Online Supplements for:

Exploring Sources of Construct-Relevant Multidimensionality in Psychiatric Measurement: A Tutorial and Illustration using the Composite Scale of Morningness

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Some Theoretical Background on the Assessment of Diurnal Preference

Chronotype or diurnal preference is an important inter-individual difference related to the time of day when a person is the most alert and awake, and to preferences for early or late awakening. Many instruments exist to assess diurnal preferences, including the Morningness-Eveningness Questionnaire (MEQ) (Horne and Östberg, 1976), the Diurnal-Type scale (DTS) (Torsvall and Âkerstedt, 1980) and the Circadian-Type Questionnaire (CTQ) (Folkard et al., 1979). The Composite Scale of Morningness (CSM) was created through the selection of the "best", or most discriminant items available in the MEQ, DTS and CTQ (Smith et al., 1989). The authors used principal component analyses (PCA) to reduce a pool of 26 items to 19 items. Then, they discarded the only item that loaded onto a fourth component, three items with low item-total correlations, and three items with content that did not match the component they are assumed to reflect. This procedure led to a 13-item scale assessing three components: *Morning Activities* (items 1,6,8,9,10,11,13), *Morning Affect* (items 3,4,5,12) and *Evening Activities* (items 2,7) (see next section for the items).

Since then, researchers interested in the structure of the CSM have found results supporting solutions including 1 to 3 factors (Di Milia et al., 2013). Unfortunately, previous EFA studies (Caci et al., 2005; Diaz-Morales and Sanchez-Lopez, 2005; Gil et al., 2008; Önder et al., 2013) have tended to rely on suboptimal criteria to select the number of factors (Preacher and MacCallum, 2003), while CFA studies have generally converged on solutions presenting only marginal fit to the data (Diaz Morales and Sanchez-Lopez, 2004; Randler and Diaz-Morales, 2007), forcing researchers to rely on suboptimal post-hoc modifications (Randler and Diaz-Morales, 2007). The *Morning Affect* factor consistently appears in all studies (Caci et al., 2005; Caci et al., 2009; Gil et al., 2008; Önder et al., 2013; Smith et al., 2002; Smith et al., 1989). However, the other factors emerge inconsistently, and with a changing content. Part of the reason for this could be that the initial study was based on PCA, which typically tends to extract a large first principal component explaining a maximum of variance, whereas reflective procedures (EFA/CFA) achieve a better distribution of the total covariance among factors. In support of this hypothesis, at least two of the items (9,13) included in the original *Morning Activities* component could equally be related to morningness or eveningness. Indeed, a recent study using the French CSM supported an alternative solution in which these two items where moved to the *Evening Activities* factor (Caci et al., 2005) – relabelled *Activity Planning*. This model thus represents a promising solution to the previous uncertainty regarding the CSM structure.

We first contrast ICM-CFA, B-CFA, ESEM, and B-ESEM representations of responses to the CSM. Then, we conduct predictive analyses to estimate the relations between CSM factors and Body Mass Index [BMI: weight(kg)/height(m)^2]. Recent studies suggested positive relations between eveningness and obesity (Wang, 2014), as well as with BMI and unhealthy eating habits in obese patients (Lucassen et al., 2013). The current study thus tests whether these results extend to a more general population sample. We also conduct tests of measurement invariances across subgroups of participants formed on the basis of age, gender, and combinations. Tests of measurement invariances are an important pre-requisite to unbiased group comparisons (Meredith, 1993). As such, these tests verify the extent to which the CSM factor structure generalizes across males and females of different age groups, which is interesting in light of reports that diurnal preferences may present variations among gender and age groups (Caci et al., 2005; Kim et al., 2002; Smith et al., 2002).

Composite Scale of Morningness

Smith CS, Reilly C, Midkiff K. Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. J Appl Psychol. 1989;74(5):728-38.

Items 3, 4, 5, 11 reflect a preference for mornings, whereas items 1, 2, 6, 7, 8, 9, 10, 12, 13 reflect a preference for evenings.

Please check the response for *each* item that best describes *you*.

1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan you day?
   - 5:00-6:30 a.m.
   - 6:30-7:45 a.m.
   - 7:45-9:45 a.m.
   - 9:45-11:00 a.m.
   - 11:00 a.m.-12:00 (noon)
2. Considering only your "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening?
   - 8:00-9:00 p.m.
   - 9:00-10:15 p.m.
   - 10:15 p.m.-12:30 a.m.
   - 12:30 a.m.-1:45 a.m.
   - 1:45 a.m.-3:00 a.m.
3. Assuming normal circumstances, how easy do you find getting up in the morning?
   - Not at all easy
   - Slight easy
   - Fairly easy
   - Very easy
4. How alert do you feel during the first half hour after having awakened in the morning?
   - Not at all alert
   - Slightly alert
   - Fairly alert
   - Very alert
5. During the first half hour after having awakened in the morning, how tired do you feel?
   - Very tired
   - Fairly tired
   - Fairly refreshed
   - Very refreshed
6. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is 7:00-8:00 a.m. Bearing in mind nothing else but your own "feeling best" rhythm, how do you think you would perform?
   - Would be in good form
   - Would be in a reasonable form
   - Would find it difficult
   - Would find it very difficult
7. At what time in the evening do you feel tired and, as a result, in need of sleep?
   - 8:00-9:00 p.m.
   - 9:00-10:15 p.m.
   - 10:15 p.m.-12:30 a.m.
   - 12:30 a.m.-1:45 a.m.
   - 1:45 a.m.-3:00 a.m.

8. You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day, and considering only you own "feeling best" rhythm, which ONE of the four testing times would you choose?
    - 8:00-10:00 a.m.
    - 11:00 a.m. - 1:00 p.m.
    - 3:00-5:00 p.m.
    - 7:00-9:00 p.m.
9. One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?
    - Definitively a morning type
    - More a morning than an evening type
    - More an evening than a morning type
    - Definitively an evening type
10. When would you prefer to rise (provided you have a full day's work - 8 hours) if you were totally free to arrange your time?
    - Before 6:30 a.m.
    - 6:30-7:30 a.m.
    - 7:30-8:30 a.m.
    - 8:30 a.m. or later
11. If you always had to rise at 6:00 a.m., what do you think it would be like?
    - Very difficult and unpleasant
    - Rather difficult and unpleasant
    - A little unpleasant but no great problem
    - Easy and not unpleasant
12. How long a time does it usually take before you "recover your senses" in the morning after rising from a night's sleep?
    - 0-10 minutes
    - 11-20 minutes
    - 21-40 minutes
    - more than 40 minutes
13. Please indicate to what extent you are a morning or evening *active* individual.
    - Pronounced morning active (morning alert and evening tired)
    - To some extent, morning active
    - To some extent, evening active
    - Pronounced evening active (morning tired and evening alert)

Discussion of the Substantive Results About the CSM

Our results also have relevance for our understanding of the CSM as an instrument and for extending knowledge on the construct of diurnal preference. First, our results supported the revised three factor-structure of the CSM (Caci et al., 2005). However, they also showed that the CSM items could be used to reflect a well-defined global diurnal preference factor. Over and above this global factor, most CSM items also serve to define specific factors related to *Morning Affect* and *Bedtime Preference*. An additional S-Factor related to *Time of Rising* retained a lower level of specificity but was shown to present meaningful associations with categorical (age-groups, gender) and continuous (BMI) covariates. More precisely, although the B-ESEM representation of CSM proved to be completely invariant across gender and age-groups, the results showed meaningful latent means differences between groups: (a) older females presented a more positive morning affect than younger females; (b) males preferred getting up earlier than females; (c) men preferred getting into bed later than females, and older males preferred doing so earlier than younger males. These results are generally in line with previous results (Caci et al., 2005; Carrier et al., 1997; Smith et al., 2002), and future studies are needed to further explore the reasons underlying these differences. Finally, and perhaps most interestingly, the results showed small but meaningful relations between *Morning Affect* and lower levels of BMI, and between *Time of Rising* and higher levels of BMI. These results are particularly important as they extend the results from previous studies (Lucassen et al., 2013) suggesting relations between diurnal preference and obesity. Our results show that this relation generalizes to more normative BMI variations, but also differs according to the specific dimension of diurnal preference that is considered. Future research should devote more attention to the mechanisms underlying these relations.

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Wang L. (2014). Body mass index, obesity, and self-control: a comparison of chronotypes. *Social Behavior and Personality: an international journal* **42**(2): 313-320.

Title: ICM-CFA

```
! Statements preceded by ! are comments not part of the input setup.
! The following statement is used to identify the data file. Here, the data file is labelled CSM.dat.
DATA:
FILE IS CSM.dat;
! The variables names function identifies all variables in the data set, in order of appearance.
! The usevariables command identifies the variables used in the analysis.
! The categorical command identifies the variables that are ordered-categorical in nature.
VARIABLE:
NAMES ARE SEX AGE BMI CAT CSM1-CSM13;
USEVARIABLES ARE CSM1-CSM13;
CATEGORICAL ARE CSM1-CSM13;
! The next section defines the analysis. Here robust weighed least square estimation
! (WLSMV) is used.
! With WLSMV estimation, it is often useful to increase the number of iterations.
ANALYSIS:
ESTIMATOR IS WLSMV;
ITERATIONS = 10000;
! The next section defines the model.
! The @ symbol is use to fix parameter estimates to a specific value.
! The * symbol indicates the free estimation of a parameter value (or provide a start value).
! Each input lines ends with ;
! Factor loadings are noted with BY, regressions with ON, correlations with WITH,
! means and thresholds are noted between brackets [];
! variances and residuals are noted without brackets.
! Here, An ICM-CFA model is specified
! with 3 factors (F1 to F3) defined by their respective items.
! the model is identified by fixing the factor variance to 1 (F1-F3@1), allowing first factor
loading to be freely estimated (*)
MODEL:
 F1 BY CSM3* CSM4 CSM5 CSM12;
 F2 BY CSM1* CSM6 CSM8 CSM10 CSM11;
 F3 BY CSM2* CSM7 CSM9 CSM13;
 F1@1; F2@1; F3@1;
 F1 WITH F2 F3;
 F2 WITH F3;
! Specific sections of output are requested.
OUTPUT:
  SAMPSTAT STANDARDIZED RESIDUAL CINTERVAL TECH1 TECH2  TECH4
MODINDICES(ALL);
```

! Redundant sections are not repeated, we only focus on sections that differ from previous models.

Title: Bifactor-CFA

```
! A bifactor CFA model is specified with 3 specific factors (FS1 to FS3)
! All items are also used to define a global factor FG.
! All factors are set to be orthogonal (correlations @0)
MODEL:
 FG BY  CSM4* CSM3 CSM5 CSM12 CSM1 CSM6 CSM8 CSM10 CSM11 CSM2 CSM7 CSM9
 CSM13;
 FS1 BY CSM3* CSM4 CSM5 CSM12;
 FS2 BY CSM1* CSM6 CSM8 CSM10 CSM11;
 FS3 BY CSM2* CSM7 CSM9 CSM13;
 F1@1; F2@1; F3@1;
 FG@1;
 FS1 WITH FS2 FS3@0;
 FS2 WITH FS3@0;
 FG WITH FS1 FS2 FS3@0;
```

Title: ESEM

```
! An ESEM model is specified with target oblique rotation.
ANALYSIS:
ESTIMATOR IS WLSMV; ITERATIONS = 10000;
ROTATION = TARGET;
! The factors (F1 to F3) are defined with main loadings from their respective items,
! In addition to these main loadings, all other cross-loadings are estimated but targeted
! to be as close to 0 as possible (~0).
! Factors forming a single set of ESEM factors (with cross-loadings between factors)
! are indicated by using the same label in parenthesis after * (*1).
MODEL:
F1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
F2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
F3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
```

Title: Bifactor-ESEM

```
! A Bifactor-ESEM model is specified with orthogonal target rotation.
ANALYSIS:
ESTIMATOR IS WLSMV; ITERATIONS = 10000;
ROTATION = TARGET (orthogonal);
! The specific factors (FS1 to FS3) are defined with main loadings from their respective items.
! All other cross-loadings are estimated but targeted to be as close to 0 as possible (~0).
! The global factor is defined through main loadings from all items, and is included in
! the same set of ESEM factors as FS1-FS3 (*1)
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);

FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
```

Title: Including an Outcome Variable

! The predictor (here BMI), is added to the usevariables list.
! Because BMI is a continuous variable, it is not added to the categorical list.
VARIABLE:
NAMES ARE SEX AGE BMI CAT CSM1-CSM13;
USEVARIABLES ARE CSM1-CSM13;
CATEGORICAL ARE CSM1-CSM13;
! Then, in the model sections, the following statements are added to indicate that the factors are used
! to predict BMI:
! ICM-CFA and ESEM:
IMC ON F1 F2 F3;
! Bifactor-CFA and Bifactor-ESEM:
IMC ON FG FS1 FS2 FS3;

Title: Measurement Invariance across Gender – Configural Invariance.

```
DATA:
FILE IS CSM.dat;
! The grouping variable is used to identify the groups and labels are given to each of the value
! An observed grouping variables does not need to be included in the usevariables or categorical list.
VARIABLE:
NAMES ARE SEX AGE BMI CAT CSM1-CSM13;
USEVARIABLES ARE CSM1-CSM13;
CATEGORICAL ARE CSM1-CSM13;
GROUPING IS SEX (1=women 2=men);
! As before.
! Parameterization = theta is added in order to be able to test for the invariance of uniquenesses.
ANALYSIS:
  TYPE IS GENERAL;
  ESTIMATOR IS WLSMV;
  ITERATIONS = 10000;
  PARAMETERIZATION=THETA;
  ROTATION = TARGET (orthogonal);
! The global model section is used to define the global model used in both groups.
! Parameter freely estimated across groups will be specified in group-specific sections.
! See Morin, Moullec et al. (2011) and Guay, Morin et al. (2014), cited in main manuscript, for
!additional details on specifications of invariance testing for WLSMV estimation.
! The first part is as above for the bifactor-ESEM model.
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
! Here, thresholds are specified. For X answers categories, there are X-1 thresholds to be specified
! using the $1, $1, $3, etc. symbol. By default, thresholds are invariant across groups so only non-
! invariant thresholds need to be specified here.
! For tests of configural invariance, the first threshold from each item is set to be invariant, and the
! second threshold from a referent indicator for each factor.
!Referent indicator for FS2 (5 categories):
[CSM1$3]; [CSM1$4];
!Referent indicator for FS3 (5 categories):
[CSM2$3]; [CSM2$4];
!Referent indicator for FS1 (4 categories):
 [CSM3$3];
!Referent indicator for FG (4 categories):
 [CSM4$3];
! Other indicators:
[CSM5$2]; [CSM5$3];
[CSM6$2]; [CSM6$3];
[CSM7$2]; [CSM7$3]; [CSM7$4];
[CSM8$2]; [CSM8$3];
[CSM9$2]; [CSM9$3];
[CSM10$2]; [CSM10$3];
[CSM11$2]; [CSM11$3];
[CSM12$2]; [CSM12$3];
[CSM13$2]; [CSM13$3];
```

```
! In the group specific statement, all parameter to be freely estimated in the other group are specified.
! For X groups, X-1 group-specific statement are needed, starting with group 2.
! By default, the factor variances are set to 1 in all groups
! which is as should be for configural invariance.
! By default the latent means are fixed to 0 in group 1, and freely estimated in group 2 and subsequent,
! which is as should be for configural invariance.
! By default, uniquenesses are set to 1 in the first group and freely estimated in the other groups,
! which is as should be for configural invariance.
MODEL men:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
!Referent indicator for FS2 (5 categories):
[CSM1$3]; [CSM1$4];
!Referent indicator for FS3 (5 categories):
[CSM2$3]; [CSM2$4];
!Referent indicator for FS1 (4 categories):
 [CSM3$3];
!Referent indicator for FG (4 categories):
 [CSM4$3];
! Other indicators:
[CSM5$2]; [CSM5$3];
[CSM6$2]; [CSM6$3];
[CSM7$2]; [CSM7$3]; [CSM7$4];
[CSM8$2]; [CSM8$3];
[CSM9$2]; [CSM9$3];
[CSM10$2]; [CSM10$3];
[CSM11$2]; [CSM11$3];
[CSM12$2]; [CSM12$3];
[CSM13$2]; [CSM13$3];
! Specific sections of output are requested.
OUTPUT:
  SAMPSTAT STANDARDIZED RESIDUAL CINTERVAL TECH1 TECH2  TECH4
MODINDICES(ALL);
! The following section is used to request a save data file to be used in the calculation of Chi-
! square differences tests based on WLSMV estimation.
SAVEDATA:
  DIFFTEST = BESEM_sex_conf.dat;
```

! Redundant sections are not repeated, we only focus on sections that differ from previous models.

Title: Measurement Invariance across Gender – Weak Invariance.

! The DIFFTEST function is used to request a chi square difference test, using the saved data file from
! the previous model in the sequence.

```
ANALYSIS:
  TYPE IS GENERAL;
  ESTIMATOR IS WLSMV;
  ITERATIONS = 10000;
  PARAMETERIZATION=THETA;
  ROTATION = TARGET (orthogonal);
  DIFFTEST = BESEM_sex_conf.dat;
```

! The only difference between this model and the previous one is that the specification of factor
! loadings is not repeated in the group-specific section. These are invariant at default. Also, when the
! loadings are invariant, the factor variances are freely estimated in all groups but the first.

```
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
 [CSM1$3]; [CSM1$4];
 [CSM2$3]; [CSM2$4];
 [CSM3$3];
 [CSM4$3];
 [CSM5$2]; [CSM5$3];
[CSM6$2]; [CSM6$3];
[CSM7$2]; [CSM7$3]; [CSM7$4];
[CSM8$2]; [CSM8$3];
[CSM9$2]; [CSM9$3];
[CSM10$2]; [CSM10$3];
[CSM11$2]; [CSM11$3];
[CSM12$2]; [CSM12$3];
[CSM13$2]; [CSM13$3];
MODEL men:
 [CSM1$3]; [CSM1$4];
 [CSM2$3]; [CSM2$4];
 [CSM3$3];
 [CSM4$3];
 [CSM5$2]; [CSM5$3];
[CSM6$2]; [CSM6$3];
[CSM7$2]; [CSM7$3]; [CSM7$4];
[CSM8$2]; [CSM8$3];
[CSM9$2]; [CSM9$3];
[CSM10$2]; [CSM10$3];
[CSM11$2]; [CSM11$3];
[CSM12$2]; [CSM12$3];
[CSM13$2]; [CSM13$3];
SAVEDATA:
  DIFFTEST = BESEM_sex_weak.dat;
```

Title: Measurement Invariance across Gender – Strong Invariance.

```
ANALYSIS:
  TYPE IS GENERAL;
  ESTIMATOR IS WLSMV;
  ITERATIONS = 10000;
  PARAMETERIZATION=THETA;
  ROTATION = TARGET (orthogonal);
  DIFFTEST = BESEM_sex_weak.dat;
! The only difference between this model and the previous one is that thresholds are invariants across !
group by default and thus do not need to be specified.
! When thresholds are invariant, the factor means are freely estimated in all groups but the first.
! Again: Loadings are invariant by default; variances and uniquenesses are fixed to be 1 in the first
! group and free in the other groups.
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
MODEL men:
! Empty
SAVEDATA:
  DIFFTEST = BESEM_sex_strong.dat;
```

Title: Measurement Invariance across Gender – Strict Invariance.

```
ANALYSIS:
  TYPE IS GENERAL;
  ESTIMATOR IS WLSMV;
  ITERATIONS = 10000;
  PARAMETERIZATION=THETA;
  ROTATION = TARGET (orthogonal);
  DIFFTEST = BESEM_sex_strong.dat;
! The only difference between this model and the previous one is that here uniquenesses are set to be
! fixed to 1 in all groups.
! Again: Loadings and thresholds are invariant by default;
! Variances and uniquenesses are fixed to be 1 in the first group and free in the other groups.
! Means are fixed to be 0 in the first group and free in the other groups.
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
MODEL men:
CSM1-CSM13@1;
SAVEDATA:
  DIFFTEST = BESEM_sex_strict.dat;
```

Title: Measurement Invariance across Gender – Variance-Covariance Invariance.

```
ANALYSIS:
  TYPE IS GENERAL;
  ESTIMATOR IS WLSMV;
  ITERATIONS = 10000;
  PARAMETERIZATION=THETA;
  ROTATION = TARGET (orthogonal);
  DIFFTEST = BESEM_sex_strict.dat;
! Here, the variances are fixed to 1 in all groups.
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
! The unrotated covariances (even if the rotated covariances are orthogonal) need to be fixed to
! invariance across groups. The labels in parentheses indicate that these covariance are fixed
! to invariance across groups.
FS1 WITH FS2 (c1);
FS1 WITH FS3 (c2);
FS2 WITH FS3 (c3);
FG WITH FS1 (c4);
FG WITH FS2 (c5);
FG WITH FS3 (c6);
MODEL men:
CSM1-CSM13@1;
FG@1; FS1@1; FS2@1; FS3@1;
SAVEDATA:
  DIFFTEST = BESEM_sex_vc.dat;
```

Title: Measurement Invariance across Gender – Latent Mean Invariance.

```
ANALYSIS:
  TYPE IS GENERAL;
  ESTIMATOR IS WLSMV;
  ITERATIONS = 10000;
  PARAMETERIZATION=THETA;
  ROTATION = TARGET (orthogonal);
  DIFFTEST = BESEM_sex_vc.dat;
! Here, the means are fixed to 0 in all groups.
MODEL:
FG BY CSM1 CSM2 CSM3 CSM4 CSM5 CSM6
CSM7 CSM8 CSM9 CSM10 CSM11 CSM12 CSM13 (*1);
FS1 BY CSM1~0 CSM2~0 CSM3 CSM4 CSM5 CSM6~0
CSM7~0 CSM8~0 CSM9~0 CSM10~0 CSM11~0 CSM12 CSM13~0 (*1);
FS2 BY CSM1 CSM2~0 CSM3~0 CSM4~0 CSM5~0
CSM6 CSM7~0 CSM8 CSM9~0 CSM10 CSM11 CSM12~0 CSM13~0 (*1);
FS3 BY CSM1~0 CSM2 CSM3~0 CSM4~0 CSM5~0
CSM6~0 CSM7 CSM8~0 CSM9 CSM10~0 CSM11~0 CSM12~0 CSM13 (*1);
FS1 WITH FS2 (c1);
FS1 WITH FS3 (c2);
FS2 WITH FS3 (c3);
FG WITH FS1 (c4);
FG WITH FS2 (c5);
FG WITH FS3 (c6);
MODEL men:
CSM1-CSM13@1;
FG@1; FS1@1; FS2@1; FS3@1;
[FG@0]; [F1@0]; [F2@0]; [F3@0];
```

Title: Measurement Invariance across Age

```
! Here we used age-groups. In the data set, age is measured as a continuous variable, so it needs to be
! recoded. This is achieved using the cut command of the define function. The number in parentheses
! indicates the maximum value of age included in the category 0. Every value over that is coded 1.
! Then the grouping function of the variable command defines and labels the two groups thus created.
! The rest of the code for tests of invariance is then exactly as in the previous examples using gender
! as the grouping variable, except that the group sections of the model commands are defined using
! the new labels.
VARIABLE:
NAMES ARE SEX AGE BMI CAT CSM1-CSM13;
USEVARIABLES ARE CSM1-CSM13;
CATEGORICAL ARE CSM1-CSM13;
GROUPING IS age (0=younger 1=older);
DEFINE:
CUT AGE (39.999999);
[…]
Model:
[…]
Model older:
[…]
```

Title: Measurement Invariance across Age * Gender

```
! Here the If function of the define command is used to define four groups based on the combination o
! information from the sex variable defining gender and the continuous age variable. The function EQ
! means “equal” (e.g. sex EQ 1 identifies women); the function LT means “lower than” (LT 40
! identifies participants aged less than 40 exclusively); the function GE means “greater or equal to”
! (GE 40 identifies participants aged 40 inclusively or more).
! The four groups are then identified and labeled using the grouping function (YF: younger females;
! OF: older females; YM: younger males; OM: older males).
! Variables created using the define function need to be added as the end of the usevariables list.
! The rest of the code for tests of invariance is then exactly as in the previous examples using gender
! as the grouping variable, except that there are now more group sections in the model, and these are
! defined using the new labels.
VARIABLE:
NAMES ARE SEX AGE BMI CAT CSM1-CSM13;
USEVARIABLES ARE CSM1-CSM13 group;
CATEGORICAL ARE CSM1-CSM13;
GROUPING IS group (1=YF 2=OF 3=YM 4=OM);
DEFINE:
IF (SEX EQ 1 AND AGE LT 40) THEN group=1;
IF (SEX EQ 1 AND AGE GE 40) THEN group=2;
IF (SEX EQ 2 AND AGE LT 40) THEN group=3;
IF (SEX EQ 2 AND AGE GE 40) THEN group=4;
[…]
Model:
[…]
Model OF:
[…]
Model YM:
[…]
Model OM:
[…]
```