# True Change Models

## Goal

Explaining inter-individual differences in intra-individual change

**Means**

Introducing into a structural equation model latent variables the values of which are true change scores



# True Change Models

Based on:

Steyer, R., Eid, M. & Schwenkmezger, P. (1997). Modeling true intraindividual change: True change as a latent variable. *Methods of Psychological Research-Online 2*, 21-33. (http://www.mpr-online.de)

Steyer, R., Partchev, I. & Shanahan, M. (2000). Modeling True Intra-Individual Change in Structural Equation Models: The Case of Poverty and Children´s Psychosocial Adjust-ment. In: Little, T. D., Schnabel, K. U., & Baumert, J. (Eds.), Modeling longitudinal and multiple-group data: Practical issues, applied approaches, and specific examples (pp. 109-126). Hillsdale, NJ: Erlbaum.

Steyer, R., Krambeer, S. & Hannöver, W. (in press). Modeling Latent Trait-Change. K. Van Montfort, H. Oud & A. Satorra (eds.), Recent developments in structural equation modeling: theory and applications. Amsterdam: Kluwer Academic Press.

# True Change Models

## Basic Idea

Consider a pretest $Y_1$ and a posttest $Y_2$

and its true-score and error components:

$$Y_1 = \tau_1 + \varepsilon_1$$

$$Y_2 = \tau_2 + \varepsilon_2.$$

I we are interested in the change $\tau_2 - \tau_1$ of the true score variables, we can rewrite the decomposition of $Y_2$:

$$Y_2 = \tau_1 + (\tau_2 - \tau_1) + \varepsilon_2.$$

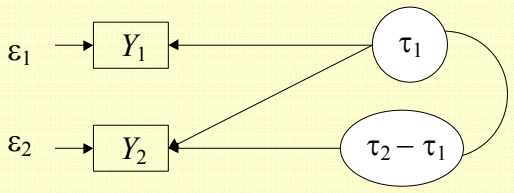


# True Change Models

Translating these equations into a path diagram

$$Y_1 = \tau_1 + \varepsilon_1$$

$$Y_2 = \tau_1 + (\tau_2 - \tau_1) + \varepsilon_2$$



## Baseline Model

Suppose we have 4 occasions $t$ of measurement at each of which we have the *CTT*-decomposition

$$Y_t = \tau_t + \varepsilon_t, \quad t = 1, \ldots, 4.$$

We may then rewrite these equations as follows:

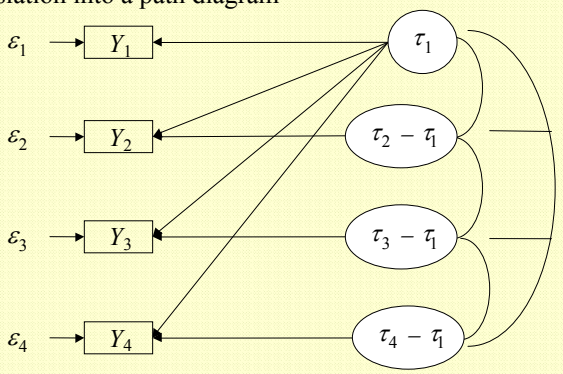
$$Y_1 = \tau_1 + \varepsilon_1$$
$$Y_2 = \tau_1 + (\tau_2 - \tau_1) + \varepsilon_2$$
$$Y_3 = \tau_1 + (\tau_3 - \tau_1) + \varepsilon_3$$
$$Y_4 = \tau_1 + (\tau_4 - \tau_1) + \varepsilon_4.$$

We call this a *baseline model*.



## Baseline Model

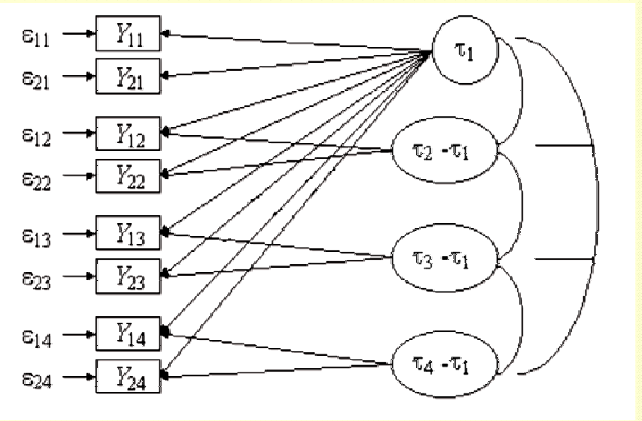
Translation into a path diagram




$$Y_1 = \tau_1 + \varepsilon_1 \qquad Y_2 = \tau_1 + (\tau_2 - \tau_1) + \varepsilon_2$$
$$Y_3 = \tau_1 + (\tau_3 - \tau_1) + \varepsilon_3 \qquad Y_4 = \tau_1 + (\tau_4 - \tau_1) + \varepsilon_4$$

# Baseline Model

Baseline model with 4 occasions of measurement and 2 indicators for each occasion






# Neighbor Model

Suppose we have 4 occasions $t$ of measurement at each of which we have the *CTT*-decomposition

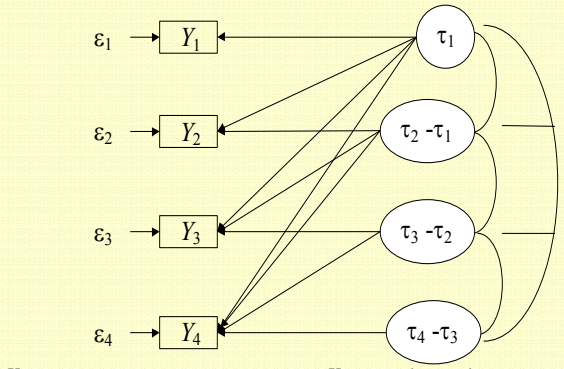
$$Y_t = \tau_t + \varepsilon_t, \quad t = 1, \ldots, 4.$$

We may then rewrite these equations as follows:

$$Y_1 = \tau_1 + \varepsilon_1$$
$$Y_2 = \tau_1 + (\tau_2 - \tau_1) + \varepsilon_2$$
$$Y_3 = \tau_1 + (\tau_3 - \tau_2) + (\tau_2 - \tau_1) + \varepsilon_3$$
$$Y_4 = \tau_1 + (\tau_4 - \tau_3) + (\tau_3 - \tau_2) + (\tau_2 - \tau_1) + \varepsilon_4.$$

# Neighbor Model

Neighbor model with 4 occasions of measurement



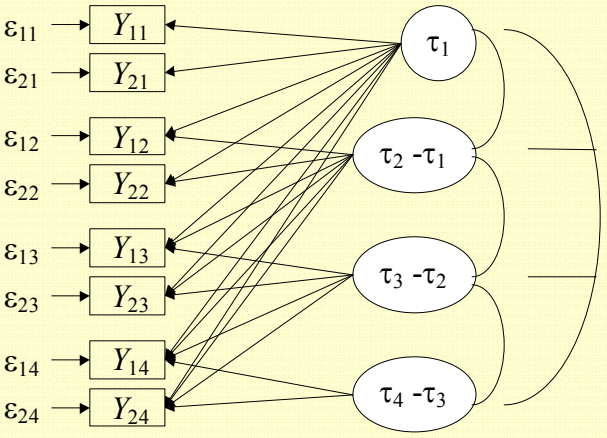

$Y_1 = \tau_1 + \varepsilon_1$ $Y_2 = \tau_1 + (\tau_2 - \tau_1) + \varepsilon_2$

$Y_3 = \tau_1 + (\tau_3 - \tau_2) + (\tau_2 - \tau_1) + \varepsilon_3$ $Y_4 = \tau_1 + (\tau_4 - \tau_3) + (\tau_3 - \tau_2) + (\tau_2 - \tau_1) + \varepsilon_4$



# Neighbor Model

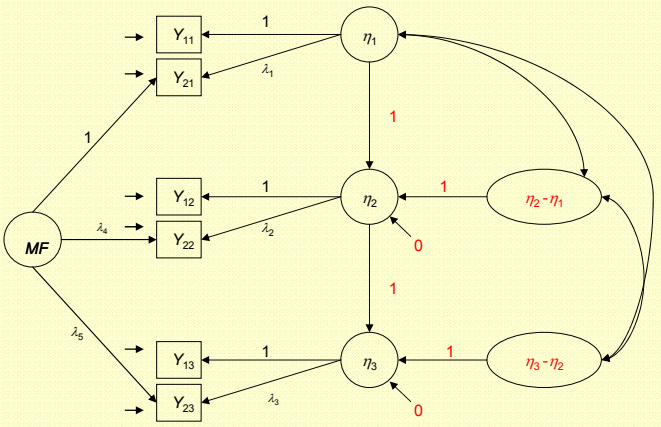
Neighbor model with 4 occasions of measurement and 2 indicators for each occasion



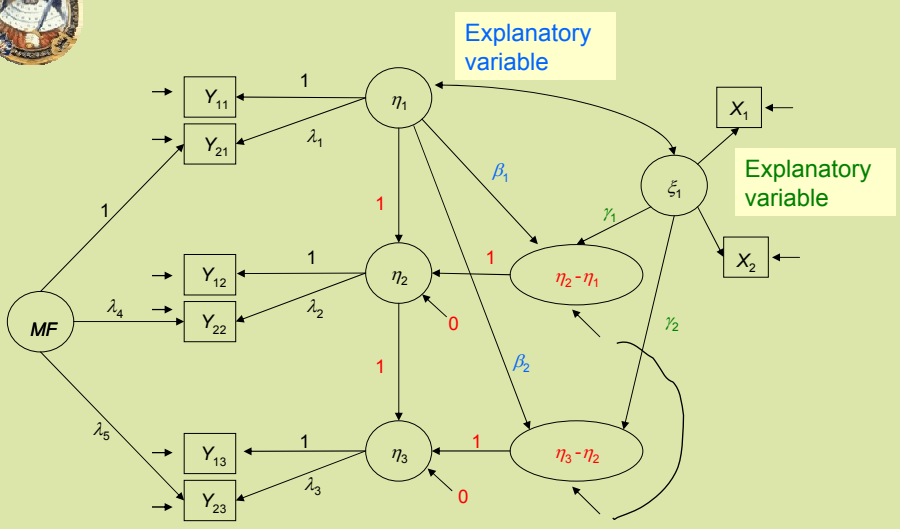
# Neighbor model

An alternative way of introducing latent difference variables

$\eta_2 = 1\ (\eta_2 - \eta_1) + 1\ \eta_1$ $\eta_3 = 1\ (\eta_3 - \eta_2) + 1\ \eta_2$





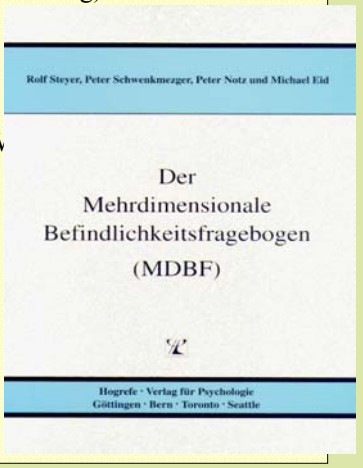




An alternative way of introducing latent difference variables

Der MBDF ist eine Adjektivliste zur Erfassung der momentanen Befindlichkeit (Stimmung).

Die Items erfassen 3 bipolare Dimensionen:

- Wachheit vs. Müdigkeit (W
- Ruhe vs. Unruhe (RU)
- Gute vs. Schlechte Stimmung (GS)






MDBF - Langform (Teil 1)

| Im Moment fühle ich mich | überhaupt nicht | | | | sehr |
|---|---|---|---|---|---|
| 1. zufrieden | O | O | O | O | O |
| 2. ausgeruht | O | O | O | O | O |
| 3. ruhelos | O | O | O | O | O |
| 4. schlecht | O | O | O | O | O |
| 5. schlapp | O | O | O | O | O |
| 6. gelassen | O | O | O | O | O |
| 7. müde | O | O | O | O | O |
| 8. gut | O | O | O | O | O |
| 9. unruhig | O | O | O | O | O |
| 10. munter | O | O | O | O | O |
| 11. unwohl | O | O | O | O | O |
| 12. entspannt | O | O | O | O | O |

## MDBF - Langform (Teil 2)

| Im Moment fühle ich mich | überhaupt nicht | | | | sehr |
|---|---|---|---|---|---|
| 13. schläfrig | O | O | O | O | O |
| 14. wohl | O | O | O | O | O |
| 15. ausgeglichen | O | O | O | O | O |
| 16. unglücklich | O | O | O | O | O |
| 17. wach | O | O | O | O | O |
| 18. unzufrieden | O | O | O | O | O |
| 19. angespannt | O | O | O | O | O |
| 20. frisch | O | O | O | O | O |
| 21. glückl ich | O | O | O | O | O |
| 22. nervös | O | O | O | O | O |
| 23. ermattet | O | O | O | O | O |
| 24. ruhig | O | O | O | O | O |

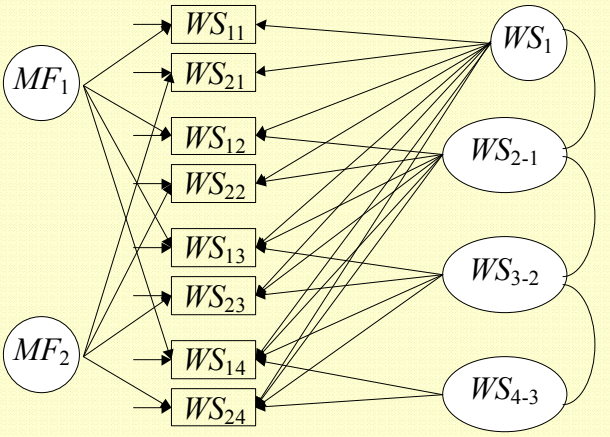


## MDBF – Kurzformen

Zuordnung der Items zu den Skalen und den Kurzformen

| Skala | Kurzform A | | Kurzform B | |
|---|---|---|---|---|
| GS | 1 | zufrieden | 14 | wohl |
| | 8 | gut | 21 | glücklich |
| | 4 | schlecht | 16 | unglücklich |
| | 11 | unwohl | 18 | unzufrieden |
| WM | 2 | ausgeruht | 17 | wach |
| | 10 | munter | 20 | frisch |
| | 5 | schlapp | 13 | schläfrig |
| | 7 | müde | 23 | ermattet |
| RU | 6 | gelassen | 24 | ruhig |
| | 12 | entspannt | 15 | ausgeglichen |
| | 3 | ruhelos | 19 | angespannt |
| | 9 | unruhig | 22 | nervös |

TIC$_2$-Modell, empirisches Modell für Well-being state (WS$_{ik}$)
Modell 1






Varianz -Kovarianz -Matrix der latenten Variablen
des Modell 1

| | $WS_1$ | $WS_{2-1}$ | $WS_{3-2}$ | $WS_{4-3}$ |
|---|---|---|---|---|
| Var | 0.661 | 1.055 | 0.999 | 0.831 |
| $WS_1$ | 1.000 | | | |
| $WS_{2-1}$ | -.573 | 1.000 | | |
| $WS_{3-2}$ | .000 | -.494 | 1.000 | |
| $WS_{4-3}$ | .000 | .000 | -.495 | 1.000 |

## Ausschnitt aus dem DHU

1. Ich habe vergeblich auf jemanden gewartet.
2. Jemand gab mir einen hilfreichen Rat.
3. Ich habe jemandem eine Freude gemacht.
4. Ich habe erlebt, dass meine Meinung richtig war.
5. Ich habe einen Geldbetrag oder Gewinn erhalten.
6. Ich hatte Streit mit jemandem.



Matrix der manifesten Variablen (gesamt)

| | $WS_{11}$ | $WS_{21}$ | $WS_{12}$ | $WS_{22}$ | $WS_{13}$ | $WS_{23}$ | $WS_{14}$ | $WS_{24}$ | $WT_1$ | $WT_2$ | $DH_{11}$ | $DH_{21}$ | $DH_{12}$ | $DH_{22}$ | $DH_{13}$ | $DH_{23}$ | $DH_{14}$ | $DH_{24}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3.751 | 3.649 | 3.773 | 3.715 | 3.753 | 3.669 | 3.871 | 3.773 | 3.436 | 3.416 | 3.496 | 3.532 | 3.487 | 3.479 | 3.501 | 3.418 | 3.483 | 3.515 |
| Std | 0.878 | 0.918 | 0.911 | 0.939 | 0.922 | 0.915 | 0.866 | 0.880 | 0.750 | 0.752 | 0.411 | 0.530 | 0.456 | 0.516 | 0.465 | 0.521 | 0.461 | 0.527 |
| $WS_{11}$ | 1.0000 | | | | | | | | | | | | | | | | | |
| $WS_{21}$ | .8191 | 1.0000 | | | | | | | | | | | | | | | | |
| $WS_{12}$ | .2197 | .2272 | 1.0000 | | | | | | | | | | | | | | | |
| $WS_{22}$ | .2235 | .2864 | .8907 | 1.0000 | | | | | | | | | | | | | | |
| $WS_{13}$ | .2303 | .2209 | .2777 | .2893 | 1.0000 | | | | | | | | | | | | | |
| $WS_{23}$ | .2484 | .2865 | .3007 | .3468 | .8895 | 1.0000 | | | | | | | | | | | | |
| $WS_{14}$ | .2579 | .2182 | .3393 | .3293 | .3338 | .3571 | 1.0000 | | | | | | | | | | | |
| $WS_{24}$ | .2304 | .2438 | .3233 | .3501 | .3664 | .4279 | .8772 | 1.0000 | | | | | | | | | | |
| $WT_1$ | .3851 | .4648 | .3342 | .3728 | .3602 | .4302 | .3350 | .4189 | 1.0000 | | | | | | | | | |
| $WT_2$ | .3480 | .4209 | .3830 | .4313 | .3628 | .4290 | .3979 | .4749 | .9285 | 1.0000 | | | | | | | | |
| $DH_{11}$ | .2845 | .3302 | .1393 | .1574 | .1374 | .1533 | .1774 | .1867 | .2889 | .2598 | 1.0000 | | | | | | | |
| $DH_{21}$ | .4021 | .3790 | .1393 | .1397 | .2094 | .2396 | .2042 | .1729 | .2969 | .2802 | .4724 | 1.0000 | | | | | | |
| $DH_{12}$ | .1371 | .1432 | .3694 | .3820 | .1388 | .1691 | .2104 | .1761 | .2631 | .2929 | .3625 | .3613 | 1.0000 | | | | | |
| $DH_{22}$ | .1565 | .1543 | .4310 | .4163 | .1774 | .1942 | .2014 | .1643 | .2533 | .2866 | .3099 | .4011 | .5358 | 1.0000 | | | | |
| $DH_{13}$ | .1380 | .1369 | .1834 | .1842 | .3471 | .3611 | .2491 | .2426 | .2808 | .2884 | .3354 | .3058 | .3648 | .2514 | 1.0000 | | | |
| $DH_{23}$ | .1482 | .1298 | .1929 | .1877 | .4623 | .4392 | .2936 | .2790 | .3093 | .3192 | .2348 | .3943 | .2899 | .4072 | .5009 | 1.0000 | | |
| $DH_{14}$ | .0991 | .1242 | .1579 | .1704 | .1452 | .2045 | .3896 | .4025 | .3013 | .3129 | .3111 | .2621 | .3459 | .2809 | .4006 | .3391 | 1.0000 | |
| $DH_{24}$ | .1315 | .1281 | .1939 | .1731 | .1793 | .2244 | .4360 | .4306 | .2601 | .2905 | .2220 | .3123 | .2642 | .3443 | .3253 | .3755 | .5797 | 1.0000 |

Korrelationsmatrix der manifesten Variablen (Well being state)

| | $WS_{11}$ | $WS_{21}$ | $WS_{12}$ | $WS_{22}$ | $WS_{13}$ | $WS_{23}$ | $WS_{14}$ | $WS_{24}$ |
|---|---|---|---|---|---|---|---|---|
| Mean | 3.751 | 3.649 | 3.773 | 3.715 | 3.753 | 3.669 | 3.871 | 3.773 |
| Std | 0.878 | 0.918 | 0.911 | 0.939 | 0.922 | 0.915 | 0.866 | 0.880 |
| $WS_{11}$ | 1.0000 | | | | | | | |
| $WS_{21}$ | .8191 | 1.0000 | | | | | | |
| $WS_{12}$ | .2197 | .2272 | 1.0000 | | | | | |
| $WS_{22}$ | .2235 | .2864 | .8907 | 1.0000 | | | | |
| $WS_{13}$ | .2303 | .2209 | .2777 | .2893 | 1.0000 | | | |
| $WS_{23}$ | .2484 | .2865 | .3007 | .3468 | .8895 | 1.0000 | | |
| $WS_{14}$ | .2579 | .2182 | .3393 | .3293 | .3338 | .3571 | 1.0000 | |
| $WS_{24}$ | .2304 | .2438 | .3233 | .3501 | .3664 | .4279 | .8772 | 1.0000 |



Korrelationsmatrix der manifesten Variablen (daily hassles and uplifts)

| | $WT_1$ | $WT_2$ | $DH_{11}$ | $DH_{21}$ | $DH_{12}$ | $DH_{22}$ | $DH_{13}$ | $DH_{23}$ | $DH_{14}$ | $DH_{24}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3.436 | 3.416 | 3.496 | 3.532 | 3.487 | 3.479 | 3.501 | 3.418 | 3.483 | 3.515 |
| Std | 0.750 | 0.752 | 0.411 | 0.530 | 0.456 | 0.516 | 0.465 | 0.521 | 0.461 | 0.527 |
| $WT_1$ | 1.0000 | | | | | | | | | |
| $WT_2$ | .9285 | 1.0000 | | | | | | | | |
| $DH_{11}$ | .2889 | .2598 | 1.0000 | | | | | | | |
| $DH_{21}$ | .2969 | .2802 | .4724 | 1.0000 | | | | | | |
| $DH_{12}$ | .2631 | .2929 | .3625 | .3613 | 1.0000 | | | | | |
| $DH_{22}$ | .2533 | .2866 | .3099 | .4011 | .5358 | 1.0000 | | | | |
| $DH_{13}$ | .2808 | .2884 | .3354 | .3058 | .3648 | .2514 | 1.0000 | | | |
| $DH_{23}$ | .3093 | .3192 | .2348 | .3943 | .2899 | .4072 | .5009 | 1.0000 | | |
| $DH_{14}$ | .3013 | .3129 | .3111 | .2621 | .3459 | .2809 | .4006 | .3391 | 1.0000 | |
| $DH_{24}$ | .4306 | .2601 | .2905 | .2220 | .3123 | .2642 | .3443 | .3253 | .3755 | .5797 | 1.0000 |

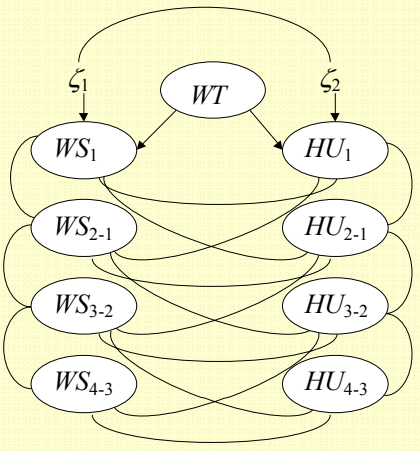
Matrix der manifesten Variablen (*WS* und *DH*)

| | $WS_{11}$ | $WS_{21}$ | $WS_{12}$ | $WS_{22}$ | $WS_{13}$ | $WS_{23}$ | $WS_{14}$ | $WS_{24}$ |
|---|---|---|---|---|---|---|---|---|
| $WT_1$ | .3851 | .4648 | .3342 | .3728 | .3602 | .4302 | .3350 | .4189 |
| $WT_2$ | .3480 | .4209 | .3830 | .4313 | .3628 | .4290 | .3979 | .4749 |
| $DH_{11}$ | .2845 | .3302 | .1393 | .1574 | .1374 | .1533 | .1774 | .1867 |
| $DH_{21}$ | .4021 | .3790 | .1393 | .1397 | .2094 | .2396 | .2042 | .1729 |
| $DH_{12}$ | .1371 | .1432 | .3694 | .3820 | .1388 | .1691 | .2104 | .1761 |
| $DH_{22}$ | .1565 | .1543 | .4310 | .4163 | .1774 | .1942 | .2014 | .1643 |
| $DH_{13}$ | .1380 | .1369 | .1834 | .1842 | .3471 | .3611 | .2491 | .2426 |
| $DH_{23}$ | .1482 | .1298 | .1929 | .1877 | .4623 | .4392 | .2936 | .2790 |
| $DH_{14}$ | .0991 | .1242 | .1579 | .1704 | .1452 | .2045 | .3896 | .4025 |
| $DH_{24}$ | .1315 | .1281 | .1939 | .1731 | .1793 | .2244 | .4360 | .4306 |



Strukturmodell welches gut mit den Daten vereinbar war

Modell 2



Varianz -Kovarianz -Matrix der latenten Variablen des Modell 2

| | $WS_1$ | $WS_{2-1}$ | $WS_{3-2}$ | $WS_{4-3}$ | $HU_1$ | $HU_{2-1}$ | $HU_{3-2}$ | $HU_{4-3}$ | $WT$ |
|---|---|---|---|---|---|---|---|---|---|
| Var | 0.656 | 1.055 | 0.997 | 0.835 | 0.103 | 0.092 | 0.111 | 0.103 | 0.524 |
| $WS_1$ | 1.000 | | | | | | | | |
| $WS_{2-1}$ | -.568 | 1.000 | | | | | | | |
| $WS_{3-2}$ | .000 | -.497 | 1.000 | | | | | | |
| $WS_{4-3}$ | .000 | .000 | -.499 | 1.000 | | | | | |
| $HU_1$ | .553 | -.216 | .000 | .000 | 1.000 | | | | |
| $HU_{2-1}$ | -.358 | .630 | -.357 | .000 | -.398 | 1.000 | | | |
| $HU_{3-2}$ | .000 | -.286 | .588 | -.214 | .000 | -.524 | 1.000 | | |
| $HU_{4-3}$ | .000 | .000 | -.285 | .538 | .000 | .000 | -.402 | 1.000 | |
| $WT$ | .454 | .000 | .000 | .000 | .438 | .000 | .000 | .000 | 1.000 |