the measurements (manifest variables)?

Exploratory Factor Analysis



(Kleinke et al 2017: Figure 2.2)

Exploratory Factor Analysis

```
TITLE:     EFA basierend auf den Elementen Fremdenfeindlichkeit,
           Rassismus und Islamophobie

DATA:      FILE IS GMF05_Querschnitt_CFA.dat;

VARIABLE:  NAMES ARE qcp_ser he01hq4 sx03q4r sx04q4r he01oq4r
           he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
           ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r
           ka05q4r zu01q4k;

           USEVARIABLES ARE as01q4r as02q4r ra01q4r ra03q4r
           he05mq4r he12mq4r;

ANALYSIS:  TYPE IS EFA 1 3;
```

Note: oblique rotation of geomin per default
Specification of rotation:
ANALYSIS: ROTATION = GEOMIN (OBLIQUE, .5);
ANALYSIS: ROTATION = CF-VARIMAX (ORTHOGONAL);

Code: M2, taken from Kleinke (et al 2017).

Exploratory Factor Analysis

Model 2. Results for Exploratory Factor Analysis

EIGENVALUES FOR SAMPLE CORRELATION MATRIX

	1	2	3	4	5
1	2.702	0.921	0.881	0.606	0.499

EIGENVALUES FOR SAMPLE CORRELATION MATRIX

	6
1	0.390

Code: M2, taken from Kleinke (et al 2017).

Exploratory Factor Analysis

EXPLORATORY FACTOR ANALYSIS WITH 1 FACTOR(S):

MODEL FIT INFORMATION

Number of Free Parameters	18

Loglikelihood

H0 Value	-12195.173
H1 Value	-11999.859

Information Criteria

Akaike (AIC)	24426.346
Bayesian (BIC)	24525.044
Sample-Size Adjusted BIC (n* = (n + 2) / 24)	24467.860

Chi-Square Test of Model Fit

Value	390.628
Degrees of Freedom	9
P-Value	0.0000

RMSEA (Root Mean Square Error Of Approximation)

Estimate	0.154	
90 Percent C.I.	0.142	0.168
Probability RMSEA <= .05	0.000	

CFI/TLI

CFI	0.840
TLI	0.734

Chi-Square Test of Model Fit for the Baseline Model

Value	2404.353
Degrees of Freedom	15
P-Value	0.0000

SRMR (Standardized Root Mean Square Residual)

Value	0.061

EXPLORATORY FACTOR ANALYSIS WITH 2 FACTOR(S):

TESTS OF MODEL FIT

Chi-Square Test of Model Fit

Value	98.888
Degrees of Freedom	4
P-Value	0.0000

Chi-Square Test of Model Fit for the Baseline Model

Value	2404.353
Degrees of Freedom	15
P-Value	0.0000

CFI/TLI

CFI	0.960
TLI	0.851

Loglikelihood

H0 Value	-12049.303
H1 Value	-11999.859

Information Criteria

Number of Free Parameters	23
Akaike (AIC)	24144.606
Bayesian (BIC)	24270.720
Sample-Size Adjusted BIC (n* = (n + 2) / 24)	24197.651

RMSEA (Root Mean Square Error Of Approximation)

Estimate	0.116	
90 Percent C.I.	0.096	0.136
Probability RMSEA <= .05	0.000	

SRMR (Standardized Root Mean Square Residual)

Exploratory Factor Analysis

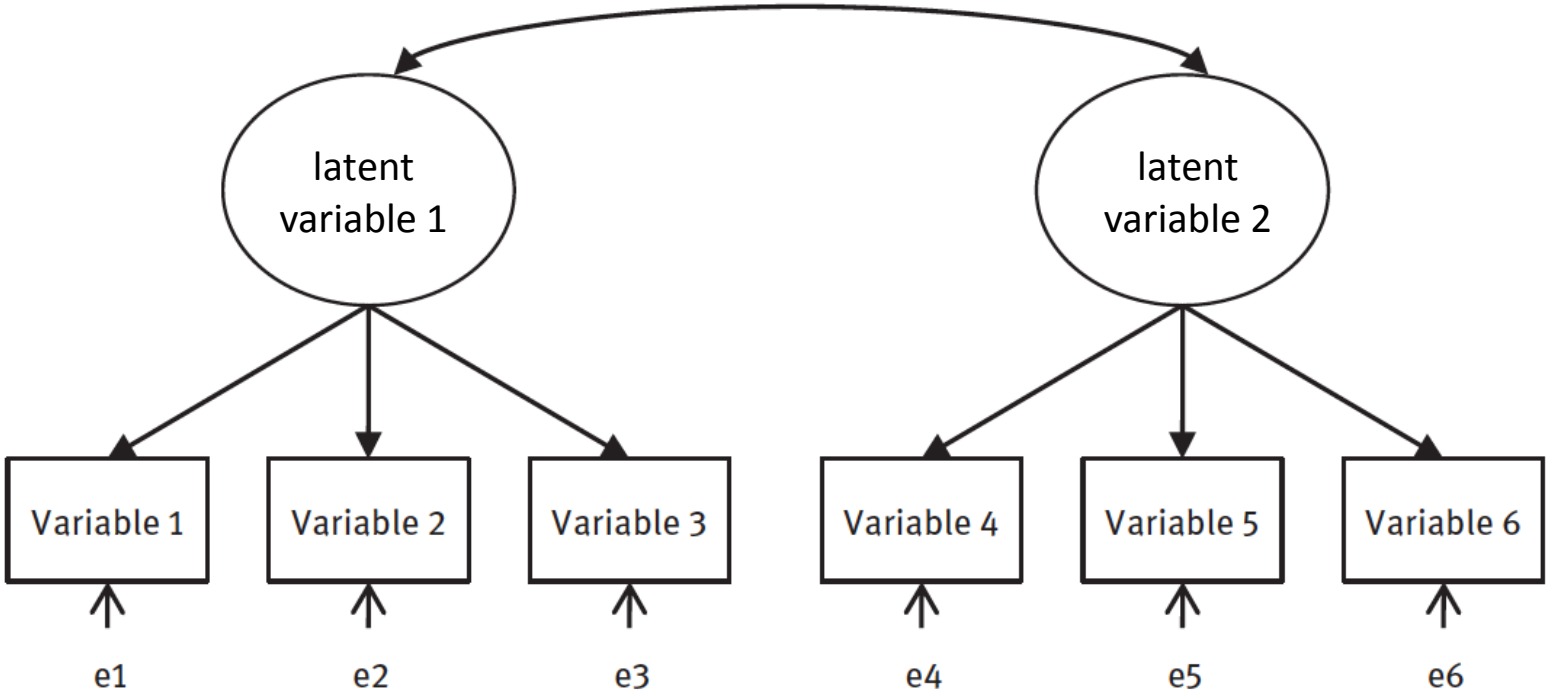
GEOMIN ROTATED LOADINGS (* significant at 5% level)

	1	
AS01Q4R	0.696*	Jews have too much influence
AS02Q4R	0.714*	Jews responsible for own persecution
RA01Q4R	0.413*	German ancestry immigrants should be better off than others
RA03Q4R	0.530*	White people should rule the world
HE05MQ4R	0.542*	Muslims make me feel like a stranger
HE12MQ4R	0.569*	Muslims should be prohibited

GEOMIN ROTATED LOADINGS (* significant at 5% level)

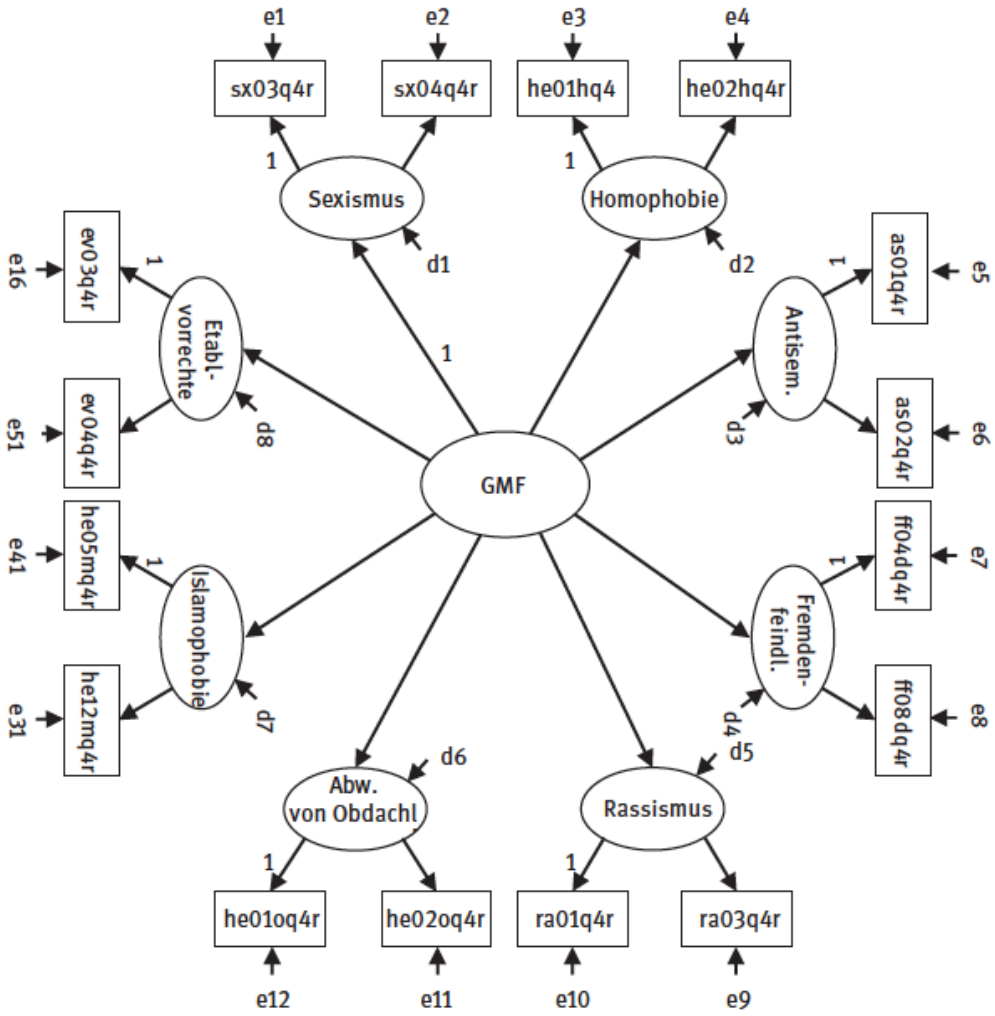
	1	2
AS01Q4R	0.529*	0.224*
AS02Q4R	0.937*	-0.003*
RA01Q4R	0.101*	0.361*
RA03Q4R	0.248*	0.332*
HE05MQ4R	-0.006	0.677*
HE12MQ4R	0.001	0.719*

Confirmatory Factor Analysis



(Kleinke et al 2017: Figure 2.3)

Confirmatory Factor Analysis



(Kleinke et al 2017: Figure 2.4)

Confirmatory Factor Analysis

Model 3. CFA

```
TITLE:    Konfirmatorische Faktorenanalyse in Mplus

DATA:     FILE IS GMF05_Querschnitt_CFA.dat;

VARIABLE: NAMES ARE qcp_ser he01hq4 sx03q4r sx04q4r he01oq4r
          he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
          ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r
          ka05q4r zu01q4k;

          USEVARIABLES ARE he01hq4 sx03q4r sx04q4r he01oq4r
          he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
          ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r;

          MISSING ARE he01oq4r he02oq4r (99);

MODEL:    sexism BY sx03q4r sx04q4r;          ! Spezifikation der
          homoph BY he01hq4 he02hq4r;         ! Faktoren 1. Ordnung
          antisem BY as01q4r as02q4r;
          fremdenf BY ff04dq4r ff08dq4r;
          rass BY ra01q4r ra03q4r;
          obdachl BY he01oq4r he02oq4r;
          islamph BY he05mq4r he12mq4r;
          etabl BY ev03q4r ev04q4r;

          gmf BY sexism homoph antisem fremdenf ! Spezifikation
          rass obdachl islamph etabl;           ! des Faktors 2. Ordnung

OUTPUT:   STDYX;
```

Code: M3, taken from Kleinke (et al 2017).

Confirmatory Factor Analysis

```
TESTS OF MODEL FIT

Chi-Square Test of Model Fit

          Value                           2412.577
          Degrees of Freedom                   104
          P-Value                           0.0000

Chi-Square Test of Model Fit for the Baseline Model

          Value                           9064.830
          Degrees of Freedom                   120
          P-Value                           0.0000

CFI/TLI

          CFI                                0.742
          TLI                                0.702

Loglikelihood

          H0 Value                      -34249.455
          H1 Value                      -33043.166

Information Criteria

          Number of Free Parameters             48
          Akaike (AIC)                   68594.909
          Bayesian (BIC)                 68858.105
          Sample-Size Adjusted BIC       68705.612
            (n* = (n + 2) / 24)

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.112
          90 Percent C.I.                    0.108  0.116
          Probability RMSEA <= .05           0.000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.071
```

Code: M3, taken from Kleinke (et al 2017).

Confirmatory Factor Analysis

Model 3. Results for Confirmatory Factor Analysis, STDYX

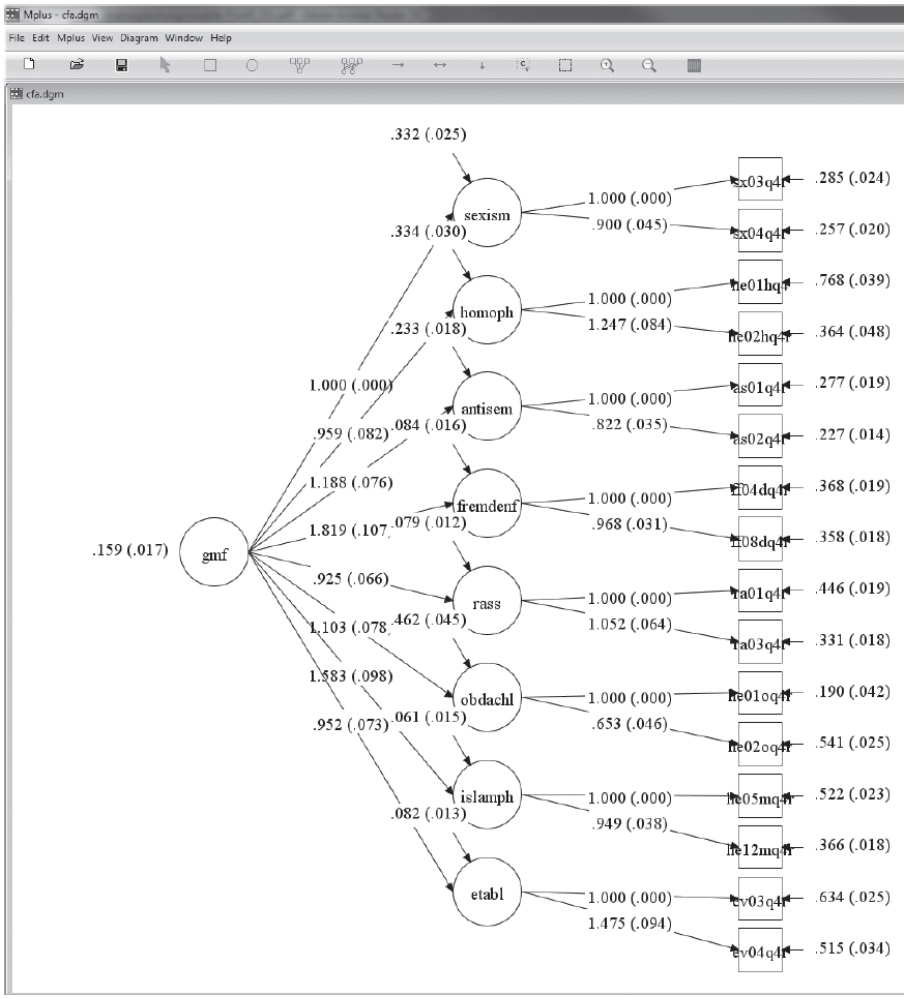
STANDARDIZED MODEL RESULTS

STDYX Standardization

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
SEXISM BY				
SX03Q4R	0.795	0.020	39.880	0.000
SX04Q4R	0.780	0.020	39.196	0.000
HOMOPH BY				
HE01HQ4	0.620	0.024	25.773	0.000
HE02HQ4R	0.820	0.026	30.969	0.000
ANTISEM BY				
AS01Q4R	0.789	0.017	46.603	0.000
AS02Q4R	0.760	0.017	44.454	0.000
FREMDENF BY				
FF04DQ4R	0.790	0.013	61.986	0.000
FF08DQ4R	0.784	0.013	61.090	0.000
RASS BY				
RA01Q4R	0.570	0.023	24.838	0.000
RA03Q4R	0.647	0.023	27.860	0.000
OBDACHL BY				
HE01OQ4R	0.880	0.029	30.779	0.000
HE02OQ4R	0.584	0.024	24.001	0.000
ISLAMPH BY				
HE05MQ4R	0.684	0.017	40.870	0.000
HE12MQ4R	0.728	0.016	45.036	0.000
ETABL BY				
EV03Q4R	0.512	0.023	22.088	0.000
EV04Q4R	0.699	0.024	29.026	0.000
GMF BY				
SEXISM	0.569	0.023	25.121	0.000
HOMOPH	0.552	0.025	21.655	0.000
ANTISEM	0.700	0.019	36.101	0.000
FREMDENF	0.929	0.013	71.190	0.000
RASS	0.795	0.026	30.712	0.000
OBDACHL	0.543	0.026	21.206	0.000
ISLAMPH	0.931	0.016	56.495	0.000
ETABL	0.798	0.026	30.399	0.000

Code: M3, taken from Kleinke (et al 2017).

MPLUS Diagrammer



Confirmatory Factor Analysis

Model 4. Alternative CFA

```
TITLE:      Prüfung eines alternativen Messmodells

DATA:       FILE IS GMF05_Querschnitt_CFA.dat;

VARIABLE:   NAMES ARE qcp_ser he01hq4 sx03q4r sx04q4r he01oq4r
            he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
            ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r
            ka05q4r zu01q4k;

            USEVARIABLES ARE he01hq4 sx03q4r sx04q4r he01oq4r
            he02oq4r he02hq4r ff04dq4r ff08dq4r ev03q4r ev04q4r
            ra01q4r ra03q4r as01q4r as02q4r he05mq4r he12mq4r;

            MISSING ARE he01oq4r he02oq4r (99);

MODEL:      gmf BY sx03q4r sx04q4r          ! Spezifikation einer
            he01hq4 he02hq4r                ! latenten Variablen
            as01q4r as02q4r
            ff04dq4r ff08dq4r
            ra01q4r ra03q4r
            he01oq4r he02oq4r
            he05mq4r he12mq4r
            ev03q4r ev04q4r;

OUTPUT:     STDYX;
```

Code: M4, taken from Kleinke (et al 2017).

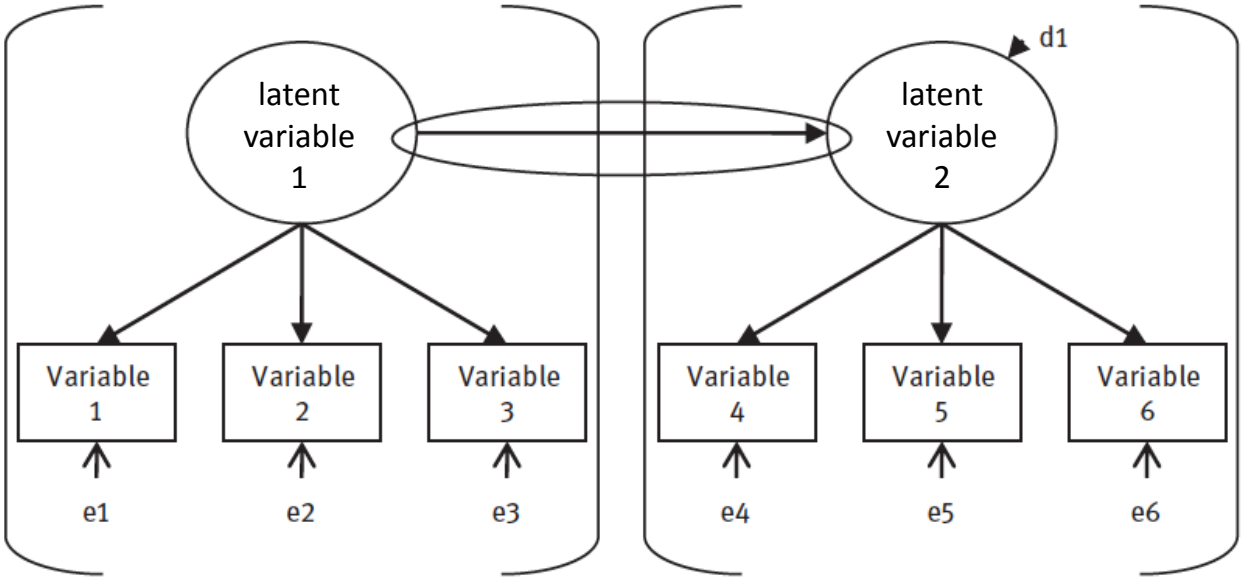
Confirmatory Factor Analysis

```
MODEL FIT INFORMATION

Number of Free Parameters                       48

Loglikelihood

          H0 Value                      -34249.455
          H1 Value                      -33043.166

Information Criteria

          Akaike (AIC)                   68594.909
          Bayesian (BIC)                 68858.105
          Sample-Size Adjusted BIC       68705.612
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                           2412.577
          Degrees of Freedom                  104
          P-Value                           0.0000

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.112
          90 Percent C.I.                    0.108  0.116
          Probability RMSEA <= .05           0.000

CFI/TLI

          CFI                                0.742
          TLI                                0.702

Chi-Square Test of Model Fit for the Baseline Model

          Value                           9064.830
          Degrees of Freedom                  120
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.071
```

Model 4. Alternative CFA

Code: M4, taken from Kleinke (et al 2017).

Structural Equation Model



(Kleinke et al 2017: Figure 3.1)

Structural Equation Model

Model 5. SEM

```
Title:     SEM Intergruppenkontakt und GMF

Data:      FILE IS GMF07_Querschnitt_SEM.dat;

VARIABLE:  NAMES ARE qcp_ser sx03q6r sx04q6r he01oq6r he02oq6r
           he01hq6 he02hq6r ff04dq6r ff08dq6r he05mq6r he12mq6r
           ev03q6r ev04q6r ra01q6r ra03q6r as01q6r as02q6r
           dy04q6r dy02q6r ka03nq4r;

           USEVARIABLES sx03q6r sx04q6r he01oq6r he02oq6r
           he01hq6 he02hq6r ff04dq6r ff08dq6r he05mq6r he12mq6r
           ev03q6r ev04q6r ra01q6r ra03q6r as01q6r as02q6r ka03nq4r;

           MISSING ARE ALL (99);

MODEL:     sexism BY sx03q6r sx04q6r;  ! Messmodelle für die Elemente
           homoph BY he01hq6 he02hq6r; ! von GMF
           antisem BY as01q6r as02q6r;
           fremdenf BY ff04dq6r ff08dq6r;
           rass BY ra01q6r ra03q6r;
           obdachl BY he01oq6r he02oq6r;
           islamph BY he05mq6r he12mq6r;
           etabl BY ev03q6r ev04q6r;

           GMF BY sexism homoph antisem fremdenf rass ! Messmodell GMF
           obdachl islamph etabl;

           GMF ON ka03nq4r; ! Regression von GMF auf Intergruppenkontakt

OUTPUT:    STDYX MODINDICES;
```

Code: M5, taken from Kleinke (et al 2017).

Structural Equation Model

STANDARDIZED MODEL RESULTS

STDYX Standardization

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
SEXISM BY				
SX03Q6R	0.703	0.034	20.379	0.000
SX04Q6R	0.839	0.037	22.613	0.000
HOMOPH BY				
HE01HQ6	0.732	0.034	21.832	0.000
HE02HQ6R	0.762	0.034	22.395	0.000
ANTISEM BY				
AS01Q6R	0.769	0.028	27.578	0.000
AS02Q6R	0.749	0.028	26.695	0.000
FREMDENF BY				
FF04DQ6R	0.770	0.019	40.122	0.000
FF08DQ6R	0.753	0.020	38.225	0.000
RASS BY				
RA01Q6R	0.529	0.033	16.264	0.000
RA03Q6R	0.667	0.033	20.253	0.000
OBDACHL BY				
HE01OQ6R	0.789	0.040	19.567	0.000
HE02OQ6R	0.588	0.036	16.232	0.000
ISLAMPH BY				
HE05MQ6R	0.698	0.022	31.579	0.000
HE12MQ6R	0.831	0.019	43.408	0.000
ETABL BY				
EV03Q6R	0.615	0.032	19.149	0.000
EV04Q6R	0.655	0.032	20.304	0.000
GMF BY				
SEXISM	0.485	0.036	13.428	0.000
HOMOPH	0.532	0.035	15.174	0.000
ANTISEM	0.643	0.031	20.852	0.000
FREMDENF	0.972	0.019	51.173	0.000
RASS	0.853	0.037	22.820	0.000
OBDACHL	0.560	0.038	14.820	0.000
ISLAMPH	0.896	0.021	43.371	0.000
ETABL	0.760	0.035	21.674	0.000
GMF ON				
KA03NQ4R	-0.244	0.035	-7.015	0.000

Model 5. Full SEM – Measurement plus Path Model

Code: M5, taken from Kleinke (et al 2017).

Structural Equation Model

```
MODEL FIT INFORMATION

Number of Free Parameters                       57

Loglikelihood

          H0 Value                      -15742.260
          H1 Value                      -15552.900

Information Criteria

          Akaike (AIC)                   31598.519
          Bayesian (BIC)                 31869.929
          Sample-Size Adjusted BIC       31688.912
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            378.719
          Degrees of Freedom                   111
          P-Value                           0.0000

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.053
          90 Percent C.I.                    0.047  0.059
          Probability RMSEA <= .05           0.205

CFI/TLI

          CFI                                0.937
          TLI                                0.923

Chi-Square Test of Model Fit for the Baseline Model

          Value                           4397.721
          Degrees of Freedom                   136
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.045
```

Code: M5, taken from Kleinke (et al 2017).

Structural Equation Model

MODEL MODIFICATION INDICES

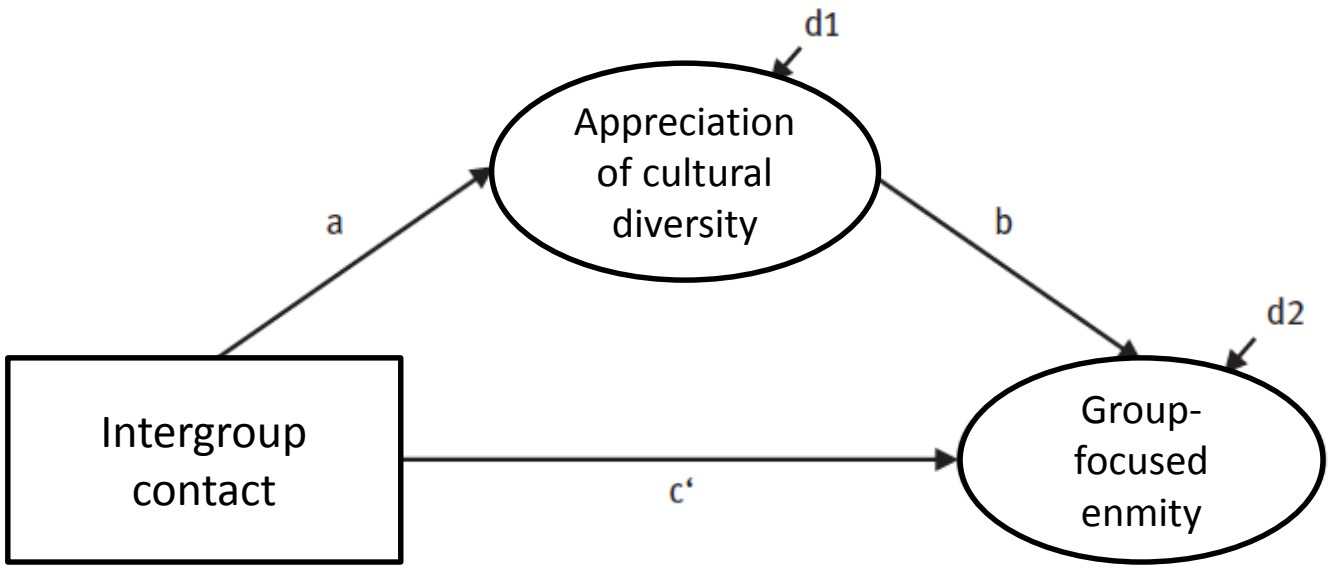
NOTE: Modification indices for direct effects of observed dependent variables regressed on covariates may not be included. To include these, request MODINDICES (ALL).

Minimum M.I. value for printing the modification index 10.000

			M.I.	E.P.C.	Std E.P.C.	StdYX E.P.C.
BY Statements						
SEXISM	BY	HE01HQ6	23.846	0.322	0.192	0.186
SEXISM	BY	FF04DQ6R	11.084	-0.188	-0.112	-0.117
SEXISM	BY	FF08DQ6R	17.361	-0.218	-0.129	-0.148
HOMOPH	BY	SX03Q6R	25.657	0.234	0.176	0.208
FREMDENF	BY	SX04Q6R	25.445	-2.074	-1.527	-2.059
FREMDENF	BY	HE05MQ6R	17.292	2.580	1.900	1.911
FREMDENF	BY	HE12MQ6R	23.200	2.620	1.930	2.155
RASS	BY	EV04Q6R	24.957	1.430	0.601	0.608
OBDACHL	BY	HE02HQ6R	12.285	0.206	0.158	0.155
ISLAMPH	BY	HE02HQ6R	14.116	-0.652	-0.452	-0.445
ISLAMPH	BY	FF04DQ6R	28.100	0.925	0.642	0.671
ISLAMPH	BY	FF08DQ6R	14.995	0.620	0.430	0.493
ETABL	BY	RA01Q6R	42.358	0.701	0.425	0.535
ON/BY Statements						
SEXISM	ON	HOMOPH /				
HOMOPH	BY	SEXISM	60.058	0.330	0.418	0.418
SEXISM	ON	FREMDENF /				
FREMDENF	BY	SEXISM	40.796	-2.869	-3.553	-3.553
SEXISM	ON	RASS /				
RASS	BY	SEXISM	14.219	0.788	0.557	0.557

Code: M5, taken from Kleinke (et al 2017).

Mediation Model: Indirect and Direct Effects



(Kleinke et al 2017: Figure 3.2)

Mediation Model: Indirect and Direct Effects

Model 6. Direct and Indirect

```
Title:    SEM Intergruppenkontakt und GMF, Model Indirect
          Sobel-Test

Data:     FILE IS GMF07_Querschnitt_SEM.dat;

VARIABLE: NAMES ARE qcp_ser sx03q6r sx04q6r he01oq6r he02oq6r
          he01hq6 he02hq6r ff04dq6r ff08dq6r he05mq6r he12mq6r
          ev03q6r ev04q6r ra01q6r ra03q6r as01q6r as02q6r
          dy04q6r dy02q6r ka03nq4r;

          USEVARIABLES sx03q6r sx04q6r he01oq6r he02oq6r
          he01hq6 he02hq6r ff04dq6r ff08dq6r he05mq6r he12mq6r
          ev03q6r ev04q6r ra01q6r ra03q6r as01q6r as02q6r ka03nq4r
          dy04q6r dy02q6r;

          MISSING ARE ALL (99);

MODEL:    sexism BY sx03q6r sx04q6r;   ! Messmodelle für die Elemente
          homoph BY he01hq6 he02hq6r; ! von GMF
          antisem BY as01q6r as02q6r;
          fremdenf BY ff04dq6r ff08dq6r;
          rass BY ra01q6r ra03q6r;
```

Code: M6, taken from Kleinke (et al 2017).

Mediation Model: Indirect and Direct Effects

Model 6

```
          obdachl BY he01oq6r he02oq6r;
          islamph BY he05mq6r he12mq6r;
          etabl BY ev03q6r ev04q6r;

          GMF BY sexism homoph antisem fremdenf rass ! Messmodell GMF
          obdachl islamph etabl;

          wertsch BY dy04q6r dy02q6r;   ! Messmodell für Wertschätzung
                                        ! kultureller Vielfalt

          GMF ON ka03nq4r;      ! Direkter Effekt von Kontakt auf GMF (c')
          wertsch ON ka03nq4r;  ! Effekt von Kontakt auf Wertschätzung
                                ! kultureller Vielfakt (a)

          GMF ON wertsch;       ! Effekt von Wert. kultureller Vielfalt
                                ! auf GMF (b)

          MODEL INDIRECT:
          GMF IND ka03nq4r;     ! Prüfung des indirekten Effekts von Kontakt
                                ! auf GMF
OUTPUT:   STDYX;
```

Code: M6, taken from Kleinke (et al 2017).

Mediation Model: Indirect and Direct Effects

Model 6. Direct and Indirect Effects

STANDARDIZED TOTAL, TOTAL INDIRECT, SPECIFIC INDIRECT, AND DIRECT EFFECTS

STDYX Standardization

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
Effects from KA03NQ4R to GMF				
Total	-0.245	0.035	-7.074	0.000
Total indirect	-0.162	0.025	-6.467	0.000
Specific indirect				
GMF WERTSCH KA03NQ4R	-0.162	0.025	-6.467	0.000
Direct				
GMF KA03NQ4R	-0.083	0.033	-2.484	0.013

Code: M6, taken from Kleinke (et al 2017).

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       65

Loglikelihood

          H0 Value                      -15751.784
          H1 Value                      -15545.122

Information Criteria

          Akaike (AIC)                   31633.569
          Bayesian (BIC)                 31936.172
          Sample-Size Adjusted BIC       31729.766
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            413.324
          Degrees of Freedom                   142
          P-Value                           0.0000

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.050
          90 Percent C.I.                    0.044  0.055
          Probability RMSEA <= .05           0.538

CFI/TLI

          CFI                                0.940
          TLI                                0.928

Chi-Square Test of Model Fit for the Baseline Model

          Value                           4684.962
          Degrees of Freedom                   171
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.044
```

Model 7. Exact Fit Test. Fit Statistics for Mediation Model

Models must be nested for chi-square tests!

Code: M7, data from Kleinke (et al 2017).

(see Kline 2016; also easy to follow discussion from David A. Kenney http://davidakenny.net/cm/fit.htm)

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       65

Loglikelihood

          H0 Value                      -15751.784
          H1 Value                      -15545.122

Information Criteria

          Akaike (AIC)                   31633.569
          Bayesian (BIC)                 31936.172
          Sample-Size Adjusted BIC       31729.766
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            413.324
          Degrees of Freedom                   142
          P-Value                           0.0000

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.050
          90 Percent C.I.                    0.044  0.055
          Probability RMSEA <= .05           0.538

CFI/TLI

          CFI                                0.940
          TLI                                0.928

Chi-Square Test of Model Fit for the Baseline Model

          Value                          4684.962
          Degrees of Freedom                   171
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.044
```

Model 7. Exact Fit Test. Fit Statistics for Mediation Model

Code: M7, data from Kleinke (et al 2017).

(see Kline 2016; also easy to follow discussion from David A. Kenney http://davidakenny.net/cm/fit.htm)

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       65

Loglikelihood

          H0 Value                      -15751.784
          H1 Value                      -15545.122

Information Criteria

          Akaike (AIC)                   31633.569
          Bayesian (BIC)                 31936.172
          Sample-Size Adjusted BIC       31729.766
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            413.324
          Degrees of Freedom                   142
          P-Value                           0.0000

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.050
          90 Percent C.I.                    0.044  0.055
          Probability RMSEA <= .05           0.538

CFI/TLI

          CFI                                0.940
          TLI                                0.928

Chi-Square Test of Model Fit for the Baseline Model

          Value                          4684.962
          Degrees of Freedom                 171
          P-Value                         0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.044
```

Model 7. Exact Fit Test. Fit Statistics for Mediation Model

Chi-Square (χ^2)

Degrees of Freedom

Significance – Tests whether this model fits the data *worse* than the baseline model. A significant p means *it does not fit worse*.

Code: M7, data from Kleinke (et al 2017).

(see Kline 2016; also easy to follow discussion from David A. Kenney http://davidakenny.net/cm/fit.htm)

Model Fit

RASS	ON WERTSCH /				
WERTSCH	BY RASS	12.885	0.166	0.254	0.254
OBDACHL	ON ISLAMPH /				
ISLAMPH	BY OBDACHL	11.405	-0.842	-0.784	-0.784
ISLAMPH	ON FREMDENF /				
FREMDENF	BY ISLAMPH	26.270	3.866	4.056	4.056
ISLAMPH	ON OBDACHL /				
OBDACHL	BY ISLAMPH	11.403	-0.149	-0.160	-0.160
ISLAMPH	ON ETABL /				
ETABL	BY ISLAMPH	14.083	-0.372	-0.319	-0.319
ISLAMPH	ON WERTSCH /				
WERTSCH	BY ISLAMPH	34.958	-0.334	-0.311	-0.311
ETABL	ON RASS /				
RASS	BY ETABL	30.631	1.248	0.885	0.885
ETABL	ON ISLAMPH /				
ISLAMPH	BY ETABL	14.083	-0.781	-0.912	-0.912
GMF	ON RASS /				
RASS	BY GMF	11.604	0.434	0.708	0.708
GMF	ON ISLAMPH /				
ISLAMPH	BY GMF	30.548	-0.650	-1.744	-1.744
WERTSCH	ON RASS /				
RASS	BY WERTSCH	11.949	1.172	0.766	0.766
WERTSCH	ON ISLAMPH /				
ISLAMPH	BY WERTSCH	33.683	-1.795	-1.930	-1.930
WITH Statements					
HE01HQ6	WITH SX03Q6R	17.478	0.086	0.086	0.201
HE02HQ6R	WITH HE02OQ6R	12.866	0.084	0.084	0.169
FF08DQ6R	WITH SX04Q6R	15.463	-0.051	-0.051	-0.240
EV03Q6R	WITH HE01OQ6R	12.072	0.088	0.088	0.185
RA01Q6R	WITH EV04Q6R	33.236	0.122	0.122	0.250
AS02Q6R	WITH RA03Q6R	11.293	0.040	0.040	0.163
DY04Q6R	WITH HE02HQ6R	11.931	0.065	0.065	0.182
HOMOPH	WITH SEXISM	43.934	0.115	0.366	0.366
FREMDENF	WITH SEXISM	30.182	-0.070	-0.951	-0.951
ISLAMPH	WITH FREMDENF	26.283	0.082	2.134	2.134
ISLAMPH	WITH OBDACHL	11.403	-0.058	-0.354	-0.354
ETABL	WITH RASS	30.632	0.065	0.748	0.748
ETABL	WITH ISLAMPH	14.083	-0.054	-0.539	-0.539
GMF	WITH RASS	11.605	0.023	0.506	0.506
GMF	WITH ISLAMPH	30.545	-0.045	-0.872	-0.872
WERTSCH	WITH RASS	11.948	0.061	0.426	0.426
WERTSCH	WITH ISLAMPH	33.685	-0.125	-0.750	-0.750

Model 7. Exact Fit Test. Fit Statistics for Mediation Model

Modification Indices ('MODINDICES')

Savedata: 'DIFFTEST' (for MLMV WLSMV)

```
OUTPUT:    STDYX MODINDICES;
SAVEDATA: DIFFTEST is semindir.dat;
```

Code: M7, data from Kleinke (et al 2017).

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       76

Loglikelihood

          H0 Value                      -16467.809
          H1 Value                      -16375.733

Information Criteria

          Akaike (AIC)                   33087.619
          Bayesian (BIC)                 33441.432
          Sample-Size Adjusted BIC       33200.095
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            184.153
          Degrees of Freedom                   133
          P-Value                           0.0022

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.022
          90 Percent C.I.                    0.014  0.030
          Probability RMSEA <= .05           1.000

CFI/TLI

          CFI                                0.989
          TLI                                0.985

Chi-Square Test of Model Fit for the Baseline Model

          Value                           4684.962
          Degrees of Freedom                   171
          P-Value                           0.0000
```

Model 8. Equal Fit Test after Modifications

Table 1. Chi-Square Tests for M7 and M8

χ^2	M7	M8	M7-M8
value	413.3	184.2	229.2
df	142	133	9
p-value	0.0000	0.0022	0.0000
test type	Exact	Exact	Equal

Table 1. Excel Chi-Square Calculator

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       76

Loglikelihood

          H0 Value                      -16467.809
          H1 Value                      -16375.733

Information Criteria

          Akaike (AIC)                   33087.619
          Bayesian (BIC)                 33441.432
          Sample-Size Adjusted BIC       33200.095
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            184.153
          Degrees of Freedom                   133
          P-Value                           0.0022

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.022
          90 Percent C.I.                    0.014  0.030
          Probability RMSEA <= .05           1.000

CFI/TLI

          CFI                                0.989
          TLI                                0.985

Chi-Square Test of Model Fit for the Baseline Model

          Value                           4684.962
          Degrees of Freedom                   171
          P-Value                           0.0000
```

Model 8. Equal Fit Test after Modifications

Table 1. Chi-Square Tests for M7 and M8

χ^2	M7	M8	M7-M8
value	413.3	184.2	229.2
df	142	133	9
p-value	0.0000	0.0022	0.0000
test type	Exact	Exact	Equal

Exact Fit Hypothesis:
That the tested model is significantly different from the baseline (p>0.05 rejects; supports tested model)

Equal Fit Hypothesis:
That the larger model (less df) is significantly better fitting than the smaller model (more df) (p>0.05 rejects; supports the smaller model)

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       76

Loglikelihood

          H0 Value                      -16467.809
          H1 Value                      -16375.733

Information Criteria

          Akaike (AIC)                   33087.619
          Bayesian (BIC)                 33441.432
          Sample-Size Adjusted BIC       33200.095
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            184.153
          Degrees of Freedom                   133
          P-Value                           0.0022

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.022
          90 Percent C.I.                    0.014  0.030
          Probability RMSEA <= .05           1.000

CFI/TLI

          CFI                                0.989
          TLI                                0.985

Chi-Square Test of Model Fit for the Baseline Model

          Value                           4684.962
          Degrees of Freedom                   171
          P-Value                           0.0000
```

Model 8. Equal Fit Test after Modifications

RMSEA:
Reviewer approved… <0.05

$$\frac{\sqrt{(\chi^2 - df)}}{\sqrt{[df(N - 1)]}}$$

(where df = Model df (i.e., "moments" or estimated "parameters"))

Note: Universal cutoffs are a 'bad' idea (Chen et al 2008)

(see Kline 2016; also easy to follow discussion from David A. Kenney http://davidakenny.net/cm/fit.htm)

Model Fit

```
MODEL FIT INFORMATION

Number of Free Parameters                       76

Loglikelihood

          H0 Value                      -16467.809
          H1 Value                      -16375.733

Information Criteria

          Akaike (AIC)                   33087.619
          Bayesian (BIC)                 33441.432
          Sample-Size Adjusted BIC       33200.095
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            184.153
          Degrees of Freedom                   133
          P-Value                           0.0022

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.022
          90 Percent C.I.                    0.014  0.030
          Probability RMSEA <= .05           1.000

CFI/TLI

          CFI                                0.989
          TLI                                0.985

Chi-Square Test of Model Fit for the Baseline Model

          Value                           4684.962
          Degrees of Freedom                   171
          P-Value                           0.0000
```

Model 8. Equal Fit Test after Modifications

Paradigm Shift Looming…
or, Chi-square is THE ONLY global fit test one needs

"A telling anecdote in this regard comes from Dag Sorböm, a long-time collaborator of Karl Joreskög, one of the key pioneers of SEM and creator of the LISREL software package. In recounting a LISREL workshop that he jointly gave with Joreskög in 1985, Sorböm notes that, in his lecture Karl would say that the Chi-square is all you really need. One participant then asked 'Why have you then added GFI [goodness-of-fit index]?' Whereupon Karl answered 'Well, users threaten us saying they would stop using LISREL if it always produces such large Chi-squares. So we had to invent something to make people happy. GFI serves that purpose'" (McIntosch 2012:10)

(see Kline 2016; also easy to follow discussion from David A. Kenney http://davidakenny.net/cm/fit.htm)

Non-Convergence

- Identification?
  - Under-identified
  - See discussion of “counting rule” in Kline (2016:145)
- Mplus identifies parameter problems
  - TECH 4 in Mplus
- More iterations?
- Start Values
  - Maximum Likelihood, depends on
  - *# …in Mplus
  - (*var*, init(#)) …in Stata

Thank You

- Technical appendix with Stata syntax and a dictionary of SEM terms (still under construction)
- Follow all hyperlinks in the slides, or find all examples in this folder
- SEMNET, a vibrant listserv for SEM questions and discussion
- Mplus discussion forum at www.statmodel.com

References

- Bollen, Kenneth A. 1989. *Structural Equations with Latent Variables*. New York, NY: John Wiley & Sons.
- Bollen, Kenneth A, and Judea Pearl. 2013. “Eight Myths about Causality and Structural Equation Models.” In *Handbook of Causal Analysis for Social Research*, ed. Stephen L. Morgan. Dordrecht, Netherlands: Springer Science & Business Media, 301–28.
- Chen, Feinian, Patrick J. Curran, Kenneth A. Bollen, James Kirby, and Pamela Paxton. 2008. “An Empirical Evaluation of the Use of Fixed Cutoff Points in RMSEA Test Statistic in Structural Equation Models.” *Sociological Methods & Research* 36(4):462–94.
- Kline, Rex B. 2016. *Principles and Practice of Structural Equation Modeling*. 4th Edition. New York and London: Guilford Press.
- Kleinke, Kristian, Elmar Schlüter, and Oliver Christ. 2017. *Strukturgleichungsmodelle Mit Mplus: Eine Praktische Einführung*. Oldenburg: Walter de Gruyter.
- McIntosh, Cameron N. 2012. “Improving the Evaluation of Model Fit in Confirmatory Factor Analysis: A Commentary on Gundy, C.M., Fayers, P.M., Groenvold, M., Petersen, M. Aa., Scott, N.W., Sprangers, M.A.J., Velikov, G., Aaronson, N.K. (2011). Comparing Higher-Order Models for the EORTC QLQ-C30. Quality of Life Research, doi:10.1007/s11136-011-0082-6.” *Quality of Life Research* 21(9):1619–21.

Further Reading

- Hayduk, Leslie A. and H. Pazderka-Robinson. 2007. “Fighting to Understand the World Causally: Three Battles Connected to the Causal Implications of Structural Equation Models.” in *Sage Handbook of Social Science Methodology*, edited by W. Outhwaite and S. Turner. London: Sage Publications.
- Hayduk, Leslie A., Greta Cummings, Kwame Boadu, Hannah Pazderka-Robinson, and Shelley Boulianne. 2007. “Testing! Testing! One, Two, Three – Testing the Theory in Structural Equation Models!” *Personality and Individual Differences* 42(5):841–50.
- Hayduk, Leslie A. 2014. “Seeing Perfectly Fitting Factor Models That Are Causally Misspecified: Understanding That Close-Fitting Models Can Be Worse.” *Educational and Psychological Measurement* 74(6):905–26.

SEM History

- Pearl, Judea. 2015. “Trygve Haavelmo and the Emergence of Causal Calculus.” *Economic Theory* 31:152–79.
- Wright, Sewall. 1934. “The Method of Path Coefficients.” *The Annals of Mathematical Statistics* 5(3):161–215.

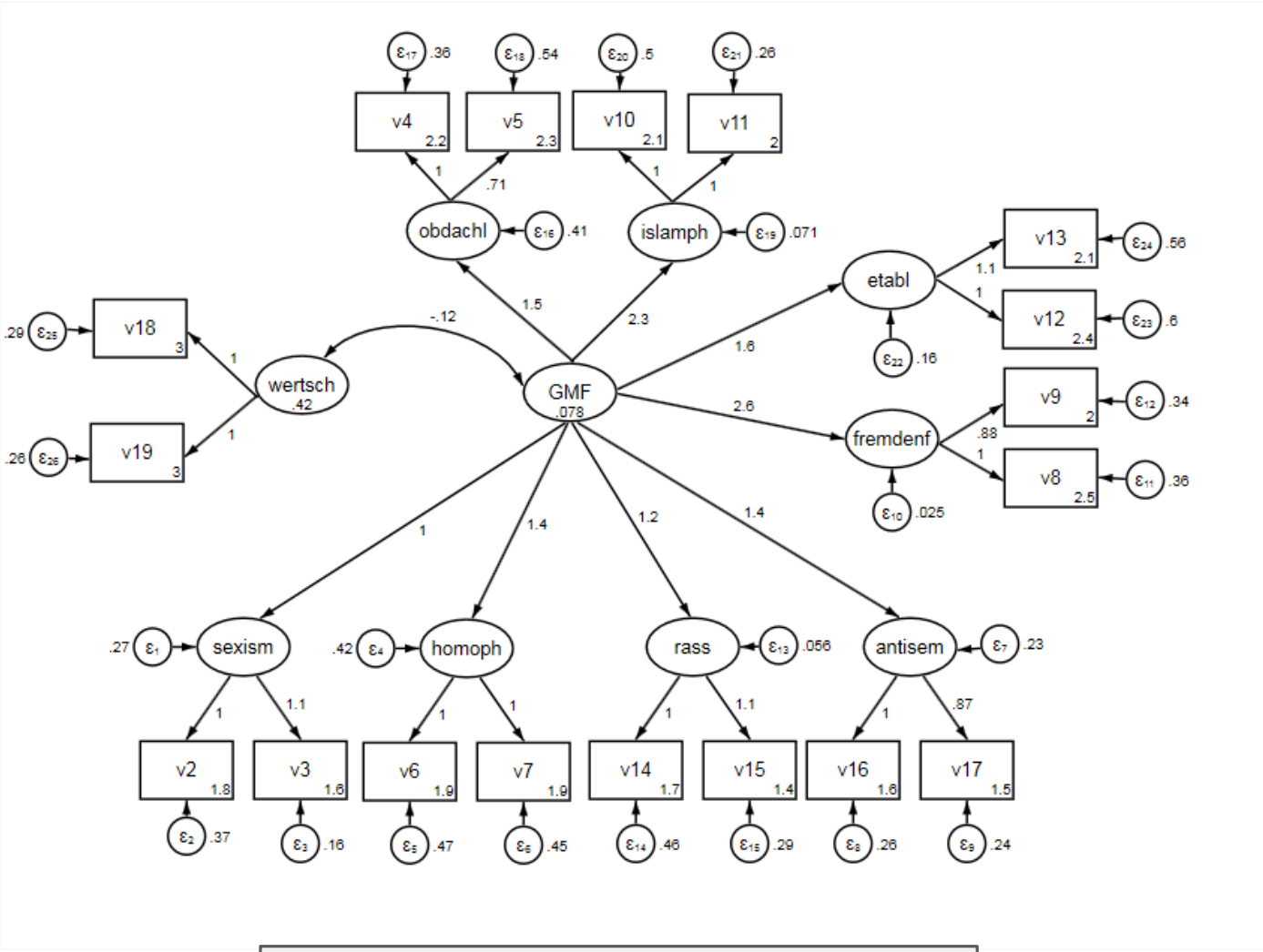
(Kleinke et al 2017)

Tabelle 2.1: Variablennamen und Variablenlabels des Datensatzes „GMF05_Querschnitt_CFA.sav“

Variablenname		Variablenlabel
qcp_ser	v1	Id-Nr. des Datensatzes
he01hq4	*	Gleichgeschlechtliche Ehen erlaubt
sx03q4r	v2	Frauen wieder Rolle der Ehefrau u. Mutter
sx04q4r	v3	Für Frau sollte es wichtiger sein, dem Mann bei der Karriere zu helfen
he01oq4r	v4	Obdachlose aus Fußgängerzonen entfernen
he02oq4r	v5	Obdachlose in den Städten unangenehm
he02hq4r	v6	Ekelhaft, wenn Homosexuelle sich in der Öffentlichkeit küssen
ff04dq4r	v8	Es leben zu viele Ausländer in Deutschland
ff08dq4r	v9	Wenn Arbeitsplätze knapp werden, sollte man die Ausländer in die Heimat schicken
ev03q4r	v12	Wer neu ist, sollte sich mit weniger zufrieden geben
ev04q4r	v13	Wer schon immer hier lebt, sollte mehr Rechte haben
ra01q4r	v14	Aussiedler sollten besser gestellt werden als Ausländer, da deutscher Abstammung
ra03q4r	v15	Die Weißen sind zurecht führend in der Welt
as01q4r	v16	Juden haben in Deutschland zu viel Einfluss
as02q4r	v17	Juden sind an ihren Verfolgungen mitschuldig
he05mq4r	v10	Durch die vielen Muslime fühle ich mich wie ein Fremder
he12mq4r	v11	Muslimen sollte die Zuwanderung untersagt werden
ka05q4r	v20	Hatten Sie schon einmal Kontakt zu Ausländern?
zu01q4k	.	Schulabschluss, gruppiert nach 3 Kategorien

dy04q6r v18 – different cultures enrich German culture
dy02q6r v19 – appreciation of different cultures

A Stata Example



Code: StataModel, or see Technical Appendix, data from Kleinke (et al 2017).