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# Beyond congruence measures for the evaluation of personality factor structure replicability: An exploratory structural equation modeling approach

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ABSTRACT

The present study aims to illustrate an encompassing approach to the evaluation of personality factor structure replicability based on novel exploratory structural equation modeling (ESEM) methods. This approach comprises formal tests of measurement invariance applied to the flexible ESEM framework and overcomes the limitations of congruence measures that have traditionally been used to assess factor replicability in personality research. On the basis of 1566 responses to the widely-used NEO Five-Factor-Inventory (NEO-FFI), we demonstrate this ESEM approach in the context of examining the invariance of the NEO-FFI factor structure across gender. The approach is shown to converge with traditional congruence measures and extend these measures for examining factorial structure consistency. In addition, more general replicative data supporting the validity of the NEO-FFI are reported. We discuss the ESEM approach as a viable alternative to the congruence approach and acknowledge some important limitations of the method.



## 1. Introduction

The Five-Factor Model (FFM) is predicated on the postulate that personality can be captured in five dimensions: openness to experience (O); conscientiousness (C); extraversion (E); agreeableness (A); and neuroticism (N). These dimensions have been replicated in peer, parent, and self-report ratings of personality, and in heterogeneous populations and different languages (McCrae & Costa, 2008). Indeed, factor replicability is recognized as one of the "pillars" on which the validity of the FFM rests. However, there are limitations to traditional approaches to the evaluation of replicability (viz., congruence measures) (McCrae, Zonderman, Costa, Bond, & Paunonen, 1996). The present study illustrates an alternative approach to the assessment of personality factor replicability, based on the novel ESEM methodology, using a large sample of data obtained from the widely-employed NEO Five Factor Inventory (NEO-FFI). We compare the congruence and ESEM approaches to illustrate the advantages of the latter in the evaluation of personality factor structure consistency. In addition, we examine the criterion validity of the NEO-FFI with respect to relevant vocational and academic outcomes, including career adaptability (CO), career optimism (CA), and academic achievement (AA) (Rottinghaus & Miller, 2013). These replicability and validity analyses are performed in a general ESEM framework.

### *1.1. Congruence measures for evaluating personality factor structure replicability*

Researchers have traditionally relied on congruence measures to evaluate personality factor replicability. These congruence coefficients index the degree of factor pattern similarity (i.e., the equality of factor loadings) across discrete matrices from two independent samples (Chan, Ho, Leung, Chan, & Yung, 1999; McCrae et al., 1996). Arguably, the most common congruence measure is Tucker's (1951) factor congruence coefficient, computed as per Eq. (1) below:

$$r_{ab} = \frac{\sum_{i=1}^{p}\lambda_{ix}\lambda_{iy}}{\sqrt{\sum_{i=1}^{p}\lambda_{ix}^{2}}\sqrt{\sum_{i=1}^{p}\lambda_{iy}^{2}}}, \quad (1)$$

where $p$ is the number of observed variables in the two samples, $\lambda_{ix}$ is the loading of variable $i$ on factor $x$ in sample one, and $\lambda_{iy}$ is the

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loadings of variable *i* on factor *y* in sample two. In addition, variable and total congruence coefficients have been proposed (see McCrae et al., 1996). Although it is possible to compare varimax rotated factors from independent factor analyses using the congruence measures, McCrae et al. (1996) recommend a Procrustes (i.e., targeted) rotation for the assessment of personality factor replicability in which a factor solution is orthogonally rotated to adhere to a pre-specified target factor structure. The extent to which the target and rotated structures are similar, quantified via congruence coefficients, is taken as evidence for factor replicability, with coefficients greater than .90 or .95 typically indicative of factor invariance (Lorenzo-Seva & Ten Berge, 2006; Mulaik, 1972). Beyond heuristics, bootstrap resampling procedures have been developed to provide significance tests of the congruence measures absent of a theoretical sampling distribution of these coefficients (Chan et al., 1999).

Notwithstanding the wide use of congruence indices in personality research, these measures have known limitations. For example, Horn (1967) showed that congruence coefficients may indicate high factor replicability even when random data are rotated to a target matrix using oblique Procrustes rotation. Paunonen (1997) also demonstrated that the expected value of congruence measures is contingent on several model characteristics, including the number of variables in the model and the number of salient loadings per factor. Furthermore, though statistical tests of congruence coefficients are available based on empirical resampling methods under null hypotheses of both factor congruence and incongruence, these are typically cumbersome to perform (Dolan, Oort, Stoel, & Wicherts, 2009). Finally, and most importantly, a sizeable congruence coefficient does not constitute evidence of the complete replicability of factor structures as factor pattern congruence is a necessary but not sufficient condition for factor invariance (Dolan et al., 2009; Meredith, 1993; Reise, Waller, & Comrey, 2000). Instead, evidence of strict measurement invariance is required for claims of complete measurement equivalence in line with Mellenbergh's (1989) definition of unbiasedness in the common factor model (Meredith, 1993).

An ostensibly elegant analytic option for redressing the limitations of congruence measures is the conduct of factor replicability studies within a multi-group (MG) confirmatory factor analysis (CFA) framework. Indeed, procedures for testing complete measurement equivalence in MG-CFA have been available for at least 25 years (Byrne, Shavelson, & Muthén, 1989; Marsh & Hocevar, 1985). However, there are cautions against the use of CFA for evaluating the factor structure of multidimensional personality measures due to its restrictiveness (Church & Burke, 1994; McCrae et al., 1996). CFA tests of many widely-used five-factor personality inventories, including the NEO-FFI, have largely failed to support the FFM theoretical structure (Hopwood & Donnellan, 2010; Marsh et al., 2010). Furthermore, personality factor correlations in CFA solutions appear substantially inflated relative to EFA correlations. One reason for both data-model misfit and inflated factor correlations may be the imposition of the restrictive independent clusters model (ICM) of CFA onto factorially complex personality item data (Marsh et al., 2010). According to the ICM-CFA model, each scale item is postulated to load onto one factor only, with cross-loadings constrained to zero. For multidimensional personality inventories, such as the NEO-FFI, the ICM-CFA specification may be too restrictive because personality items may be fallible indicators of constructs that tap more than one dimension (Hopwood & Donnellan, 2010). The constraint of cross-loadings to zero in the ICM-CFA specification may result in both model-data misfit as error is propagated by model misspecification and inflated factor correlations, as any relation between an item and non-target factor that should be accounted for by a secondary loading can only be expressed as a factor correlation in the ICM-CFA (Marsh et al., 2010; Morin, Arens, & Marsh, in press). As the FFM is not a perfect simple structure, there is no theoretical reason why traits should not index more than one factor (McCrae et al., 1996); thus, the ICM-CFA may not be an appropriate analytic structure for multidimensional personality data.

### 1.2. ESEM as an alternative approach

ESEM is a more appropriate analytic formulation for the conduct of factor replicability studies, which overcomes the limitations of congruence measures and the ICM-CFA. ESEM differs from the ICM-CFA to the extent that all primary and secondary loadings are freely estimated (conditional on the imposition of minimal identifying restrictions) and ESEM factors, like EFA factors, can be rotated (Morin, Marsh, & Nagengast, 2013). Thus, ESEM provides a less restrictive framework for the evaluation of factor structures that can sufficiently account for the psychometric multidimensionality of NEO-FFI items. As ESEM is an integration of EFA within a general SEM framework, the statistical advances of CFA/SEM are available to EFA measurement models, including SEM parameter estimates, standard errors, fit indices, correlated uniquenesses to represent complex residual structures, and full invariance tests (Marsh, Morin, Parker, & Kaur, 2014). These latter two features are particularly advantageous to examining factor replicability based on data from the NEO-FFI. The flexibility to specify a priori correlated uniquenesses in the ESEM frameworks may account for presumed intradimensional local dependence in the NEO-FFI generated by high item content overlap due to unmodeled facet structures (Marsh et al., 2010), which cannot be accommodated under the traditional EFA specification. The failure to specify these sources of common variation can lead to inflated estimates of parameters (e.g., factor loadings).

Formal MG tests of factor structure invariance, typically reserved for CFA models, can be conducted in the ESEM framework; this is substantively important for replicability studies. Dissimilar to congruence measures, which may only be used to infer weak factorial invariance, MG-ESEM provides tests of complete measurement invariance required for inferences of complete factor structure consistency (Morin et al., 2013). In addition, the equality of factor variance–covariance matrices and latent means (i.e., structural invariance) can be tested, though these tests are not considered in the present study.

Marsh et al. (2009) operationalized a taxonomy of 13 models for testing invariance in the ESEM framework. We propose an extension of this taxonomy to include tests of the invariance of correlated uniquenesses as the presence of methods effects due to item idiosyncrasies or response biases, which can be controlled using a priori correlated residuals, is likely to be the rule rather than the exception for many personality inventories (Marsh, Lüdtke, Nagengast, Morin, & Von Davier, 2013). As shown in Table 1, the proposed taxonomy of 25 nested ESEM models ranges from a configurally invariant model, in which no equality constraints are imposed on the parameters, to a model of complete measurement and structural invariance, in which there is equality of factor loadings, intercepts, uniquenesses, and factor mean and variance–covariance structures, with additional equality constraints on the correlated residuals imposed. In the present study, we propose this extended taxonomy of invariance tests, specifically models 1–16 addressing measurement invariance, as an alternative to congruence measures for establishing evidence of cross-sample factor structure replicability. This procedure is illustrated in the context of measurement invariance tests across gender for the NEO-FFI data. Nonetheless, the procedure can be used to test for factor equivalence across virtually any independent samples that differ in some substantive way or extended to factor invariance tests over time for single-group repeated measures data (see Morin et al., 2013).

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